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ENERGY SAVING BEHAVIOR IN HIGHER EDUCATION INSTITUTIONS: A BIBLIOMETRIC ANALYSIS OF PAST AND FUTURE RESEARCH TRENDS

Alya Natasya[1]
Universitas Islam Riau, Pekanbaru, Indonesia
alyanatasya@student.uir.ac.id

Gusman Nawanir[2]
Universitas Islam Riau, Pekanbaru, Indonesia
gusmannawanir@eco.uir.ac.id

Abstract

This article aims to provide a comprehensive overview of the implementation of energy-saving behaviors in higher education institutions, highlighting past research trends and future challenges. This article uses a bibliometric approach involving 677 journal articles from the Web of Science. This study conducts co-citation and co-word analysis to map influential publications and predict trends. Past research trends on energy-saving behaviors have focused on cross-disciplinary approaches to create energy efficiency solutions, sustainability, and technology applications in various contexts, both households and buildings. In the future, research on energy-saving behaviors will increasingly focus on the integration of human behavior, technology, and design to support energy sustainability in facing global challenges. This article will benefit researchers and practitioners by improving their understanding and implementing energy-saving behaviors in higher education institutions. This article provides valuable practical implications for higher education institutions to achieve resource efficiency and support environmental sustainability. With a large student and staff population and high energy needs for campus operations, energy-saving behaviors can significantly reduce energy consumption and environmental impacts.

Keywords: Energy Saving Behavior, Higher Education Institutions, Bibliometric Analysis, Sustainability

INTRODUCTION

The importance of energy-saving behavior is increasing along with the increasing global energy consumption driven by rapid economic growth and industrialization. Inefficient energy use not only results in a waste of resources but also plays a major role in significantly damaging the environment. This situation is increasingly urgent amid the global energy crisis and the threat of climate change, thus demanding sustainable solutions in energy management (Passas, 2024). Higher education institutions, especially campuses, are the right place to start this change. Educational facilities not only serve as places to learn and research but also as a small picture of society that can be used as an example of implementing energy-saving practices (Martinho, 2022). With the large number of students and employees on campus, it certainly requires significant energy consumption for daily activities such as room lighting, air conditioning, and the use of laboratory equipment and computers.

In determining the focus of the study, the researcher chose to emphasize the importance of energy-saving behavior carried out in higher education institutions. This decision was made because although there have been many previous studies discussing energy-saving behavior in higher education institutions, the results of these previous studies have not provided a comprehensive picture of the trend of energy-saving behavior from the past and future. This study focuses on mapping the structure of knowledge, identifying descriptions in previous studies, and providing valuable insights for researchers, as well as learners and administrators in higher education institutions. This study can also provide opportunities and suggestions for related efforts that support the formation of policies and practices in higher education. By highlighting significant previous publications, primary research, and future trends.

The main objective of this study is to gain a comprehensive understanding of the previous literature on energy-saving behavior in higher education institutions, covering research, teaching, and other activities. To achieve this objective, the researcher used a bibliometric approach, which systematically analyzes relevant literature. This approach involves two different bibliometric analyses, each of which addresses a different aspect of the literature and can shed light on the past and future research journeys related to energy-saving behavior in higher education institutions.

Therefore, this research is structured based on the following specific objectives, each of which is aligned with the components of bibliometric analysis:

1. To investigate the trends of previous energy-saving behavior, research on energy-saving behavior using co-citation analysis.
2. To investigate future research trends in energy-saving behavior using co-word analysis.

This article follows a structured format consisting of a concise introduction, a comprehensive section outlining the bibliometric methodology used, and then a summary of the findings. The results focus on contemporary and prospective trends in energy-saving behavior research in higher education institutions. Subsequent segments describe the implications and limitations of the study and offer recommendations for future research.

RESEARCH METHOD

Bibliometric Approach

This article uses a bibliometric analysis approach method used to analyze research trends in energy-saving behavior in higher education institutions. Bibliometrics is one of the research methods used in the field of library and information science. This method uses quantitative and statistical analysis to describe publication patterns in a particular field, topic, or institution (Mustafa et al., 2020). The bibliometric approach has several significant advantages in studying research trends and scientific structures. First, bibliometrics presents objectivity through quantitative data from publications and citations, thus providing a strong empirical basis for understanding the development of a scientific discipline (Donthu et al., 2021). This method also produces informative visualizations through the VOSviewer tool, thus facilitating understanding of the collaborative network of researchers and institutions (van Eck & Waltman, 2010). Furthermore, bibliometrics shows flexibility in its application, can be applied to various scientific fields ranging from social, and science, to engineering, and allows a deeper exploration of the evolution of research fields compared to traditional methods (Zupic & Čater, 2015).

