Energy management systems in SME: State of research and methodical considerations

Marcus Triller[1,*,†] and Kurt Sandkuhl[1,†]

[1] *University of Rostock, Albert Einstein Strasse 22, 18059 Rostock, Germany*

Abstract

With the increasing importance of sustainability and the corresponding regulations, the reduction of energy consumption, the avoidance of energy waste, and the role of energy management have increased in companies. For large organisations, reports about successful implementations of energy management systems (EnMS) are available, but the situation for small and medium-sized enterprises regarding EnMS is not well-researched. The main objective of the research presented in this paper is to contribute to a better understanding of the state of research and the state of practice in energy management of SME as a foundation for future research in the field. The main contributions of this paper are (1) the results of a survey among SMEs confirming the relevance of energy management and a lack of knowledge how to implement energy management systems, (2) the results of a systematic literature study structuring the existing work in the field of energy management for SME, and (3) the outline of a proposal how to support SME in energy management.

Keywords

Energy management, small and medium-sized enterprises, SME, relevance, requirements, literary analysis, survey, management systems.

1. Motivation

With the increasing importance of sustainability and the corresponding regulations, like the European Union's "Green Deal[2]" and the United Nation's sustainability goals[3], reduction of energy consumption, avoidance of energy wasting and the role of energy management increased in companies. For large organisations, reports about successful implementations of EnMS are available (see, e.g. [1]), but the situation for small and medium-sized enterprises when it comes to EnMS is not well-researched. Energy management is only one of many challenges for SMEs that are also affected by digital transformation or economic challenges in the context of recovery from the COVID-19 pandemic.

The European Commission (EC) describes SMEs as the "engine of the European economy", as they have a decisive influence on job creation and the stimulation of economic

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* Corresponding author.

† These authors contributed equally.

marcus.triller@uni-rostock.de (M. Triller); kurt.sandkuhl@uni-rostock.de (K. Sandkuhl)

0000-0002-7709-0353 (M. T); 0000-0002-7431-8412 (K. S)

[2] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en

[3] https://sdgs.un.org/goals

growth [2]. They accounted for 99.4% of companies in Germany in 2021. At 54.8%, they employed a large proportion of the labour force and accounted for 28.7% of total German turnover. Together, they generated 42.4% of gross value added in Germany [3]. This emphasises the importance of SMEs for the German economy. A survey conducted by the German Economic Institute in 2023 revealed that German industry is in crisis. Around two thirds of the companies surveyed stated that high energy, raw material and material costs are impacting their competitiveness [4]. IW Brief Report 43/2023 reports that energy prices and supply insecurity seriously impact capital outflows in Germany [5].

Only ten years ago, energy was not considered a strategic business opportunity in the corporate context. In its International Energy Outlook 2013 report, the International Energy Agency (IEA) stated that in most sectors and countries, energy played a subordinate role in the calculation of competitiveness [6]. However, due to constantly rising costs for energy sources and their security of supply, the topic of energy management has increasingly become the focus of companies in recent years [7]. For this reason, energy management can be attributed a steadily increasing importance, similar to quality and environmental management. A comparison between large companies and SMEs by Bath et al. shows that large companies generally perform better than SMEs in various dimensions, including the management of energy and sustainability issues [8]. Altenburger describes how SMEs often have less systematic approaches to energy management than large companies due to limited resources and organisational structures [9]. Due to their limited resources and expertise, they are often less able to implement comprehensive energy management strategies than large companies [10]. However, the sustainable orientation of companies is increasingly becoming a decision criterion for potential orders [10]. For this reason, the authors of this paper have decided to investigate the relevance of energy management for SMEs in more detail and to identify the support SMEs need when planning and implementing energy management initiatives.

The main contributions of this paper are (1) the results of a survey among SMEs confirming the relevance of energy management and a lack of knowledge how to implement EnMS, (2) the results of a systematic literature study structuring the existing work in the field of energy management for SME, and (3) the outline of a proposal how to support SME in energy management.

The paper is structured as follows: Section 2 gives a brief introduction to energy management and management systems. Section 3 describes the research process. Section 4 contains a survey among SME on the status of energy management. Section 5 present the results of a systematic literature analysis. Section 6 uses the results of the survey and the literature analysis to motivate the need for methodical support for implement energy management in SME.

