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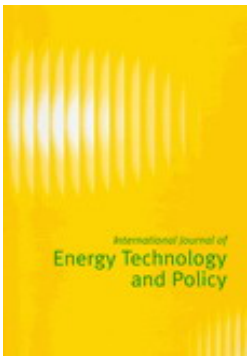

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Energy management audits, systematic literature review and framework proposition

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Abstract: Energy management has become an extremely important topic for organisations around the world, many of which are implementing energy management solutions to comply with legislation and improve energy usage. Given this fact, the present study aims to characterise the topic 'use of audits to implement energy management', as well as its fundamentals, theoretical framework, research opportunities identified in the literature, and the proposition of a framework for conducting audits. The method used was Proknow-C (knowledge development process-constructivist). as a result, 34 articles relevant to the research theme were found in an international database. It was also possible to identify the main approaches proposed by the authors of the bibliographic portfolio regarding types of audits performed, standards and industries, identification of gaps for research on the subject, and proposing a framework for conducting audits based on the ISO 50001 standard.

Keywords: energy management; Proknow-C; audit; industry; ISO 50001.

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1 Introduction

According to Neagle (2016), energy has evolved into a great opportunity for companies to create value, establishing a competitive advantage over their competitors. Among the various reasons that lead companies to adopt an energy management system are increasing profits, reducing costs, and improving their image in society. However, there is also a considerable number of circumstances that prevent companies from investing or transitioning to more energy-efficient forms of production. These are mainly related to a lack of knowledge or competence, a lack of involvement in guidelines, or budgetary constraints (Munguia et al., 2018; Huang et al., 2023). One way to implement Energy Management is to carry out audits, which is considered the first step to improving energy efficiency, helping to identify losses in processes, often caused by poor management of the energy used (Boharb et al., 2016; Jalo et al., 2021).

Based on these joint discussions and their practical importance in both fields, let us examine the current scientific scenario regarding audits for energy management in the industry.

This study is justified by its contribution to the scientific community through the survey and analysis of the results regarding the use of audits for energy management in the industry. Its aim is to help gain knowledge and identify research opportunities on the subject. Thus, the specific objectives were defined as follows:

1 selecting a significant portfolio of literature on energy management audits

2 conducting a portfolio analysis

3 proposing a framework for carrying out audits in energy management.

2 Energy management

According to Abdelaziz et al. (2011), energy management is a strategy aimed at meeting energy demand precisely when and where it is needed. This can be accomplished by adjusting and optimising energy usage systems and procedures to minimise energy requirements per unit of production. The objective is to maintain or reduce the overall production costs while achieving the desired output from these systems. In this sense, energy management is important to support organisations that seek to increase energy efficiency and minimise their environmental impact (Iturralde Carrera, et al., 2023).

Energy management has evolved as a support function in industries over the past 20 years. Companies have recognised its potential as an effective lever to enhance their production systems and operations, aiming to improve energy efficiency and consequently reduce energy consumption and associated costs (Schulze et al., 2016; Boharb et al., 2016; Haraldsson and Johansson, 2019).

2.1 Energy auditing

According to Henriques and Catarino (2017), an energy audit is an inspection, survey, and analysis of energy flows conducted to conserve energy. Its primary objective is to reduce the amount of energy consumed within a system without adversely impacting production. Consequently, energy auditing is an effective way to help organisation managers develop plans and achieve energy saving methods, allowing the definition of an action plan and execution of improvement projects to achieve defined objectives (Li et al., 2010; El Majaty et al., 2023).

The audit can be likened to an X-ray of the process, providing insights from both an economic standpoint and the perspective of the consumer organisation. The objectives outlined by Gabriel (2005) include:

- Determining the types of energy utilised.
- Assessing how costs are associated with energy usage.
- Establishing the structure of energy consumption.
- Identifying consumption patterns by process, operation, or equipment.
- Correlating energy consumption with production and/or the operational level of the facility.
- Identifying opportunities to enhance energy efficiency.
- Conducting technical and economic evaluations of the identified alternatives.
- Setting consumption targets without altering the existing processes.
- Proposing a program for necessary actions and investments.
- Suggesting the implementation of an organised energy management system in the organisation if one does not already exist.

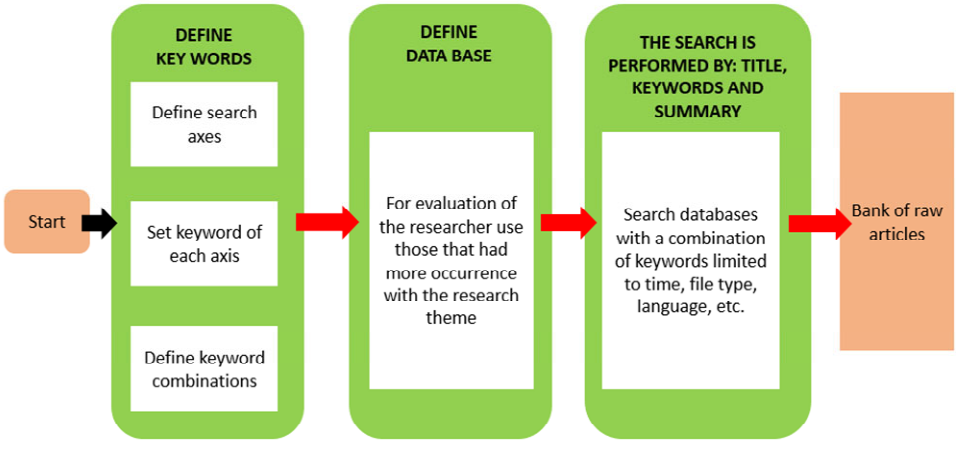
Energy auditing serves as a crucial tool for decision-making in the field of energy management, providing a reliable and systematic approach. It enables organisations to analyse their energy costs, identify areas where energy consumption can be reduced, and

