Abstract

Purpose – This paper aims to analyse the bibliometric characteristics of the ISO 50001 publication, map the state of the art of the research topic and identify future research issues.

Design/methodology/approach – This research is a bibliometric study. The data were collected from Scopus. Both performance and science mapping analysis were performed.

Findings – The research results showed the top author, paper and country of ISO 50001 publications. There are four author collaboration clusters and five country collaboration clusters. Eight research themes were mapped into four quadrants based on the density and centrality. The bibliometric coupling analysis showed six research clusters. Finally, the research issues were mapped. The implications were discussed.

Practical implications – This research gave several implications for researchers, practitioners and public policymakers. For researchers, the bibliometric analysis provides several research issues that can be followed up by future research. For practitioners, the bibliometric analysis showed that applied tools and methods that can assist the implementation of ISO 5001-based energy management have been developed. For public policymakers, the bibliometric analysis offered the knowledge structure on ISO 50001 that can be used in public policymaking development. The author collaboration cluster and the bibliometric coupling cluster can be used to trace the scientific information that is needed as the foundation of public policy.

Originality/value – Many ISO 50001 studies have been performed. However, based on the search in several main academic scientific paper databases, there is no bibliometric study on the research topic. This is the first bibliometric study on ISO 50001 publication. This study takes a holistic approach combining performance analysis and science mapping analysis that includes elaborated thematic mapping and evolution analysis.

Keywords ISO 50001, Energy management systems, Bibliometric

Paper type Literature review

Thanks are conveyed to the Research Centre for Testing Technology and Standards. Do not forget the National Research and Innovation Agency’s library services in providing papers. All authors are main author.
1. Introduction

Inefficient energy utilization, which causes energy waste and increases greenhouse gas emission has become a global issue (Lira et al., 2019). Greenhouse gas (GHG) emission significantly contributes to global warming and anthropogenic climate change (Li and Tao, 2017). Related to this issue, to implement an energy efficiency-oriented management approach, the International Organization for Standardization (ISO) introduced an Energy Management Systems (EnMS) standard, namely, ISO 50001 (International Organisation for Standardization, 2011).

According to Ranky (2012), a lot of organizations have adopted ISO 50001 principles. The organizations came from various sectors, such as health care, aerospace, automotive and transportation product manufacturers and energy generation companies (Ranky, 2012). More clearly, there were more than 20,000 organizations have been ISO 50001 certified worldwide as of 31 December 2021 (ISO, 2021). This condition indicated that ISO 50001 is an essential and interesting topic to be studied.

ISO 50001 has attracted a lot of researchers. Numerous studies on ISO 50001 have been performed. Using the keyword “ISO 50001”, our search performed in March 2023 showed there were 206 papers that contained the keyword in the Scopus database. This condition indicated the need of performing bibliometric analysis on ISO 50001 literature. Bibliometric analysis is important to be performed since it can provide the overall picture of the intellectual structure of a research topic (Sousa, 2021). It also can be used to evaluate the impact of the studies previously performed on the topic as well as the author’s contribution to the topic (Kar and Harichandan, 2022). Furthermore, it can be used to assess the progress of research topics and identify future research opportunities (Sharifi, 2021). Briefly, bibliometric analysis is needed to map the state of the art of a research topic and the knowledge area of the topic that is still needed for further investigation (Ülker et al., 2022).

Bibliometric study has been performed in various environmental related study, such as green energy (Obaideen et al., 2023), climate change (Fu and Waltman, 2022), circular economy (Theeraworawit et al., 2022), waste (Li et al., 2022), ecology (Tang et al., 2022), urban ecology (Sharifi et al., 2023) and deforestation (Tan et al., 2022). However, up to date, there is no bibliometric analysis of ISO 50001 literature.

Bibliometric analysis consists of two types of analysis, namely, science mapping analysis and performance analysis (Farooq et al., 2019). Performance analysis is the descriptive analysis of the publication parameter that can be used to present the performance of the parameter such as the number of papers, author productivity and number of citations, while science mapping analysis uses network analysis among the parameters (Farooq et al., 2019). There are still a few bibliometric analysis that conducted both performance and science mapping analysis (Farooq et al., 2019). Furthermore, regarding the science mapping analysis, most researchers identified the research topic stream, trend and gaps through bibliometric coupling analysis, keyword analysis and citation analysis. The limitation of the approaches is it is difficult to map the strategic position and the evolution of the research topic. The emergence of the thematic map and thematic evolution analysis can cover the limitation. However, the use of thematic maps and thematic evolution analysis is still limited.

In the context of environmental studies, the bibliometric studies carried out also tend to be dominated by performance analysis (Fu and Waltman, 2022; Tang et al., 2022; Sharifi et al., 2023; Theeraworawit et al., 2022; Tan et al., 2022; Obaideen et al., 2023). Studies that carry out science mapping analysis are generally limited to efforts to identify themes and/or author networks (Fu and Waltman, 2022; Tang et al., 2022; Sharifi et al., 2023; Theeraworawit et al., 2022; Tan et al., 2022). Bibliometric studies that comprehensively involve performance
analysis and science mapping analysis using bibliometric coupling, thematic map and thematic evolution techniques are still very limited.

To fill the gap in the literature, this paper aimed to perform a bibliometric analysis of ISO 50001 literature. This bibliometric study performed both science mapping analysis and performance analysis. In addition to the traditional approach on science mapping analysis, this study performed a thematic map and thematic evolution analysis. More specifically, this paper answered the following questions:

**Q1.** What is the trend of the number of publications and citation of ISO 5001 literature?

**Q2.** What is the performance analysis of the author, country and paper of ISO 5001 publications?

**Q3.** What is the science mapping analysis of ISO 5001 publication in terms of author collaboration, country collaboration, bibliometric coupling, thematic map and thematic evolution analysis?

