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Energy Management Systems in SMEs: Relevance, State of Research and Requirements

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Abstract. Energy management and its organizational implementation by energy management systems (EnMS) have increased substantially in importance during the last few years. Some of the reasons for this trend are a growing number of regulations in the area of sustainability, the need to reduce energy consumption due to higher costs, and the intention to avoid energy waste. EnMS is not a new topic, and there is some research on how to introduce and operate EnMS in large organizations, but the situation for small and medium-sized enterprises (SMEs) regarding EnMS is not well-researched. The main objective of the research presented in this article is to contribute to a better understanding of the state of research and also the state of practice in energy management of SMEs as a foundation for future research in the field. The contributions of this article are (1) the results of a survey among SMEs confirming the relevance of energy management and a lack of knowledge of how to implement energy management systems, (2) the results of a systematic literature study structuring the existing work on EnMS for SMEs, (3) the outline of a proposal how to support SMEs in energy management, and (4) interviews with experts from SMEs to elicit basic requirements for EnMS implementation in practice. The main finding of the article is that there is a demand in SMEs for tailored support in EnMS introduction, but no suitable solution in the scientific body of knowledge.
Keywords: Energy Management, Small And Medium-Sized Enterprises, SME, Relevance, Requirements, Literature Analysis, Survey, Management Systems.

1 Motivation

With the increasing importance of sustainability and related regulations, such as the European Union's "Green Deal[†]" and the United Nations' sustainability goals, the reduction of energy consumption, the avoidance of energy waste, and the role of energy management in companies

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

have increased. For large organizations, reports on the successful implementation of EnMS are available (see, e.g. [1]), but the situation for small and medium-sized enterprises with regard to EnMS is not well researched. Energy management is only one of many challenges for SMEs, which 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 impact on job creation and stimulating economic growth [2]. In 2021, they accounted for 99.4% of enterprises in Germany. They employed 54.8% of the workforce and accounted for 28.7% of total German turnover. Together, they generated 42.4% of Germany's gross value added [3]. This underlines the importance of SMEs for the German economy. A survey conducted by the German Institute for Economic Research in 2023 revealed that German industry is in crisis. Around two-thirds of the companies surveyed said that high energy, raw material, and material costs were affecting their competitiveness [4]. Institut der Deutschen Wirtschaft Brief Report 43/2023 informs that energy prices and supply insecurity are having a serious impact on capital outflows in Germany [5].

As recently as 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) found that in most sectors and countries, energy played a minor role in the calculation of competitiveness [6]. However, due to the ever-increasing cost of energy sources and their security of supply, energy management has become an increasingly important issue for companies in recent years [7]. For this reason, energy management, like quality and environmental management, is becoming increasingly important. A comparison between large companies and SMEs by Bath et al. shows that large companies generally perform better than SMEs in several dimensions, including the management of energy and sustainability issues [8, p. 601]. Altenburger [9, C1–C1] describes how SMEs often have less systematic approaches to energy management than large companies due to limited resources and organizational structures. Due to their limited resources and expertise, they are often less able to implement comprehensive energy management strategies than large companies [10, p. 1–2]. However, the sustainable orientation of companies is increasingly becoming a decision criterion for potential contracts [10, p. 1–2]. For this reason, the authors of this article have decided to investigate the relevance of energy management for SMEs in more detail and to identify the support SMEs need to plan and implement energy management initiatives.

The main contributions of this article[‡] are (1) the results of a survey among SMEs confirming the relevance of energy management and the lack of knowledge on how to implement EnMS, (2) the results of a systematic literature review structuring the existing work in the field of energy management for SMEs, (3) the outline of a proposal on how to support SMEs in energy management, and (4) interviews with experts from SMEs to confirm their needs for EnMS implementation in practice. The main finding of the article is that there is a need in SMEs for tailor-made support in the implementation of EnMS, but that there is no suitable solution in the scientific knowledge.

The article is structured as follows: Section 2 provides a brief introduction to energy management and management systems. Section 3 describes the research methodology. Section 4 presents a survey of SMEs on the status of energy management. Section 5 presents the results of a systematic literature review. Section 6 discusses data collection as a pivotal area of operational energy management and identifies the specific needs of SMEs. Section 7 uses a series of interviews to gather information on the status quo of EnM in SMEs, which corresponds to the actual needs of SMEs. Section 8 summarises the identified requirements for methodological and technical support

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for SMEs in implementing EnMS. Section 9 discusses the findings, describes the limitations of this work, and provides an outlook for the authors' future research.

2 Background: 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 organization of companies. Those structures influence the behavior of the employees and organizational units. Furthermore, the MS is a management tool that 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 organizational structures adjusted to the activities. It comprises the structural and procedural organization, which have to be purposefully organized and harmonized with each other to support the accomplishment of a company's strategic business goals. MSs have been an element of organizational 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 critical for enterprises to reduce costs, enhance sustainability, and comply with regulations. Energy management involves implementing a MS for monitoring, controlling, and optimizing 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, analyzing data, and implementing improvements, often following standards such as ISO 50001 [7].

3 Design Science Research Process

The main objective of the research presented in this article is to contribute to a better understanding of the state of research and the state of practice in energy management of SMEs as a foundation for future research in the field. Furthermore, this article aims to identify what requirements SMEs have when it comes to supporting them in introducing and conducting energy management. The research covered in this article is part of a larger project, which follows the paradigm of design science research (DSR) [15]. DSR aims at problem-solving in organizational settings, focusing on developing valid and reliable knowledge for designing the required solutions. The envisioned solution, called an "artifact" in DSR, in our research, is methodical and technological support for implementing EnMS in SMEs. However, this article does not cover the complete artifact but the initial steps of the DSR, which lead to the requirements for this artifact.

DSR research projects typically consist of several phases and require the use of different research methods depending on the DSR phase and the intended design solution. The first phase, and one topic of this article, is to define the problem under investigation and demonstrate its relevance to business and research. The business relevance of our research is investigated by conducting a survey among SMEs, which collects and analyses information on SMEs' views on energy management and their requirements. This survey, including the research methodology used to collect and analyze the data, is described in Section 4. Relevance to research typically includes an examination of the existing knowledge base, i.e., the state of research, which is the focus of

Section 5. In this context, the research method is a systematic literature review, which is presented in detail in Section 5.