detect potential sources of waste. Through energy auditing, organisations can plan and implement effective energy conservation methods that enhance their overall energy efficiency (Saidur and Mekhilef, 2010).

3 Methodology

To facilitate the selection of a theoretical framework and acquire the requisite knowledge for the research, the Proknow-C (knowledge development process-constructivist) methodology, proposed by Ensslin et al. (2010), was employed. This methodology encompasses a series of procedures, culminating in the filtering and selection of articles relevant to the research topic (Afonso et al., 2011). The method consists of two primary phases, the first of which involves selecting the raw article database, while the second focuses on the process of filtering articles. The first phase is illustrated in Figure 1.

Figure 1 The Proknow-C method (see online version for colours)

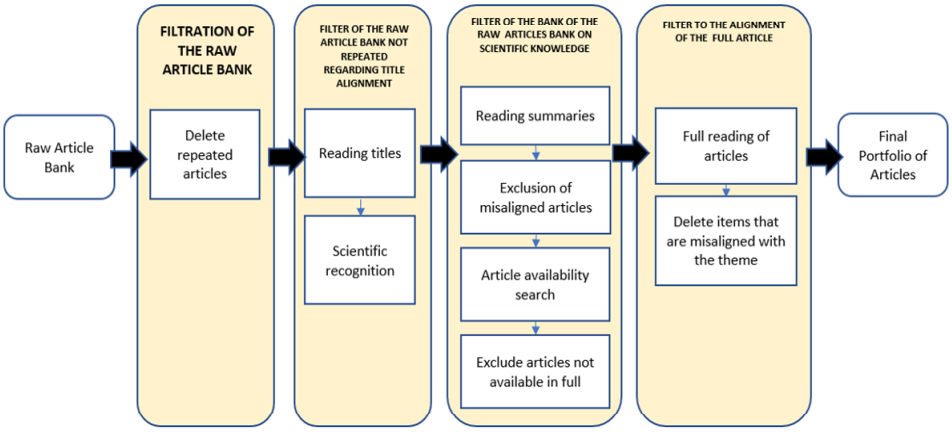


Source: Adapted from Ensslin et al. (2010)

Three research axes were established, namely 'energy management', 'audit', and 'industry'. For the energy management axis, five keywords were selected: energy management, energy efficiency, energy conservation, energy saving, and energy consumption. The audit axis employed the keyword 'audit*', while the industry axis utilised the keyword 'industry*'. Once the keywords were defined, combinations were formed among them, resulting in a total of five combinations.

The search was conducted across four databases: Web of Science, Scopus, Sage Journals, and Gale OneFile. Combinations of keywords were utilised in the search process. The search fields that were enabled included title, abstract, and keywords. The search was restricted to articles published between the years 2000 and 2022. To ensure the alignment and relevance of the articles, an adherence test was conducted during the selection stage of the raw article database. This test aimed to identify if there was a necessity to include additional keywords to maintain the focus of the portfolio. Following the completion of the selection stage, the process of filtering the raw article database commenced, as depicted in Figure 2.

Figure 2 Filtering of the raw articles database (see online version for colours)



Source: Adapted from Ensslin et al. (2010)

The filtering of the raw article database initiates with the removal of duplicate articles. The second step involves reading the titles of the articles, during which the scientific recognition of each article is assessed. This evaluation commences by searching for the number of citations in Google Scholar for each article. Subsequently, the abstracts of the articles are read to determine their alignment with the research topic. Based on this assessment, the articles are either retained in the database or discarded.

4 Results

The process initially yielded a total of 13,380 articles. Among these, 586 were found in the Web of Science database, 1,015 in the Scopus database, 1,702 in the Sage Journals database, and 10,077 in the Gale OneFile database. Out of these, 12,117 articles were excluded as they were duplicates or not journal articles. Subsequently, the titles of the remaining 1,263 articles were read to assess their alignment with the research theme, resulting in 269 articles. The next step involved identifying the scientific recognition of the articles, leading to the selection of the 163 most cited articles, which accounted for 99% of the total citations. The abstracts of these selected articles were then read, resulting in a final set of 55 articles.

A further analysis was conducted on the remaining 106 articles with unconfirmed scientific recognition. These articles underwent an additional filtering process for selection. As a result, 17 more articles were added to the initial set of 55, totalling 72 articles. These 72 articles were then checked for the availability of the full document. The entire process is illustrated in Figure 3, depicting the filtering and selection stages.