**Q4.** What is the future research issue on ISO 5001?

This research will provide significant insights into the intellectual landscape of ISO 5001 research, bridge existing knowledge gaps and guide future research attempts in the field of energy management. Unlike prior bibliometric analyses, our study takes a holistic approach. By amalgamating performance analysis and science mapping analysis that includes bibliometric coupling analysis, thematic mapping and evolution analysis, we offer a more multifaceted understanding of ISO 5001 literature. Through the application of thematic mapping and thematic evolution analysis, our study sheds light on emerging themes and trends in ISO 5001 research. This novel approach allows us to uncover shifts and developments that may not have been apparent in earlier studies. This study is among the first to specialize exclusively in ISO 5001 literature. This specialization ensures the uniqueness of our study within the broader context of energy management research.

Our study systematically maps the research trends related to ISO 50001-based energy management systems. By combining various analytical techniques, this study not only provides a comprehensive view of the intellectual terrain within ISO 5001 research but also provides scholars, policymakers and organizations with the information they need to make informed decisions and advances in the field of energy management.

The rest of the article is organized as follows. Section 2 describes the understanding of ISO 5001. Section 3 discusses the method. Database selection data collection and cleansing are properly detailed. The data analysis, comprising both performance and science mapping analysis, is also explained. Section 4 presents the results of our bibliometric analysis and provides a comprehensive discussion of the findings. Finally, in Section 5, we conclude the results of the study and address the limitations that need to be considered in future ISO 5001 bibliometric research.

### 2. ISO 50001

ISO 50001 is an international standard that was prepared by Technical Committee ISO/TC 301 “Energy management and energy savings” and Technical Committee CEN/CLC/JTC 14 “Energy management, energy audits, energy savings” (International Organisation for Standardization, 2018). This standard provides the requirements that should be fulfilled by an organization in establishing the systems and processes needed to improve its energy performance continually (International Organisation for Standardization, 2011; International Organisation for Standardization, 2018). Furthermore, the standard was developed to be the driver of GHG emission reduction (International Organisation for Standardization, 2011).
The ISO 50001 standard mandates the establishment of an energy policy for all organizations seeking certification. This policy outlines comprehensive rules and objectives aimed at reducing energy consumption through the active participation of all stakeholders (International Organisation for Standardization, 2011). This standard champions a data-driven approach, analysing measured energy consumption and additional relevant data to evaluate energy performance (EnPI) and energy baselines (EnB) (Fitzgerald et al., 2023).

ISO 50001 adopted the plan-do-check-act (PDCA) continual improvement framework (International Organisation for Standardization, 2011, 2018). Furthermore, it makes energy management become organization’s daily process business (International Organisation for Standardization, 2011, 2018). Visually, Figure 1 shows the conceptual model of ISO 50001.

ISO 50001 was first published in 2011. ISO 50001:2011 consists of seven main clauses of energy management system requirements, namely, general requirements, management responsibility, energy policy, energy planning, implementation and operation, checking and management review. In 2018, ISO 50001 was revised. ISO 50001:2018 also has seven main clauses of energy management system requirements. However, it has different main clauses of energy management system requirements with ISO 50001:2011. The ISO 50001:2018’s main clauses of energy management system requirements are the context of the organization, leadership, planning, support, operation, performance evaluation and improvement.

There are several main changes in ISO 50001:2018 compared to ISO 50001:2011 (International Organisation for Standardization, 2018). For example, the 2018 version adopted the ISO’s requirements for management system standards (International Organisation for Standardization, 2018). Therefore, the structure, core text and common terms and definitions of the 2018 version are similar with the other ISO management standards (International Organisation for Standardization, 2018). ISO 50001:2018 introduced new concepts, such as the normalization of energy performance indicators (EnPI(s)) and

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Figure 1. PDCA cycle for energy management system

Source: ISO, 2018
associated energy baselines (EnB(s)) (International Organisation for Standardization, 2018). The 2018 version provided a higher focus on the role of top management (International Organisation for Standardization, 2018). Furthermore, it clarified several concepts, such as energy review, energy performance indicators (EnPI(s)) and energy baselines (EnB(s)) (International Organisation for Standardization, 2018).

It is believed that ISO 50001 is an effective instrument for organizations to continuously improve their energy performance (Marimon and Casadesus, 2017). According to Dzene et al. (2015) and Yücel and Halis (2016), all types and sizes of businesses that provide goods or services involving energy production, use or distribution can obtain benefits from ISO 50001 implementation. Dall’O’ et al. (2020) showed that ISO 50001 implementation can reduce energy consumption. Zimon et al. (2021) found that ISO 50001 implementation can decrease costs and fulfil external stakeholder’s expectations. Fuchs et al. (2020) revealed that ISO 50001 implementation can provide several benefits, namely, reducing cost, improving productivity, company culture and image and ensuring environmental sustainability.

Although the potential benefits of ISO 50001 have been recognized in the literature, as observed by Fitzgerald et al. (2023), the relative novelty of the ISO 50001 standard compared to other major ISO standards such as ISO 90001 and ISO 14001, coupled with its applicability to diverse organizations, has resulted in the need for research that can support the implementation of ISO 50001. Considering that management system standards can be implemented in various ways and provide diverse impacts (Marimon and Casadesus, 2017), the results of ISO 50001 research can, at the very least, serve as a reference for formulating strategies and increasing the effectiveness of implementing the ISO 50001 energy management system. Hence, this paper maps out research that has been undertaken within the ISO 50001 field through a comprehensive bibliometric analysis that uses two different analysis methods: science mapping analysis and performance analysis. This holistic approach surpasses previous bibliometric studies by illuminating emerging themes, trends and shifts within the domain of ISO 50001 literature, paving the way for future research endeavours in energy management.