The second DSR phase, also covered in this article, aims at defining requirements and the initial design of an artefact that is supposed to solve the identified problems. As mentioned above, the artifact in our case is methodical and technological support for the implementation of EnMS in SMEs. In Section 6, we identify the main features of SMEs in implementing EnMS that need to be considered in the requirements for the artifact. In Section 7, expert interviews will be conducted to verify whether the requirements identified in the previous methodological studies correspond to the object of practice and the needs of SMEs. The remaining phases of the DSR, i.e., the design and evaluation of the artifact, its demonstration, and final evaluation, will be part of future work.

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**: What specific features and needs of SMEs when implementing EnMS are addressed in existing literature reviews?
- **RQ5**: Is there a need for management system support in the field of energy management among SMEs?
- **RQ6**: What are the requirements for SME practitioners for energy management system implementation?

In RQ1, RQ2, and RQ5, we start from the perspective of German SMEs and contrast our findings with statistics at the European level. With the results of the survey and the literature analysis, we want to prepare the second and third phases of the DSR project: the requirements definition and the initial design of the artefact. For this purpose, we discuss potential methodological and technological support for EnMS in SMEs. 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 Future Centre Mecklenburg-Western Pomerania + (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 issues, 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 the participants was carried out using guided question-based interviews. An external service provider (Dukath) was contracted to carry out the interviews. Several criteria were defined for the selection of the companies.

- A total of at least 500 enterprises should be surveyed.
- Their distribution in terms of size and sector of activity should correspond to that of the federal state.
- All administrative districts should be equally represented.

The Statistical Yearbook of MV 2022 [16] served as the basis for the last 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 survey aims to determine 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 4-point Likert scale based on the work of the Federal Environment Agency [17] and Schulze [18] was used to answer the guideline-based interviews. The pretests of the study took place from 02.11.2023 to 03.11.2023 and were accompanied interdisciplinary by the Work and

Organisational 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 interviewed. The composition of the sample corresponds to the distributions in the federal state in terms of sector distribution and enterprise size. The enterprises were fairly evenly distributed across all districts. The following figures (Figure 1 and Figure 2) show the distribution of the sample by sector and enterprise size.

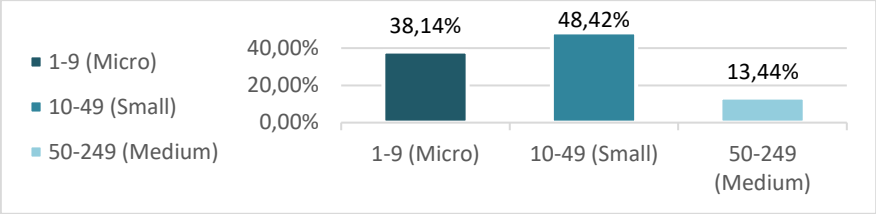
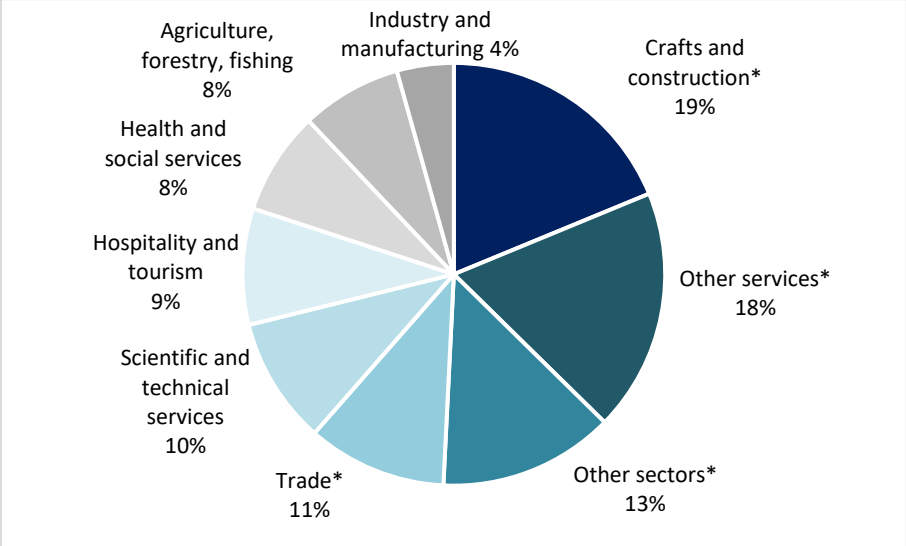


Figure 1. Distribution by company size based on SME definition of [19] (n = 506)



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 include 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].

Figure 2. Distribution of the sample by sector (n = 506)

4.1 Relevance of Operational Energy Management for German SMEs (RQ1)

The survey on the relevance of energy management in one's own company was carried out using a 4-point Likert scale and asked of all companies. Responses ranged from "very low relevance" to "very high relevance". It is clear that the larger the company, the more important energy management is to the company (Figure 3). Micro companies rated the relevance of energy management to their business with an average score of 2.56, small companies with an average score of 2.88, and medium-sized companies with an average score of 3.74.

We analyzed the relationship between company size and the rating of the relevance of energy management using the Spearman rank correlation coefficient. The calculation of the coefficient showed a correlation of 0.295, which is significant at the 0.01 level with an N of 506.

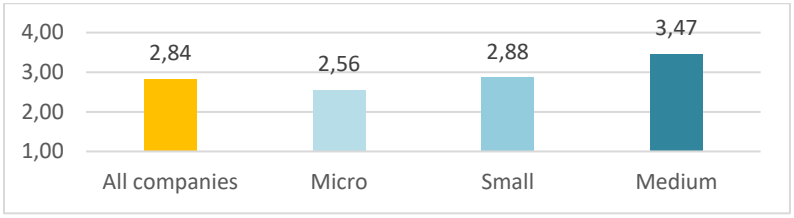


Figure 3. Assessment of the relevance of energy management in the company based on the mean value (n = 506)

While the survey gives an average rating of 2.84 for the relevance of an 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 crafts (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 the increasing demand and numerous applications of smart meters. Energy management is considered necessary for smart 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% from EUR 2.8 billion (2023) to up to EUR 4.6 billion by 2028 [21]. This underlines the growing importance of these MSs 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 rating of the relevance of energy management, we analysed the reasons for a low or high rating 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).