Techniques used in bibliometric analysis such as co-citation and co-word analysis can help reveal conceptual relationships, topic proximity, and relevant key terms in the

literature (Donthu et al., 2021; Tozzi et al., 2023). The following is an explanation of co-citation analysis and co-word analysis:

1. Co-citation analysis aims to identify important publications and map past research trends at a certain time (Shiau et al. 2023). This technique is used to identify pairs of documents that are frequently cited together (Lu et al., 2023). If two documents are frequently cited together, it indicates that they discuss the same topic or have made similar contributions to the field. Through co-citation analysis, conceptual proximity can be revealed by showing which works have had significant influence and how these works are interrelated into the knowledge structure of the field. Researchers can identify works that have had a major influence on a field and understand the dynamics of the development of research trends over time (Park & Shea, 2020).
2. Co-word analysis is a technique that focuses on identifying keywords that frequently appear together in a single article (Scharp, 2021). This analysis allows for the grouping of specific research themes and can be used to identify research focuses or trends that have the potential to develop in the future.(Wu et al., 2023). By integrating co-citation and co-word analysis, researchers can provide a comprehensive overview of past and future research directions, as well as clarify emerging trends in promoting energy-saving behaviors in higher education institutions. This methodological approach explains emerging trends in energy-saving behaviors in higher education institutions and also provides an in-depth evaluation of the topic structure and suggests potential future directions (Bernatović et al. 2022).

Search Strategy and Data Collection Procedures

The search and data collection were conducted on November 3, 2024, using secondary data obtained from the academic database Web of Science. The Web of Science database is valued for its outstanding quality and wide coverage, making it an optimal choice for bibliometric research. Yan (2023). This database provides a comprehensive representation of leading researchers worldwide (Birkle et al. 2020). By combining data from the Web of Science, this study is expected to provide a more holistic and representative picture of the relevant literature. To narrow the search, focus was used on titles, abstracts, and keywords. The researchers used search strings to identify relevant documents in the Web

of Science (WoS) Core Collection database. The main keywords used for this study focused on energy-saving behavior and higher education institutions diversified by using synonyms, related terms, and their variations to retrieve metadata from the database: TS:("energy saving" OR "energy efficient*" OR "energy conserve*" OR "power saving" OR "energy reduction*" OR "energy optimiz*" OR "energy efficiency us*" OR "energy management" OR "resource efficiency *") AND ("behav*r" OR "attitude*" OR "habit*") AND ("campus*" OR "universit*" OR "collage*" OR "higher education" OR "HEI*" OR "higher learning" OR "IHL*").

RESULTS AND DISCUSSION

Descriptive Analysis

The search results using the Web of Science database produced 677 documents, which have been cited 5,948 times, of which 5,866 citations came from other researchers without self-citations with an H index of 35 with an average of 9.24 citations per article. Figure 1 shows the number of publications and citations from 2020 to November 3, 2024. The 677 articles reflect the growing interest in studying energy-saving behavior in higher education institutions. Based on the bibliometric analysis, there is a consistent increase in the number of publications and citations, indicating a growing interest in research in this field. This trend is projected to continue to increase along with the increasing issue of energy efficiency in the context of environmental sustainability in the higher education sector. This growth in literature provides a substantial contribution to the development of knowledge about strategies and implementation of energy-saving behavior in the campus environment.