The following is Section 3, which discusses the methodology used in this research, providing detailed insights into the science mapping analysis and performance analysis. The section sets this research apart from previous studies.

3. Method

Bibliometric analysis was used in this study. This paper used both science mapping analysis and performance analysis. As previously mentioned, performance analysis involves the descriptive analysis of the publication parameter to present the performance of the parameter while science mapping analysis uses network analysis among the parameters (Farooq et al., 2019). The performance metrics and science mapping techniques used in this study were described in the data analysis subsection.

Bibliometric analysis involves several steps. Generally, it consists of three stages, namely, database selection, data collection and cleansing and data analysis. In the data collection and cleansing step, the method of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was used. PRISMA is widely used by previous bibliometric studies, such as Moher et al. (2015). Furthermore, based on Malapane et al. (2022), the steps of PRISMA can ensure the validity and reliability of the data. More specifically, the screening and eligibility stage ensures that the data obtained are valid since it checks the compliance of the data with the exclusion and inclusion criteria. Furthermore, the screening and eligibility stage ensures the reliability of data since it checks the inconsistency and redundancy that may be available in the data set.
3.1 Database selection
Database selection is the first step of bibliometric analysis. Several academic publication databases can be used as bibliometric analysis data sources. In this study, we selected the Scopus database as the data source. This is based on several considerations. Firstly, Scopus is the best database in terms of number of journal coverage (Falagas et al., 2008; Farooq, 2022; Zyoud et al., 2015). Scopus is the biggest academic publication database with more than 69 million papers from four basic fields, namely, Life Sciences, Physical Sciences, Social Sciences and Health Sciences (Elsevier, 2022). Secondly, it has several features that make bibliographic searches and analysis easier (Farooq, 2022), such as the “refine results” feature, “analyze search results” feature, “view citation overview” and “view cited by”. Thirdly, a lot of studies also only used the Scopus database as their data source, such as Lusmilasari et al. (2022), Shushtari et al. (2021) and Farooq (2022).

3.2 Data collection and cleansing
The data collection and cleansing of this study was performed using PRISMA. Figure 2 visualizes the data collection and cleansing process we performed. In the identification stage, a systematic search was applied in this study by using the keyword: (“ISO 50001”). The keyword should appear on the keywords sections or the title section of scientific publications included in the Scopus database. The keyword “ISO 50001” was used in the systematic search because it focused on ISO 50001 studies. The search was performed in March 2023. The search results showed there were 206 papers containing “ISO 50001” in Scopus database.

In the screening and eligibility stage, we used several inclusion criteria. Firstly, regarding the document type, we included only articles. Review, conference papers, book chapters, books, conference reviews, notes and short surveys were excluded. Secondly, regarding the source type, we included only journals. Trade journals, conference proceedings, book series and books were excluded. Thirdly, ISO 50001 should be one of the main topics/objects of the papers. The results of the screening and eligibility stage showed that 82 relevant papers were found and can be used in the data analysis stage.

Figure 2.
Preferred reporting items for systematic reviews and meta-analyses (PRISMA)

Source: Authors’ own creation
3.3 Data analysis
The bibliometric analysis performed consisted of performance and science mapping analysis. The performance analysis included the publication distribution per year and the performance of the author, paper, and country. Two indicators of performance used were the number of documents and the number of citations. The science mapping analysis consisted of co-authorship network analysis, country co-authorship network analysis, and bibliographic coupling analysis. Furthermore, the science mapping analysis also included a thematic map and evolution analysis. The analysis was supported by VOSviewer and R-Bibliometrix software.

Having discussed the methods used in this study, the next section presents a comprehensive discussion of results, findings, and implications of this study.

4. Result and discussion
There were 82 papers filtered according to the methodology. The general information of the papers can be seen in Table 1. The studies on ISO 50001 took place from 2011 to 2023 (March). The papers were spread across 51 journals. There were 247 unique keywords regarding ISO 50001 studies. In terms of authors, 262 authors have published papers related to ISO 50001, with only six people detected as single authors. This indicated that most of the ISO 50001 papers were the result of a collaboration process. The level of collaboration per paper was 3.6. This means a paper was averagely produced by three up to four authors. The level of international writing collaboration was identified as 21.95%.

4.1 Performance analysis
4.1.1 Document and citation trends. During the past ten years (2011–2023/March), the trend of ISO 50001 publication tends to be increased (see Figure 3). The peak of the increase occurred in 2020. There was a sharp increase from 10 papers in 2019 to 19 papers in 2020. However, the opposite condition happened for the citation trend of ISO 50001 publication.

