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Barriers to and Drivers of Energy Management in Swedish SMEs

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Abstract: The energy efficiency gap is known as the difference between optimal level of energy efficiency and the actual level of achieved energy efficiency. Energy management has proven to further close the energy efficiency gap. Energy management may differ depending on whether it concerns a large, energy-intensive company or small and medium-sized enterprises (SMEs). SMEs are of high interest since they form a large share of the economy today. For SMEs, a lighter form of energy management, in the form of energy efficiency network participation, has proven to deliver sound energy efficiency impact, while for larger, energy-intensive firms, a certified energy management system may be more suitable. However, various barriers inhibit adoption of energy efficiency measures. While there is an array of research on barriers to and driving forces for energy efficiency in general, research on barriers to, and driving forces for, energy management is rare, one exception being a study of energy-intensive pulp and paper mills. This holds even more so for industrial SMEs. This paper aims to identify the barriers to, and drivers for, energy management in manufacturing SMEs. Results of this explorative study show that the top four barriers to energy management are lack of time/other priorities, non-energy-related working tasks are prioritized higher, slim organization, and lack of internal expert competences, i.e., mainly organizational barriers. The top four drivers for energy management are to reduce production waste, participation in energy efficiency networks, cost reduction from lower energy use, and commitment from top management. Furthermore, results show that energy management among the studied SMEs seems to not be as mature, even though the companies participated in an energy management capacity building program in the form of energy efficiency networks, which, in turn, shows a still largely untapped potential in the societal aim to reduce the energy efficiency and management gaps. The main contribution of this paper is a first novel attempt to explore barriers to, and drivers for, energy management among SMEs.

Keywords: energy management; energy efficiency; barriers; drivers; industry; SMEs

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1. Introduction

There has been increased attention towards improving the efficiency of production since the industrial revolution that led to using natural resources intensively [1]. Energy is among the inputs for production that have to be improved by energy management [2]. Globally, the industrial sector consumes around one-third of global energy use [3]. Typically, small and medium-sized enterprises (SMEs) represent 99% of enterprises and use more than 13% of total global energy demand [4]. In Sweden, industrial energy use was about 38% of the total energy use of the country in 2019 [5], and 17% of the industrial energy use is by SMEs [6]. Non-energy intensive SMEs are defined as "companies whose energy costs do not exceed 2% of their turnover," as investigated by previous studies in this field [7]. In order to promote energy efficiency within these SMEs, it is important to understand their problems that, academically, are described as barriers to energy efficiency improvements. To successfully design and implement policies in this regard, policymakers need to understand what motivates these SMEs, which are academically known as drivers. There are different barriers and drivers studied in industry, and such factors can be on different levels such as energy management, energy efficiency, and energy efficient technologies.

Energy efficiency improvement is one of the sustainable development goals to reduce energy use and greenhouse gas emissions [8]. Unfortunately, the full energy efficiency potential is not tapped due to the existence of what is explained as the energy efficiency gap, i.e., a gap between the potential level of energy efficiency and the actual level of realized energy efficiency [9]. The energy efficiency gap has been illustrated in various research papers (e.g., refs. [10,11]), where the earliest example is from the late 1970s by York et al. [12]. One of the most cited papers explaining the energy efficiency gap is by Jaffe and Stavins, explaining how the level of efficiency potential varies depending on the view of market-related barriers; the technologist's potential and the economist's potential [9]. Furthermore, in later research, the energy efficiency gap is extended to also include an energy management gap (e.g., refs. [13,14]). This means that investments in energy efficient technologies will not close the full energy efficiency gap by themselves, but there is also a need for energy management practices.

Management practices may include monitoring and operational routines, as well as awareness and knowledge, in relation to processes, flows, and energy efficiency at the company site [13]. In a quantification of the energy efficiency gap in Swedish electricity-intensive industry, 60% of the potential was estimated to relate to energy efficient technologies [15]. The energy efficiency gap can be reduced by considering both energy efficient technologies and proactive energy management, which, together, are referred to as the extended energy efficiency gap [16]. The importance of energy management has been studied in several empirical studies such as Christofferson et al. [17] and Thollander and Ottosson [18]. Johansson and Thollander proposed success factors for efficient energy management that can guide towards closing the energy efficiency gap [19]. In industry, energy management is referred to as the procedure to address energy use such as improving energy efficiency. Energy efficiency means producing the same output (products) with less input (energy) [20].

Most studies are focused on addressing barriers to, and drivers for, energy efficiency in different contexts, which are a part of energy management. The context can be firm size, energy intensive or non-energy intensive, and type of firm (for example manufacturing or foundry). With a few survey exceptions, such as de Groot et al. [11] about Dutch companies and Schleich and Gruber [21] about German companies, the research field about barriers to, and drivers for, energy efficiency normally has been conducted as case study research, e.g., a study of barriers to energy efficiency in Swedish non-energy intensive SMEs [22] and empirical investigations of drivers [23] and barriers [24] among SMEs located in the Lombardy region in Italy. The reason that most barrier studies are conducted through case study research is that national industrial sectors normally are not large enough to collect more than 100 responses, e.g., the Swedish pulp and paper industry uses half of the Swedish industrial energy use but consists of only 48 companies [25]. This paper adds to the current array of case study research. To the authors' awareness, there are few scientific papers related to barriers and drivers of energy management and in limited contexts, e.g., [25]. There are, to the authors' knowledge, no similar studies in relation to barriers and drivers of energy management among industrial SMEs.

The aim of this exploratory study is to identify the major barriers to and drivers for energy management in industrial SMEs. The novelty of this study comes from studying the barriers to, and drivers for, energy management in manufacturing SMEs. The results will provide important insights into energy management practices in SMEs and could, in turn, be a help to reduce the energy efficiency gap. The lack of identification of drivers and barriers to energy management is a challenge when it comes to understanding how advanced SMEs are in energy management and designing suitable policies to enhance drivers and reduce barriers to energy management in industry.