The most common reasons why respondents rated the relevance of energy management as low were existing low energy consumption (55.36%), subsidized energy costs for businesses (53.57%), excessive time or staff 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. Figure 4 shows the reasons for the low rating of the role of energy management in the company.

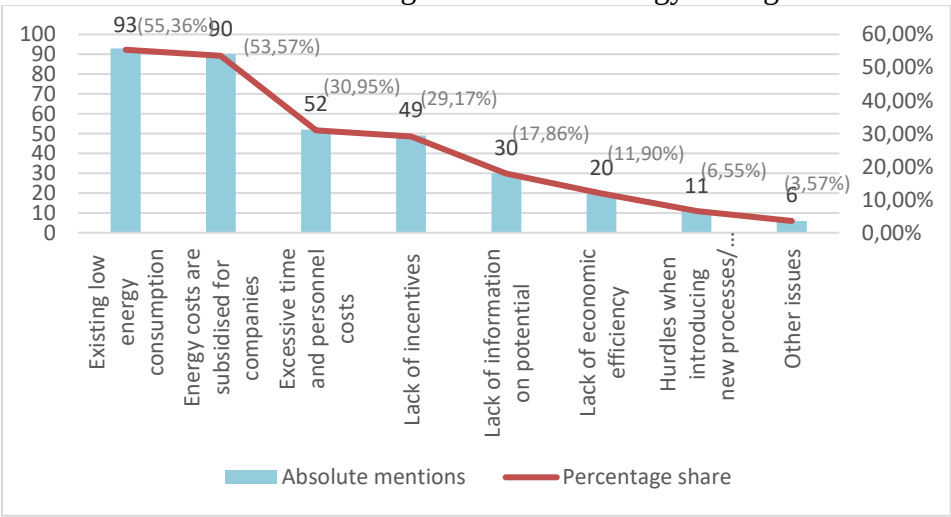


Figure 4. Reasons for low rating of the role of energy management in the company based on absolute and (relative) frequency (n = 168) – Multiple selection possible

We also analyzed the reasons for high relevance (Figure 5). The main reason given by respondents for their assessment was the motivation to reduce costs to the company (97.93%). Other drivers were the desire to gain a competitive advantage (34.02%), to support security of supply (19.82%) and to gain a technological advantage (15.98%). Planned certification (0.89%) was particularly unimportant for SMEs.

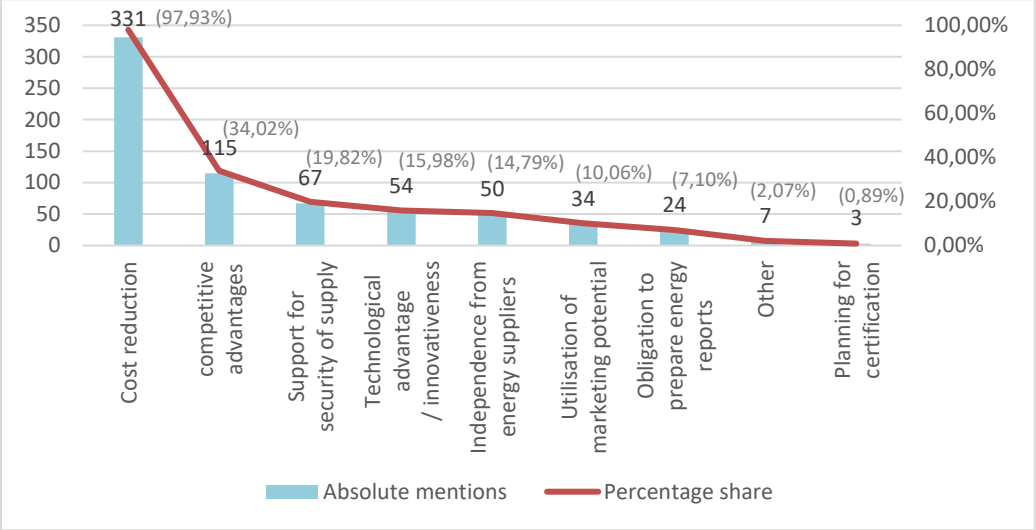


Figure 5. Reasons for the high rating of the role of energy management in the company based on absolute and (relative) frequency (n = 338) – Multiple selections possible

5 Systematic Literature Analysis on EnMS Research

The aim of the literature review is to analyze the current state of research in the field of EnMS in an operational context. A systematic literature review was carried out to identify the required knowledge according to Kitchenham [22]. We chose this approach because it was designed to identify what has already been published on a research topic, compare it with each other and thus identify and analyse potential research gaps. Following the Kitchenham approach, we proceeded in six steps. First, we formulated three broad research questions (as stated in Section 3).

- **RQ3**: Which topics have been focused on in previous research on energy management systems in the corporate context?
- **RQ4**: What specific features and needs of SMEs when implementing EnMS are addressed in existing literature reviews?
- **RQ5**: Is there a need for management systems support in the field of energy management among SMEs?

We then conducted a systematic literature review using several search strings and identified relevant literature (see Section 5.2). In addition to formulating search strings, inclusion criteria were also defined. In a further step, we identified the relevant data from the selected studies and summarised the results in tabular form. The development of the search terms is shown in the following section.

5.1 Development of the Search String

Once the research questions had been defined, the systematic literature search began with an initial search for the term ‘energy management system’. The search focused on identifying reviews to provide an overview of the topic. Synonyms were used for the term 'literature review' in order not to exclude relevant papers from the search. For the same reason, the search term was not limited to the SME sector. In addition to the search for reviews on energy management, a further search

string was created for SMEs. The purpose of this separate search was to ensure that the specific characteristics of SMEs were taken into account in the implementation of EnMS. In a further step, we used keywords to refine the search queries. We used the Scopus database to develop the search terms. The resulting search string was deliberately broad to gain a comprehensive insight into the topic and not to inadvertently exclude relevant literature. The search was then extended to the IEEE-Explore, AISeL, and ScienceDirect databases. The search query was adapted to the syntax of the databases used. The final search terms of the systematic literature review and the number of hits per database are shown 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 of literature" OR "review of publications" OR "analysis of literature" OR "literature analysis" OR "literature overview" OR "search of 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. This systematic approach resulted in a total of 50 hits for the first search string and 48 hits for the second search string after comparing duplicates (See Figure 6).