<table>
<thead>
<tr>
<th>Description</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timespan</td>
<td>2011:2023</td>
</tr>
<tr>
<td>Sources (Journals)</td>
<td>51</td>
</tr>
<tr>
<td>Documents</td>
<td>81</td>
</tr>
<tr>
<td>Document average age</td>
<td>4.65</td>
</tr>
<tr>
<td>Average citations per documents</td>
<td>14.52</td>
</tr>
<tr>
<td>References</td>
<td>3,630</td>
</tr>
<tr>
<td><strong>Document contents</strong></td>
<td></td>
</tr>
<tr>
<td>Keywords plus (ID)</td>
<td>496</td>
</tr>
<tr>
<td>Author's keywords (DE)</td>
<td>247</td>
</tr>
<tr>
<td><strong>Authors</strong></td>
<td></td>
</tr>
<tr>
<td>Authors</td>
<td>262</td>
</tr>
<tr>
<td>Authors of single-authored docs</td>
<td>6</td>
</tr>
<tr>
<td><strong>Authors collaboration</strong></td>
<td></td>
</tr>
<tr>
<td>Single-authored docs</td>
<td>6</td>
</tr>
<tr>
<td>Co-authors per doc</td>
<td>3.6</td>
</tr>
<tr>
<td>International co-authorships %</td>
<td>21.95</td>
</tr>
<tr>
<td><strong>Document types</strong></td>
<td></td>
</tr>
<tr>
<td>Article</td>
<td>82</td>
</tr>
</tbody>
</table>

Source: Authors’ own analysis using R-bibliometrix

Table 1. General information of ISO 50001 papers
In general, the trend of the citation of ISO 50001 publications tends to be decreased. Specifically, it can be seen that although in 2020 there was a peak in the number of ISO 50001 publications, the number of citations was similar to the previous years. This indicated that ISO 50001 papers tend to cite more papers outside the ISO 50001 publication than the ISO 50001 publications themselves. Furthermore, this indicates a broader and evolving ISO 50001 research landscape. This phenomenon occurs for several reasons. Firstly, ISO 50001 is increasingly recognized as a best practice in energy management that can be implemented in various sectors. Secondly, the growing encouragement to integrate ISO 50001 with other standards like ISO 9001, ISO 45001 or ISO 14001 necessitates broader
references in research. Thirdly, the nature of energy management research demands a wider range of disciplines and sources (Cohen et al., 2021).

4.1.2 Top author. This subsection elaborates on the authors who were actively researching ISO 50001. Figure 5 displays the top ten authors of ISO 50001 publications based on their number of ISO 50001 publications. Morejón M.B. and Ochoa G.V. are the authors with the highest productivity in publishing ISO 50001 study. Both Morejón M.B. and Ochoa G.V. have produced three ISO 50001 publications. Based on the perspective of research continuity, it appeared that Morejón M.B. published the ISO 50001 study more consistently for three consecutive years (see Figure 6). Meanwhile, Ochoa G.V. published the ISO 50001 study for two consecutive years, although the number of papers produced is the same as Morejón M.B.

Morejón M.B. has consistently researched the implementation of an ISO 50001-based approach in energy planning and management from 2018 to 2020. Morejón M.B. conducted an

Sources: Authors’ own analysis using R-bibliometrix

Figure 5. Top ten authors of ISO 50001 publication based on the number of published papers

Figure 6. Top ten ISO 50001 publication author’s production over time

Sources: Authors’ own analysis using R-bibliometrix
ISO 50001 study in the context of industrial laundry, battery factories and university buildings (Angarita et al., 2019; Madrigal et al., 2018; Ocampo Batlle et al., 2020). Meanwhile, Ochoa G.V. conducted ISO 50001 research from 2019 to 2020. For two years, Ochoa G.V. produced three ISO 50001 publications related to the efficiency level resulting from implementing ISO 50001. Ochoa G.V. conducted a study on measuring the level of efficiency obtained by implementing ISO 50001-based energy management in pyrotubular boilers and the paper manufacturing industry (Blanco et al., 2020; Ochoa et al., 2019b). In addition, Ochoa G.V. conducted a survey study of 14 companies in the Colombian Caribbean Region industrial sector that had implemented ISO 50001 and its impact on efficiency levels (Ochoa et al., 2019a).

4.1.3 Top country. There are 39 countries actively performed ISO 50001 study. Table 2 displays the top ten countries performing research on ISO 50001. Colombia has the highest degree of ISO 50001 publication productivity (22 publications). Based on Table 2, it can also be seen that developed countries dominate the ISO 50001 study. This indicated that developed countries more care about sustainability energy issues and/or GHG emission related issues. Further elaboration on this issue can be found in the discussion section.

4.1.4 Top paper. This subsection discusses the ISO 50001 publications that have a noteworthy influence. The impact of a paper was measured by using Total Citation per Year (TCpY). As shown in Table 3, the paper by Jovanović and Filipović (2016) has the maximum

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of publication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colombia</td>
<td>22</td>
</tr>
<tr>
<td>USA</td>
<td>14</td>
</tr>
<tr>
<td>Spain</td>
<td>12</td>
</tr>
<tr>
<td>China</td>
<td>9</td>
</tr>
<tr>
<td>Ireland</td>
<td>9</td>
</tr>
<tr>
<td>Serbia</td>
<td>9</td>
</tr>
<tr>
<td>Brazil</td>
<td>8</td>
</tr>
<tr>
<td>Germany</td>
<td>8</td>
</tr>
<tr>
<td>Italy</td>
<td>6</td>
</tr>
<tr>
<td>Iran</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 2.**
Top ten countries of ISO 50001 publication

Source: Authors’ own creation

<table>
<thead>
<tr>
<th>Paper</th>
<th>DOI</th>
<th>Total citations (TC)</th>
<th>TC per Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ates Sa, 2012, Energy</td>
<td>10.1016/j.energy.2012.03.032</td>
<td>96</td>
<td>8.00</td>
</tr>
<tr>
<td>Jovanović B, 2016, J Clean Prod</td>
<td>10.1016/j.jclepro.2015.10.023</td>
<td>82</td>
<td>10.25</td>
</tr>
<tr>
<td>Antunes P, 2014, Energy Policy</td>
<td>10.1016/j.enpol.2014.06.011</td>
<td>82</td>
<td>8.20</td>
</tr>
<tr>
<td>Marimon F, 2017, Sustainability</td>
<td>10.3390/su9101740</td>
<td>46</td>
<td>6.57</td>
</tr>
<tr>
<td>Bottcher C, 2016, J Clean Prod</td>
<td>10.1016/j.jclepro.2014.06.013</td>
<td>44</td>
<td>5.50</td>
</tr>
<tr>
<td>Chiu Ty, 2012, Energies</td>
<td>10.3390/en5125324</td>
<td>43</td>
<td>3.58</td>
</tr>
<tr>
<td>Jovanović B, 2017, J Clean Prod</td>
<td>10.1016/j.jclepro.2017.06.140</td>
<td>37</td>
<td>5.29</td>
</tr>
</tbody>
</table>