2. Research Background

2.1. Energy Management in Industry

Energy management in industry used to be a rarely studied subject [26]. In academic literature, there was, historically, an inconsistent understanding of energy management, although the adoption of energy management was increasing in business firms [13]. Different energy management definitions emerged, after the oil crises in 1973, such as O'Callaghan & Probert [27], Kannan & Boie [28], Capehart et al. [29], Abdelaziz et al. [30], Bunse et al. [3], and Ates & Durakbasa [31]. One of the latest definitions of energy management was provided by Schulze et al. [32]. Schulze et al. defined industrial energy management as a set of activities, procedures, and routines that include elements for strategy/planning, implementation/operation, controlling, organization and culture, and involve support and production processes under the aim of continuous reduction in energy and cost within industrial firms [32]. The authors also established an integrative energy management framework based on a systematic literature review [32].

The effective implementation of energy management practices, hand in hand with technology improvement, can extend the energy efficiency gap [13]. The energy efficiency gap is explained as the difference between the potential energy efficiency and what is actually achieved. Energy efficiency gap can be attributed to the existence of energy efficiency barriers that prevent energy efficiency from reaching its full potential [13].

One key factor needed to successfully realize the energy efficiency potential is to work with internal energy management [33]. Successful implementation of energy management may vary greatly and depend highly on factors such as the size and type of the industry [34]. Studies on energy management have some similarities. John recommended practices for strategic energy management: capture data, set efficiency goals, and communicate ongoing energy performance to stakeholders [35]. Abdelaziz et al. highlighted three parts for successful energy management, which are energy auditing, courses and training, and maintaining awareness and housekeeping [30]. Training has been proven to increase the level of competence of employees in big companies. It has the potential to increase knowledge in all trained areas, which relates to energy management [36]. Only 40–50% of Swedish energy-intensive industries could be described as successful when it comes to energy management [18]. There are also studies related to energy management systems, e.g., Zimon et al. investigated the impact of implementing ISO 50001 requirements on performance of sustainable supply chain management [37], and Gopalakrishnan at al. developed a standard methodology of using a flow chart and software to facilitate using ISO 50001 in companies [38].

2.2. Energy Management in SMEs

According to the European Commission, SMEs are defined as "enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million" [39].

SMEs seem to have more informal energy management compared to large businesses [40]. Prashar explained that SMEs do not effectively follow energy-saving activities, such as energy-saving guidelines and energy management standards, due to the scarcity of their resources [41], which, in turn, leads to high energy costs. SMEs are dominated by the technical perspective and not much on the energy-saving strategy perspective [41]. In general, there is a lack of strategic orientation towards energy management in energy-intensive SMEs [42]. A full-scale internal energy management might not be justifiable for SMEs with limited resources [26]. Successful energy management is highly dependent on having an energy manager, and it is recommended that top management be in charge of this position [32]. Kannan and Boie highlighted that SMEs have a challenge when it comes to assigning a dedicated energy manager, as the cost from energy savings would not be enough to pay for the position [28]. A part-time energy manager can work for SMEs and be handled by the production facility manager [43].

Nicolini explained the practices of energy management within SMEs as assisting in delivering routinized energy practices, focusing on investment opportunities that engage with senior staff, paying attention to how various knowledge is produced and sustained in the organization and how they are influenced by external advisors, and observing how certain activities are produced at the expense of others [44]. Hampton suggested the external advisors for energy and material consumption, as they play an important role in the knowledge creation process and guide SMEs [45]. The provision of expert energy advisors is a preferred approach by policy makers when they design policies that address challenges for SMEs [4].

2.3. Barriers

There are several barriers to energy efficiency that can explain the energy efficiency gap. According to the definition by Sorrell et al., a barrier is "a postulated mechanism that inhibits a decision or behavior that appears to be both energy efficient and economically efficient" [46].

Barriers to energy efficiency have been studied widely and in different contexts. Rohdin and Thollander identified barriers to energy efficiency in non-energy intensive manufacturing SMEs [7] and foundries [47]. Thollander and Ottosson identified barriers to energy efficiency in the Swedish pulp and paper industry [48]. Sorrell et al. identified barriers to industrial energy efficiency with a taxonomy to the identified barriers in their literature review [49]. Fleiter et al. reviewed a bottom-up model for industrial energy demand with particular focus on the model's ability to model barriers to the adoption of energy efficient technologies [50]. Cagno and Trianni identified barriers to energy efficiency that prevent implementing best available technologies and practices, in non-energy intensive manufacturing SMEs, in northern Italy [51]. Apeaning and Thollander ranked the barriers to improved energy efficiency in one of Ghana's largest industrial areas [52]. Dixon et al. ranked the barriers to energy efficiency in the food retail sector [53]. Backman identified barriers to energy efficiency in the Swedish non-energy intensive SMEs [22].

Barriers to energy efficiency in industrial SMEs have, so far, mainly been studied from a European context [54]. The main barriers to energy efficiency vary due to factors such as company size, sector, geographic location, etc. Trianni et al. identified barriers to industrial energy efficiency in European foundries [55] and in manufacturing SMEs [56].

Other studies addressed barriers and drivers of individual components of energy management, such as the study by Thollander and Ottosson that investigated the drivers and barriers for investing in energy efficient technology [48]. Cagno and Trianni identified barriers to energy efficiency measures in lighting, compressed air, motors, and heating, ventilation, and air conditioning (HVAC) systems in non-energy intensive SMEs to enhance the adoption rate of a specific industrial energy efficiency measure [57]. Nehler et al. ranked the importance of barriers for compressed air systems measures [58]. Lane et al. ranked the barriers to battery storage of a photovoltaic system in modern agriculture [59].