2. Energy management and management systems

Management systems (MS) have been a subject of research for more than three decades and several approaches exist. Schwaninger [11] describes MS as a “system for the design, control and development” that implements structures for the organisation of companies.

Those structures influence the behaviour of the employees and organisational units. Furthermore, the MS is a management tool which can increase a company's success, e.g. through an improved ability to respond or the coordination of the several subsystems as well as the interdependences between them, the employees and the technical instruments [11]. The International Organization for Standardization (ISO) defines MS as general activities and their combined effects and thereby as the functioning of a company to reach its strategic business goals. ISO states that an MS does not have to be documented explicitly, and the activities can be grouped thematically or according to their goals [12]. An MS consists of different purposefully-used activities as well as organisational structures adjusted to the activities. It comprises the structural and procedural organisation which have to be purposefully organised and harmonised with each other to support the accomplishment of a company's strategic business goals. MS have been an element of organisational practice in many enterprises for establishing systematic quality management [13], environmental management or information security management [14].

Systematic management of energy consumption and use in an enterprise is expected to significantly lower operational expenses by minimizing energy wastage and optimizing energy usage. In many industrial areas, energy management is considered as critical for enterprises to reduce costs, enhance sustainability, and comply with regulations. Energy management involves implementing a MS for monitoring, controlling, and optimising energy use in an organization. It includes identifying energy-saving opportunities, implementing efficient practices, and tracking performance to reduce costs and environmental impact. An EnMS is a framework that integrates policies, procedures, and tools. It involves setting objectives, measuring consumption, analysing data, and implementing improvements, often following standards like ISO 50001 [7].

3. Design science research process

The main objective of the research presented in this paper is to contribute to a better understanding of the state of research and the state of practice in energy management of SME as a foundation for future research in the field. The project follows the paradigm of design science research (DSR) [15]. DSR is aiming at problem-solving in organisational settings, focusing on developing valid and reliable knowledge for designing the required solutions. The envisioned solution, called "artefact" in DSR, in our research, is methodical and technological support for implementing EnMS in SMEs.

DSR research projects typically consist of several phases and require the use of different research methods depending on the DSR phase and intended design solution. The first phase and focus of this paper is to define the investigated problem and show its relevance for businesses and research. Relevance for research typically has to include an investigation of the existing knowledge base, i.e. the state of research, which is the focus of section 4. In this context, the research method is a systematic literature analysis introduced in section 4 in detail. Relevance for businesses in our research is investigated by performing a survey among SMEs that collects and analyses information on SMEs' views on energy management and their demands. The research questions defined for our work are as follows:

- **RQ1**.: What relevance does operational energy management have for SMEs?

- **RQ2**.: What are the reasons for energy management's low or high relevance in SMEs?
- **RQ3**.: Which topics were the focus of previous research on energy management systems (EnMS) in the corporate context?
- **RQ4**.: To what extent do existing literature reviews take the specific features and needs of SMEs into account when implementing EnMS?
- **RQ5**.: Is there a need for management systems support in the field of energy management among SMEs?

In RQ1, RQ2 and RQ5, we start with the perspective of German SMEs and contrast our findings with statistics on European level. With the results of the survey and the literature analysis, we intend to prepare the second and third phases of the DSR project: requirements definition and initial design of the artefact. For this purpose, we discuss potential methodical and technological support for EnMS in SME. This part of our work follows an argumentative-deductive research approach.

4. Survey on the relevance of energy management for SMEs

The survey was conducted as part of the overall survey of the Zukunftszentrum Mecklenburg-Vorpommern + (ZUK-1-0006). The survey focused on identifying future issues and support needs of SMEs in Mecklenburg-Vorpommern (MV) for the year 2024. By future topics we mean challenges and development issues that a company considers crucial for its future success. In this context, the survey provides answers to the question of the relevance of energy management for SMEs in MV and which factors are decisive. The anonymous survey of participants was carried out using guided question-based interviews. An external service provider (Dukath) was contracted to conduct the interviews. Several criteria were defined for the selection of companies.

- A total of at least 500 companies should be interviewed.
- Their distribution in terms of size and sector affiliation should correspond to the ratio of the federal state.
- All administrative districts should be equally represented.