**Table 3.**
Top ten ISO 50001 publications

Source: Authors’ own creation
impact (10.25 TCpY) compared to other papers. This paper discussed the ISO 50001-based energy management maturity model. More specifically, the model can be used to measure the maturity level of ISO 50001-based energy management that was implemented by an organization. The model was applied and tested in four ISO 50001-certified organizations. It was concluded that the model is generic and can be used in both the service and manufacturing sectors. Furthermore, the model can be used as a foundation for national awards for excellence in the energy sector. The acquired data from the award can be used as the baseline for benchmarking research in many fields and countries.

4.2 Science mapping analysis
4.2.1 Author collaboration network. To understand the collaboration network of the ISO 50001 publication authors, co-authorship network analysis was conducted. Figure 6 depicts the results of the co-authorship network analysis. Figure 7 shows that there are only four biggest co-authorship clusters among the ISO 50001 publications analysed. This suggested that the collaboration in the study of ISO 50001 from 2012 to 2023 (March) is low. More clearly, Table 4 displays the four co-authorship clusters that were generated. There are five

Sources: Authors’ own analysis using VOSviewer
authors in the first cluster, four authors in the second and third and three authors in the fourth (see Table 4).

The first cluster of five authors focuses on exploring the critical success factor of ISO 50001 implementation (Mahmood et al., 2022a, 2022b). The second cluster was formed by the collaboration among Cañón-Zabala G., Garcia-Díaz J.C., Poveda-Orjuela P.P. and Pulido-Rojano A. The four authors collaborated to research the integration of ISO 5001 with other components of comprehensive management systems and their impact on energy performance (Poveda-Orjuela et al., 2019, 2020).

The third cluster focuses on studying the application of the ISO 50001 approach in energy planning and management (Angarita et al., 2019; Madrigal et al., 2018). The last author collaboration cluster that was formed consisted of three authors. This cluster researched to find out the current situation regarding the ISO 50001 implementation in the hospitality industry (Rajić et al., 2020, 2022).

4.2.2 Country collaboration network. To understand the country collaboration in studying ISO 50001, country co-authorship network analysis was performed. Figure 8 shows the results of country co-authorship network analysis of ISO 5001 publications. Based on the differences in node colours, there are five primary clusters of country collaboration networks. Furthermore, the size of the node represents the publication contribution of a country (Wahid et al., 2020). The major country, which has the highest contribution on the topic, is the country with the greatest size of node (Farooq, 2022; Wahid et al., 2020). Given this, the major countries of the five clusters of ISO 50001 publications are the USA, Colombia, Iraq, Ireland and Brazil, ordered from Cluster 1 to Cluster 5 (Table 5). Furthermore, even though the countries studying ISO 50001 are both eastern and western countries, the country collaboration analysis shows that the country collaboration that involves both eastern and western countries is very limited. Further elaboration on this issue can be found in the discussion section.

4.2.3 Thematic map. This sub-discussion explores the research main themes of ISO 50001 publications and their strategic position. To understand the strategic position of the research themes, based on Cobo et al. (2015), thematic mapping analysis was performed. The analysis used centrality and density of keywords as the criteria for mapping the strategic position. Centrality, which quantifies the extent to which a keyword network interacts with

<table>
<thead>
<tr>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ajmi A.A.</td>
<td>Cañón-Zabala G.</td>
<td>Eras J.C.</td>
<td>Maksimović R.M.</td>
</tr>
<tr>
<td>Jamaludin K.R.</td>
<td>García-Díaz J.C.</td>
<td>Herrera H.H.</td>
<td>Milosavljević P.</td>
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<tr>
<td>Kaidi H.M.</td>
<td>Poveda-Orjuela P.P.</td>
<td>Morejón M.B.</td>
<td>Rajić M.N.</td>
</tr>
<tr>
<td>Mahmood N.S.</td>
<td>Pulido-Rojano A.</td>
<td>Santos V.S.</td>
<td></td>
</tr>
<tr>
<td>Talib H.H.A.</td>
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<td></td>
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</tr>
</tbody>
</table>

Source: Authors’ own analysis using VOSviewer

Figure 8.
Results of country co-authorship network analysis of ISO 5001 publications

Sources: Authors’ own analysis using VOSviewer
other keyword networks (Cobo et al., 2015), represents the importance of the theme in the research area (Tanwar et al., 2022a). Density, that measures the internal strength of a network or the degree to which these words are interconnected (Cobo et al., 2015), represents the development level of the theme (Tanwar et al., 2022a). We can divide the themes into four categories based on their centrality and density (Cobo et al., 2015):

1. Motor themes: important and well-developed research field structuring themes. They are in the upper-right quadrant of the strategic map.
2. Niche themes are extremely specialized and peripheral topics. This location is in the upper left quadrant.
3. Emerging or declining themes are represented by themes with low density and low centrality. Lower left quadrant.
4. Basic themes are significant themes that have not yet been thoroughly explored in the research field. These themes, located in the lower right quadrant, are fundamental, general and cross-disciplinary to the research field.

