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Energy-Saving Behavior in Workplaces: A Bibliometric and Visualization Analysis

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ABSTRACT

Promoting individual energy-saving behavior is crucial to addressing environmental challenges and advancing sustainable development. While this topic has been explored in the existing literature, research specifically examining energy-saving behavior in workplaces (ESBW) through a bibliometric analysis remains scarce. This study aims to fill this gap by conducting a bibliometric approach using performance analysis and science mapping techniques to evaluate and synthesize research on ESBW. A comprehensive search strategy was employed to extract relevant documents published in the Scopus database. The collected data were analyzed using VOSviewer and RStudio software. A total of 194 documents were identified as scientifically published in this field from 2005 to 2024. The analysis highlights the most prolific sources, authors, countries, and articles. Furthermore, based on keyword co-occurrence analysis, this study found the main thematic clusters of ESBW, including energy-saving related to behavioral theories, motivational and social factors promoting sustainability, energy conservation in the workplace, and occupant behavior connected with energy efficiency. The theoretical foundation can benefit future research in developing effective policies and strategies to encourage energy-saving practices in workplace environments.

1. INTRODUCTION

1.1 Background

Energy is a central aspect of human life and development. The use of energy continues to rise as populations grow, along with the expansion of economic and industrial activities [1]. However, the excessive use of energy has created numerous environmental problems [2], linked to abundant carbon emissions, environmental pollution, and global warming [3]. According to the Centre for Research on the Epidemiology of Disasters (CRED) report, such natural hazards impacted 93.1 million people with a total of 86,473 deaths and caused US$202.7 billion in economic losses worldwide in 2023 [4]. Amongst the climate change-induced disasters include the Indonesian drought, the European heat waves, the Congo flood, the Greek forest fire, and many more. Therefore, energy efficiency and energy saving have become worldwide concerns, not only in the way energy is produced but also in its consumption patterns [5].

The building sector is one of the biggest energy consumers and a significant contributor to carbon emissions [6]. Laaroussi et al. [7] revealed that this sector consumes around 36% of worldwide energy produced and creates approximately 40% of total carbon dioxide (CO_2) emissions globally. In 2014, the Intergovernmental Panel on Climate Change (IPCC) report estimated that buildings contributed to about 32% of global energy use and 19% of energy-related greenhouse gas (GHG) emissions. The IPCC projection suggested that these figures could be doubled or tripled by 2050 [8]. In the United States, residential and commercial buildings accounted for 27.6% of the nation's total energy consumption in 2023 [9]. In this regard, reducing building-related energy use is crucial to lowering global energy consumption to achieve targeted emission reductions.

1.2 Research gap and novelty of the study

Existing literature has acknowledged the importance of occupant behavior in promoting energy savings and enhancing overall energy performance. Some of them have also employed review methods to examine occupants' energy-saving behavior in different contexts, including households and workplaces, through both manual and systematic reviews. For example, Staddon et al. [10] conclude that energy saving in the office depends not only on the employees' individual and collective actions but also on the management's commitments, broader organizational changes, and more advanced

investment in energy-efficient technology.

Despite the growing academic interest in this topic, several critical issues remain puzzling. First, previous studies examine occupant behavior from a single perspective, yet a wide range of contextual factors, such as physical environment and social norms, shape this topic. A single approach may depart from having a comprehensive and systematic understanding of the research focuses and trends [11].

Second, much research on energy-related behaviors has focused largely on the residential sector and left office environments underexplored, particularly those that examine beyond a thorough method [5, 11, 12]. Residential occupants and office workers exhibit different characteristics in terms of energy-related behavior; thus, it cannot simply be generalized [13]. Office workers have less control over the building system—for example, the lighting, heating, and air conditioning systems differ from those in the household. Additionally, they are not responsible for paying electricity bills, as the occupants are typically in the household. As a result, behavior strategies that succeed in the household may not be effective in the workplace.

Third, to the best of our knowledge, there has been no bibliometric study on energy-saving behavior in workplaces (ESBW). Several researchers have conducted bibliometric studies related to energy saving, e.g., [14]; energy efficiency, e.g., [1, 15, 16]; or energy conservation [17]. More specifically, several previous studies also examined bibliometric studies on energy saving in various contexts, such as technology [18], green wall [19], machine learning [20], agriculture [21], and building [14, 22, 23]. Although there have been bibliometric studies conducted on energy saving, bibliometric studies on individual behavior related to energy saving behavior are nonexistent. Moreover, it has never been performed in workplace settings. The workplace setting in this study refers to the physical environments or buildings where individuals engage in job-related tasks and activities. It includes offices [24, 25], factories [26, 27], commercial buildings [28, 29], hospitals [30], hotels [31, 32], and educational institutions such as schools and universities [33].

To address these gaps, a comprehensive study examining ESBW is both timely and necessary. A broader perspective may provide a deeper understanding of the complex framework and contribute to the development of a more nuanced theory on this topic [1, 2, 34]. This study employs bibliometric analysis to evaluate the body of research on ESBW. Among the available review methods, bibliometric analysis is particularly valuable for identifying influential works, tracking topic evolution, assessing progress and trends, and uncovering emerging topics [35]. It should be noted that bibliometric and other review methods are equally important. However, bibliometric offers a more comprehensive review by rigorously exploring and analyzing large volumes of scientific publications [36, 37]. Additionally, it also has the unique ability to outline the evolution, connections, and growth of the main topic in the literature [38].

Given the aforementioned gaps, this study addresses the following research questions: First, what are the current publication trends in the discussion of ESBW, with respect to timeframes, sources, authors, countries, and articles? Second, what are the key research themes of ESBW, and how can the findings on these themes be synthesized? Third, what are the gaps and potential directions for future research that need to be addressed in this rapidly evolving domain? As a contribution, this study aims to provide fresh insights into the existing literature on ESBW, identify underexplored areas, and assess the spatial relevance of these behaviors.

2. METHODOLOGY

To achieve the purpose of this study, we conducted the bibliometric approach. Bibliometric analysis is "a quantitative linguistic technique used to analyze bibliometric data in order to identify patterns and trends in a particular field of research" [39]. Meanwhile, a particular field of this study was ESBW. The phases of this bibliometric study are depicted in Figure 1.