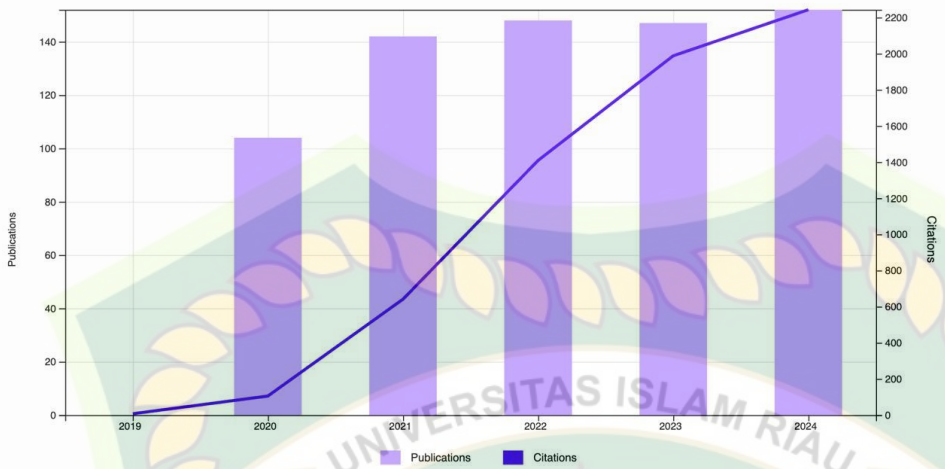

Figure 1.
Number of Publications and Citations on Energy-Saving Behavior in the WoS Database
Source: WoS database, retrieved November 3rd, 2024

Co-Citation Analysis

Using the same database, co-citation analysis presented 58 out of 3340 keywords that met 7 occurrence thresholds, resulting in four clusters. The thresholds were decided based on the strong clusters generated in the analysis with relevant underlying themes. The thresholds were determined by testing different threshold levels to find the strongest and most appropriate clusters. The threshold should not be too high, causing excessive filtering, and only a few publications should be displayed on the network map. Rejeb et al. (2022). Likewise, the threshold should not be too low, so that many clusters are repeated and are not significant in the map. Table 1 presents the top 10 documents in the co-citation analysis.

Table 1
Top 10 Documents in Co-Citation Analysis and Total Link Strength

Ranking	Publication	Number of Citation Documents	Total Link Strength
1	Ajzen i et al. (1991). Organization Behavior and Human Decision Processes	31	161
2	Ru, Wang, and Yan (2018). Exploring the effects of normative factors and perceived behavioral control on individuals' energy-saving intentions: An empirical study in eastern China	10	76
3	Abrahamse et al. (2005)A review of intervention studies aimed at household energy conservation	15	71

Ranking	Publication	Number of Citation Documents	Total Link Strength
4	Stern, P.C. (2000). New environmental theories: Toward a Coherent Theory of Environmentally Significant Behavior	14	69
5	Gao et al. (2017). Application of the extended theory of planned behavior to understand individual's energy saving behavior in workplaces	11	64
6	Du et al. (2021). Examining energy saving behaviors in student dormitories using an expanded theory of planned behavior	8	58
7	Kollmus and Agyeman (2015). Environmental Education Research	14	56
8	Delmas, Fischlein, and Asensio (2013). Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012	12	55
9	Pothitou et al (2016). Environmental knowledge, pro-environmental behavior, and energy savings in households: An empirical study	8	48
10	Yan et al. (2017). IEA EBC Annex 66: Definition and Simulation of Occupant Behavior in Buildings	11	48