In terms of studying barriers to energy management, Lawrence et al. reviewed barriers and drivers to energy management in the Swedish pulp and paper industry [25]. The main barriers were related to technical risks, lack of access to capital, lack of time/other priorities, and slim organization [25]. There is also a previous paper by Sa et al. addressing barriers and drivers of an energy management program that consists of a mix of large enterprises and SMEs [60]. However, there are no similar studies of barriers and drivers to energy management in industrial SMEs.

Categorization of Barriers

In a taxonomy by Sorrell et al. [61], barriers are categorized into economic (market and non-market failures), behavioral, and organizational barriers. Sorrell et al. established a taxonomy for barriers to energy efficiency that discusses the nature, operation, and consequences of each barrier [49]. Thollander and Ottosson divided empirical barriers to energy efficiency into market-related, behavioral, and organization-related barriers [48]. In a more recent categorization by Cagno et al., there is a clear distinction between external and internal barriers [62]. Internal barriers are economic, behavioral, organizational, and competence/awareness-related barriers, while the external barriers are related to market, politics, energy suppliers, etc. This categorization was developed to be applicable to empirical studies [62].

2.4. Drivers

A driver can be considered a factor that promotes private investments in energy efficiency, i.e., facilitates implementation of energy efficiency measures, increases the return, and reduces the risk of investments [63]. Ren defined drivers as factors that positively affect a company's intention for innovation, and thus assist innovation activities [64]. In a more recent study, Cagno and Trianni suggested a definition of drivers as "factors facilitating the adoption of both energy-efficient technologies and practices, thus going beyond the view of investments and including the promotion of an energy-efficient culture and awareness" [65]. In the previously conducted studies on drivers, drivers are also entitled driving forces.

As highlighted before in this study, there is a lack of identification of drivers of energy management. There are few energy management drivers that are identified or ranked in few studies. Instead, there is a significant interest in identifying drivers of energy efficiency or specific energy efficiency measures.

In terms of drivers of energy efficiency, Rohdin and Thollander identified drivers of energy efficiency in non-energy intensive manufacturing SMEs [7] and foundries [47] in addition to barriers to energy efficiency. Trianni et al. identified drivers of industrial energy efficiency in European SMEs [56]. In one of Ghana's largest industrial areas, Apeaning and Thollander ranked the driving forces of improved energy efficiency [52]. Dixon et al. found the main drivers for energy efficiency, in the food retail sector, to be reduced energy cost, energy efficiency subsidies, future energy costs, cheap energy efficiency equipment, energy efficiency information, energy supplier, green image, examples, competitive advantage, free energy audit, and head office requirement [53]. In a review of empirical drivers to energy efficiency among manufacturing firms, it was found that the main drivers were of organizational and economic nature where management and operating costs played an important role [66]. Nehler et al. ranked 34 drivers for compressed air system measures [58]. Lane et al. ranked 16 drivers for battery storage of a photovoltaic system in modern agriculture [59]. In addition to this, a study of manufacturing firms in Norway suggests that higher education among the workforce, as well as external cooperation with competitors or universities, leads to increased energy efficiency innovation among the sector [67].

For energy management drivers, a formal energy management system is a driver for energy management, as it is defined as a "set of interrelated or interacting elements to establish an energy policy and energy objectives, and processes and procedures to achieve those objectives" [68]. Lawrence et al. ranked and categorized 33 drivers to energy management in the pulp and paper industry [25]. The drivers were categorized into organizational, knowledge, and economic-related categories [25].

Categorization of Drivers

There have been attempts to categorize drivers of improved energy efficiency. Thollander and Ottosson divided the empirical drivers of energy efficiency into market-related, current and potential policy instruments, organizational, and behavioral categories [48]. Thollander et al. categorized empirical drivers of energy efficiency into financial, informational, organizational and external [69]. In a more recent categorization, Trianni et al. categorized the driving forces according to the type of action the driving force represents:

regulatory, economic, informative, and vocational training [70]. For each identified category of driving forces, the author categorized them further into internal and external [70]. For energy efficiency drivers, Lane et al. categorized the empirical drivers for battery storage of a photovoltaic system as financial, environmental, and other drivers [59].

2.5. Multi-Level Perspective as Analytical Framework for Energy Management in SMEs

Multi-level perspective (MLP) is a transition framework developed, in 1998, by Rip and Kemp [71], and theoretically elaborated by Geels and others, in order to understand transitions of sociotechnical systems [72–75]. MLP is a useful analytical framework for understanding transitions by highlighting the dynamics and complexity of both incremental and radical innovation [76]. Transitions are conceptualized as system innovations, where a change from one sociotechnical system to another is taking place.

MLP postulates that transitions happen through interaction processes between three analytical levels: (i) sociotechnical landscape (macro level); (ii) sociotechnical regimes (meso-level); technological niches (micro level) [74]. Firstly, the sociotechnical regime (i.e., meso-level) includes Nelson and Winter's [77] technological regime and the dominant social groups. A technological regime is comprised of complex "engineering practices, production process technologies, skills and procedures, ways of handling relevant artefacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures" [71]. The dominant social groups that also contribute to patterning of technological development are firms, institutions, policy-makers, users, special interest groups, etc. [78,79]. Each of these groups is both independent and interacting with each other, but on the other hand, because they have their own distinctive features and environment, they have relative autonomy. Hence, this level includes the broader community of social groups acting together with firms and their activities, highlighting that actors are embedded in structures that can change their strategies, preferences, and aims [78]. These interactions are represented by the concept of sociotechnical regime.