The following section explains the process of article selection and the inclusion criteria used during and after the development of the search terms.

5.2 Selection Procedure & Inclusion Criteria

In order to structure the literature selection process and to make the literature comparable, inclusion criteria that an article should contain to be considered relevant were defined.

The criteria can be divided into two overarching categories - the content and the qualitative relevance of the literature review. In terms of content, the search for literature reviews should focus on EnMS (criterion 1 in Figure 6) and consider the operational context (criterion 2 in Figure 6). During the search process, we repeatedly came across papers that focused on smart home applications or energy management in terms of human health practices. However, this research aims to gather information to support organizations in implementing and operating an EnMS. Therefore, we decided to exclude papers that go 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. Therefore, 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 to ensure the transparency and comprehensibility of the work (criterion 3 in Figure 6). While it was possible to limit the selection of literature to the last ten years by searching the databases, the remaining criteria were considered manually.

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

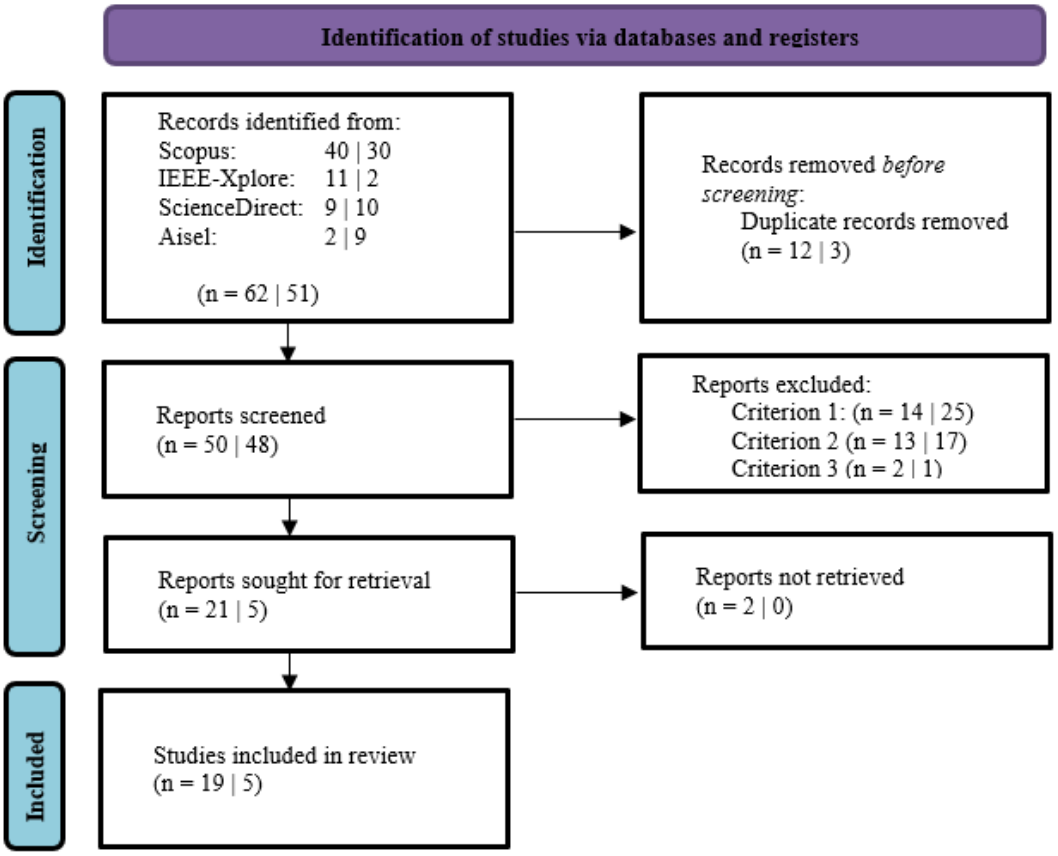


Figure 6. Overview of literature search based on Page et al. [23]

5.3 Results of the Literature Analysis (RQ3 and RQ5)

The literature review showed that the focus of the previous review literature (S1) on EnMS has a very technical background (see Table 2). In recent years, research has focused intensively on the optimization of EnMS (13 sources) and microgrids (8 sources). Many studies have analysed the benefits and challenges of these systems. Extensive research has been carried out on building energy management systems (BEMS) (7 sources), demand side management (DSM) (7 sources), and the use of algorithms to reduce costs or provide forecasts (9 sources). Other approaches focus on the use of distributed systems (3 sources), the integration of digital technologies (3 sources), or regulatory frameworks (4 sources). Recent literature has also discussed the use of AI solutions (3 sources) and, increasingly, the use of renewable energy (4 sources) and energy storage systems (3 sources). Despite significant progress in EnMS research, the SME sector remains largely unexplored. The topic of EnMS in the SME sector is only indirectly addressed in two literature reviews [24], [25], but is not a focus of the work. However, neither Alonso et al. [24] nor Chang et al. [25] address the specificities of implementing energy management initiatives, which points to an existing research gap. The other reviews do not pursue the topic of SMEs.

However, the analysis identified a high relevance of MS. In their study, Chang et al. emphasize the need to use an MS to control and monitor energy consumption and to identify waste. They do not limit themselves to a specific application area but describe that this applies to both industrial standards and households [25]. In their work, Santolamazza et al. [26] propose IT-based solutions that support the decision-making process of energy managers, using the potential of Industry 4.0 approaches. In their study, Muqeet et al. [27] consider very large campus microgrids, which would not be controllable without IT-supported MS. They suggest further optimizing MS with modern approaches such as blockchain, artificial intelligence, or machine learning. The reviews primarily pursue management-based approaches to optimizing energy processes. For instance, Ali et al. [28]

address the use of a power flow MS to control different energy generators in order to optimize their yields. Raya-Armenta et al. [29, p. 4] discuss a load MS as a subsystem of an EnMS and emphasize the need for IT support to enable economic benefits. Hannan et al. [30, p. 39009] describe a data MS using sensors, sub-meters, and smart meters to assess building performance.