The results of the thematic mapping analysis are shown in Figure 9. Figure 9 shows the mapping of the themes based on four quadrants (Cobo et al., 2015). There are eight nodes in the map which can represent eight themes. The theme was inferred from the keyword cluster formed by the thematic analysis. Based on Figure 8, it can be seen that “energy management system” and “management maturity” are in the first quadrant. Thus, ISO 50001 research themes related to “energy management system” and “management maturity” can be classified as motor themes. In other words, these themes are highly important and well-developed. “Decision making” has high density and moderate centrality. This indicated ISO 50001 research theme related to “decision making” is well-developed. However, the importance of the theme is moderate. “Energy conservation” has high centrality and moderate density. This indicated that the ISO 50001 research theme related to “energy conservation” is highly important. However, the theme still needs to be developed. In the second quadrant, there is a theme, namely, “comprehensive management”. This means the theme is considered extremely specialized and peripheral. In other words, even though the ISO 5001 research theme related to “comprehensive management” is highly important, the theme is still not well-developed. “Regression analysis” and “benchmarking” are in the third quadrant. This means the themes are unimportant and weakly developed. Based on the position of the theme in the quadrant, it can be seen that the ISO 50001 research theme related to “regression analysis” can be categorized as a declining theme.

<table>
<thead>
<tr>
<th>Cluster 1</th>
<th>Cluster 2</th>
<th>Cluster 3</th>
<th>Cluster 4</th>
<th>Cluster 5</th>
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<td>Austria</td>
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<td>Ireland</td>
<td>Brazil</td>
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**Source:** Authors' own creation
“benchmarking” can be categorized as an emerging theme. ISO 50001 research themes that can be classified as basic themes are “sustainability” and “energy conservation”. These research themes are in the fourth quadrant. This means the themes are important but weakly developed.

4.2.4 Thematic evolution. ISO 50001 was first published in 2011 and was updated in 2018. Given this, it is necessary to carry out an in-depth exploration of whether there has been a change in the study theme related to ISO 50001 in the 2011–2018 and 2019–2023 periods. The method used by Cobo et al. (2011) is also applicable to the research theme of evolution analysis. Basically, in the 2011–2018 period, there were five major themes in studies related to ISO 50001 (see Figure 10). In this period, the ISO 50001 research themes related to “benchmarking”, “climate change”, “energy management”, “investments” and “environmental management” have received high interest from the scientific community. In the 2019–2023 period, four topics (except “investments”) previously discussed reappeared in this period, and two new study themes emerged regarding “energy policy” and “energy performance”.

Figure 10 assists the analysis of the changing themes between the analysis periods. In detail, we can see that “benchmarking” has evolved to remain the same in the following period. Meanwhile, “climate change” evolved to remain the same, and a small part evolved into “energy management”. “Energy management” evolved into four other study themes: “climate change”, “energy performance”, “energy management” and a small part, “energy policy”, in the 2019–2023 period. “Investments” disappeared and evolved into “energy performance” in the 2019–2023 period. “Environmental management” evolved into three other research themes: “environmental management”, “energy management” and “energy policy” in the 2019–2023 period.
4.2.5 Bibliographic coupling. Figure 11 shows the ISO 50001 bibliographic coupling network that formed. It appears that six groups of bibliographic pairs have been formed. Table 6 shows the details of members (articles) belonging to the same group of bibliographic pairs. The same group indicates that the articles have similarities in terms of the source of the

Source: Authors’ own creation
The elaboration of the meaning of each group of bibliography pairs can be inferred based on the central node in that group. The central node of the first cluster is Laskurain et al. (2017). Based on Laskurain et al. (2017), it can be stated that the first cluster focused on the research theme of the relationship between environmental management and energy management. Jin et al. (2021) is the central node of the second cluster. Based on Jin et al. (2021), it can be inferred that the second cluster investigated the energy management maturity model. The third cluster has Sola and Mota (2020) as the central node. Based on Sola and Mota (2020), the third cluster focuses on the influencing factors of energy management implementation. Jovanović and Filipović (2016) is the central node of the fourth cluster. This cluster focused on energy management benchmarking. The central node of the fifth cluster is Jovanovic et al. (2017). Based on Jovanovic et al. (2017), it can be inferred that this cluster investigated the implementation process of the energy management system. Păunescu and Blid (2016) is the central node of the sixth cluster. The sixth cluster focused on the energy management system design and planning.

### 4.3 Discussion

Based on the performance analysis and science mapping analysis on ISO 50001 publication, it can be generated several issues related to ISO 50001 research. Regarding the theme of the
ISO 50001 publications, it can be revealed that several major themes have been explored. Briefly, the research themes can be divided into two streams. The first stream is the applied research stream. Under this research stream, the researcher tried to develop and propose applied tools and methods that can assist the implementation of energy management, such as the energy management maturity model (e.g. Jin et al., 2021), energy management system planning, design and implementation process (e.g. Mahmood et al., 2022a, 2022b; Ochoa et al., 2019a, 2019b), energy efficiency measurement method (e.g. Schützenhofer, 2021), comprehensive management framework (e.g. Mahmood et al., 2022a, 2022b; Poveda-Orjuela et al., 2020), investment cost (e.g. Karim et al., 2020; Ocampo Batlle et al., 2020) and benchmarking method (e.g. Rajić et al., 2022). Based on thematic map analysis, it can be revealed that the themes under this stream tended to have an important role and well-developed. Based on the author collaboration network analysis, the author collaboration tended to be formed to study this theme stream. This indicated the maturity and sustainability development of the first theme stream.