Following the verification process, 58 articles were identified for a thorough reading of the complete document to confirm their alignment with the research theme. Out of these, 34 articles were found to be aligned with the research theme and were subsequently included in the bibliographic portfolio. Please refer to Table 1 for further details.

Table 1 Bibliographic portfolio

Andersson, E. et al. (2017) 'A study of the comparability of energy audit program evaluations', *Journal of Cleaner Production*, Vol. 142, pp.2133–2139.

Aranda-Usón, A. et al. (2012) 'Energy consumption analysis of Spanish food and drink, textile, chemical and non-metallic mineral products sectors', *Energy*, Vol. 42, No. 1, pp.477–485.

Backman, F. (2017) 'Barriers to energy efficiency in Swedish non-energy-intensive micro- and small-sized enterprises – a case study of a local energy program', *Energies*, Vol. 10, No. 1, p.13.

Boharb, A. et al. (2016) 'Auditing and analysis of energy consumption of an industrial site in Morocco', *Energy*, Vol. 101, pp.332–342.

Boharb, A. et al. (2017) 'Energy conservation potential of an energy audit within the pulp and paper industry in Morocco', *Journal of Cleaner Production*, Vol. 149, pp.569–581.

Cagno, E. et al. (2010) 'Quick-e-scan: a methodology for the energy scan of SMEs', *Energy*, Vol. 35, No. 5, pp.1916–1926.

Cay, A. (2018) 'Energy consumption and energy saving potential in clothing industry', *Energy*, Vol. 159, pp.74–85.

Chiaroni, D. et al. (2017) 'Overcoming internal barriers to industrial energy efficiency through energy audit: a case study of a large manufacturing company in the home appliances industry', *Clean Technologies and Environmental Policy*, Vol. 19, No. 4, pp.1031–1046.

Fernando, Y. and Hor , W.L. (2017) 'Impacts of energy management practices on energy efficiency and carbon emissions reduction: a survey of Malaysian manufacturing firms', *Resources Conservation and Recycling*, Vol. 126, pp.62–73.

Fresner, J. et al. (2017) 'Energy efficiency in small and medium enterprises: lessons learned from 280 energy audits across Europe', *Journal of Cleaner Production*, Vol. 142, pp.1650–1660.

Gordić, D.R. et al. (2009) 'Energy auditing and energy saving measures in 'zastava automobili' factory', *Thermal Science*, Vol. 13, No. 1, pp.185–193.

Habib, M.A. et al. (2016) 'Energy consumption, energy saving and emission reduction of a garment industrial building in Bangladesh', *Energy*, Vol. 112, pp.91–100.

Haman, W.G. (2000) 'Total assessment audits (TAA) in Iowa', *Resources Conservation and Recycling*, Vol. 28, Nos. 3–4, pp.185–198.

Haraldsson, J. and Johansson, M.T. (2019) 'Barriers to and drivers for improved energy efficiency in the Swedish aluminium industry and aluminium casting foundries', *Sustainability*, Vol. 11, No. 7, p.27.

Henriques, J. and Catarino, J. (2017) 'Sustainable value – an energy efficiency indicator in wastewater treatment plants', *Journal of Cleaner Production*, Vol. 142, pp.323–330.

Howells, M.I. (2006) 'The targeting of industrial energy audits for DSM planning', *Journal of Energy in Southern Africa*, Vol. 17, No. 1, pp.58–65.

Kalantzis, F. and Revoltella, D. (2019) 'Do energy audits help SMEs to realize energy-efficiency opportunities?', *Energy Economics*, Vol. 83, pp.229–239.

Lazzarin, R.M. and Noro, M. (2015) 'Energy efficiency opportunities in the production process of cast iron foundries: an experience in Italy', *Applied Thermal Engineering*, Vol. 90, pp.509–520.

Li, Y. et al. (2010) 'Energy auditing and energy conservation potential for glass works', *Applied Energy*, Vol. 87, No. 8, pp.2438–2446.

Markis, T. and Paravantis, J.A. (2007) 'Energy conservation in small enterprises', *Energy and Buildings*, Vol. 39, No. 4, pp.404–415.

Table 1 Bibliographic portfolio (continued)