The 2022 Statistical Yearbook of MV [16] served as the basis for the latter two criteria. The interview guide was developed in an iterative process and supported by a pre-test to check the comprehensibility of the items. The aim of the survey is to identify the relevance of energy management for SMEs. It also asks about the reasons for high or low relevance and the status of energy data collection. A 4th Likert scale is used to answer the guideline-based interviews and is based on [17] and [18]. The pretests of the study took place from 02.11.2023 to 03.11.2023 and were accompanied interdisciplinary by the Work and Organizational Psychology of the University of Greifswald and the Business Informatics of the University of Rostock. The interviews were conducted from 06.11.2023 to 20.11.2023.

A total of 506 SMEs in MV were surveyed. The composition of the sample corresponds to the distribution in the federal state in terms of sector distribution and enterprise size. The enterprises were broadly evenly distributed across all districts. The following figures (1 and 2) show the distribution of the sample by sector and enterprise size.

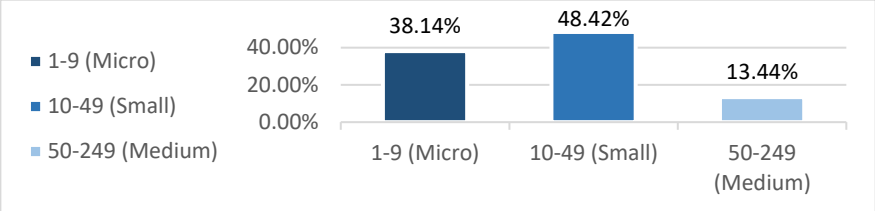

Figure 1: Distribution by company size based on SME definition of [19] (n = 506)

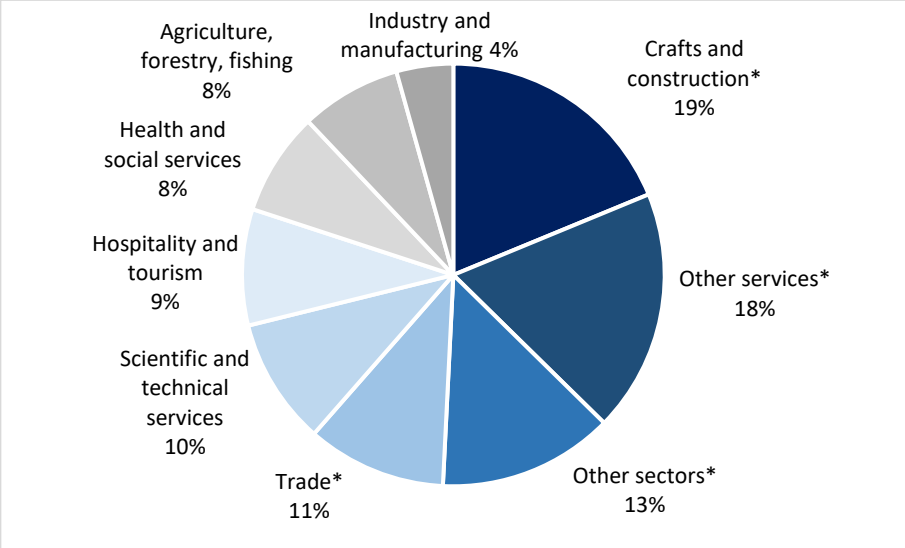

Figure 2: distribution of the sample by sector (n = 506)

Note: * = Summary of individual sectors: Construction includes building construction (0.8%), civil engineering (0.8%), other construction and craft enterprises (0.8%); Trade includes retail trade (8.5%) and wholesale trade (2.2%); Other services includes maintenance and repair of motor vehicles (2.3%), digital economy (1.8%), education (1.6%), financial and insurance activities (1.8%), other services (10.1%); Other sectors include real estate (4.2%), transport, storage and warehousing (3.8%), arts, entertainment and recreation (2.0%), information and communication (1.6%), energy (1.2%), water supply, mining and quarrying (0.4%), food and beverage manufacturing (0.2%). The sector categorization is based on that of the State Office for Internal Administration [16].