The second stream of ISO 50001 publication can be categorized as the theoretical research stream. Under this research stream, the researcher tried to understand the phenomenon of ISO 50001 implementation. More specifically, the researcher investigated the factors influencing energy management system implementation (e.g. Tanwar et al., 2022a, 2022b) and the impact of the energy management system implementation, such as sustainability (e.g. Grudzien and Osinski, 2022) and energy performance (e.g. Halis and Halis, 2022). Based on the thematic map analysis, the themes under this research stream can be categorized as basic themes. This indicates the themes are important. However, the themes are not well-developed. The author collaboration network analysis also indicated there is no optimum collaboration effort on this theme.

The high level of novelty and dynamics in the energy sector has led to the need for solutions to address the challenges of energy utilization, such as renewable energy transformations, emission reductions, smart transmission and distribution systems and energy-efficient buildings (Schmidt and Weigt, 2015). In addition, in terms of energy sector policies, decision makers need scientific support in dealing with the transformation process (Negro et al., 2012). This condition causes applied research in the energy sector to be more attractive and developed than theoretical research. In addition, the complexity of the energy sector in research increasingly requires interdisciplinary collaborations (Negro et al., 2012).

Another reason that makes applied research streams dominate the ISO 50001 literature could also be because ISO 50001 is an international standard which is seen as a best practice in energy management (Marimon and Casadesus, 2017). This standard was formulated based on the consensus of many countries and involved experts (International Organisation for Standardization, 2018; Marimon and Casadesus, 2017). Therefore, researchers are more inclined to prioritize the tools and supporting devices needed to implement these standards. This is because the management system standards issued by ISO tend to be generic so when applied they require tools and supporting methods (Marimon and Casadesus, 2017).

Given the complexity of the energy sector, it does not only require scientific collaboration but also the theoretical research theme is important to be further studied (Schlüter et al., 2022). This is because research on this theme can provide important findings that can increase the understanding of ISO 50001 implementation phenomenon. The findings can be used as the foundation for developing applied tools and methods that can assist the implementation of ISO 50001-based energy management. In performing research on a theoretical research theme, to strengthen the foundation of the finding and provide a more comprehensive understanding of the phenomenon, the researcher may involve several management grand theories, such as resource-based view theory (Freeman et al., 2021).
industrialization/organization theory (Davis and DeWitt, 2021) and information asymmetric theory (Phillips et al., 2023), that are relevant with the phenomenon being studied. Existing research on ISO 50001 publication tended not to involve management grand theory.

Regarding the context of ISO 50001 publications, the bibliometric analysis provided an interesting issue. From the country analysis, it can be stated that various countries have performed ISO 50001 research. However, most countries studying ISO 50001 can be categorized as developed countries. This condition indicated the need to perform ISO 50001 research in the context of developing countries.

The fact that the majority studies on ISO 50001 were performed indicated that developed countries are more care on sustainability energy issues and/or GHG emission-related issue. Developed countries contribute 75% of CO₂ emissions to the planet (Shoaib et al., 2020). This is because developed countries are the highest energy users (Doğan et al., 2021). Pollution caused by developed countries has an impact on the environment which is getting worse and this prevents developing countries from investing in environmental issues (Seetanah et al., 2018). Fossil energy sources are non-renewable energy but the higher demand will have an impact on environmental sustainability and economic growth so developed countries must restructure energy consumption (Lira et al., 2019). To reduce emissions of GHG and increase energy efficiency, the implementation of ISO 50001 is important. ISO 50001 certification is the highest in European countries, but China shows a significant increase every year and leads East Asia and the Pacific (Lira et al., 2019). Indirectly, ISO 50001 has been widely adopted by countries with high energy consumption and industrial countries.

In terms of country geography, the countries studying ISO 50001 are both eastern and western countries. However, based on the country collaboration analysis, there is a very limited country collaboration that involves both eastern and western countries. This low level of collaboration is possible due to a different focus in terms of energy security. Western countries have a faster renewable energy transition than eastern countries (Mata Pérez et al., 2019). It is well-known that in 2019 the European Union (EU) was mandated to make the energy transition the main policy (Tagliapietra et al., 2019). The EU has the potential to become a global leader in terms of low-carbon technologies, such as wind turbines, electric cars and new-generation batteries (Tagliapietra et al., 2019). This shows that the EU has a more prepared energy transition. In addition, Gavin and Lee (2007) states that the EU countries cooperate with oil-producing countries such as Russia, in contrast to Northeast Asian countries which do not cooperate and tend to compete in terms of energy resources although currently Japan is starting to open up in terms of cooperation. This phenomenon indicates low collaboration from eastern countries. Meanwhile, achieving the goal of reducing GHG emissions requires contributions from all countries and this can be accelerated by collaboration from various countries, between developed and developing countries, eastern and western countries. Western countries can be a model of the energy transition of eastern countries (Gavin and Lee, 2007).

The bibliometric analysis, especially the thematic analysis, also provided interesting research issues regarding the research method. It was revealed that the use of regression analysis can be categorized as a declining theme. The phenomenon related to the implementation of management systems is a complex phenomenon. Furthermore, the explanation of this phenomenon generally involves the role of factors that mediate the relationship between factors (Rachmawati et al., 2019). On the other hand, regression cannot be used to test a research model that involves mediating factors (Nooy, 2023). Regression analysis is also prone to have deficiencies in low accuracy and sensitivity to unbiased values so it is less able to handle non-linear data (Caballero et al., 1997).
Therefore, regression analysis is less desirable in terms of predictions and looking at causal relationships (Nooy, 2023).

4.4 Implications
Our study has far-reaching implications that extend to both the academic and practitioner domains, enriching the understanding and application of ISO 50001-based energy management.