The micro level is made of technological niches, in which radical innovation emerges, being carried and developed by small networks of dedicated actors. Niches provide locations for a learning process which occurs on many dimensions, e.g., technology, user preferences, regulation, production systems, etc. The macro level, sociotechnical landscape, is understood to be the wider context (i.e., environmental, socio-economic, and cultural) in which actors and institutions are situated, where changes usually take place slowly, and is beyond the direct influence of niche and regime actors. The main dynamics of change happen mostly within and between the regime and niche levels, where destabilization of regime creates windows of opportunity for niche innovations. Niche innovations are developed through learning processes, price/performance improvements, and support from powerful groups. To understand regime change, interactions with the other two levels are of major importance. Changes at the landscape level create pressure and destabilization of the regime, and the interaction of all three of these processes enables radical novelties [73,78]. The relationship between these three levels, i.e., niches, regimes, and landscape, is a "nested hierarchy", where regimes are embedded within landscapes and niches within regimes [74]. Hence, MLP researchers are particularly interested in how such processes interact in order to produce both change and stability in a particular socio-technical system.

3. Method

3.1. Case Study

The method used in this study is an exploratory case study inspired by Yin [80] in which data were collected before formulating any hypothesis. This study is based on a multiple case study that consists of 14 manufacturing SMEs located in Sweden. Descriptive figures about the included companies are found in Table 1. The majority of the SMEs belong to the engineering industry, and their activities are based on metal-working and the manufacturing and machining of parts. Two of the SMEs belong to the vehicle manufacturing industry and two SMEs belong to the food industry. Finally, there is one

SME belonging to the plastic manufacturing industry. These SMEs are assumed to be non-energy intensive since they are not part of the energy intensive industry sectors such as pulp and paper, iron and steel, aluminum, cement, chemicals, and petrochemicals. This exploratory study is of a qualitative nature based on respondents' perception of the importance of barriers to, and drivers of, energy management. The method used for this purpose is deductive by using some drivers and barriers from previous studies such as Nehler et al. [58], Lawrence et al. [25], and Lane et al. [59] and ranks their importance in the energy management context by using a questionnaire. The purpose of such ranking is to illustrate the maturity of energy management in SMEs, the main drivers, and barriers. Such identification of drivers and barriers might enable policymakers to design their policies towards enhancing the involvement of SMEs in energy management.

Table 1. Description of companies included in the study.

	Sector (Nace Rev. 2)	Number of Employees (2019)	Turnover, kSEK (2019)
Company 1	25.62	58	83,600
Company 2	24.51	25	34,400
Company 3	25.62	7	9600
Company 4	25.62, 28.22	46	86,900
Company 5	29.10	17	43,100
Company 6	25.62	32	57,000
Company 7	25.99	14	22,400
Company 8	30.20	8	17,100
Company 9	10.39	6	41,000
Company 10	10.71	8	8700
Company 11	22.21	17	31,500
Company 12	25.61	5	6900
Company 13	28.92	110	348,400
Company 14	28.22	181	6,099,800 [1]

[1] Company 14 is part of a larger corporate group. The annual turnover is for the corporate group, i.e., not for the specific single site.

3.2. Questionnaire Formulation

The questionnaire used in this study was from the similar study on the drivers and barriers of energy management, on the pulp and paper industry, by Lawrence et al. [25]. The majority of the questionnaire is the same, to enable comparisons, with some modifications, additions, and/or removals related to the drivers and barriers to customize it to SMEs.

The questionnaire was formulated in five main sections. The first section is an introductory part where the purpose of the research is explained. The second section contains short questions about the history of the company with energy management. Each question has five answers in which the respondents should choose one answer that suits them the most. The purpose of this section is to understand the maturity level of individual energy management constituents within SMEs. The third and the fourth parts were about ranking 38 drivers for and 28 barriers to energy management. A five-point Likert scale was used to rank the drivers and barriers as 1 highly disagree, 2 disagree, 3 neutral, 4 agree, and 5 highly agree. The respondents gave the point 0 if the barrier/driver was not applicable to them. The last part included general information about the respondents to indicate their background and proficiency in energy management.

3.3. Data Collection

The questionnaire was sent to manufacturing SMEs, which are participating, or have participated, in three different energy efficiency network programs in Sweden, with a response rate of approximately 5%. This response rate may seem low, but a previous study by de Groot et al. shows that this is a common response rate and that the response rates vary between sectors (1.46% for textile industry and 8.73% in horticulture) [11]. Therefore, the response rate for this study is recognized as low but considered acceptable.

The network programs are the Swedish national energy efficiency network program for SMEs, Energig, and Enerlean. The Swedish national energy efficiency program aimed to increase knowledge regarding energy efficiency of the participating SMEs [81]. Energig is a regional network in Gävleborg aimed to improve energy efficiency by offering energy audits, lectures on energy efficiency, presentation of realized measures, consultancy with energy experts, and network meetings for experience sharing for SMEs in the region [82]. Enerlean is a regional lean-based network that aims to contribute to energy efficient and carbon-dioxide efficient industrial production in the region of Gävleborg's SMEs [83].

Prior to distributing the questionnaire, the contact information for the most suitable employees to answer was collected from the coordinators of the programs they are enrolled in. Customized emails were sent to these employees, separately, that contained the questionnaire in Swedish to maximize the level of understanding. The total number of respondents was 14. The respondents were mainly chief executive officers (CEOs), workshop managers, site managers, purchasing managers, property managers, and environmental engineers. All companies included in the study are SMEs (this paper follows the definition of SMEs by the European Commission) in the manufacturing sector. Besides the ranking of the drivers and barriers, qualitative data were gathered regarding the existence/absence of energy policy, energy management, staff training in energy matters, energy performance indicators, communication on energy issues, and investments in energy efficiency measures. Other information was collected regarding written energy targets, the last installed energy efficient technology, and introduced routines of energy management. The collected data were also about performing energy audits within the SMEs and their comprehensiveness. The authors were also able to collect data regarding the existing identified energy management measures and the degree of implementing them. Finally, information regarding the usual payback period for the implemented energy efficiency measures/investments was gathered.