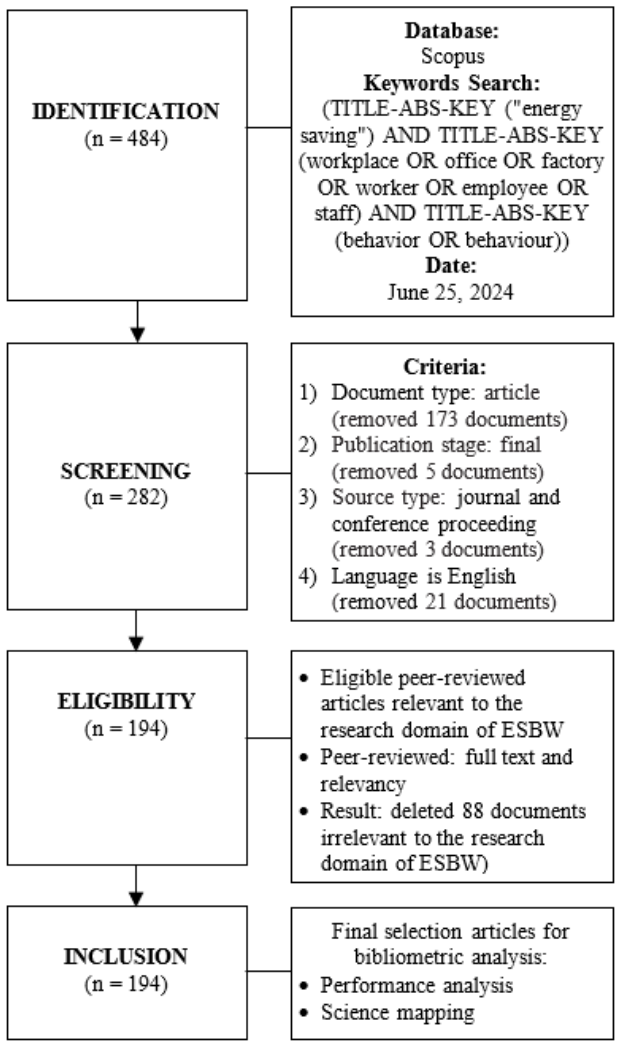

Figure 1. Data collection and cleanup process

2.1 Database selection

In this bibliometric study, we used Scopus database. Scopus was selected because (1) it provided thorough bibliometric information for the works it indexes, and (2) it included articles that met a stringent set of requirements for indexation (like being intellectually and scientifically significant) [40]. Moreover, many previous bibliometric studies on consumer behavior have only used the Scopus database, e.g., [41-43].

2.2 Data collection and cleanup

This data collection stage was conducted using the protocol of preferred reporting items for systematic reviews and meta-

analyses (PRISMA), namely identification, screening, eligibility, dan inclusion. These stages are shown in Figure 1. In identification stage, data were retrieved from the Scopus database using the following search string (TITLE-ABS-KEY ("energy saving") AND TITLE-ABS-KEY (workplace OR office OR factory OR worker OR employee OR staff) AND TITLE-ABS-KEY (behavior OR behaviour)) on June 25, 2024. This search string extracted 484 documents. In the screening stage, documents were selected based on four criteria: (1) document type is only an article, (2) publication stage is final, (3) source types are journal and conference proceedings, and (4) language is only English. This process generated 282 articles. In the eligible stage, these documents were screened further based on their relevance to the ESBW domain. Each article was once again checked and verified in full text by two team members with knowledge of ESBW. They meticulously applied the pre-defined inclusion and exclusion criteria to ensure consistent and objective selection. If there is a difference in decision between two team members, the decision is determined by all members to reach consensus. This stage also referred to previous research [44]. In this step, 88 articles were removed and the final number of documents for bibliometric analysis was 194 documents.

2.3 Bibliometric analysis

In this study, bibliometric analysis focuses on performance analysis and science mapping. The performance analysis is used to analyze data related to publication trends, top sources, top authors, top countries, and top articles. Moreover, science mapping is utilized to analyze keyword co-occurrence and thematic map. These bibliometric analyses were conducted using VOSviewer and RStudio software [42, 45, 46] that are freely available to researchers [47].

3. RESULTS

3.1 Performance analysis

Performance analysis is descriptive analysis aiming to assess the major scientific players in contributing to a given research field's scientific productivity [42]. In this study, performance analysis is used to evaluate the top publication trend, top publication sources, top authors, top country, and top article of ESBW. Before conducting the analysis, this study depicted the preliminary information about the collected data for 194 publications related to ESBW (Table 1).

3.1.1 Publication trend

Bibliometric analysis reveals different publication trends of ESBW over the past two decades. The publication trend of ESBW is shown in Figure 2. It can be seen that the research topic of ESBW shows slow growth in the early years. There is only one publication in 2005 and 2006 and none in 2007, 2008, and 2010. However, the number of publications shows an overall increasing trend from 2009 to 2023, while there are some years that experience a decrease compared to the previous year, such as in 2010, 2013, 2015, 2018, and 2023. The highest number of publications occurred in 2022 with 27 articles. In particular, this research field has experienced significant growth starting from 2014 (10 articles) and a steady increase in output in the following years, especially from 2016 onwards, where the number of publications consistently exceeds 10 articles each year. The increase in publications may have been driven by external factors. For example, the increase in publications after 2014 coincided with the increasing global attention to Sustainable Development Goals (SDGs) and energy efficiency commitments. One of them was the Paris Agreement in 2015 [48]. These global and national policies may have motivated researchers to examine ESBW. In addition, the increase in publications is also in line with the increasing changes in energy efficiency technology [49].

Table 1. The preliminary information on performance analysis

Description	Results
Main Information about Data	
Timespan	2005:2024
Sources (Journals, Books, etc.)	100
Documents	194
Annual growth rate %	10.78
Document average age	5.14
Average citations per doc	25.25
References	10051
Document Contents	
Keywords plus (ID)	1242
Author's keywords (DE)	703
Authors	
Authors	668
Authors of single-authored docs	14
Authors Collaboration	
Single-authored docs	15
Co-authors per doc	4.07
International co-authorships %	24.74
Document Types	
Article	194

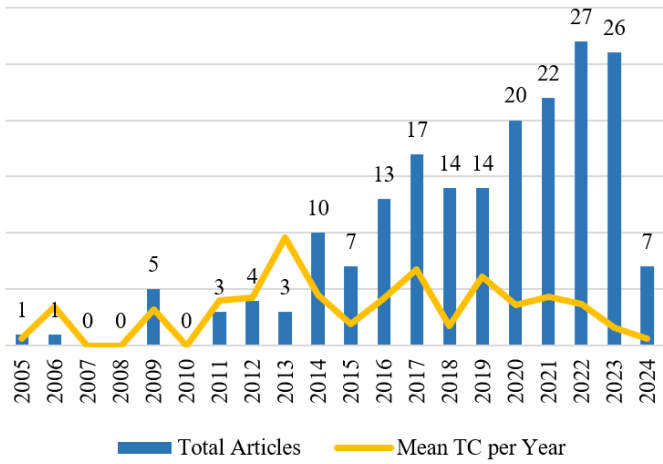

Figure 2. Total publications and average citations per year

Despite the growing number of publications, the impact of ESBW publications fluctuated from 2005 to 2024. In this study, the impact of ESBW publications was seen based on the mean total citations (TC) per year. Figure 2 shows that the highest publication impact occurred in 2013, with the mean TC per year of 9.56. In fact, in 2013, only three articles on ESBW were published. In other words, there were articles in 2013 that had a big impact. Likewise, in 2017, the average TC was 6.76 with 17 articles, indicating that 2017 also produced very influential research. However, the last few years (2021-2024) have shown a decrease in the impact of the situation. There was a decrease in the average TC to 1.56 in 2023, even though the number of articles was high. This is reasonable

because the ESBW publications from 2021 to 2024 have not been released for long. Based on the analysis, it is estimated that the number of citations may increase in the future because the citations tend to grow over time, especially considering the already large volume of publications between 2021 and 2024. Moreover, some considerations for ESBW research will increase the number of publications and citations in the coming year: (1) one of the main concerns of the SDGs' 2030 agenda is energy efficiency [50], (2) climate change will have an increasingly negative impact on human life globally if no efforts are made to address it [51-53], and (3) the use of energy-efficient devices is growing [54].