4.4.1 Academic implication. For researchers, our bibliometric analysis provides several research issues that can be followed up by future research. Firstly, it was important to perform future research on theoretical research stream in ISO 50001 implementation phenomenon. Secondly, it was essential to conduct more ISO 50001 studies in the context of developing countries. Thirdly, future research should use more advance research analysis than regression analysis.

By recommending a heightened focus on theoretical research streams, we aim to contribute to the theoretical underpinning of ISO 50001 adoption. This not only advances our current understanding but also sets the stage for the development of new theoretical frameworks that can guide future research in the broader field of energy management systems.

Moreover, our call for an increased emphasis on studies in the context of developing countries carries significant academic weight. This recommendation acknowledges the importance of contextual nuances and cultural factors in the implementation of ISO 50001. Exploring unique challenges and opportunities in developing countries not only adds depth to the academic discourse but also provides valuable insights that can inform the development of more inclusive and context-specific energy management strategies.

The suggestion for future research to use advanced analytical methods beyond traditional regression analysis is a strategic move to elevate the sophistication of research methodologies in this domain. Future research could investigate the effectiveness of different theoretical models in explaining ISO 50001 implementation success in diverse organizational contexts. Embracing advanced analytical tools and techniques, such as machine learning algorithms or simulation models, holds the potential to uncover intricate patterns and relationships within the ISO 50001 phenomena. This not only enhances the robustness of academic inquiries but also fosters innovation in research methodologies, contributing to the broader advancement of research practices in the field of energy management.

4.4.2 Practical implication. The findings of this study carry practical implications that resonate directly with practitioners involved in ISO 50001 implementation. The implications for practitioners arising from our study offer pragmatic insights that bridge the gap between academic research and real-world application of ISO 50001-based energy management. The identification of existing applied tools and methods, such as the energy management maturity model, energy efficiency measurement method and benchmarking method, serves as a valuable resource for practitioners in this field. These tools, developed and refined within the context of energy management systems, provide practical assistance to practitioners involved in planning, designing and implementing ISO 50001-based strategies.

The significance of these tools lies in their potential to streamline and enhance the efficacy of energy management initiatives within organizations. By leveraging these established tools, practitioners can optimize their efforts, ensuring a more systematic and efficient approach to ISO 50001 adoption. This not only facilitates the implementation process but also contributes to the overall effectiveness of energy management practices,
potentially resulting in improved energy performance and sustainability outcomes. However, the need to assess the suitability of these tools and methods within the developing country context is a critical consideration. While these tools have demonstrated efficacy in developed countries, their applicability in developing country settings may vary due to distinct socioeconomic, infrastructural and organizational factors. Therefore, it becomes imperative for practitioners to subject these tools to rigorous testing and adaptation, such as energy audits, data management platforms or training programmes, to ensure their alignment with the unique challenges and requirements prevalent in developing country contexts. Practitioners in developing countries could collaborate with researchers to co-create culturally sensitive and resource-efficient tools for ISO 50001 implementation.

The broader significance of this implication lies in the potential for practitioners to harness the expertise and resources developed in advanced economies and adapt them to suit the specific needs and constraints of developing countries. This not only facilitates knowledge transfer but also encourages innovation and customization of tools, fostering a more inclusive approach to ISO 50001 implementation on a global scale. Furthermore, our bibliometric analysis offers a strategic framework for policymakers to leverage scientific knowledge in the shaping of public policies related to ISO 50001. By analysing the collaborative networks and thematic clusters, policymakers can identify areas of consensus, emerging research trends and knowledge gaps. This allows them to develop targeted and informed policies that address current challenges and anticipate future needs in the field of energy management. The broader significance lies in the potential for more effective and relevant public policies. Grounding policy decisions in a comprehensive understanding of the scientific landscape fosters an environment conducive to successful ISO 50001 adoption. This ensures that policies are not only evidence-based but also adaptable to evolving needs and challenges.

These academic and practical implications are complementary and can be viewed as integral components of a comprehensive strategy aimed at promoting the successful adoption and integration of energy management systems based on ISO 50001 as they foster a synergetic collaboration among researchers, practitioners and public policymakers. Researchers play a pivotal role in providing the theoretical and analytical foundation, policymakers use scientific knowledge to shape effective policies and practitioners are responsible for implementing practical ISO 50001 related tools and methods.

5. Conclusion

Based on the bibliometric study we performed, it can be concluded that the trend of ISO 50001 publication tends to be increased. However, the trend of the citation tends to be decreased. In ISO 50001 literature, Morejón M.B. and Ochoa G.V. are the top authors, Colombia is the top affiliated country, and Jovanović and Filipović (2016) is the top paper. There are only four biggest co-authorship clusters, five primary clusters of country collaboration networks and six bibliometric coupling clusters in ISO 50001 publications. Regarding the research themes, based on the results of thematic map analysis, “energy management system”, “management maturity” and “decision making” can be categorized as well-developed themes. “Sustainability” and “energy conservation” are important themes but still need to be developed further. Finally, there are three future research proposals, namely, performing more ISO 50001 theoretical research stream, more studies in developing countries and more advanced research analysis than regression analysis.

Although our study has found important findings, we addressed several limitations. Firstly, ISO 50001 papers can be written in various languages. However, we had a language barrier to be able to involve all the papers. Therefore, we only included
English language papers. Future research should consider including papers written in non-English languages. In other words, a research collaboration between countries is needed to create a more complete ISO 50001 bibliometric study. Secondly, ISO 50001 papers may also be published in non-Scopus indexed publications. While many studies have recommended Scopus as a data source for bibliometric research, including ISO 50001 papers from publications outside Scopus will enhance the comprehensiveness of bibliometric studies.

References


Further reading


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