3.4. Data Analysis

The analysis of this study is based on analyzing the maturity level of energy management, within SMEs, and ranking the barriers and drivers to energy management. For the first part, an Excel spreadsheet was created to calculate the number of answers to each question. Maturity levels of energy management have previously been studied, for large companies, by Jovanovic and Filipovic [84]. However, some of the maturity aspects in this study are not covered in the study by Jovanovic and Filipovic and vice versa [84]. Lawrence et al. have studied maturity levels of energy management in the Swedish pulp and paper industry [25].

The second part uses Likert scale ranks for the drivers and barriers to energy management as the main focus of this study. For this purpose, the authors gathered the answers in an Excel spreadsheet. The values for the drivers and barriers were normalized and ranked in separate sheets based on the average number of points each driver/barrier got. Furthermore, the authors categorized the drivers of, and barriers to, energy efficiency, according to Lawrence et al., where the categories followed were knowledge, organizational, and economic [25]. To summarize the analysis part, the authors used the Likert scale questions for the ranking analysis and the previous taxonomies for categorization. Meanwhile, the qualitative data were used as a secondary source of information to draw a comprehensive understanding about the case study and draw better conclusions about the maturity level of energy management in the SMEs.

4. Results and Analysis

4.1. Maturity of Energy Management in SMEs

By gathering responses from the companies' representatives, it is possible to illustrate energy management in the studied SMEs. Figure 1 illustrates the average level of energy management maturity among the SMEs. As for most energy management constituents, the level of maturity is moderate. As for training, the level is lower, which means that the companies do not work regularly with training of staff in energy-related matters. This is similar to the energy-intensive pulp and paper industry, where the lowest level of maturity is also found in the training of staff [25]. None of the constituents show a high level of maturity, which indicates that SMEs have improvements to make in all areas of energy management. The highest level of maturity is found in the performance measurement and prioritization of investments; however, they are still only on a moderate level. These two constituents show similar levels of maturity as in the pulp and paper industry, while all others are lower for SMEs than for pulp and paper [25]. In four of the six constituents of energy management, i.e., energy policy, organization, training, and communication, SMEs show lower levels of maturity in comparison to the energy intensive pulp and paper industry.

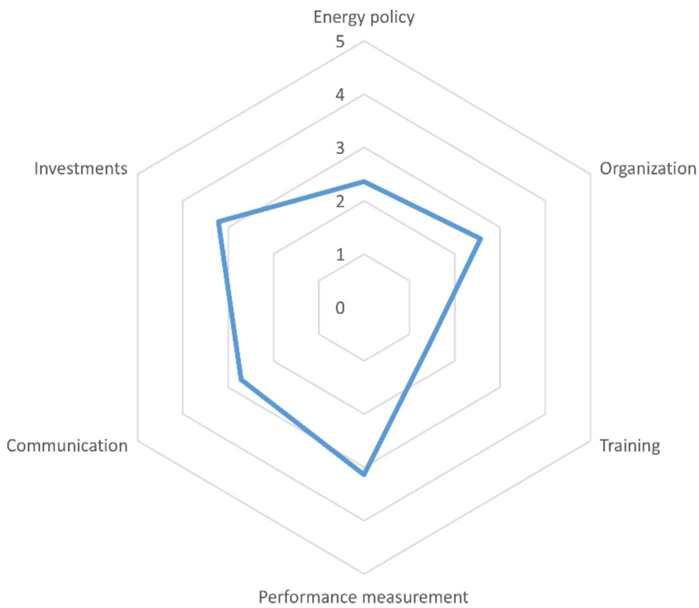

Figure 1. The average maturity level of the SMEs: 5 represents a high level of maturity, 3 represents a moderate level of maturity, and 0 represents a low level of maturity.

Six out of the 14 responding companies have no explicit policies about energy management. Additionally, five SMEs have no division of responsibilities for the energy management work. In eleven of the companies, there is no energy-related staff training offered. Further, six of the respondents admitted that the level of measures of energy performance is invoice checks only. Five of the studied SMEs have informal contacts to promote energy efficiency as the type of communication used to communicate energy issues, and two SMEs have no communication related to this. Seven of the companies participating in this study have some assessment criteria when it comes to the prioritization of investment in energy efficiency measures.

When it comes to companies' strategic energy work and energy policy, eight of the companies have no energy policies. Five of the respondents admitted that they have done their last installations of efficient technologies in the past year, while four SMEs did their installations in the last two to three years. In six of the companies, new routines of energy management have been introduced in the last year due to participation in networks. Eleven of the SMEs perform energy audits every four years. Five of the responding companies do not perform energy mapping, while four SMEs do comprehensive measurement of all important processes. Seven representatives admitted that the degree of not implementing the proposed energy efficiency measures is approximately one-fourth. One to three years is the normal payback period required for energy-related investments and measures, as stated by six of the SMEs, while another six respondents claimed that the payback period is more than three years.

4.2. Barriers to Energy Management in SMEs

The results of the ranking of barriers to energy management from the questionnaire are found in Figure 2. Lack of time/other priorities is perceived as the top barrier to energy management in SMEs. Non-energy related working tasks are prioritized higher in the second ranked barrier, and slim organization is ranked third.