Source: Created by Writing Using VOSviewer Analysis

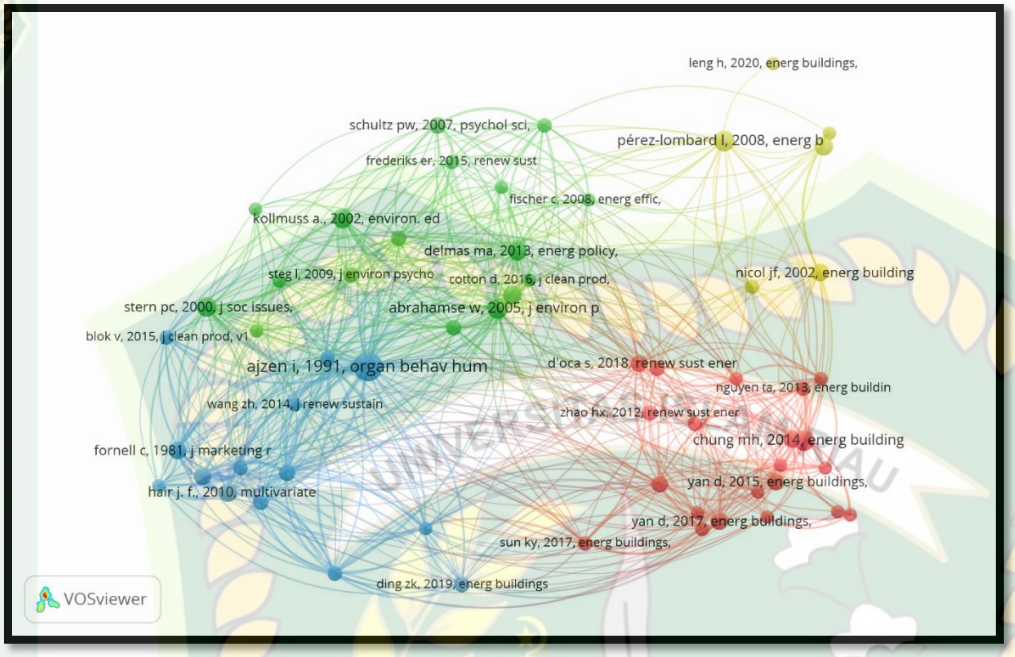

Figure 2.
Co-citation analysis of Energy Saving Behavior in the context of Higher Education Institutions
Source: Created by the Author Using VOSviewer

Table 2
Co-Citation Analysis of Energy-Saving Behavior in the Context of Higher Education Institutions

Cluster No. and Color	Representative Publication	Number of Publications	Cluster Labels
1 (red)	Azar et al. (2017);Chung and Rhee (2014); D'Oca, Hong, and Langevin (2018);Delzendeh et al. (2017);Ge et al. (2018)	21	Behavioral and Structural Approaches to Energy Efficiency and Sustainability in the Built Environment
2 (green)	Abrahamse et al. (2005);Abrahamse et al. (2007);Allcott (2011);The Last Supper (2018);Carrico and Riemer (2011)	17	A multidisciplinary approach to household energy conservation through psychology, behavioral economics, and social dynamics

3 (blue)	Ajzen (1991); Anderson(1988);Block et al. (2015);Ding et al. (2019);Du and Pan (2021)	14	Behavioral Psychology and Multidisciplinary Approaches to Promote Sustainability and Energy Efficiency
4 (yellow)	Altan (2010); Dear (1998); Fanger Po (1970); Leng et al. (2020); Nicol and Humphreys (2002)	6	Thermal Comfort Model and Its Application in Sustainable Building Environment

Source: Created by the Author Based on VOSviewer and Bibliometric Metadata

The network structure of the co-citation merger is presented in Figure 2, showing 4 clusters representing four different themes in the domain. These four clusters are labeled according to the author's interpretation. Here is a further explanation of each cluster:

Cluster 1 (Red): Behavioral and Structural Approaches to Energy Efficiency and Sustainability in the Built Environment. Consisting of 17 publications that focus on the importance of an interdisciplinary approach that combines psychological, social, and technological strategies to create long-term impacts on energy-saving behavior. Key studies in this cluster include research by Abrahamse et al. (2005), which classifies energy-saving intervention strategies into antecedent and consequence approaches. This cluster also includes research Fisher (2008), on the effectiveness of visual feedback in increasing energy awareness. As well as research by Steg and Vlek (2009), highlights the importance of environmental values and social norms in behavioral change. And Frederiks et al (2015), discuss psychological barriers and strategies to overcome them. This study highlights the importance of combining technology, psychological motivation, and social collaboration in sustainable behavior change.

The conclusion from the above explanation is that combining technology, psychological motivation, and social collaboration has proven effective in encouraging sustainable behavioral change. The use of technology such as visual feedback, reinforcement of environmental values, and social norms, as well as reduction of psychological barriers, can improve energy efficiency in the built environment. This study shows that the combination of these factors is essential to achieving sustainable behavioral change.

Cluster 2 (Green): Multidisciplinary approach to household energy conservation through psychology, behavioral economics, and social dynamics. Consisting of 16 publications investigating energy efficiency in the building sector, highlighting the role of design, technology, and operations. Key studies in this cluster include research by Hong et al. (2015,2016), which discusses the integration of technology and design strategies to improve building energy efficiency. Zhao and Magoulès (2012), examine the role of renewable energy in supporting sustainable building operations. The cluster also highlights identifying hidden energy consumption due to user habits, such as standby energy consumption (Masoso & Grobler, 2010). As well as D. Yan et al. (2015,2017), which studies the optimization of building design through simulation to reduce energy consumption throughout its life cycle. This research emphasizes the importance of technological innovation, data-driven design approaches, and user behavior in improving energy efficiency in the building sector.

The conclusion from the explanation above is the importance of technological innovation, data-based design, and understanding user behavior in improving energy efficiency in the building sector. The use of renewable energy, efficient building design, and awareness of hidden energy consumption are essential to improving overall energy efficiency.