4.1. Relevance of operational energy management for German SMEs (RQ1)

The survey of the relevance of energy management in one's own company was recorded using a 4. Likert scale and asked of all companies. The respondents' ratings ranged from "very low relevance" to "very high relevance". It is clear that the greater the size of the company, the more important energy management becomes for the company. Micro companies rated the relevance of energy management for their company with a mean value of 2.56, small companies with a mean value of 2.88 and medium-sized companies with a mean value of 3.74.

We analysed the relationship between company size and the assessment of the relevance of energy management using the Spearman rank correlation coefficient. The calculation of the coefficient resulted in a correlation of .295 and is significant at a level of 0.01 with an N of 506.

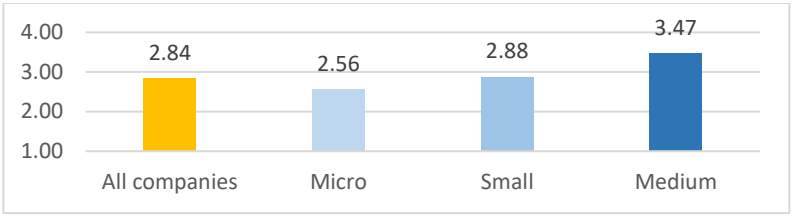

Figure 3: Assessment of the relevance of energy management in the company based on the mean value (n = 506)

While the survey gives an average rating of 2.84 for the relevance of EnMS across all company sizes, there are significant deviations from this average when differentiating between sectors. Hospitality and tourism (3.18), agriculture, forestry and fishing (3.41) and industry and manufacturing (3.82) rated the importance of an EnMS significantly higher. In contrast, scientific and technical services (2.00) and craft trades (2.39) rated the importance of an EnMS significantly lower.

Looking at the market for EnMS in Europe, it is clear that this economic sector will become increasingly important in the coming years. The European market for EnMS is currently worth around USD 17.14 billion. According to forecasts by [20], this market is expected to grow to around USD 36.26 billion by 2029. The market for EnMS is growing rapidly due to increasing demand and numerous applications of smart meters. Energy management is considered necessary for smarter grids because it is automated and does not require human interaction. An identical trend is forecast for the smart home market for energy management products and services, which is expected to grow by more than 50 per cent from EUR 2.8 billion (2023) to up to EUR 4.6 billion by 2028 [21]. This underlines the increasing relevance of these MS not only in the corporate context, but also in the private sector.

4.2. Reasons for low or high relevance of energy management in German SMEs (RQ2)

In addition to the assessment of the relevance of energy management, we analysed the reasons for a low or high assessment of relevance. Individuals who had previously selected low or very low relevance for their organization were then asked about the reasons for their rating (N = 168).