Table 2. Overview of previous research focuses (S1)

Focus topics of the study	Microgrid	BEMS | ZEB	Process optimization	Demand side management	EnMS infrastructure	Algorithms for cost reduction or forecast + simulation	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 analyses	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						

Note: 'X' emphasizes a topic covered in the work. '(X)' indicates that the specified topic is only dealt with as a partial aspect of the work.

6 EnMS for SMEs: Special SME Needs

To analyze the specific needs of SMEs, we used the results of the second literature review (S2), the part of the survey that focused on data collection, and the ISO 50001:2018 standard as a framework for implementing energy management systems.

A fundamental part of an organization's energy management is the recording of the organization's energy status. ISO 50001 [43] describes data collection as an essential part of an EnMS. In order to assess and improve the energy performance of an organization, relevant energy data needs to be collected and measured. Gathering basic information on the energy consumption of an organization can, therefore, be seen as a good starting point for the implementation of an EnMS. However, most SMEs do not have appropriate data collection in place. The initial investment in metering equipment can be a significant barrier, especially for smaller companies. This is a serious challenge for SMEs and makes it difficult to identify potential energy savings [44, p. 241]. They rarely have sufficient expertise [45, p. 78], [46], [47, p. 174], staff capacity or financial resources [46], [48, p. 23].

Although SMEs in Europe are currently exempt from carrying out energy audits [49], data collection as a starting point for operational energy management remains a prerequisite for successful and sustainable system implementation, regardless of the size of the company. In our

survey, only 18.77% of respondents were able to confirm the collection of energy data, regardless of its form (see Figure 7). However, there is a clear difference between company sizes.

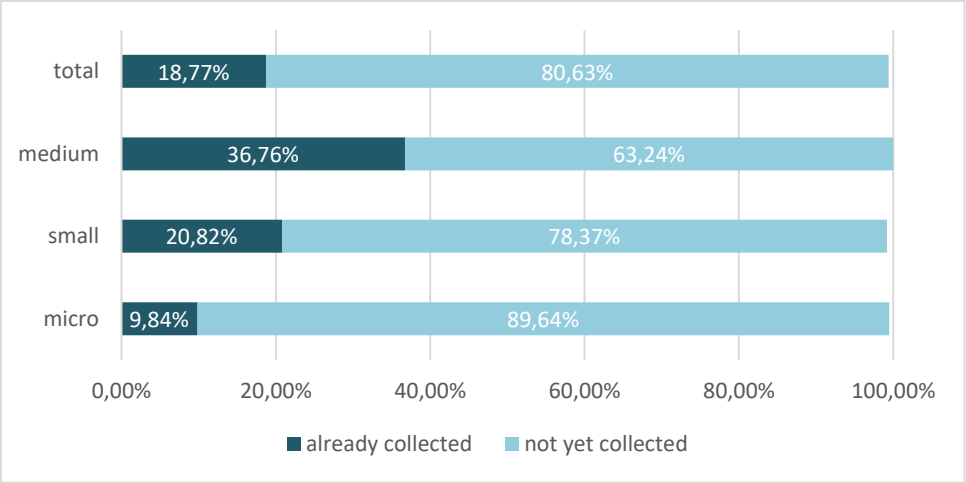


Figure 7. Recording of energy data in companies by company size (n = 506)

While more than a third of medium-sized enterprises reported that they record their energy consumption, only 20.82% of small enterprises and 9.84% of micro-enterprises answered affirmatively. Regarding the types of systems used to record this consumption data, it is clear that energy and environmental management systems play a subordinate role. More than half of the enterprises (56.36%) currently use planning and cost accounting systems with environmental data (see Figure 8).

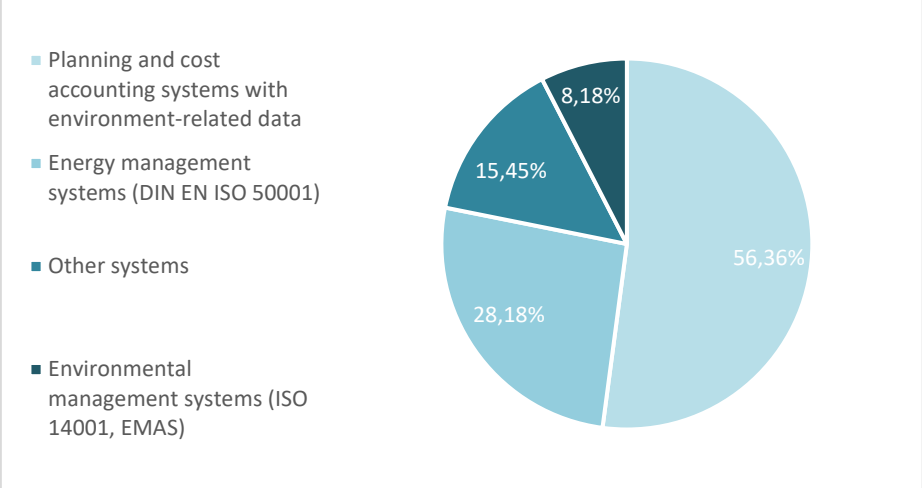


Figure 8. The proportion of systems used to record energy-related data (n = 95)

Comparing the number of companies that rated the importance of corporate energy management as high for them (338 enterprises) with those that have already taken a first step towards implementation by collecting data (95 enterprises), it becomes clear that there is a discrepancy in the SME sector between recognizing the importance of the issue and implementing measures.