Cluster 3 (blue): Behavioral Psychology and Multidisciplinary Approaches to Promote Sustainability and Energy Efficiency. Consisting of 14 publications that focus on human behavior theory as well as statistical approaches to understanding the factors that influence environmentally friendly behavior. Ajzen (1991)introduced the TPB as a framework for predicting human intentions and behavior, including environmentally friendly behavior. Fornell & Larcker (1981) highlights the measurement of validity and reliability in multivariate models. Hair et al. (2010) present a practical guide to the use of SEM. And Trot (2018)presents social and psychological factors that influence energy-saving behavior. This study highlights the importance of combining psychological theory and statistical analysis to understand and encourage sustainable behavior.

The conclusion from the explanation above is the importance of combining psychological theories, such as TPB, with statistical analysis approaches to understand and

encourage behavior environmentally friendly. The use of SEM and validity measurements in behavioral models provides more accurate guidance in designing sustainable behavioral interventions.

Cluster 4 (Yellow): Thermal comfort models and their application in sustainable building environments. This cluster contains 6 publications that focus on thermal comfort research and its impact on energy efficiency in buildings. Important contributions include Fanger (1970) developing a standard method for assessing thermal comfort in indoor spaces. by Dear & Brager (1998) presents an adaptive thermal comfort model and highlights how users can adapt to environmental conditions. Pérez-Lombard et al. (2008) analyze energy consumption in the building sector and offer strategies to improve energy efficiency without sacrificing user comfort. And Altan (2010)evaluates the relationship between building design, thermal comfort, and energy efficiency. This study emphasizes the need for a balance between user comfort and energy savings through innovative design and technology approaches.

The conclusion from the explanation above is the need for a balance between user comfort and energy savings. Innovative design and technology approaches that take into account user thermal comfort can improve energy efficiency in buildings without sacrificing comfort.

Co-word Analysis

Using the same database, the co-word analysis presented 59 out of 4353 keywords that met the ten-occurrence threshold with a minimum of eleven. Similarly, setting the co-citation threshold too high could potentially lead to over-filtering, so that some important clusters may not be detected. Conversely, setting the threshold too low would result in too many clusters, leading to the repetition of the same theme (Geng et al. 2020). Based on the co-word analysis, the keyword “performance” was the most frequently used keyword, appearing 106 times, followed by “consumption” with 80 occurrences and “behavior” with 90 occurrences.

Table 3
Table of Top 315 Keywords in Co-Word Analysis

Ranking	Keywords	Emergence	Total Link Strength
1	Performance	106	328
2	Consumption	80	290
3	Behavior	95	251
4	Energy efficiency	93	214
5	Buildings	50	191
6	Model	70	184
7	Design	62	181
8	Thermal comfort	48	168
9	Impact	45	163
10	Simulation	50	159
11	Efficiency	37	139
12	Optimization	47	113
13	University	25	110
14	Energy saving	37	105
15	Conservation	20	104