3.1.2 Top publication sources

Referring to previous research, top publication sources were analyzed by volume and citation [41, 42, 44]. The bibliometric analysis demonstrates the publication sources that have significantly contributed to the field of study of ESBW, both in terms of volume and citation impact (Table 2). Journal of Building and Environment stands out as the most prolific source, with 12 publications and a notable citation count of 735, reflecting its central influence on the subject. This journal is published by Elsevier and has been indexed by Scopus since 1976. This journal is the most prolific source because the scope of its discussion is very relevant to the theme of energy saving. Some of the subject areas discussed in this journal are renewable energy, sustainability and the environment, environmental engineering, and civil and structural engineering. In second place, Sustainability (Switzerland) published 11 articles, while Energy Research and Social Science contributed 9 articles. Other important sources include Energy and Buildings and Energies, each publishing 8 articles, and Applied Energy, with 7 articles. In terms of citations, Energy Policy and Applied Energy also demonstrated strong influence, with 345 and 297 citations, respectively. Although these journals, such as Journal of Building Engineering and Energy Efficiency, published fewer articles, they still contributed meaningfully to the discourse, with 129 and 110 citations, respectively. These findings demonstrate that the majority of journals with the highest volume also have the highest citation impact. However, it is not always consistent. For example, the Journal of Resources, Conservation, and Recycling has the second-highest number of citations (611), even though it is ranked 10th in terms of total publications. Likewise, the Tourism Management Journal received 116 citations even though only 1 article was published. In other words, it demonstrated its significant influence in the research field of ESBW, even though it published fewer articles.

Table 2. Top publication source based on volume and citation

Publication			Citation		
Rank	**Journal**	**Total**	**Rank**	**Journal**	**Total**
1	Building and Environment	12	1	Building and Environment	735
2	Sustainability (Switzerland)	11	2	Resources, Conservation and Recycling	611
3	Energy Research and Social Science	9	3	Energy Research and Social Science	363
4	Energies	8	4	Energy Policy	345
5	Energy and Buildings	8	5	Applied Energy	297
6	Applied Energy	7	6	Energy and Buildings	249
7	Journal of Building Engineering	6	7	Journal of Building Performance Simulation	146
8	Buildings	5	8	Journal of Building Engineering	129
9	Energy Efficiency	4	9	Journal of Cleaner Production	128
10	Energy Policy	4	10	Tourism Management	116
10	Journal of Cleaner Production	4			
10	Resources, Conservation and Recycling	4			

Source: Authors' elaboration based on Scopus.

3.1.3 Top authors

Top authors were examined by volume and citation, with reference to previous studies [41, 42, 44]. The bibliometric analysis identifies top authors contributing to research on ESBW based on both publication output and citation impact (Table 3). Chen Chien-Fei is the most prolific author with six published articles. She is a professor at the Department of Sociology, Anthropology and Criminal Justice, Clemson University, USA.

In terms of citation impact, Wang Shanyong stands out as the most influential author, with a total of 87 citations, even though only published two publications. One of the articles written by Wang Shanyong is an article entitled "Application of the extended theory of planned behavior (TPB) to understand individuals' energy saving behavior in workplaces". This article has become the most cited article with a total number of citations of 379. This article is the result of Wang S.'s collaboration with his colleagues at the School of Management, University of Science and Technology of China, namely Gao Lan, Li Haidong, and Li Jun, placing the three of them in second place as the most influential authors. Furthermore, Zhang Yixiang, Wang Zhaohua and Zhou Guanghui also showed substantial influence by collecting 376, 369 and 355 citations respectively from their two collaborative publications and other publications. While Chen Chien-Fei, the most prolific author, has received 274 citations, authors such as Dong Bing (240 citations) and Xu Xiaojing (208 citations) have also played an important role in shaping the research landscape.

An interesting aspect of these results is that a higher number of publications by an author does not always correlate with a higher number of citations. For instance, while Chen Chien-Fei and Xu Xiaojing are the most prolific authors with six and five publications each, Wang Shanyong, with only two publications, leads in citations with a total of 387. Likewise, Gao Lan, Li Haidong, Li Jun, who only published one article in collaboration with Wang Shanyong has garnered a higher citation count. This suggests that the citation impact is not strictly tied to the number of publications but rather the significance and visibility of the individual studies.

In the context of this study, Wang Shanyong, Gao Lan, Li Haidong, and Li Jun emerged as the researchers with the highest citations. This dominance was mainly due to their article which had a very large number of citations, surpassing other researchers who may have higher publication volumes. This article is also the most influential article in the context of

ESBW research due to its high relevance to the topic. The main contribution of this article lies in the development and extension of the TPB. TPB itself is one of the most established and widely used theoretical frameworks in understanding human intentions and behaviors, especially in environmental psychology and pro-environmental behavior. Furthermore, they empirically showed that the extended TPB model has better explanatory power than the original TPB model. The use of Structural Equation Modeling (SEM) in testing the energy-saving behavior model has also made this article an important reference for other researchers in further studies.

Table 3. Top authors based on total publication volume and citation

Publication			Citation		
Rank	**Authors**	**Total**	**Rank**	**Authors**	**Total**
1	Chen C.-F.	6	1	Wang S.	387
2	Xu X.	5	2	Gao L.	379
3	Kotsopoulos D.		2	Li J.	379
3	Bardaki C.	4	2	Li H.	379
3	Endrejat P.C.	4	3	Zhang Y.	376
3	Kauffeld S.	4	4	Wang Z.	369
3	Manika D.	4	5	Zhou G.	355
			6	Chen C.-F.	274
			7	Dong B.	240
			8	Xu X.	208

Source: Authors' elaboration based on Scopus.

Based on a minimum of three publications, the collaborations among authors are illustrated in Figure 3. While the network displays the number of collaborations, the size of the nodes indicates the number of articles written by authors [44]. Figure 3 indicates that the collaboration network is predominantly composed of authors with names that appear to be of Chinese origin. However, upon further investigation, some of them turned out to be affiliated with institutions or organizations in the United States, such as Chen Chien-Fei, Xu Xiaojing, and Dong Bing. This indicates that the collaboration among authors that occurred was not only national in nature, but also involved international networks across institutions.