Meyers, S. et al. (2016) 'Energy efficiency, carbon emissions, and measures towards their improvement in the food and beverage sector for six European countries', *Energy*, Vol. 104, pp.266–283.
Mkhaimer, L.G. et al. (2017) 'Effective implementation of ISO 50001 energy management system: applying Lean Six Sigma approach', *International Journal of Engineering Business Management*, Vol. 9, p.1847979017698712.
Munguia, N. et al. (2018) 'Driving, competitive advantage through energy efficiency in Mexican maquiladoras', *Journal of Cleaner Production*, Vol. 172, pp.3379–3386.
Nagaveni, P. et al. (2019) 'Electrical energy audit –an experience in a small scale textile mill', *International Journal of Innovative Technology and Exploring Engineering*, Vol. 8, No. 10, pp.4102–4107.
Noro, M. and Lazzarin, R.M. (2016) 'Energy audit experiences in foundries', *International Journal of Energy and Environmental Engineering*, Vol. 7, No. 4, pp.409–423.
Petek, J. et al. (2016) 'Comprehensive approach to increase energy efficiency based on versatile industrial practices', *Journal of Cleaner Production*, Vol. 112, pp.2813–2821.
Prashar, A. (2017) 'Adopting PDCA (Plan-Do-Check-Act) cycle for energy optimization in energy-intensive SMEs', *Journal of Cleaner Production*, Vol. 145, pp.277–293.
Saidur, R. and Mekhilef, S. (2010) 'Energy use, energy savings and emission analysis in the Malaysian rubber producing industries', *Applied Energy*, Vol. 87, No. 8, pp.2746–2758.
Saidur, R. et al. (2009) 'End-use energy analysis in the Malaysian industrial sector', *Energy*, Vol. 34, No. 2, pp.153–158.
Schleich, J. (2004) 'Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany', *International Journal of Energy Technology and Policy*, Vol. 2, No. 3, pp.226–239.
Shatalova, T.N. et al. (2016) 'Controlling system as a key factor energy management of an industrial enterprise', *International Review of Management and Marketing*, Vol. 6, No. 1, pp.7–12.
Shen, B. et al. (2012) 'Energy audit practices in China: national and local experiences and issues', *Energy Policy*, Vol. 46, pp.346–358.
Trianni, A. et al. (2016) 'Barriers, drivers and decision-making process for industrial energy efficiency: a broad study among manufacturing small and medium-sized enterprises', *Applied Energy*, Vol. 162, pp.1537–1551.
Vela, R. et al. (2017) 'Improved energy efficiency in wineries using data from audits', *Ciencia E Tecnica Vitivinicola*, Vol. 32, No. 1, pp.62–71.

A bibliometric analysis was conducted as a significant phase of the bibliographic portfolio qualification process. Upon evaluating the journals, the notable ones were 'Energy' and 'Journal of Cleaner Production,' each having seven articles, followed by 'Applied Energy' with three articles. The word 'energy' appeared 19 times, 'audit' appeared 14 times, 'energy conservation' and 'industry' appeared seven times, while 'barriers' and 'energy savings' appeared six times. These keywords exhibited the highest frequency in the bibliographic portfolio. Among the authors, Boharb, A., and Saidur, R. had the highest participation, with two articles each.

Through the content analysis of the bibliographic portfolio, the types of companies and countries were identified, as well as the utilisation of Energy Management standards, the audit process, the presentation of the audit instrument, and the presentation of indicators. Furthermore, the study cited various drivers and barriers, as outlined in Table 2.

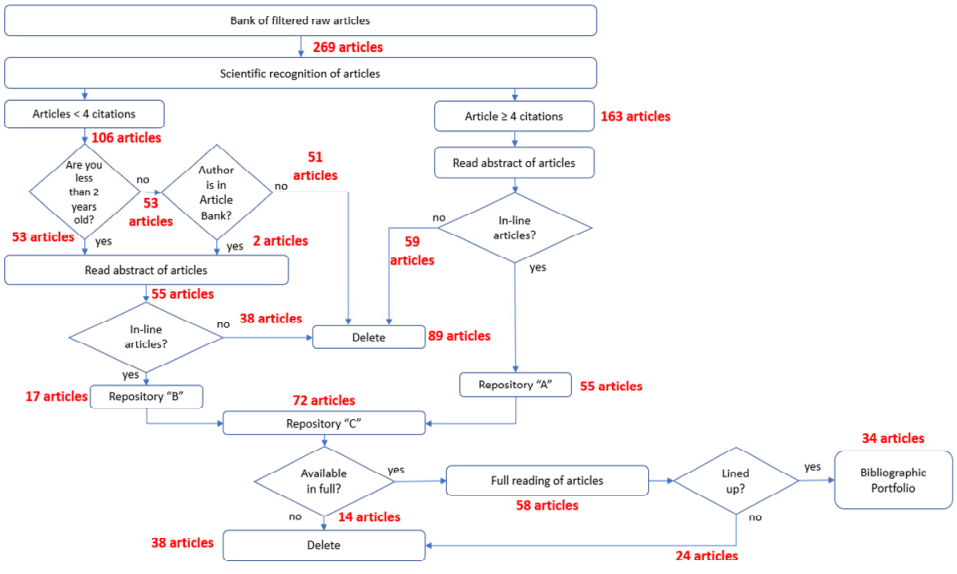
Table 2 Analysis of the bibliographic portfolio