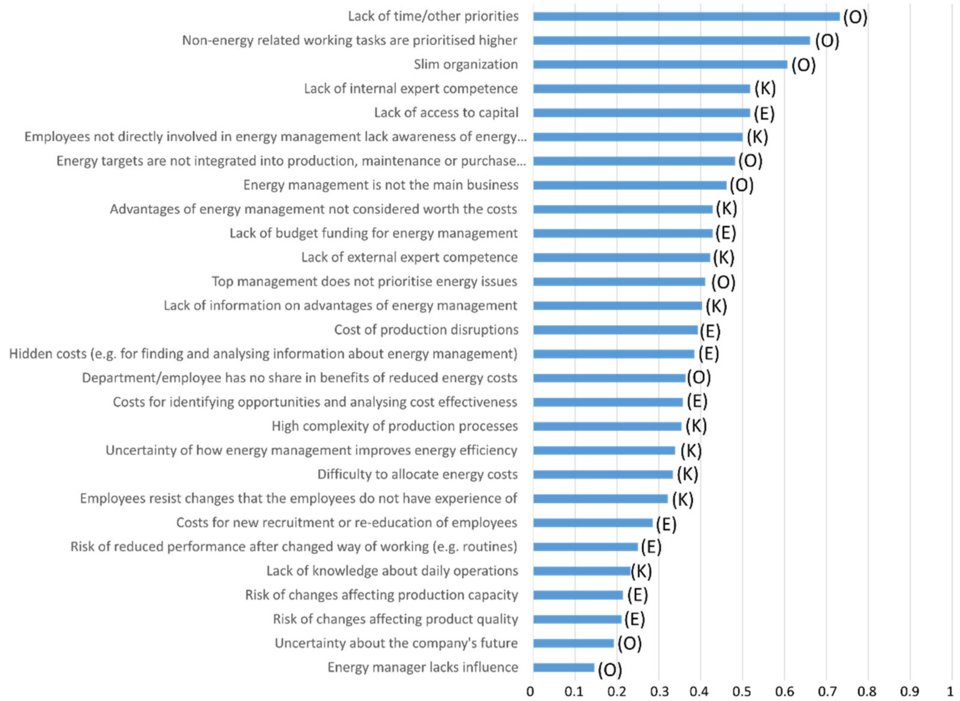

Figure 2. Barriers to energy management, ranked from the responses from the questionnaire, where 1 corresponds to a barrier of high importance, 0.5 to a barrier of moderate importance, and 0 to a barrier of very low importance. O = organizational barrier, K = Knowledge-related barrier, and E = economic barrier.

Three other barriers to energy management in the studied SMEs, that are among the top ten barriers, are that employees not directly involved in energy management lack awareness of energy issues, lack of internal expert competence, and lack of access to capital. In addition, energy targets are not integrated into production, maintenance, or purchase routines, energy management is not the main business, advantages of energy management are not considered worth the costs, and lack of budget funding for energy management are also among the top ten barriers to energy management in SMEs.

The three top barriers in studied SMEs are similar to the barriers to energy management in the Swedish pulp and paper mills but in a different ranking. The top three barriers to energy management in the pulp and paper mills are slim organization, lack of time/other priorities, and non-energy related working tasks are prioritized higher [25]. Lack of time/other priorities is among the top barriers to energy efficiency in the non-energy intensive manufacturing industry in Sweden [7] and among the barriers to energy efficiency in the Swedish pulp and paper industry [48].

4.2.1. Organizational Barriers

The top three barriers to energy management all relate to organizational barriers: lack of time/other priorities, non-energy related working tasks are prioritized higher, and slim organization. The same result was found in the pulp and paper industry, where the same three organizational barriers were ranked highest, but in a different order [25]. This indicates that it may not be specific to SMEs to face organizational barriers to energy management. This can be compared to previous studies of Swedish SMEs and non-energy intensive industries, and barriers to implementation of energy efficiency measures, where the top three ranked barriers also included economic barriers [7,22]. The major barriers to energy management seem to be more of organizational form than the barriers to energy efficiency measures.

Other organizational barriers that are ranked moderately high are energy targets not integrated into production, maintenance, or purchase routines and energy management is not the main business.

The two lowest ranked barriers are of organizational type; uncertainty about the company's future and energy manager lacks influence, of which the latter is a mid-ranked barrier to energy management for Swedish pulp and paper industries [25]. This may be a result of the fact that smaller organizations generally have shorter distance between the CEO and the organization, as well as the fact that they seldom have a designated energy manager.

4.2.2. Knowledge-Related Barriers

The two top ranked knowledge-related barriers (ranked as 4 and 6) are employees not directly involved in energy management, lack of awareness of energy issues, and lack of internal competences.

Lack of awareness of energy issues among staff who are not directly involved in energy management work was also among the barriers to energy efficiency in the Swedish foundry industry [47], the Swedish pulp and paper industry [48], and in European foundries [55]. Lack of internal competence was among the top ten barriers to energy management in the Swedish pulp and paper industry [25].

When comparing the ranking of knowledge-related barriers to the similar study of the pulp and paper industry, there is a clear difference when it comes to the barrier of high complexity of production processes, which is ranked as the fourth most important barrier for the pulp and paper industry [25], while the SMEs rank the barrier in the lower mid-section of barriers. This could be since the non-energy intensive SME sector generally has a less complex production than the energy-intense pulp and paper industry, but it could also be due to the fact that the management has a better knowledge of the specific processes in a smaller industry. This also relates to the lowest ranked knowledge-related barrier which is lack of knowledge about daily operations.

4.2.3. Economic Barriers

In this study, there are two economic barriers among the top ten barriers to energy management in SMEs. Lack of access to capital is the highest ranked economic barrier and is ranked as the fifth most important barrier. This barrier was also ranked the top economic barrier to energy management in the pulp and paper industry and the fifth among all barriers [25]. In a study of barriers to energy efficiency measures in non-energy intensive industries in Sweden, the same barrier was ranked among the top ten barriers [7]. This barrier was also the top barrier to energy efficiency for the Swedish foundry industry [47] and the fifth barrier to energy efficiency in the Swedish pulp and paper industry [48]. Advantages of energy management not considered worth the costs is ranked the ninth barrier to energy management in SMEs and the 20th barrier to energy management in the pulp and paper industry [25]. Lack of budget funding for energy management is ranked tenth in SMEs and 15th in the pulp and paper industry [25]. The lowest ranked economic barriers to energy management were related to risks of changes affecting product quality or capacity.