The three main barriers to implementing energy management initiatives are time, prioritization of activities considered more important, and a lean organization [46]. Other barriers and the resulting requirements for the successful implementation of energy management in SMEs have been sufficiently discussed in the literature. An overview of the minimum requirements is summarised based on Schulze et al. [50]:

- 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, organizations have been provided with an internationally valid standard to support the implementation of an EnMS and the fulfillment of these requirements [51]. The standard has structural similarities to other frameworks, such as ISO 9001:2015 or ISO 14001:2015. This allows existing systems to be extended to include energy-specific aspects. This means that existing structures and processes can be used rather than having to create them from scratch [52]. Sola and Mota [53] recommend that a company's top management, in particular, should undertake long-term strategic planning for the implementation of an EnMS in accordance with ISO 50001. The standard is designed to be sector-neutral and applicable to organizations of all sizes. Accordingly, companies have to do a kind of translation work to make the standard applicable to their organization. This weakness in practical application particularly affects SMEs due to their limited management capacity. In their work, Rampasso et al (2019) [54] report a fundamental challenge of the standard. ISO 50001 does not specify how companies should implement the individual items. This leads to difficulties in achieving the energy targets set by the standard. The need for continuous measurement tools and the complexity of data and the standard make it even more difficult to adapt the standard to the specific needs of an SME [55]. SMEs face high certification costs and a lack of available resources when adopting the ISO standard. This can be further complicated by a lack of management commitment. Due to the specific requirements of SMEs, in particular, in terms of limited human and organizational resources and the necessary transformation effort, ISO 50001 proves to be too general to be easily integrated into the structures of SMEs.

This challenge is exacerbated by the fact that existing EnMSs are often not aligned with ISO 50001. While ISO 50001 already has integration difficulties in SMEs due to its general framework, many available operational energy management software solutions have a similar approach - they are designed to cover broad requirements. For small companies, an EnMS is often an oversized starting point for an initial examination of the problem [48, p. 23]. Software systems on the market for operational energy management also show that the systems are designed to meet as many general requirements as possible [51, p. 53], but do not take into account the specifics of SMEs. Rajic et al. [56, p. 13] have shown that such system approaches can only be implemented inadequately and that appropriate management support is needed for the special challenges of SMEs.

7 Expert Interviews

The aim of the expert interviews in the context of this article is twofold: the first objective is to gather information on the status quo of EnMS in SMEs to provide the basis for the validation and further refinement of the identified requirements. The second objective is to provide a practical assessment that demonstrates the relevance of the research findings for SMEs and considers their applicability in operational processes, i.e., would the implementation of the requirements lead to an improvement of the status quo?

For an initial categorization of our findings, we conducted expert interviews with directors and managers from three SMEs in the service sector. This limited number of interviews will be supplemented by further interviews in future work.

The companies differ in terms of size, focus of business purpose, and energy situation. While the largest of the companies with more than 200 employees is a medium-sized company (abbreviated as "JG") providing social services, the other companies are small businesses in the catering and accommodation sector. One of the two companies is still in the development phase (RB), and the other has been on the market for several years (TB). Although the companies are fundamentally different in terms of their framework conditions, they are very similar in their assessment of the energy situation for their company.

A semi-structured interview procedure was used for data collection, which allowed the experts to describe their experiences with energy management. The interview guide included open-ended and thematic questions to encourage the experts to explore relevant aspects of the research topic. Before the actual data collection, the interview guide was pre-tested twice to check the comprehensibility and relevance of the questions and make any necessary adjustments. The interviews were conducted face-to-face in the experts' company environment to ensure the highest possible quality of dialogue and an atmosphere of trust. The experts were allowed to express themselves freely while, at the same time, covering the main topics of the interview guide. All interviews were recorded with the consent of the participants and then transcribed verbatim to allow for a clear analysis of the content of the statements. The content of the interviews was analyzed according to Mayring's approach [57].

The transcribed form of the interviews and the underlying interview guidelines are available at [58]. During the interviews, the experts commented on several key issues. These ranged from the energy situation, motivators, drivers, and barriers to the challenges faced by the company in relation to operational energy management.

Table 3 shows an aggregated form of the experts' statements. The thematic focus of the expert statements is shown in the first column of the table. In the second column, the above-given abbreviations of SME sizes are used to show to which type of SME the statements correspond. Expert statements are provided in the third column.

Table 3. Overview of expert statements according to key topics

Thematic focus:	**Proof in:**	**Expert statement:**
Actual state	RB, TB	• Companies describe the current situation as uncontrolled, unmanaged energy consumption with individual optimization approaches • Regional circumstances – especially existing public infrastructure - severely restrict companies in their energy management options and, in some cases, prevent innovative solutions • Information deficits and a lack of organizational resources make it difficult to implement measures
The corporate objective in connection with EnM	RB, TB	• Economic activity as a central objective • Ensuring security of supply • Positioning the company in the regional context
The trigger for EnM endeavors in the company	RB, TB, JG	• External pressure (obligation to audit) as an impetus for the UN to engage with EnM • endeavor to reduce costs and align the company economically
Factors with the most significant influence	RB, TB	• Efficiency and effectiveness of business operations – economic efficiency • Ensuring security of supply • Overcoming information deficits
Responsibility	RB, TB, JG	• Energy management in SMEs as a sub-task of the executive board or management • There is currently no explicit position in the UN that deals exclusively with EnM • 'Not a task for the sidelines' – Difficulty of implementation due to scarcity of resources and potential role conflicts • As the size of the UN increases, so does the cost of EnM for companies placing an additional burden on those responsible for multiple roles

Table 3. Continued

Thematic focus:	**Proof in:**	**Expert statement:**
Financial resources	RB, TB, JG	• Identified by the UN as one of the most relevant factors • Higher investment costs are not possible without external financial support • Lack of organizational resources in the form of financial and human resources has been identified as a serious obstacle to the implementation of initiatives. • Lack of external incentives/support aids prevents an increase in the efficiency of operational EnM
External incentives	JG, TB	• External incentives are important for the implementation of larger projects • There is usually a lack of external incentives to improve the company's energy efficiency • Experts perceive a lack of support in the implementation of initiatives • Existing lack of information on how measures are implemented and what funding opportunities exist • Desire for unbureaucratic financial support for projects
Legal framework	RB, TB, JG	• Political framework conditions prevent the adoption of existing solutions from abroad • Technology to increase efficiency is available – framework conditions are not right. • Information on statutory funding opportunities is essential • Lack of support for the implementation of measures | Unsuitable guidelines • Bureaucratic effort is currently perceived as very high • Government advisory services and funding programs are recognized as an introduction to the topic
Management systems	RB, TB, JG	• Support from a management system is necessary in order to tap deeper potential • Management approaches as a process support approach to relieve the burden on those responsible • Preference for automated systems over manual solutions
Influence of external actors	TB, RB	• Cooperation with regional providers beneficial for EnM initiatives • Role model function of other municipalities • The will to involve regional players is there • There is an expectation from customers to act sustainably • Energy suppliers and the regional infrastructure usually present SMEs with particularly high challenges
Influence of internal actors	TB, JG	• Employee participation is rated as essential for the introduction process • Role model function of managers and their commitment are decisive for the success of EnM initiatives
Regional conditions	TB, RG	• Regional circumstances influence company initiatives • Regional conditions, especially in rural areas, can have a negative impact on corporate energy management • Lack of infrastructure slows down efforts
Further thematized focal points	RB	• Importance of embedding in the corporate strategy • EnM as an opportunity to improve the company's image • Approach to marketing opportunities