Code	*Authors*	*Type of company*	*Country*	*Were any EM standards used?*	*Audit type*	*Was the audit process shown?*	*Was an audit instrument presented?*	*Was the audit or analysis of data from other audits performed?*	*Does it present indicators?*	*Were drivers cited?*	*Were barriers cited?*
1	Trianni et al. (2016)	Industrial SMEs	Italy	No	Not cited	No	No	Data analysis	No	Yes	Yes
2	Saidur et al. (2009)	Industries	Malaysia	No	Walkthrough	Yes	No	Data analysis	Yes	No	Yes
3	Schleich (2004)	Industrial SMEs	European Union	No	Not cited	No	No	Data analysis	No	Yes	Yes
4	Saidur and Mekhilef (2010)	Rubber industries	Malaysia	No	Walkthrough	Yes	No	Performed audit	Yes	No	Yes
5	Markis and Paravantis (2007)	Small businesses	Greece	No	Not cited	No	No	Analysed data	No	No	Yes
6	Shen et al. (2012)	Industrial companies	China	No	detailed	No	No	Analysed Chinese audit program data	No	Yes	Yes
7	Fernando and Hor (2017)	Manufacturing companies	Malaysia	ISO 14.001	Not cited	No	No	Analysed data	Yes	Yes	Yes
8	Cagno et al. (2010)	Small and medium-sized companies	Italy	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
9	Henriques and Catarino (2017)	Sewage treatment plants	Portugal	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	No
10	Fresner et al. (2017)	Small and medium-sized companies	European countries	No	walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
11	Prashar (2017)	Small paper production company	India	No	Not cited	No	No	Analysed data	No	Yes	No
12	Aranda-Usón et al. (2012)	Food, beverage, textile, chemical and metal industries	Spain	No	walkthrough	Yes	No	Analysed data	Yes	No	No
13	Lazzarin and Noro (2015)	Iron foundries	Italy	No	walkthrough	Yes	No	Performed audit	Yes	No	No
14	Li et al. (2010)	Glass industry	China	China's Energy Conservation Law	walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
15	Meyers et al. (2016)	Good and beverage SMEs	European Union countries	No	Detailed	No	No	Analysed data	Yes	Yes	Yes
16	Shatalova et al. (2016)	Industrial company	Russia	No	No	No	No	Analysed data	Yes	Yes	No

Table 2 Analysis of the bibliographic portfolio (continued)

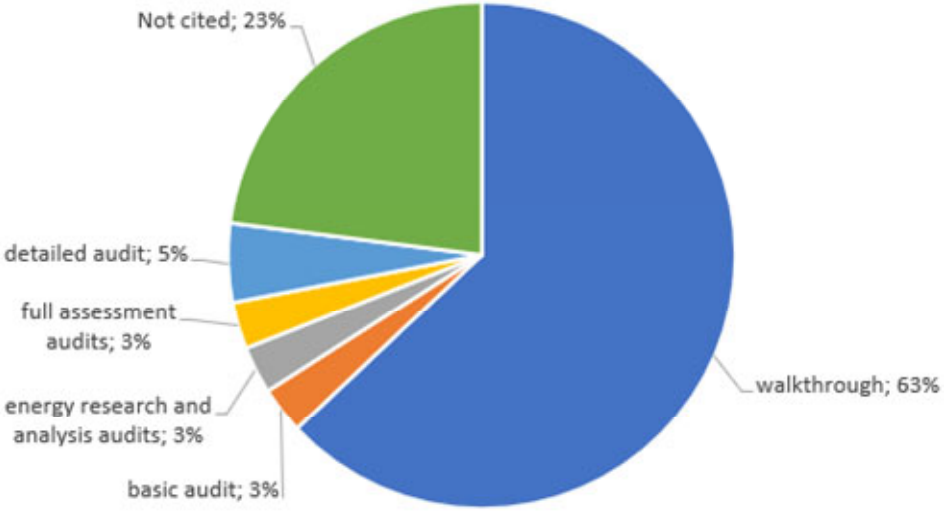
Code	*Authors*	*Type of company*	*Country*	*Were any EM standards used?*	*Audit type*	*Was the audit process shown?*	*Was an audit instrument presented?*	*Was the audit or analysis of data from other audits performed?*	*Does it present indicators?*	*Were drivers cited?*	*Were barriers cited?*
17	Petek et al. (2016)	Sugar production industry; industrial laundry; bakery industry; dairy industry	Slovenia	No	Walkthrough	Yes	No	Analysed data	No	Yes	No
18	Habib et al. (2016)	Garment industry	Bangladesh	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
19	Cay (2018)	Clothing industry	Turkey	No	Walkthrough	Yes	No	Analysed data	Yes	Yes	Yes
20	Howells (2006)	Manufacturing companies	Africa	No	Not cited	No	No	Analysed data	Yes	No	No
21	Boharb et al. (2017)	Pulp and paper industry-SME	Morocco	No	Energy research and analysis	Yes	No	Analysed data	Yes	Yes	No
22	Chiaroni et al. (2017)	Home appliance industries	Italy	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
23	Noro and Lazzarin (2016)	Iron foundry	Italy	ISO 50001	Walkthrough	Yes	No	Performed audit	No	Yes	Yes
24	Mkhaimer et al. (2017)	Pharmaceutical industry	Jordan	ISO 50001	Walkthrough	Yes	No	Performed audit	No	Yes	No
25	Backman (2017)	Intensive energy SMEs	Sweden	No	Walkthrough	No	No	Analysed data	No	Yes	Yes
26	Haman (2000)	Manufacturing companies	United States	No	Total evaluation	Yes	No	Performed audit	No	Yes	Yes
27	Boharb et al. (2016)	Cattle feed industry	Morocco	No	walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
28	Andersson et al. (2017)	Industrial SMEs	Australia; Germany; Sweden; USA	ISO 50002	Walkthrough	Yes	No	Analysed data	Yes	Yes	Yes
29	Gordić et al. (2009)	Automotive industry	Serbia	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	No
30	Munguia et al. (2018)	Maquiladoras	Mexico	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	Yes
31	Haraldsson and Johansson (2019)	Auminum industry	Sweden	No	Not cited	No	No	Analysed data	No	Yes	Yes
32	Vela et al. (2017)	Wineries	European Union countries	No	Walkthrough	No	No	Analysed data	Yes	Yes	Yes
33	Kalantzis and Revoltella (2019)	Small and medium-sized companies	European Union countries	No	Walkthrough	No	No	Analysed data	No	Yes	Yes
34	Nagaveni et al. (2019)	Textile mill	India	No	Walkthrough	Yes	No	Performed audit	Yes	Yes	No