Chen Chien-Fei and Xu Xiaojing have the most extensive network-based research cooperation on the study of ESBW. Five of Chen Chien-Fei's six publications were co-authored with Xu Xiaojing. They have also collaborated with Dong Bing, Menassa Carol, Li Da, etc. Among the 24 authors with at least 3 publications, the results reveal 8 different collaborative groups of authors that were separate from each other. Similar article qualities are shared by authors who belong to the same clusters [55]. These collaborative groups are usually formed by the similarity of the authors' disciplinary backgrounds. If mapped, in general, there are 4 disciplines that highlight the topic of energy-saving behavior, namely Economics and Management, Psychology, Sociology and Engineering. Several authors who are included in the collaborative group of the Economics and Management group are Wang Shanyong, who collaborated with Gao, Lan, Li Jun, Li Haidong, then there is Zhang Yixiang, who collaborated with Wang Zhaohua and Zhou Guanghui and Kotsopoulos Dimosthenis, who collaborated with Bardaki Cleopatra. Furthermore, from the Psychology group, there is Endrejat Paul Constantin, who collaborated with Kauffeld Simone because they both have expertise in the field of Industrial/Organizational Psychology. In addition, there is also Xu Xiaojing, a social psychologist who collaborates with Chen Chien-Fei, an environmental sociologist. Likewise, Dong Bing, who has an engineering background, collaborates with Chen Chien-Fei and Xu Xiaojing. So, cross-disciplinary collaboration is needed in this research topic to enrich the perspective.

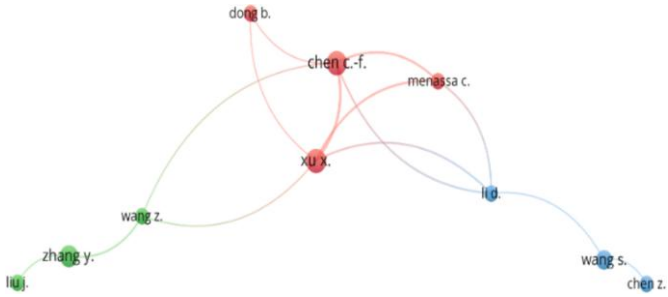

Figure 3. Co-authorship network based on authors

3.1.4 Top countries

Based on previous studies, the top countries were identified by common practice in bibliometric analysis [41, 42, 44]. The bibliometric analysis reveals top countries contributing to research on ESBW based on publication output, citation impact, and corresponding authorship (Table 4). In general, the results indicate that the top countries are dominated by developed countries. It might occur because investment in research and development (R&D spending) in developed countries such as China, the UK, and the USA is very high compared with middle-income countries [56]. They also spend huge amounts of money on clean energy, including energy efficiency [57].

China leads the field with 154 publications, making it the most prolific country in this area of research. It also dominates in terms of TC, accumulating 1,356 citations, highlighting the global influence of its research. In addition, China has the highest number of corresponding authors (39), further emphasizing its leadership role in the field. China leading top position in publications, citations, and corresponding authors can likely be attributed to its rapid growth in R&D spending, significant increase in patent numbers, and overall technological advancement in the new century [58]. Moreover, China has consistently been the world's largest investor in clean energy [57].

Following China, the UK and the USA are notable contributors, with 102 and 84 publications, respectively. However, while the UK ranks second in publication output, the USA surpasses it in citation impact, with 826 TC compared to the UK's 688. Both countries also rank highly in corresponding authorship, with the USA having 19 and the UK 16. Therefore, China, the UK and the USA are the top three, both in terms of publication output, citation impact, and corresponding authorship.

Other countries with notable contributions include Japan, which ranks fourth in both publication count (41) and corresponding authors (9), and Germany with 31 publications and 8 corresponding authors. Australia stands out with 26 publications and a relatively high citation count of 197, indicating a strong impact despite its smaller volume of research. Countries such as Greece, Italy, and Spain also contribute significantly to the research landscape, though their citation impact and corresponding author counts are more modest. Overall, the data indicate that while China, the UK, and the USA are the dominant forces in this area of research, a wide range of countries are contributing valuable insights into ESBW.

Based on a minimum of five publications, the collaborations among countries are depicted in Figure 4. It shows that international collaboration in ESBW research has occurred across multiple countries and even across three continents, namely Asia, America, and Europe. This indicates not only the global interest in the topic but also the breadth of collaboration across diverse geographic regions. More specifically, there are three key countries involved in the research collaborations on ESBW. They are the UK (13 networks), China (13 networks), and the USA (12 networks). Among the 19 countries with at least 3 publications, the results reveal 5 cluster of countries collaboration in this field: Cluster 1 (i.e., Germany, Italy, Netherland, New Zealand, Sweden, and Switzerland), Cluster 2 (i.e., Japan, Malaysia, Pakistan, and South Korea), Cluster 3 (i.e., Greece, Spain, and the UK), Cluster 4 (i.e., China, Hong Kong, and the USA), and Cluster 5 (i.e., Australia and Taiwan). An interesting aspect of these results is that the collaboration in research remains dominated by Western and Asian countries, with little to no involvement from African countries in these research partnerships.

Table 4. Top countries based on total publication volume, citation and corresponding

Publication			Citation			Corresponding		
Rank	**Country**	**Total**	**Rank**	**Country**	**Total**	**Rank**	**Country**	**Total**
1	China	154	1	China	1356	1	China	39
2	UK	102	2	USA	826	2	USA	19
3	USA	84	3	UK	688	3	UK	16
4	Japan	41	4	Australia	197	4	Japan	9
5	Germany	31	5	Japan	192	5	Germany	8
6	Greece	28	6	Italy	164	6	Italy	6
7	Australia	26	7	Hong Kong	134	6	Australia	5
8	Italy	23	8	Brazil	130	6	Greece	5
9	India	22	9	Switzerland	107	6	India	5
10	Spain	21	10	Canada	92	6	Spain	5
10	Sweden	21						