4.3. Drivers of Energy Management in SMEs

The ranking of the drivers of energy management in industrial SMEs is shown in Figure 3. Reduce production waste is the top driver of energy management in SMEs followed by participation in energy efficiency networks and cost reduction from lower energy use, which are ranked second and third respectively. As part of the top ten drivers of energy management, there are other drivers, such as commitment from top management, improved working conditions, and environmental, quality, or other management systems. Among the top ten drivers are people with real ambition, reduced need for maintenance of equipment due to optimized energy use, knowledge of daily operations, and network outside the company/group.

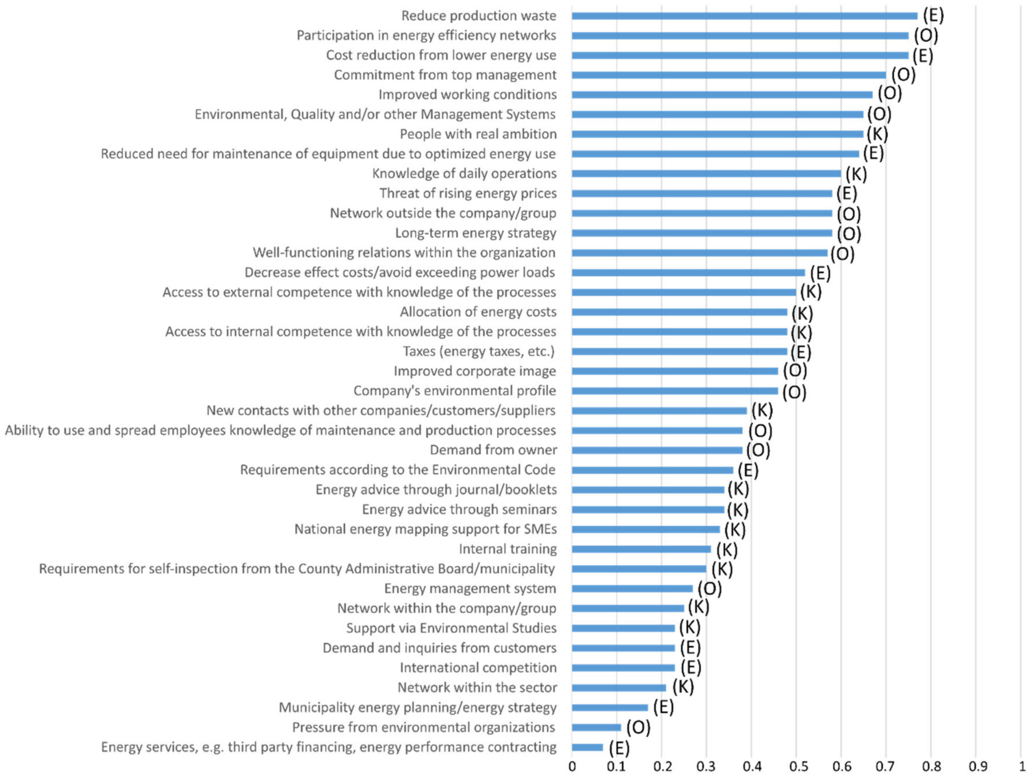

Figure 3. Drivers to energy management ranked from the responses from the questionnaire, where 1 corresponds to a driver of high importance, 0.5 to a driver of moderate importance, and 0 to a driver of very low importance. O = organizational driver, K = knowledge-related driver, and E = economic driver.

Cost reduction from lower energy use is the most important driver of energy management in the Swedish pulp and paper mills [25] and the top driver of energy efficiency in the Swedish pulp and paper industry [48].

4.3.1. Organizational Drivers

The highest ranked organizational driver is participation in energy efficiency networks, which is ranked as the second most important driver to energy management among the respondents. Other organizational drivers ranked high are commitment from top management, improved working conditions and environmental, quality or other management system, which were all ranked among the top ranked drivers among the respondents.

In the study of drivers to energy management in the Swedish pulp and paper industry, none of the four highest ranked drivers are organizational. The most important organizational driver for that sector was long-term energy strategy in fifth place, while it is ranked as the 11th most important driver to energy management among the SMEs in this study. The same driver has been ranked as the most important driver for energy efficiency measures among Swedish non-energy intensive manufacturing industries [7] as well as for the Swedish foundry industry [47]. It is worth emphasizing that the studies used for comparison had a lower number of drivers for the respondents to rank, four drivers [7] and six drivers [47] compared to 38 drivers in this study, which complicates comparison. The majority of previous studies focused on investigating drivers of energy efficiency investments, technologies, and measures.

4.3.2. Knowledge-Related Drivers

Two knowledge drivers are among the top ten drivers of energy management in SMEs. People with real ambition is the first knowledge-related driver, and it is ranked as the seventh most important among all drivers. Knowledge of daily operations is the second most important knowledge-related driver and is ranked as the ninth driver.

Knowledge-related drivers seem to be more important for the pulp and paper industry when comparing the top ranked drivers. People with real ambition was ranked among the top ten drivers of energy efficiency in Ghana [52]. Knowledge of daily operations is also the second most important knowledge-related driver for energy management in the pulp and paper industry, where it was ranked as the fourth driver, compared to ninth, as for SMEs [25].

4.3.3. Economic Drivers

Among the top ten drivers of energy management in SMEs, three of them are of economic nature. Reduce production waste is the highest economic driver and ranked as the most important among all drivers. Cost reduction from lower energy use is the second economic driver and ranked as third most important among other drivers. The third economic driver is reduced need for maintenance of equipment, due to optimized energy use, and is ranked as eighth among all drivers.

The highest ranked driver among the SMEs, reduce production waste, is ranked as the tenth most important driver for energy management in the pulp and paper industry [25]. The second economic driver, cost reduction from lower energy use, is ranked as the first among all drivers in the pulp and paper industry [25]. This driver was ranked the first among all drivers of energy efficiency improvement in the industrial area in Ghana [52]. Reduced need for maintenance, due to optimized energy use, is ranked 20th among all drivers and as the eighth economic driver of energy management in the pulp and paper industry [25].