Figure 3 Flowchart for scientific recognition of Bibliographic Portfolio Articles – Proknow-C (see online version for colours)



The main type of audit cited in the articles (Aranda-Usón et al., 2012; Meyers et al., 2016; Shatalova et al., 2016; Petek et al., 2016; Cay, 2018; Howells, 2006; Boharb et al., 2017; Backman, 2017; Andersson et al., 2017; Haraldsson and Johansson, 2019; Vela et al., 2017; Kalantzis and Revoltella, 2019) within the portfolio, accounting for 63%, was the step-by-step approach, as illustrated in Figure 4.

Figure 4 Types of audits cited in the bibliographic portfolio (see online version for colours)



According to Thumann and Younger (2008), this type of audit corresponds to a tour of the facilities for a visual inspection of each of the energies that are used. Typically, it

involves evaluating energy consumption data to analyse usage amounts and patterns. Additionally, it may provide comparisons to industry averages or benchmarks for similar installations. This type of audit is less expensive but can still generate a preliminary estimate of potential savings. It also provides a list of low-cost savings opportunities through improvements in operational and maintenance practices.

Only 9% of the articles cited Energy Management standards such as ISO 50001 and ISO 50002. The ISO 50001 standard has been available since 2011, with the current version being ISO 50001:2018. This standard outlines the requirements for establishing and maintaining an energy management system, providing guidelines for optimising energy use in equipment and processes.

It was identified that 49% of the surveyed companies are small and medium-sized companies. Furthermore, 56% of the surveys only focused on conducted audits. None of the articles presented the instrument used in the energy audit. According to Thollander et al. (2020), an audit instrument is the tool utilised to carry out the energy audit process, containing the items that can be analysed.

In 70.6% of the studies, barriers were identified that hinder the implementation of energy management systems. The classified groups of barriers (Haraldsson and Johansson, 2019; Chiaroni et al., 2017; Trianni et al., 2016) include technological, informational, skills-related, behavioural, awareness-related, organisational, governmental, and economic barriers.

According to Lawrence et al. (2015), in the adoption of energy management, it is crucial to comprehend the driving forces behind it, also referred to as drivers or motivators. In 82.4% of the surveys, drivers for energy management were mentioned. The main groups of drivers mentioned by Trianni et al. (2016) and Haraldsson and Johansson (2019) are related to economic factors, environmental concerns, organisational motivations, and energy efficiency.

Table 3 Bibliographic portfolio indicators

Indicator	*Cited by (portfolio article codes)*
Annual energy consumption	18
Energy consumption per production	14, 22
Cost of energy consumption	7
Effective cost of the program	28
Energy waste	7
Energy saving	2, 4, 10, 12, 13, 20, 21, 29, 30
Company cost effectiveness	28
Maximum energy efficiency	16
CO_2 emissions	7, 19, 28
Investments in sustainable energy	
Simple payback	4, 8, 10, 15, 18, 20, 21, 27, 28, 29, 32
Emission reduction	2, 4, 10, 15,
Fees (fines/taxes) paid for carbon emission disposal	7
Energy use per unit of revenue	7
Sustainable value	9

In 64.7% of the surveys, indicators for energy management were presented. The main indicators cited in the surveys can be seen in Table 3.

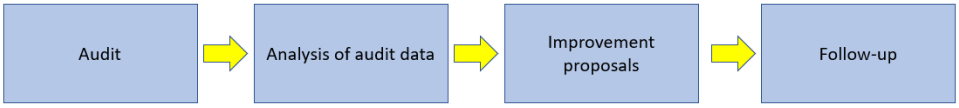
Through the analysis of the articles in the bibliographic portfolio, several important points were identified regarding the concepts of auditing in energy management. These points include:

- The lack of presentation of a detailed step-by-step audit tool to be followed was identified.
- It was observed that the main type of audit utilised is the step-by-step approach.
- There is a lack of utilisation of standards for energy management, such as ISO 50001.
- One of the articles mentioned China's energy conservation law, which includes ISO 50001 requirements, but it is a local certification.
- Many studies only analysed audits conducted by other authors.
- The use of indicators in the conducted surveys was also noted.
- Barriers and drivers are mentioned in the audit process for implementing an energy management system.