Note: Sorted by number of occurrences

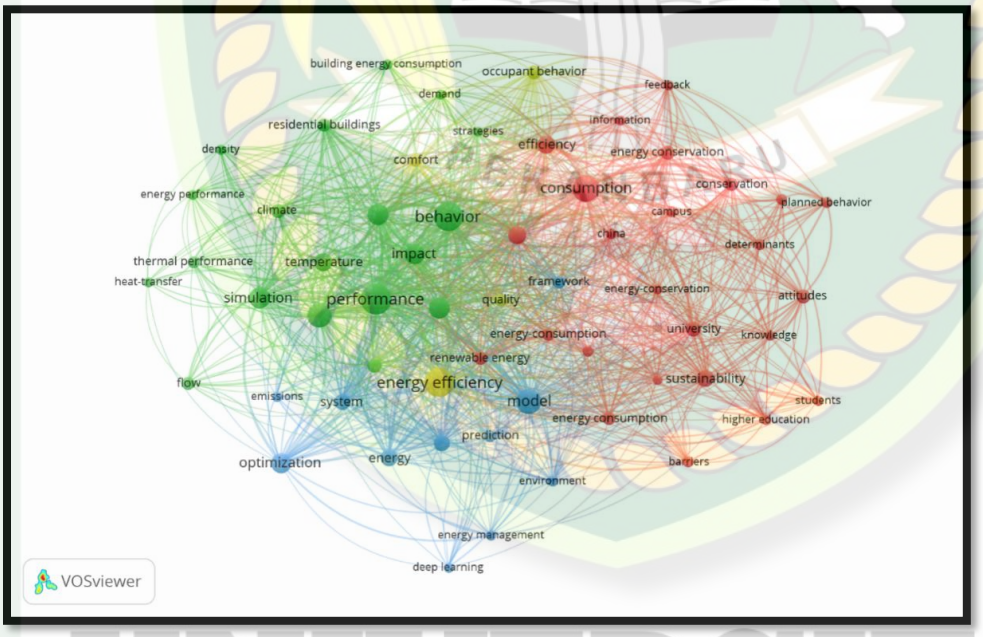

Figure 3.
Co-word Analysis of Energy Saving Behavior in the Context of Higher Education Institutions
Source: Created by Writing Using VOSviewer.

Figure 3 shows the network structure of the co-word analysis with four different clusters representing different themes. The author has labeled each cluster based on inductive interpretation. The summary of the co-word analysis is presented in Table 4, which consists of cluster numbers and colors, cluster labels, and representative keywords.

Table 4
Summary of Co-Word Analysis on Energy Saving Behavior and Higher Education Institutions

Cluster No. and Color	Representing Keywords	Number of Keywords	Class Label
1 (red)	Attitudes, barriers, campus, China, climate change, co2 emissions, conservation, consumption	25	Energy conservation behavior and barriers on campus in the face of climate change and CO2 emissions
2 (green)	Behavior, building energy consumption, buildings, climate, demand, density, design, energy performance	19	The influence of occupant behavior on building energy performance in the context of energy demand and climate change
3 (blue)	Deep learning, emissions, energy, energy management, environment, framework, management, models	11	Optimizing energy management and emission reduction through deep learning for environmental sustainability
4 (yellow)	Comfort, energy efficiency, occupant behavior, quality	4	The role of occupant behavior in improving building performance for comfort, quality, and energy efficiency

Source: Created by the Author Based on VOSviewer and Bibliometric Metadata

The network structure of the co-word analysis in Figure 3 shows four clusters representing four different themes in this domain. The four clusters are labeled according to the author's interpretation. Here is a further explanation of each cluster:

Cluster 1 (Red): Energy conservation behavior and barriers on campus in the face of climate change and CO emissions. This cluster includes 25 keywords that focus on energy behavior, psychological barriers, and social influences in the campus environment. Abrahamse et al. (2005) emphasize the importance of self-efficacy in energy-saving decision-making, which is relevant for campuses in motivating students and staff. Ajzen

(1991) stated that behavioral control and subjective norms can influence energy conservation behavior, indicating the need to build social norms on campus to reduce CO2 emissions. The study by Cotton (2016) identifies the psychological barriers faced by students in adopting energy-saving technologies, which need to be addressed to encourage energy conservation on campus.

The above explanation concludes that to encourage energy-saving behavior on campus, it is important to build self-efficacy, and social norms, and overcome psychological barriers. The formation of a supportive environment will help reduce CO2 emissions and increase the adoption of energy-saving technologies.

Cluster 2 (Green): The influence of occupant behavior on building energy performance in the context of energy demand and climate change. This cluster includes 19 keywords that focus on occupant behavior, energy consumption, and the influence of building design on energy demand. Abrahamse et al.'s (2007) study highlighted the importance of psychological factors, such as self-efficacy, in encouraging energy-saving behavior. Allcott (2011) revealed that social norms and economic incentives can reduce energy demand, relevant to energy management in campus buildings. Ajzen (1991) through the theory of planned behavior suggested that attitudes, subjective norms, and behavioral control influence occupant decisions to save energy, which is important for emission reduction and energy efficiency in buildings.

The conclusion from the above explanation is that occupant behavior, driven by attitudes, social norms, and economic incentives, plays an important role in energy management in buildings. Increasing awareness of the influence of building design can also reduce energy demand and improve energy efficiency.

Cluster 3 (Blue): Optimizing energy management and emission reduction through in-depth learning for environmental sustainability. This cluster contains 11 keywords related to energy management, deep learning, and emission reduction. Ajzen's (1991) study emphasized the role of psychology in the decision to use energy-saving technologies. Fanger (1970) showed that thermal comfort affects energy consumption, which can be optimized by a deep learning-based system. Blok et al. (2015) illustrated that the combination of

psychology and technology can improve energy efficiency, making this approach relevant in big data-based energy management for environmental sustainability.