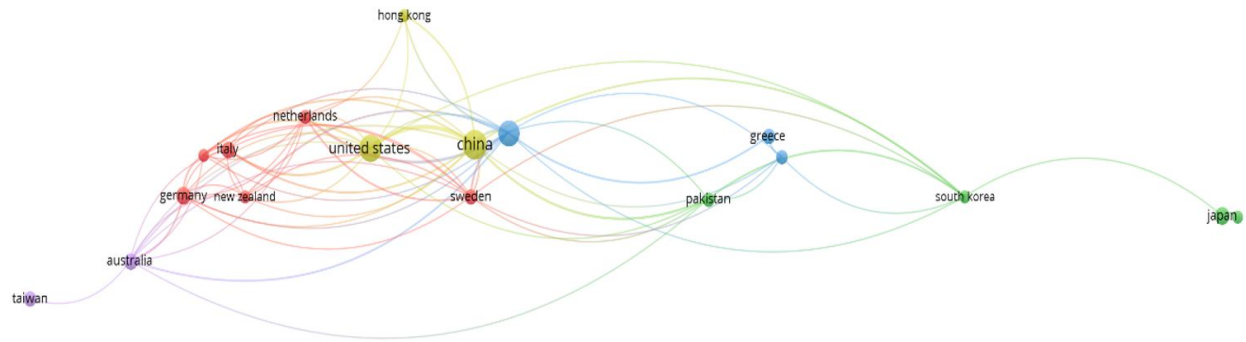

Figure 4. Co-authorship network based on countries

3.1.5 Top cited articles

The bibliometric analysis highlights the most-cited articles that have significantly contributed to the research of ESBW. The top cited article is the research work by Gao et al. [12] with 379 citations and 47.38 TC per year. It can be a top cited article for ESBW because the number of citations has continued to increase since its publication in 2017 until 2022. The article of Gao et al. [12] was published in Resources, Conservation and Recycling. It applied the TPB to examine the determinants of energy-saving behavior among individuals in workplaces. They found that attitudes, perceived behavioral control, descriptive norms, and personal moral norms play crucial roles in shaping energy-saving intentions, while subjective norms were found to have little effect. The paper by Gao et al. [12] was published in Resources, Conservation and Recycling, a journal covering subject areas in economics, econometrics, finance, and environmental science, with a focus on environmental management. As for citations, the Gao et al. [12] paper was cited by several subject areas, including environmental science, social science, energy, business management and accounting, and engineering. Conversely, the majority of authors citing this paper originated from China, aligning with the country of origin of Gao et al. [12] themselves. Aside from China, other prominent countries of origin for authors citing Gao et al.'s paper [12] include Iran, the United States, Vietnam, and Malaysia. It can be seen that ESBW is relevant to issues in developed or developing countries. Despite being published in 2017, the paper of Gao et al. [12] continues to demonstrate significant impact, as evidenced by the high number of citations it received in more recent years, particularly in 2022 and 2024.

The second most cited article is the study of Zhang et al. [5] with 257 citations published in Energy Policy. It explored the antecedents of employee electricity-saving behavior using the norm activation model (NAM), revealing that personal norms strongly influence behavior, and organizational climate can moderate this relationship. Awareness of consequences and ascription of responsibility were also found to be significant in shaping personal norms. This paper was cited by several subject areas, including accounting, environmental science, social science, energy, and engineering. The distribution of countries of origin of authors who cite Zhang et al. [5] is from the United States, South Korea, Malaysia, and Australia. An analysis of citations by publication year reveals a concentration of citations in recent years, particularly in 2024, 2023, 2022, and 2020. In other words, this suggests the paper of Zhang et al. [5] maintains its relevance within the field, despite having been published in 2013.

Other notable contributions include Hwang et al. [59], which has 157 citations and focused on occupant behavior and

thermal comfort in hot, humid climates, and Mustapa et al. [60], which studied thermal comfort and adaptive behavior in university buildings, accumulating 133 citations. Lopes et al. [61] further enriched the research landscape by integrating the TPB, NAM, and human reliability theories to assess industrial workers' energy-saving behaviors, achieving 118 citations. Additionally, newer studies like Amasyali and El-Gohary [62] used machine learning to predict cooling energy consumption in office buildings, showcasing the impact of occupant behavior on energy use. Further, Li et al. [6] proposed an integrated Motivation-Opportunity-Ability (MOA) framework to investigate energy-saving behaviors in the American workplace. Meanwhile, the more detailed information about the top articles related to top citing subject areas, countries, and years is presented in Table 5.

These results reveal several key findings. First, the top ten most-cited articles predominantly focused on developing and testing models related to ESBW. Several of these studies investigated the determinants factors of ESBW, e.g., [5, 6, 12, 61], while others, such as Hwang et al. [59] and Mustapa et al. [60], focused on thermal comfort and adaptive behavior in workplace settings. Second, all the top ten most-cited articles utilized quantitative methods, except Li et al. [63]. Moreover, the most used quantitative approach is the questionnaire survey, e.g., [5, 6, 12, 61]. Third, the TPB emerges as the most widely applied theoretical framework across these studies, e.g., [6, 12, 61, 64], highlighting its significant contribution to research on ESBW. Finally, all ten of the most-cited articles come from a single publisher, namely Elsevier, except Dong and Lam [64], published by Taylor & Francis Online. In other words, Elsevier has a concentration of high-impact publications in the research area of ESBW.

Table 5. Top articles based on TC

Rank	Authors	TC	TC per Year	Main Subject Areas of Citing Articles	Top Citing Countries	Top Citing Years
1	Gao et al. [12]	379	47.38	Environmental Science; Social Science; Energy; Business, Management and Accounting; Engineering	China; Iran; United States; Vietnam; Malaysia	2024; 2022
2	Zhang et al. [5]	257	21.42	Accounting; Environmental Science; Social Sciences; Energy; Engineering	China; United States; South Korea; Malaysia; Australia	2024; 2023; 2022; 2020
3	Hwang et al. [59]	157	9.81	Engineering; Environmental Science; Social Science; Energy; Computer Science	China; India; United States; Australia; United Kingdom	2017
4	Mustapa et al. [60]	133	14.78	Engineering; Environmental Science; Social Science; Energy; Computer Science	Japan; China; United Kingdom; Malaysia; India	2019
5	Lopes et al. [61]	118	19.67	Environmental Science; Energy; Social Science; Engineering; Business, Management and Accounting	China; Pakistan; Malaysia; United States; Vietnam	2021
6	Wells et al. [65]	116	12.89	Business, Management and Accounting; Social Science; Environmental Science; Energy; Engineering	United Kingdom; China; United States; Malaysia; Macao	2020
7	Dong and Lam [64]	111	7.93	Engineering; Computer Science; Energy; Environmental Science; Social Science	United States; Canada; China; Denmark; Australia	2018; 2017
8	Amasyali and El-Gohary [62]	109	27.25	Engineering; Energy; Computer Science; Environmental Science; Mathematics	China; United States; United Kingdom; India; Australia	2024; 2023; 2022
9	Li et al. [63]	108	9.82	Engineering; Energy; Environmental Science; Social Science; Mathematics	United States; China; United Kingdom; Spain; Canada	2021; 2020; 2017
10	Li et al. [6]	105	17.50	Social Sciences; Energy; Environmental Science; Engineering; Business, Management and Accounting	China; United States; Australia; Netherlands; United Kingdom; Italy	2023

3.2 Science mapping

Science mapping is a descriptive analysis to assess the comprehensive structural connections based on science elements to comprehend important advancements in a specific field of research [42]. Referring to previous studies, such as AlNemer [47], Farooq [66] and Farooq [67], this study conducted science mapping on keyword co-occurrence analysis and thematic mapping. Further, keyword co-occurrence analysis is employed to determine which researchers are the most representative of a given field [44]. In this study, it is used to determine the most keywords discussed in the research of ESBW. On the other side, a thematic map is conducted to identify distinct thematic clusters in the research of ESBW based on the level of development (density) and level of relevance (centrality) [47]. The results of keyword co-occurrence analysis and the thematic map are explained below.

3.2.1 Keyword co-occurrence analysis

The keywords co-occurrence network was built by VOSviewer using a frequency limit of four. It is called keyword co-occurrence when two or more keywords appear in the same article simultaneously [36]. Figure 5 depicts the visualization map result of the co-occurrence of author keywords, which shows: (1) the connection between the nodes symbolizes the co-occurrence between keywords (i.e., keywords that co-occur or occur together); (2) the node's size suggests the keyword's occurrence (i.e., the frequency with which the keyword appears); (3) the link's thickness indicates the occurrence of co-occurrences between keywords (i.e., how

many times that the keywords co-occur or occur together); and (4) each color represents a thematic cluster, wherein the keywords are part of the same cluster based on the same color [35]. Therefore, the bigger the node's size, the bigger the keyword occurrence, while the thicker the connection between nodes, the larger the occurrence of the co-occurrences between keywords [35].