5 Framework proposal

A framework was developed to represent the literature findings and the research methodology employed. In Figure 5, the flow of the proposed audits in the articles of the bibliographic portfolio can be observed.

Figure 5 Sequence of works in the bibliographic portfolio (see online version for colours)



It was observed that the studies in the bibliographic portfolio followed a linear structure, characterised by a clear beginning, middle, and end. The process typically started with the audit phase, followed by data analysis, and concluded with proposals for improvements based on the researchers' experiences.

It was noted that, according to the ISO 50001 standard, the energy management process does not begin with the audit. Instead, it starts with the establishment of the company's energy policy and strategic planning, as depicted in Figure 6.

The energy policy represents the organisation's statement of intentions and general guidelines concerning its energy performance, formally expressed by top management. The energy policy provides a framework for actions and for establishing energy objectives and targets in alignment with strategic planning.

The audit of the Energy Management System is a crucial step in verifying the implementation of the energy policy and strategic planning. According to Saidur and Mekhilef (2010), the energy audit serves as a fundamental tool for decision-making in the

field of energy management, offering a reliable and systematic approach. It enables organisations to analyse their energy costs, identify areas for potential energy reduction and waste, and develop and implement effective energy conservation methods that enhance overall energy efficiency.

In Figure 7, a proposed framework can be observed, outlining a sequence of steps for the initial approach with companies in implementing an energy management system through audits. This framework is being proposed in the current research.

Figure 6 Energy management system model for ISO 50001 standard (see online version for colours)

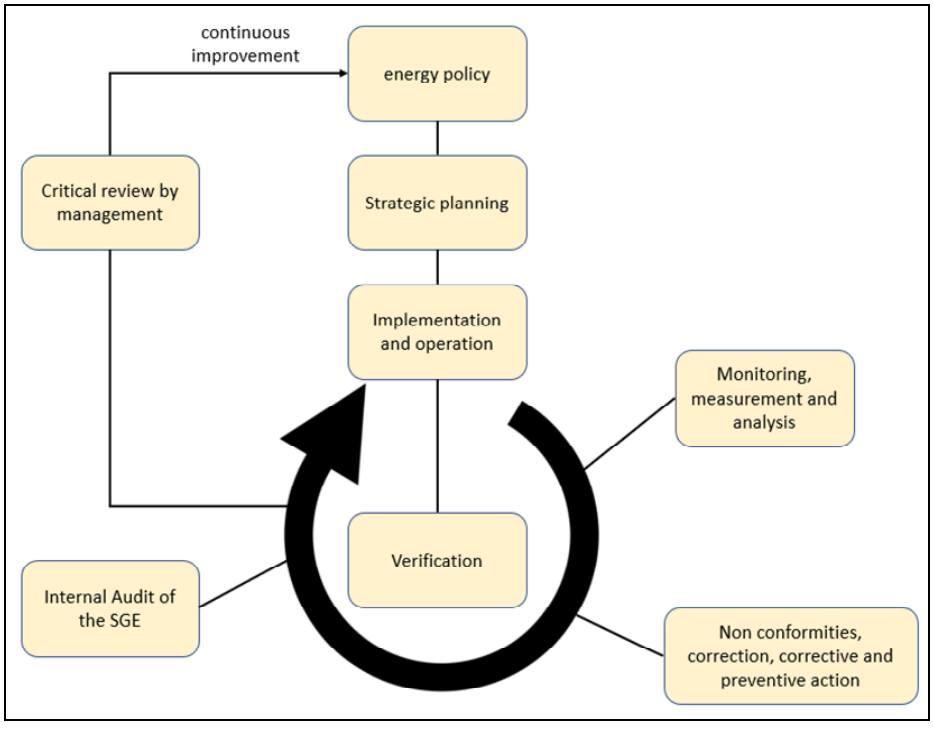
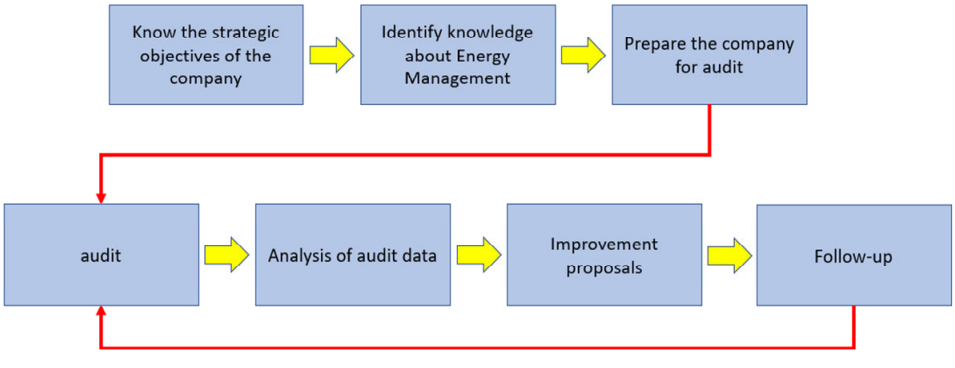


Figure 7 Proposed framework for energy management systems (see online version for colours)



Initially, it is proposed that the company conducts an analysis to assess the alignment of its strategic objectives with the energy issue. According to Schulze et al. (2016), making strategic energy management decisions is the first step towards implementing an energy management program. Subsequently, it is important to assess the level of understanding among the company and its employees regarding the concepts of energy management.