On the basis of anchor examples, the status of energy management in the companies surveyed is presented before the requirements for technical and methodological support of the EnMS implementation process in German SMEs are summarised. We will focus on selected key areas.

The assessed energy status of the companies was described by the experts as 'unmanaged and uncontrolled' although initial optimization measures had already been implemented. The security of supply plays a special role for companies located in rural areas. Economic activity and the security of supply are the primary objectives of the companies. The main reason why the companies started with energy management is the desire to reduce costs and to become more

energy efficient. Only the medium-sized company also indicated that an external requirement to carry out an energy audit was an additional motivation to deal with the issue. However, the main reason for companies to deal with operational energy management is due to the economic efforts of the stakeholders.

Anchor example 1: *"The profitability of the company... is the most important factor... – the efficiency and effectiveness of the business... Especially if you are setting up a business in the corner of the island, it is very important to know that the energy supply is firstly stable and, secondly, that you integrate yourself into the island's supply system and try to work as energy-efficiently as possible within the framework of the possibilities available there."*

Responsibility for operational EnM lies either with the management or with a manager who is essentially familiar with other tasks. None of the companies surveyed currently have an explicit role focused on operational EnM. This double burden on the management level leads to a lack of organizational resources and role conflicts. The larger the company, the greater the burden.

Anchor example 2: *"An internal barrier would be that no one has been appointed to take care of it full-time... personally, I don't think you just do it on the side."*

The financial resources of companies are essential to the success of EnM. A lack of organizational resources, both financial and human, was identified as a serious obstacle to the implementation of initiatives. Without external financial support, high-volume investments are considered by experts to be too risky to manage alone.

Anchor example 3: *"If the incentive is not there and the financial resources are not there, then I don't think the energy transition will work."*

All experts were negative about external incentives. They are considered important for the implementation of larger initiatives, such as the procurement of measuring instruments. For the most part, however, no external incentives were perceived. In particular, a lack of initial advice is considered important by the companies in order to compensate for an existing information deficit and to provide approaches to deal with the topic.

Anchor example 4: *"We've been here for over 20 years, where we end up putting every cent we earn back into the company. It's very important for us to see: How do we get funding?"*

All the experts were critical of the policy framework in which they operate. They make it clear that government advisory services and targeted funding programs would support the implementation of energy solutions - but that these are not sufficiently available. In some cases, the policy framework is perceived as not designed to make businesses and communities fit for the future.

Anchor example 5: *"Legal framework conditions are a very big issue, unfortunately. Technological restrictions are less so. This is not what the political side wants when it comes to building a community for the future ."*

In addition to the legislator as an actor, the experts also address other stakeholders. While cooperation with other regional suppliers is seen as beneficial for energy management initiatives, cooperation with regional energy suppliers is seen as a challenge by the experts. One of the experts reported on the role model function of other municipalities and companies, which was one of the main reasons for taking a closer look at the topic. Of course, the company's customers also influence the company's commitment. There is a certain expectation that the company will act in a sustainable manner. This underlines the urgency of the issue.

Anchor example 6: *"We have a lot of guests from Denmark and the Norwegian countries. They are much more advanced with electromobility. More and more of them are here with us in their Tesla or something else and, of course, the bottom line is that they also want the electric charging*

station. This is of course a very important point for us in order to keep guests here in the long term."

Other groups with an influence on energy management include employees, management and the board of directors. Employee involvement is seen by all experts as essential to the long-term success of any measure. However, the commitment of management is essential for successful employee involvement. They provide a role model for their employees and their own behaviour contributes to whether or not employees participate in a problem.

Anchor example 7: *"If I explain this to the employees in a reasonable way – Why I want what, and they understand that, then, I think, they are more likely to follow than if you impose it from above."*

This commitment and the combination of several roles in one person leads to a further shortage of management time resources. Management approaches can be helpful here. They are seen by the experts as a support to give structure and relief to those responsible. The established companies described management systems as a prerequisite for realizing the deeper potential of EnM.

Anchor example 8: *"In order to take previous progress to the next level and become even more efficient, and to bring the individual solutions that already exist into a larger whole, a control and management system would be required."*

In summary, it can be said that there is a basic interest in energy management on the part of the partners in the field, which is primarily motivated by economic considerations, in particular, the desire to reduce costs and ensure the security of supply. However, there is a lack of human and financial resources as well as structural responsibilities, which makes implementation difficult. External stimuli, such as funding programs or advisory services, are hardly perceived but are considered necessary. The political framework is seen critically and as an obstacle to forward-looking action. At the same time, external expectations – from customers, other companies, or the region – are playing an increasingly important role. Employee involvement and management support are seen as key success factors for effective EnM. Management systems are seen as a helpful tool for bundling existing approaches and developing them in a targeted way.

8 Requirements for Methodological and Technical Support for SMEs

So far, we have presented the results of a systematic literature review, a survey of over 500 SMEs, and expert interviews. We have also analyzed the ISO 50001 standard, which is the basic framework for the implementation of energy management systems.

All these methodological approaches have resulted in the requirements for technical and methodological support of the implementation process of EnMS in SMEs. The resulting requirements are summarised in Table 4. The specific needs of SMEs in the implementation process developed in Chapter 6 have also been taken into account. The challenges and needs can be condensed into the set of essential requirements that future methodical and technical support has to meet.