Keywords co-occurrence analysis offers details on the keywords that are most frequently discussed [44]. The most appeared keywords happened to be energy saving with 48 occurrences, followed by energy efficiency (26), occupant behavior (18), workplace (9) and energy conservation (10). Further, the results identified four clusters of co-occurrence analysis (Table 6). The first cluster (marked red) is the most prominent cluster that focuses on energy-saving behavior within commercial and office buildings. Cluster 1 highlights the importance of behavioral interventions (e.g., TPB) to foster energy-efficient practices. Several previous studies have examined this topic, including Gao et al. [12], Lopes et al. [61], and Obaidellah et al. [68]. Thermal comfort also emerges as a key factor in energy-saving behavior, suggesting that balancing comfort and efficiency is central to behavior modification in workplaces.

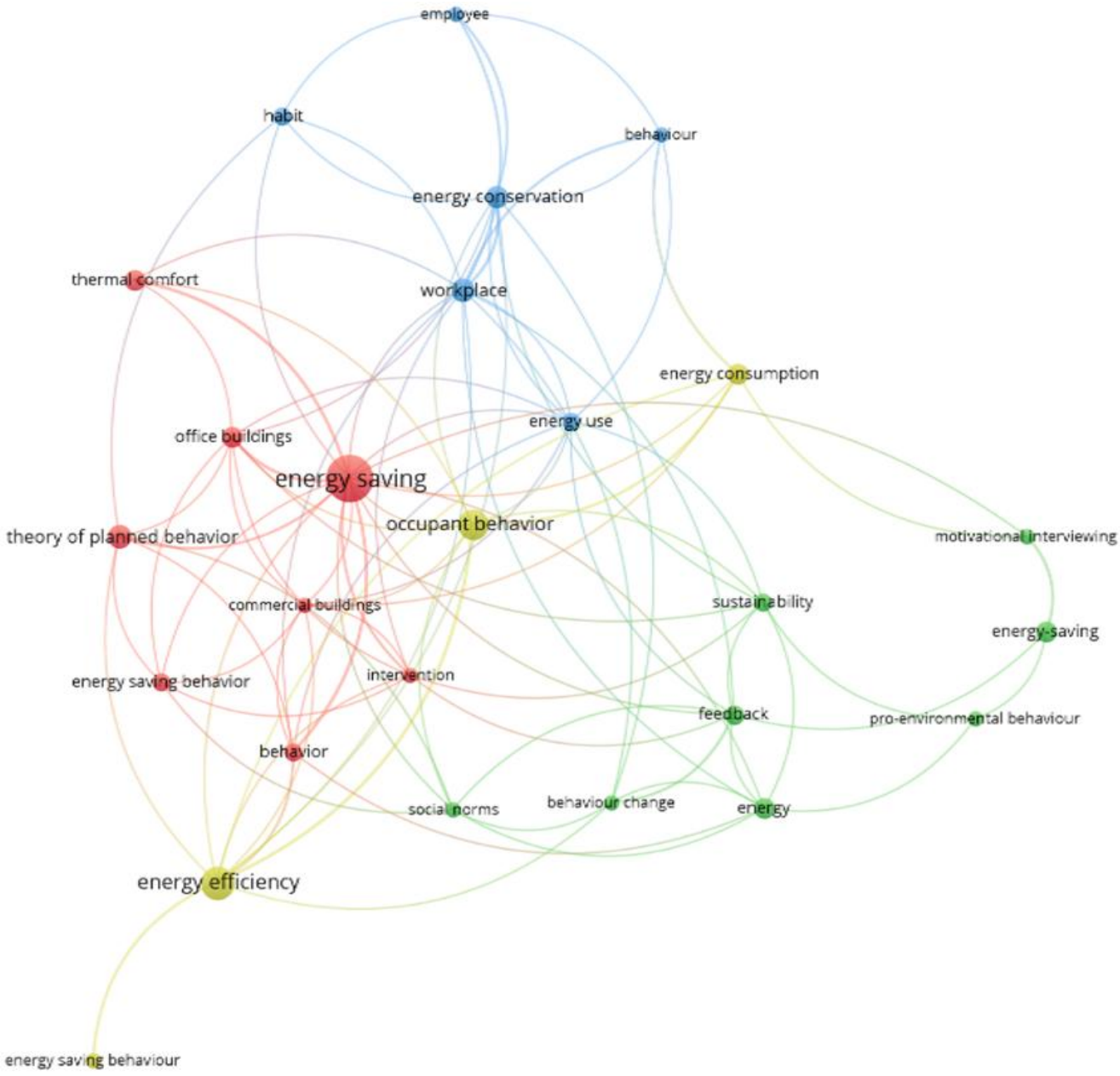

Figure 5. Visualization map of keywords co-occurrence analysis

Cluster 2 (marked green) suggests a focus on motivational and social approaches to energy-saving behavior. The use of feedback mechanisms and techniques like motivational interviewing seems central to driving behavior change. Social factors such as social norms and sustainability consciousness play a crucial role in promoting pro-environmental behaviors. In addition, cluster 3 (marked blue) connects the role of employee behavior and workplace habits in influencing overall energy conservation. The focus here is on the habitual nature of energy use at work, implying that long-term behavioral changes are required to reduce energy consumption. Cluster 4 (marked yellow) looks at energy consumption in relation to occupant behavior, which emphasizes the role of individuals within a building in driving

or reducing energy use. This final cluster focuses on energy efficiency implies a more technical or architectural perspective in tandem with behavior.

Furthermore, there are at least 96 keywords that occurred fewer than five times but have moderate to low, or even high, total link strength (TLS). Several factors may explain this pattern: the keywords might represent niche or emerging concepts, redundant or variant terms, non-standard or context-specific expressions, or semantic outliers [69-71]. For instance, keywords like "gamification", "motivational interviewing", and "norm activation model" are well-defined but narrowly used, suggesting they may be emerging concepts that have not yet gained broader traction. Some low-frequency yet high-TLS keywords might also be the result of redundant or variant terms, such as differences in spelling (e.g., "behavior" vs. "behaviour"), that fragment their representation. Non-standard or context-specific terms, like "building energy management", may also appear with limited connections to the dominant themes due to their specificity. Lastly, some keywords may function as semantic outliers, indicating highly specialized or novel tools, such as "spatiotemporal analysis".

Table 6. The theme clusters of keywords co-occurrence analysis

Cluster	Keywords	Themes
Cluster 1	Behavior; commercial building; energy saving; energy saving behavior, intervention; office buildings; TPB; thermal comfort	Behavioral theories and energy saving in commercial and office settings
Cluster 2	Behavior change; energy; energy-saving; feedback; motivational interviewing; pro-environmental behavior; social norms; sustainability	Motivational and social factors influencing energy-saving
Cluster 3	Behavior; employee; energy conservation; energy use, habit; workplace	Employee habits and energy conservation in the workplace
Cluster 4	Energy consumption; energy efficiency; energy saving behavior; occupant behavior	Occupant behavior and energy efficiency

3.2.2 Thematic map

The occurrence of keywords was mapped out based on density (y axis) and centrality (x axis) using RStudio (Figure 6). The measures of density and centrality allow the visualization of themes and their relationships in a two-dimensional map to analyze the importance and magnitude of research on the theme of investigation [47]. The centrality measures the importance of the selected theme based on the degree of correlation amongst different topics, while density measures the level of research that has already been undertaken on the chosen theme [47]. Based on the centrality and density measures, the research keywords have been plotted into four quadrants, namely (1) motor themes, (2) basic themes, (3) niche themes, and (4) emerging or disappearing themes [66, 67].