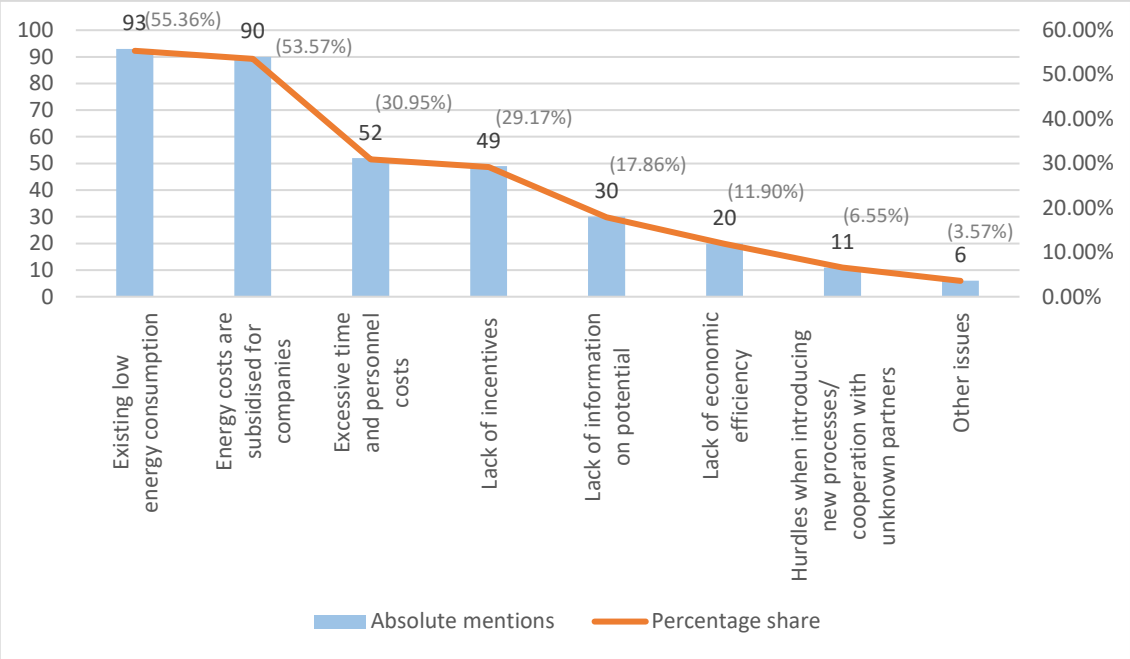

Figure 4: Reasons for low assessment of the role of energy management in the company based on absolute and (relative) frequency (n = 168) - Multiple selection possible

The most common reasons why respondents rated the relevance of energy management as low were: an existing low energy consumption (55.36%), subsidized energy costs for companies (53.57%), excessive time expenditure or personnel costs (30.95%) and lack of incentives (29.17%). This shows that many companies do not consider the additional effort and cost of an EnMS to be necessary or justified.

In contrast, we also analysed the reasons for high relevance. The main reason given by respondents for their assessment was the motivation to reduce costs for the company (97.93%). Other drivers identified were the desire to gain a competitive edge (34.02%), support for security of supply (19.82%) and a desired technological advantage (15.98%). Planned certification (0.89%) was of particularly low relevance for SMEs.

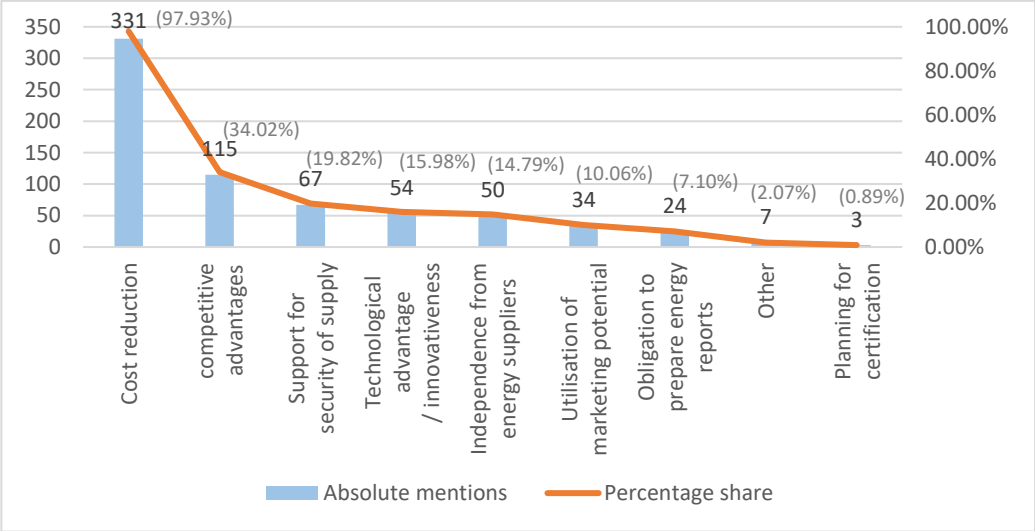

Figure 5: Reasons for high rating of the role of energy management in the company based on absolute and (relative) frequency (n = 338) - Multiple selection possible

5. Conducting a structured literature analysis

The aim of the literature review is to analyse the current state of research in the field of EnMS in an operational context. A systematic literature analysis according to Kitchenham was carried out to identify the necessary knowledge [22]. We chose this approach because it was developed to identify what content has already been published on a research topic, compare it with each other and thus identify and analyse potential research gaps. Based on the Kitchenham approach, we proceeded in six steps. First, we formulated three general research questions.

- **RQ3**: Which topics have been focused on in previous research on energy management systems in the corporate context?
- **RQ4**.: To what extent do existing reviews take into account the special features and needs of SMEs when implementing EnMS?
- **RQ5**.: Is there a need for management systems support in the field of energy management among SMEs?