The conclusion from the above explanation is that deep learning and big data-based approaches can optimize energy management and emission reduction. The right integration of psychology and technology will help achieve better energy efficiency and support environmental sustainability.

Cluster 4 (Yellow): The role of occupant behavior in improving building performance for comfort, quality, and energy efficiency. This cluster focuses on 4 keywords related to thermal comfort, energy efficiency, and building quality. Li et al. (2021) show that the use of materials with good thermal properties can reduce energy consumption for heating and cooling. In addition, efficient HVAC technology is also important to maintain occupant comfort and reduce energy consumption (ASHRAE, 2017).

The conclusion from the explanation above is that thermal comfort and energy efficiency can be achieved through proper design and the use of materials with good thermal properties. Efficient HVAC technology also plays an important role in supporting sustainable and energy-efficient building performance.

This research provides significant implications for the development of behavioral theory in the context of energy conservation, by emphasizing the importance of psychological factors such as self-efficacy and individual perceptions of environmental impacts, as suggested by Abrahamse et al. (2007). This enriches the understanding of how individual motivation can be influenced by internal factors in the context of energy conservation. In addition, this study also strengthens the findings of Steg et al 2009)which shows that individual motivation to save energy is greatly influenced by social norms and policies in their environment. The contribution of this research lies in the integration of the concepts of behavioral psychology and behavioral economics, which suggests that economic incentives and social norms, as described by Allcott (2011) play an important role in motivating energy conservation. This study also shows that although there are many studies discussing energy conservation, there is still limited research examining the relationship between campus energy policies and individual behavior, as expressed by Delmas (2013). Therefore, this

study opens up opportunities to develop and test behavior-based interventions in educational contexts to facilitate the adoption of energy efficiency technologies.

The findings of this study can be used by policymakers and decision-makers responsible for sustainability. The results of this study provide valuable insights into the various barriers to energy conservation efforts and strategies to overcome these challenges. As found in the study of Cotton (2016), campuses need to strengthen environmental education and outreach programs to increase student and staff awareness of sustainability and energy conservation. In addition, this study shows that implementing incentive programs based on social norms and strengthening campus policies can be effective in motivating behavioral change, in line with the findings of Steg et al. (2009) and Allcott (2011).

The researchers suggest that higher education institutions implement incentives that are not only economic but also social, to strengthen energy-saving habits among students and staff. Other recommendations include the need to develop energy policies that support energy conservation and the implementation of social norms that encourage sustainability. In addition, collaboration between campuses and external parties, such as government agencies or energy companies, is essential to support funding and increase the effectiveness of sustainability programs, as has been revealed in various studies in this area.

CONCLUSION

This bibliometric analysis review presents a perspective on energy-saving behavior in the context of higher education institutions. Through co-citation and co-word analysis, this study provides an overview of past and future research trends on energy-saving behavior specifically within the higher education institution environment. There are 677 articles on energy-saving behavior retrieved from the WoS database. Studies are steadily increasing and are expected to continue to increase in the coming years, which contributes to its significance in adopting energy-saving behaviors that focus on the influence of behavioral and social factors.

And its impact on CO2 emission reduction and sustainability efforts in the context of higher education institutions. This can ultimately improve operational efficiency and support environmental sustainability. The co-citation analysis resulted in four research themes that

represent past research trends in the area, while the co-word analysis also resulted in four themes that provide research directions for future researchers related to energy-saving behavior.

This review has several limitations that need to be considered. First, this study only focused on articles published in journals indexed by Web of Science. This selection was based on Web of Science's extensive coverage of high-quality, peer-reviewed journals and its compatibility with VOSviewer software for bibliometric analysis. However, this limitation has the potential to overlook important publications found in other databases. Therefore, future researchers are advised to expand the scope of data sources by including various types of publications and other databases. This approach can produce a more comprehensive analysis, especially since each database is unique in covering publication types, regional journals, or new topics that are not yet indexed in the Web of Science. This will increase the robustness of the analysis and advance energy-saving behavior in higher education institutions. Second, the classification of research themes in this study relies on the author's inductive interpretation, which is subjective. This subjectivity can affect the results of the theme classification, especially if different researchers interpret the network visualization, which can potentially produce themes that vary according to the research context. However, variations in the identification of these themes are common in qualitative research if the variations are still within the limits of relevance to the research context.

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