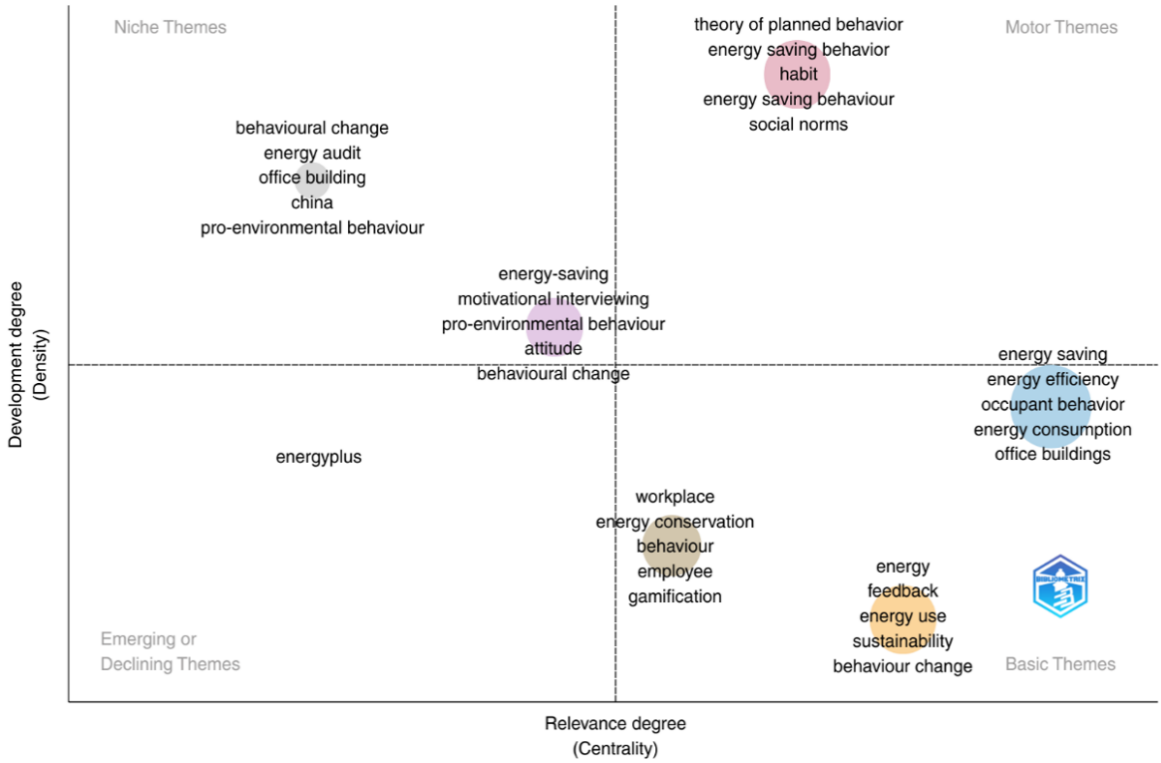

Figure 6. Thematic map based on density and centrality

Motor themes are both highly central and dense [67]. Themes of this quadrant mean that they are well-developed and important to the research field [72]. These research themes have a significant influence on ESBW and are crucial for understanding the theoretical foundations and social aspects of energy conservation. Several keywords in motor themes are energy saving behavior, habit, and social norms. The TPB emerges as a dominant framework explaining energy-saving

actions in workplace settings. This aligns with the inclusion of habit and social norms, which both play a key role in shaping energy-saving practices.

Basic themes are both highly central and slowly dense [67]. These research themes are essential to the field but are not as highly developed as motor themes [72]. This quadrant represents the foundation of workplace energy-saving research, covering practical elements like energy efficiency, occupant behavior, and workplace energy consumption. Emphasize how energy-saving and efficiency are critical concerns in workplace buildings, particularly in managing occupant behavior and energy consumption in office settings. The inclusion of employee behavior and gamification suggests innovative approaches to engage employees in energy conservation efforts. The role of feedback and sustainability in driving behavior change reflects a more dynamic approach to influencing energy use in workplaces.

Niche themes are both slowly central and highly dense [67]. These research themes are well-developed but not central [72]. In other words, they are more specialized topics within the field. In the context of this study, niche themes indicate areas that are gaining interest but may not be as widely applicable across all workplace energy-saving studies. Based on the results, the combination of motivational interviewing and pro-environmental behavior suggests a focus on psychological interventions and personal attitudes toward energy-saving. These themes reiterate the importance of gamification and employee behavior in the context of energy conservation, indicating a specialized focus on employee engagement. The inclusion of daylighting and energy audits emphasizes the role of architectural and operational interventions, particularly in optimizing energy use in office environments.

Emerging or declining themes are slowly central and dense [67]. These research themes are either emerging as new areas of interest or are in decline, reflecting trends in the research field [72]. Additionally, the emerging or declining theme of this study is energyplus. The inclusion of energyplus suggests that there is growing interest in modeling and simulating energy consumption in workplace environments. This could indicate a shift toward more data-driven and predictive approaches to managing workplace energy efficiency. In this case, in behavioral research, energyplus is most likely a disappearing one because it is a technical, engineering-focused tool. In the past, there were not many energy simulation tools available, and EnergyPlus was one of the few options [73]. However, it was very challenging to incorporate motivation or nudges into the system. Moreover, there has been a shift toward more integrated tools, like NetLogo [74], which combine technical and behavioral aspects, pushing EnergyPlus further into decline.

4. DISCUSSIONS

4.1 Theoretical contributions

This research contributes to bibliometric studies on ESBW that have been neglected by the researchers in systematic reviews, e.g., [75-77], and meta-analysis, e.g., [78-80]. Second, this study is the first study apply the bibliometric method to investigate the literature on ESBW. Although previous studies have conducted bibliometric analysis on energy-saving behavior, none have focused on workplace settings. Third, this paper demonstrated the trends, patterns, and intellectual knowledge structure of the ESBW domains. More specifically, this study identified publication trends, top publication sources, top authors, top countries, and top articles. In addition, we show a co-authorship network based on countries and authors. Fourth, this study explores emerging themes related to ESBW using science mapping. These results can help researchers in comprehending the nature of this field of study. Fifth, the study will act as a guide for researchers of various fields to evaluate the development of scientific publications in a particular theme over time, especially for those who are in the field of energy saving behaviors.