After formulating several research questions, we conducted a systematic literature analysis using several search strings and identified relevant literature (see 5.2). In addition to the formulation of search strings, inclusion criteria were also defined. In a further step, we identified the relevant data from the selected studies and summarized the results in tabular form. In the following paragraph we show the development of the search string.

5.1. Development of the search string

After defining the research questions, we started the systematic literature search with an initial search on the term "energy management system". The search was focused on identifying reviews in order to provide an overview of the topic. Synonyms were used for the term

"literature review" so as not to exclude any relevant papers from the search. For the same reason, the search string has not yet been restricted to the SME sector. In addition to the search for reviews on energy management, we set up a further search string relating to SMEs. This separate search was intended to ensure that the special features of SMEs are taken into account when implementing EnMS. In a further step, we used keywords to specify the search queries. We used the "Scopus" database to develop the search strings. The resulting search string was deliberately broad in order to gain a comprehensive insight into the topic and not unintentionally exclude relevant literature. The search was then extended to the databases "IEEE-Explore", "AISeL" and "ScienceDirect". The search query was adapted to the syntax of the databases used. The final search strings of the systematic literature analysis and the number of hits per database can be found in Table 1.

Table 1
Final search strings and results overview by database

Search string 1 (S1)		
(TITLE ("Energy management system") AND TITLE-ABS-KEY ("Literature review" OR "literature search" OR "literary review" OR "literature survey" OR "review off literature" OR "review off publications" OR "analysis off literature" OR "literature analysis" OR " literature overview" OR "search off literature"))		
Search string 2 (S2)		
TITLE-ABS-KEY ("Energy management system" AND (sme OR "Small and medium-sized enterprises"))		
Overview of hits		
Database	*Number of hits (S1)*	*Number of hits (S2)*
Scopus	40	30
IEEE-Explore	11	2
AISeL	2	10
ScienceDirect	9	9

The analysis was carried out between February and June 2024. Using this systematic approach, a total of 50 hits were identified for the first search string and 48 for the second search string after comparing duplicates.

5.2. Selection procedure & inclusion criteria

The following section explains the selection process of the articles as well as the inclusion criteria that were used during and after the development of the search terms. In order to structure the literature selection process and make the literature comparable, inclusion criteria were defined as part of this work, which a paper should contain in order to be considered relevant.

The criteria can basically be divided into two overarching categories - the content and qualitative relevance of the literature review. In terms of content, the search for literature reviews should focus on EnMS (criterion 1) and consider the operational context (criterion 2). During the search process, we repeatedly came across works that focused on smart home

applications or energy management in the sense of human health practices. However, the aim of this research is to collect information that supports organizations in the implementation and operation of an EnMS. Therefore, we have decided to exclude work that goes beyond the corporate context. In terms of quality, only literature reviews that cover current developments and trends in the field of EnMS should be considered. For this reason, we limited the search to the last ten years. In addition, only literature reviews that disclosed a clear method for selecting and analysing the included studies were included in order to ensure the transparency and comprehensibility of the work (criterion 3). While the selection of literature could already be limited to the last ten years by searching the databases, the remaining criteria were considered manually.