With these issues addressed, the next step is to prepare the company for conducting an audit. This involves providing training to personnel on the audit process and ensuring that the auditor is familiar with the company's production process. This knowledge is necessary to understand and document the sequence of the production process.

During the audit, it is essential to survey all the equipment used, including their consumption data, duration and type of usage, as well as quantities involved. In a step-by-step audit, the equipment's plate data (theoretical) are typically utilised, but energy analysers can be employed to determine the actual consumption.

According to Abdelaziz et al. (2011), an energy audit is an inspection, survey, and analysis of energy flows aimed at conservation, with the objective of reducing energy input into the system without negatively impacting production. Consequently, it serves as an effective tool to assist organisational managers in developing plans and implementing energy-saving methods (Li et al., 2010).

After conducting the audit, the data are analysed to identify the equipment consuming the most energy. Based on this analysis, recommendations are formulated to reduce consumption and enhance energy efficiency. These recommendations can stem from the auditor's expertise or from databases such as the Industrial Assessment Centers (IAC). The IAC is designed to assist small and medium-sized American manufacturers in energy savings, productivity improvement, and waste reduction. The program offers free technical assessments conducted by university teams comprising engineering students and faculty. Managed by the Office of Advanced Manufacturing in the Department of Energy's Office of Energy Efficiency and Renewable Energy, the IAC maintains an online platform showcasing its extensive work, including a wide range of energy-saving recommendations for various industrial sectors (IAC, 2021).

Post-audit activities involve the development of an action plan to implement energy efficiency measures, ensuring the successful implementation of the recommended improvements. This plan should be straightforward, outlining clear objectives, savings targets, and defined roles and responsibilities for its execution (Hasanbeigi and Price, 2010).

Table 4 Indicators proposed for energy management

Indicator	*Equation*	*Goal*	*Cited by*
Energy consumption per production	ECP = Energy consumption in the period/production in the period	Check energy consumption by the amount produced in the period	Li et al. (2010), Chiaroni et al. (2017), Hasabeigi and Price (2010)
Electricity cost	EEC = Total kWh consumed in the month * kWh cost	Check the cost of energy spent in the month	Fernando and Hor (2017)
Total energy consumed	TEC = Total energy consumption	Check the total energy consumption in the period	Habib et al. (2016)

The follow-up process can be conducted using performance indicators, enabling the company to assess whether the recommendations are impacting energy consumption. Table 4 presents a list of indicators to be utilised.

The company will have the ability to assess energy consumption per production, energy costs, and total energy consumed, enabling the monitoring of post-audit actions and facilitating decision-making regarding measures to improve energy efficiency.

'Lastly, in Figure 7, it can be observed that the monitoring phase leads back to the audit phase, as it is a continuous process. Audits can be conducted regularly for new assessments and proposals for improvements, aligning with the principles outlined in the ISO 50001 standard. According to Noro and Lazzarin (2016), energy management auditing facilitates a shift from a 'passive' perspective (where energy costs are perceived as inevitable and uncontrollable) to an 'active' approach (where energy costs are not only under control but also planned, generating added value for organisations).

It is also crucial to emphasise that this entire process must align with the company's strategic objectives, ensuring its continuity within the organisation and dissemination among all employees.

The top management of the company should serve as the primary sponsor of the energy management program, fostering the dissemination of an energy culture throughout the organisation. They should actively promote communication on energy-related matters both within and outside the company (Schulze et al., 2016).

6 Conclusions

By conducting a systematic literature review using the Proknow-C intervention method, a bibliographic portfolio consisting of 34 relevant articles was selected to represent the research topic. The bibliometric analysis provided valuable insights and knowledge, allowing for the identification of scientifically significant articles based on factors such as the journals in which they were published and the authors with notable scientific recognition. This process helped create a comprehensive portfolio of information for the research area.

There is a significant lack of studies that provide comprehensive information on audit instruments and their results within the field of energy management. Most studies have primarily focused on analysing audits conducted in industries, while the utilisation of energy management concepts, particularly the Energy ISO 50001 standard, has been found to be limited. This finding highlights a research gap within the scientific literature, considering the importance of this topic for industries seeking energy savings and sustainability through the implementation of energy management principles.

This study has proposed a framework to guide the audit process for the implementation of an energy management system. The framework serves as a valuable foundation for future research in this field and aims to assist companies in their pursuit of energy management within their facilities.

As a suggestion for future work, it is recommended to apply the proposed model in conducting audits within companies. This involves developing an instrument that can effectively capture the company's energy management context and use it to enhance its operational and production systems. The objective is to improve energy efficiency, reduce energy consumption, and subsequently lower related costs.

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