4.2 Managerial implications

In addition to its theoretical contributions, this study offers important managerial implications. Organizations should prioritize ESBW due to its numerous benefits for both the organization and the environment. By understanding ESBW and its development over time, managers can identify critical areas that require attention to improve energy saving efforts. The seminal studies identified in this research form the foundation for organizations seeking to implement energy-saving behaviors effectively. Furthermore, the study highlights key themes, domains, and articles that managers can utilize to increase organizational efficiency while promoting environmental sustainability. For those new to the field, the emerging themes provide a useful entry point to understand and engage with the latest developments in ESBW.

4.3 Future research directions

This study has identified several keywords occurrence and research themes of ESBW. However, several research themes need to be carried out in the future. Future research directions of ESBW can be carried out on research themes that have not been or are still rarely carried out by researchers. The results of this study found that TPB is the theory that is most widely applied in research on ESBW, e.g., [6, 12, 61, 64]. Another theory that has been applied is the NAM [5]. Future research can apply other theories of consumer behavior that have not been or are still rarely researched in this field. For example, protection motivation theory (PMT) explains that adoption behavior is influenced by threat appraisal and coping appraisal [61]. In other words, ESBW can be encouraged by raising threats and motivations. Referring to this theory, ESBW are influenced by six determinant factors, namely perceived severity of environmental degradation (threat), perceived vulnerability to its consequences (threat), and their response efficacy (belief that energy-saving actions can mitigate the threat), along with self-efficacy (belief in their ability to perform actions).

Further research can involve these factors to test the ESBW model. In addition, future research can also use self-concept theory (SCT). This theory explains that consumer behavior is influenced by how they view themselves [81]. There are two factors that can be used to explain behavioral changes, namely self-esteem and self-image [82]. In the context of ESBW, this theory could be applied to explore how employees' self-esteem and self-image drive them to save energy at workplaces. Further research can include these factors to test the ESBW model empirically.

Further research can also apply social learning theory (SLT). This theory explains that individuals can learn new behaviors by observing others, not just through direct

experience [83]. In the context of ESBW, further research can explore which is an effective learning model in the workplace (manager, co-worker, company leader) in promoting energy-saving behavior. Other social theories that can be applied to empirically predict the ESBW model are social identity theory (SIT) [84] and consumer culture theory (CCT) [85]. In the context of ESBW, these theories explain that employees can carry out energy-saving practices because of the similarity of values and norms of their social group to express their social identity. Therefore, further research can be applied by studying the influence of social factors, namely values, norms, and culture, on ESBW.

Hofstede's cultural dimensions (HCD) theory can also be applied to further research. HCD theory explains that cultural differences can influence individual behavior in different countries [86]. Therefore, researchers can examine cultural differences between countries in the ESBW model. For example, further research could study the cultural differences between collectivism and individualism in influencing employee compliance in implementing ESBW. In addition, further research can also test the cue utilization theory (CUT), which explains that individual assessments of a product are determined by cues or signals [87]. Related to CUT, further researchers can test the influence of the role of the existence of energy-saving labels on an electronic product to increase consumers' willingness to buy the product.

In future research, these theories can also be integrated in the development of an ESBW model. By integrating diverse theoretical frameworks, it is anticipated that a more robust and comprehensive model of ESBW can be developed. Even though this article has proposed several theories in the direction of future research on ESBW, its application still faces various challenges. Direct addition of determinant variables is not necessarily able to explain ESBW comprehensively. Therefore, the combination of theories used should be directed to build a parsimonious model that is effective and efficient in explaining ESBW. In upcoming studies, it is important to explore how the themes of this study can interact with each other. For instance, future research could explore how behavioral theories can be leveraged to design interventions that address specific employee habits, taking into account the motivational and social factors that influence these behaviors, ultimately leading to improved occupant behavior and energy efficiency within workplace settings.

Another important direction for future research on ESBW is incorporating the roles of technological advancements and evolving policy frameworks as critical enablers of behavioral change. Technological advancements, such as smart energy management systems, Internet of Things (IoT)-enabled devices, and occupancy sensors, offer automation and real-time feedback mechanisms to monitor, influence, and reinforce sustainable behaviors [88, 89]. As a result, it may shape employees' behavior by increasing awareness, providing personalized energy use data, and automating efficient responses [90, 91]. On the policy side, government regulations, green building certifications, and internal organizational energy-saving policies play a crucial role in institutionalizing sustainable practices and drive collective responsibility that shapes behavioral norms and compliance [92-94]. Therefore, future studies should explore how technology-driven interventions align with behavioral theories, such as TPB, NAM, SLT, HCD, or CUT, under varying internal and external policy scenarios. This integration will deepen our understanding of the factors driving or constraining behavioral change. Moreover, such integrative research may also support the design of more effective interventions for promoting sustainability within diverse workplace contexts.

5. CONCLUSIONS

Even though several previous studies have conducted literature reviews on energy saving behavior. This study fills the gap in previous research as there has been no previous research focusing on workplace settings. More specifically, this study primarily aims to elaborate and synthesize all the documents related to ESBW based bibliometric analysis. A total of 194 articles were identified and analyzed using performance analysis and science mapping. Based on performance analysis, the research topic of ESBW published from 2005-2024 and peaked in 2022. In addition, this study also found that: (1) the most source that published ESBW is Journal of Building and Environment; (2) the most influential author is Wang S. and the most productive authors are Chen C.-F. and Xu X.; (3) the most country based publication, citation, and corresponding is China; and (4) the most cited article titled "Application of the extended TPB to understand individual's energy saving behavior in workplaces" by Gao et al. [12].

Based on the science mapping, the keyword co-occurrences analysis indicated important research themes related to ESBW. This study found four themes cluster of ESBW: (1) behavioral theories and energy saving in commercial and office settings, (2) motivational and social factors influencing energy-saving, (3) employee habits and energy conservation in the workplace, and (4) occupant behavior and energy efficiency. This finding shows that cluster 1 is more theoretical and focused on individual psychology, while cluster 2 emphasizes social interactions and external influences. In addition, cluster 3 deals with energy conservation in the workplace environment, while cluster 4 takes a broader approach by connecting behavior to energy efficiency strategies, including architectural or technological innovations. Further, a thematic map of research on ESBW has been prepared to identify future research directions. It is evident from the analysis that future research can build on these theoretical foundations to develop more effective interventions and policies for behavior change.

We are conscious of this study's limitations, which may be taken into account for future studies. First, the data of this study are only sourced from the Scopus database. In fact, there are other databases that can be used for bibliometric analysis, for example, Web of Science (WoS). The future research can integrate the Scopus database with WoS or other databases. It may be able to produce broader findings on ESBW. Second, this study did not conduct any other bibliometric analysis, such as co-word analysis, co-citation analysis, coupling analysis, or evolution of themes. To expand the findings of this study, future research can continue with several bibliometric analyses that have not been conducted by this study. Third, this literature review research only used the bibliometric method. More specifically, performance analysis only focused on volume and citation. Therefore, further research could conduct a more in-depth analysis. Further research could also comprehensively sort out the gaps and deficiencies in existing research on ESBW. Moreover, further research can also study

ESBW using other literature review methods, for example, content analysis, meta-analysis, systematic review, semantics and scientometric analysis. Moreover, further research can integrate those analyses with bibliometric analysis.

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