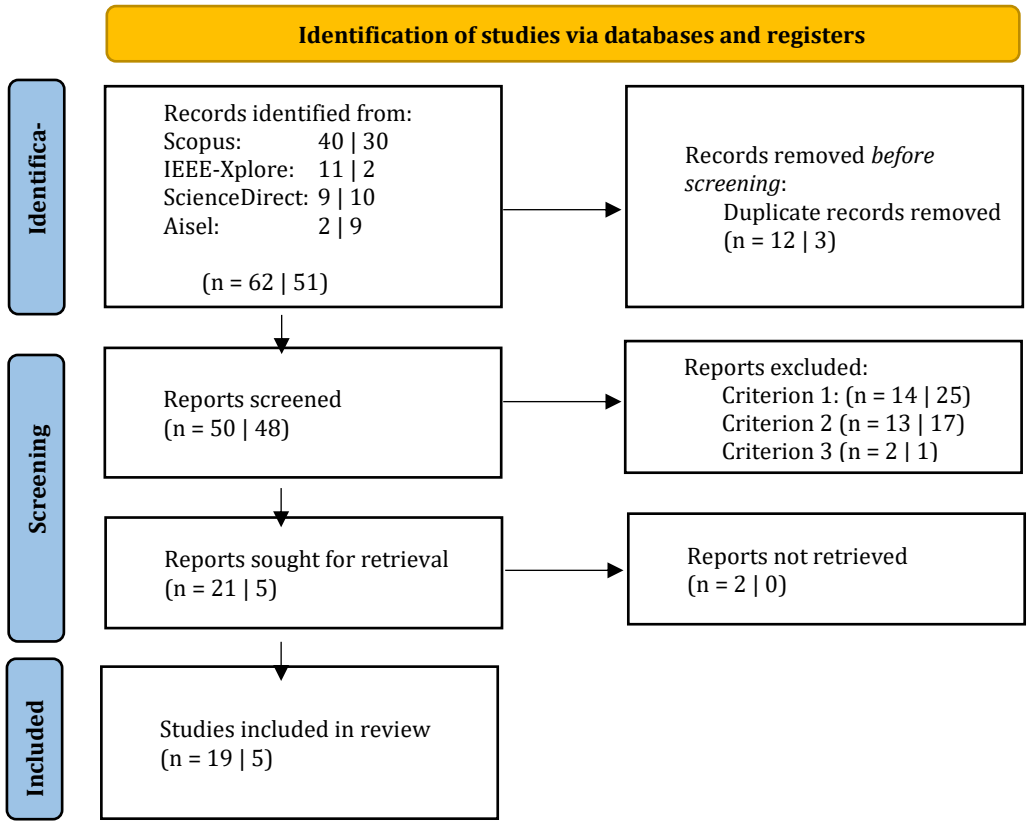

Figure 6: Overview of literature search based on Page et al. [23]

The literature analysed was selected in several steps. After the literature found was selected according to its relevance by title, the papers were reviewed and the relevance of the papers was revaluated. The inclusion criteria described above were then applied to the remaining publications. The procedure for identifying suitable literature can be seen in the diagram in Figure 6. The identification of the review literature is mapped first and the SME-specific search second (S1 | S2).

5.3. Results of the literature analysis (RQ3 and RQ5)

As part of the literature analysis, it became clear that the focus of previous overview literature (S1) on EnMS has a very technical background. In recent years, research has focused intensively on the optimisation of EnMS (13) and microgrids (8). Numerous studies have analysed the advantages and challenges of these systems. Extensive research on building energy management systems (BEMS) (7), demand side management (DSM) (7) and the use of algorithms to reduce costs or create forecasts (9) has been identified. Other approaches focus on the use of decentralised systems (3), the integration of digital technologies (3) or deal with regulatory framework conditions (4). Recent literature has also discussed the use of AI solutions (3) and, increasingly, the use of renewable energies (4) and energy storage systems (3). Despite significant progress in research into EnMS, the SME sector remains largely unexplored. The topic of EnMS in the SME sector is indirectly addressed in only two literature reviews [24; 25], but does not represent a focus of the work. However, neither Alonso et al. [24] nor Chang et al. [25] address the special features of the implementation of energy management initiatives, which points to an existing research gap. In the other reviews, the topic of SMEs is not pursued further.

However, a high relevance of MSs was identified as part of the analysis. In their study, Chang et al. emphasise the need to use a MS to control and monitor energy consumption and identify waste. They do not limit themselves to a specific area of application, but describe that this applies to both industrial standards and households [25]. In their work, Santolamazza et al. propose IT-supported solutions that support the decision-making process of energy managers and utilise the potential of Industry 4.0 approaches in the process [26]. In their study, Muqeet et al. look at very extensive campus microgrids that would not be controllable without IT-supported MS. They suggest further optimising MSs with modern approaches such as blockchain, artificial intelligence or machine learning [27]. The reviews primarily pursue management-based approaches to optimising energy processes. For example, Ali et al. address the use of a power flow MS to control various energy generators in order to optimally utilise their yields [28]. Raya-Armenta et al. discuss a load MS as a subsystem of an EnMS and emphasise the need for IT support to enable economic benefits [29]. Hannan et al. describe a data MS in which sensors, sub-meters and smart meters are used to evaluate building performance [30].