The requirements in Table 4 are organized into the following 5 categories:

- Project management (4 requirements),
- Roles (5 requirements),
- Process (7 requirements),
- Data (2 requirements),
- Tool support (5 requirements).

The table's first column shows the requirement's identifier, the second column provides the requirement, the third column describes the basis of the requirement, and the fourth column points to the source of the requirement.

Table 4. Initial requirements for methodical and technical support for EnMS introduction in SME

Req. Id.	Requirement	Basis of the requirement	Source
Category: Project management			
#PM1	Definition of the energy strategy and targets	Ensure future viability through clear goals and long-term planning	Interviews, ISO-50001, SLA
#PM2	Enabling a step-by-step and iterative introduction to energy management	Limited resources and overly complex EnMS tools hinder implementation in SMEs	Interviews, SLA
#PM3	Determining the minimum project team composition	Establish clear responsibilities through a defined team and main contact	Interviews, ISO-50001, SLA
#PM4	Involvement of external stakeholders	Consider expectations and input from external actors	Interviews
Category: Roles			
#R1	Assign dedicated time to the responsible person	Energy management is not a side task, especially with limited resources	Interviews, SLA
#R2	Enable involvement of experts	Use of energy managers with expertise or external specialists	Interviews
#R3	Effective assignment of internal roles	Need for expertise and clear process responsibilities	Interviews
#R4	Involve top management	Role model and support from leadership	Interviews, SLA
#R5	Ensure employee participation	Active involvement through information, motivation, and training	Interviews, SLA
Category: Process			
#P1	Align consumption measurement with monitoring	Relevant energy data must be regularly collected and analyzed	ISO 50001, SLA
#P2	Gradual introduction of measurement technology	High initial costs are a major barrier, especially for SMEs	SLA
#P3	Develop a system for energy performance evaluation	Company-specific indicators must be defined	SLA
#P4	Capture current energy consumption	Poor data collection hinders control and evaluation	Interviews, Survey
#P5	Use external incentives	Lack of funding and resources impedes implementation	Interviews, Survey, SLA
#P6	Provide knowledge of energy-related processes	Knowledge gaps hinder effective EnMS	Interview
#P7	Apply efficiency principle in processes	EnMS tasks should be integrated into existing processes to minimize effort	SLA, Interview
Category: Data			
#D1	Use internal and external information sources	Lack of information on funding, regulations, and implementation approaches	Interview
#D2	Provide recommendations for integration into standard software	Need for concrete guidance on software integration	Interviews
Category: Tool Support			
#TS1	Provide a management system to ensure role clarity	Structure supports responsible persons and simplifies task allocation	Interview, SLA
#TS2	Enable internal communication	Internal communication is essential for successful implementation	Interview, SLA
#TS3	Provide tools to support EnMS implementation	Companies need assistance with system implementation	Interview
#TS4	Provide tools to monitor the EnMS maturity level	Continuous improvement requires regular assessment of measures	ISO 50001
#TS5	Access to software for energy cost monitoring	Economic efficiency is key – transparency is essential	Survey, Interview

In conclusion, from the perspective of SMEs, there is a lack of guidance on how to prioritize EnMS activities for their demands, how to achieve the organizational integration of required roles and processes, and how to implement software support for energy management at reasonable time and cost efforts.

9 Summary and Conclusions

In this article, we applied the DSR approach to answer several research questions. Based on an extensive survey of SMEs in Mecklenburg-Western Pomerania, we demonstrated the relevance of the topic of corporate energy management. The survey included the opinions of over 500 participants from Mecklenburg-Western Pomerania. This is also a limitation of presented research. Extending the survey to other federal states and beyond the national context should be part of future research. The survey showed that the topic of energy management is highly relevant in the companies surveyed. With regard to the relevance of energy management in Europe, current market trends and forecasts for the energy management market were discussed, which predict a doubling of the market volume by 2028 (reference year 2024). The survey also identified the reasons for low and high relevance ratings. It was found that primarily economic reasons (cost savings, competitive advantages) are decisive for the high relevance of the topic.

In the subsequent systematic literature review, a search was conducted for energy management reviews in order to analyse the current state of research in energy management. It was clear from the papers identified that the focus of research to date has been very technical. The first literature review did not identify any work that considered the specific needs of SMEs. This aspect was specifically analysed in a second literature review. It was found that the implementation of EnMS in SMEs depends on several economic, organizational and human factors. The availability of financial, human and material resources as well as the provision of system relevant information play a special role.

This lack of organizational resources on the part of SMEs is also evident in the expert interviews conducted. The practice partners show a fundamental, economically motivated interest in energy management, primarily to reduce costs and secure energy supplies. However, implementation is hampered by a lack of human and financial resources, as well as a lack of responsibility, which needs to be taken into account in the technical and methodological support needs of SMEs. The interviews also revealed that external funding and policy frameworks are perceived as insufficient, while the influence of external expectations and the importance of employee involvement and management support are clearly emphasised. Further expert interviews will be conducted in the course of our future research in order to deepen the findings.

In addition to these three methodological studies on the DSR approach, we also analysed ISO 50001 as a framework for the implementation of energy management systems. The standard provides a basic framework that can be used as a guideline for companies. However, the standard is formulated in very general terms and needs to be interpreted on a company-specific basis. This transformational task is a challenge that many SMEs find difficult to overcome.

In the course of our research, we identified 23 requirements that describe the technical and methodological support that SMEs need when implementing EnMS and organized these requirements in 5 requirement categories.

The central result of the work is that there is a need for tailor-made support for the introduction of EnMS in SMEs, but that the state of scientific knowledge does not yet offer a suitable solution. We have come to the conclusion that SMEs need an IT-supported MS for the introduction of EnMS, which takes into account the specifics of SMEs and supports the companies in an optimal way. From an SME perspective, there is a lack of guidance on how to prioritise EnMS activities according to their needs, how to organise the necessary roles and processes, and how to implement software support for energy management at a reasonable cost and time.

Future work will address the development of planned methodological and technical support for the implementation of energy management systems in SMEs according to the DSR paradigm.

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