Table 2
Final search string and results overview by database (S1)

Focus topics of the study	Microgrid	BEMS | ZEB	Process optimization	Demand side management	EnMS infrastructure	Algorithms for cost reduction	Use of AI	Integration of digital technologies	Decentralized EnMS	Renewable energies	Energy storage	System communication	Data analysis | monitoring	Regulatory framework conditions | political instruments and guidelines	Economic efficiency anal-	User interaction	SME reference	Management systems
[31]	x		x	x	x	x	x											x
[28]	x				x		x					x	x					x
[24]			x											x	x		(x)	
[32]			x							x			x	x				
[25]		x			x					x							(x)	x
[30]		x	x					x			x							x
[33]		x	x	x		x			x							x		x
[34]						x								x				
[35]	x	x	x	x			x	x										
[36]		x	x			x										x		
[37]	x		x			x							x		x			x
[27]	x		x	x		x			x		x							x
[38]	x			x						x	x							
[39]		x		x				x										
[29]	x				x	x			x					x				x
[26]			x									x	x					x
[40]		x	x		x											x		
[41]			x	x	x	x												
[42]	x		x			x				x		x						

6. Conclusion: Special features and needs of SMEs when implementing EnMS

Compiling basic information on the company's energy consumption is an appropriate starting point for the implementation of EnMS. Most SMEs lack a data collection. The initial investment in metering equipment can be a significant hurdle. This is a serious challenge for SMEs and makes it difficult to identify opportunities for energy savings. They rarely have sufficient expertise [43], personnel capacities or financial resources [43; 44]. The three most serious obstacles to the implementation of energy management initiatives describe the lack of time, the prioritisation of activities considered to be more important and a lean organisation [43]. Further obstacles and the resulting requirements for the successful implementation of energy management in SMEs have been sufficiently discussed in the literature. An overview of minimum requirements is summarised based on Schulze et a. [45]:

- Development of a long-term strategic plan and relevant procedures
- Establishment of a management team and allocation of roles and responsibilities
- Identification of company-specific key figures
- Identification of the current status through energy audits and regular data collection, monitoring and reporting
- Planning and implementation of specific energy projects
- Active involvement of employees through information, motivation and training
- Ensuring the support of top management for energy management activities.

With the introduction of the ISO 50001 standard, companies were provided with an internationally valid standard that is intended to support the introduction of EnMS and the fulfilment of these requirements [46]. It applies to both small craft businesses and large companies. However, this standard has some shortcomings and weaknesses in practical application; this particularly affects SMEs due to their limited management capacities. For small companies, an EnMS is often an oversized starting point for an initial examination of the problem [44]. Software systems on the market for operational energy management also show that the systems are designed to meet as many general requirements as possible [46], but do not take into account the special features of SMEs. Rajic et al. have shown that such system approaches can only be implemented inadequately [47] and that suitable management support for the special challenges of SMEs is necessary.

In our work, we used the DSR process to address several research questions. Using an extensive survey conducted among SMEs in MV, we demonstrated the relevance of the topic of energy management in the corporate context. The survey included the results of 506 participants from MV. An extension of the survey to Germany or the European area should be part of future research. With regard to the relevance of energy management in Europe, we presented current market trends and forecasts for the energy management market, which predict a doubling of the market volume by 2028 (reference year 2024). Another part of the survey was the identification of reasons for a low or high assessment of the relevance of energy management. It emerged that targeted cost savings and competitive advantages are the main drivers for a high rating. In the subsequent literature analyses, reviews were

searched for in order to identify the current state of research and to identify the specific characteristics and needs of SMEs in the implementation of EnMS. It was found that existing reviews had a strong technical orientation in their research approach and did not address the specifics of SMEs. The second literature analysis revealed that the introduction of EnMS in SMEs depends on various economic, organisational and personnel factors. Of particular importance is the availability of financial, human and material resources, as well as the provision of system-relevant information. We identified several requirements that SMEs must fulfil in order to successfully implement an EnMS. As an aid for the successful introduction of such a system, ISO 50001 provides SMEs with initial approaches and represents an elementary framework that can serve as a guide for companies. However, the standard is formulated in very general terms and must be interpreted specifically for each company. In the course of our investigation, we came to the conclusion that SMEs require an IT-supported MS for the introduction of EnMS that takes into account the special features of SMEs and optimally supports the companies.

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