4.4. Multi-Level Perspective on Barriers to and Drivers of Energy Management in SMEs

The study examines the barriers to, and drivers for, energy management in SMEs to contemplate the complexity of technical and societal factors involved in the adoption of energy management by SMEs. The multilevel perspective helps to identify misalignments between those factors and to propose recommendations for the adoption of energy management in SMEs through different initiatives. The need to reflect on the levels of analysis is not a new concept in social sciences, but in barriers to and drivers for energy management for SMEs, it was not applied until the current study, to the authors' knowledge. This can provide a better understanding of the phenomena studied, as a multilevel approach can reveal the depth of sociotechnical systems, the context, and the multiple consequences of actions across different levels of social organization. First, it is important to identify and clarify the level of the analysis. For the scope of this paper, in order to understand the influence of barriers and drivers (i.e., organizational knowledge-related and economic) in the adoption of energy management in SMEs, a multilevel perspective is conceptualized, as illustrated in Figure 4. The sociotechnical system captures the SMEs, while the three categories of barriers and drivers are illustrated in different levels. Organizational related barriers are categorized under the meso level (i.e., sociotechnical regime) as it includes, mostly, the social regime within the SMEs (e.g., actors' lack of time and have other priorities, and the organization is slim, etc.).

The "organizational level" can be highly influenced by the micro level (i.e., niche), which is characterized by the "knowledge" type of barriers. This might mean that, if the dynamics of the "knowledge level" will change, it will also introduce change in the dynamics of the organizational level. By changing the dynamics of the organizational level (e.g., lack of time, other priorities, slim organization, etc.), the "economic level" might also change. We have categorized the economic level as being the landscape where the SMEs are acting. There are evident economic landscape pressures (e.g., lack of capital and funding) that are directly influencing and being influenced by the organization. As seen in the analysis, the first drivers for energy management are of economic nature and organizational, thus emphasizing the interaction among levels. This example emphasizes that the solutions adopted to overcome the barriers from each category can influence the rest of the barriers and categories, thus creating a change in the system, which, in this particular case, is in the form of the adoption of energy management within SMEs.

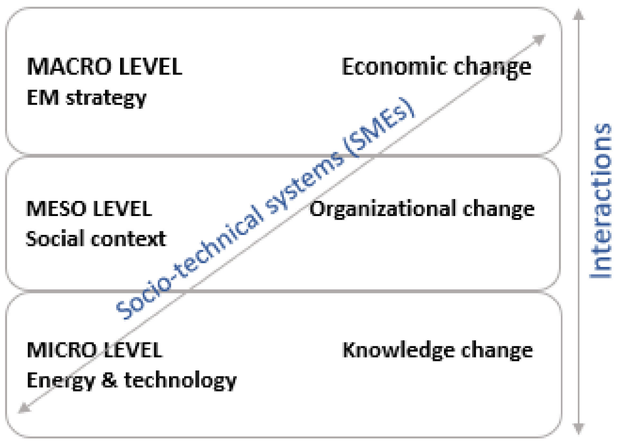

Figure 4. Visual representation of a multilevel perspective on barriers to, and drivers, for energy management in SMEs, using the multilevel model.

5. Discussion

By analyzing the results in Section 4.1, it can be understood that energy management can be described as initial for the majority of aspects, except the level of performance of energy performance measures, according to the maturity levels study presented by Jovanovic and Filipovic [84]. It should be highlighted that some of the maturity aspects in this study are not covered in the study by Jovanovic and Filipovic and vice versa [84]. Initial is the first maturity level of energy management. This means that energy management is chaotic when it comes to SMEs, and the constituents of energy management are at a low or moderate level of maturity. The foundation of energy management is not well established, and its elementary practices are not highly prioritized in SMEs. This goes in line with the conclusions made by Prashar, which was explained by the lack of resources [41]. The majority of the companies in the case study do not have energy policies and no division in energy management work. Most of the companies lack training in energy management as well as proper communication regarding energy issues. The level of energy measurement, within SMEs, is by checking their invoices only. Energy use in invoices is usually on an unspecified level, i.e., they do not go in details with all energy end-using processes. The absence of proper energy measurement prevents the organizations from knowing where energy is lost and where potential efficiency measures are found. Energy mapping is important since it allows for knowledge about energy end-use for processes in different levels within companies [85]. SMEs are not obligated to undertake energy audits every fourth year and, thus, do not normally have any energy mapping of their own processes such as for large companies. However, some SMEs have rough energy mapping for the major energy end-using processes. The majority of SMEs in this study had some assessment criteria when it comes to prioritizing investments in energy efficiency measures. According to the SMEs' representatives, a quarter of the proposed energy efficiency measures are not implemented, which indicates a relatively large, untapped energy efficiency potential.

From the top ten barriers to energy management in the SMEs, it can be noted that the organizational barriers are of high importance since five out of ten top barriers are related to the organization. This can be attributed to the lack of organization and the lack of formal energy policy for the majority of SMEs in the study, as presented in Section 4.1. This means that, for SMEs to overcome these barriers, they have to work on improving their organizations and work on formulating energy policy to be more adaptive to energy management. For SMEs to have successful implementation of energy management, they have to assign enough time and prioritize energy-related tasks. It is recommended that SMEs overcome barriers related to slim organization by hiring someone devoted to energy management work. In-house energy management can lower energy use and, therefore, fuel cost. For effective energy management, SMEs not only have to consider energy targets in production, maintenance, and purchasing routines but also consider energy management as part of their core business. The term "core business" is contextual and depends on the organization's definition of it, so the core business for one firm might not be the same for another. Therefore, in the questionnaire used in this study, the definition of core business was not pre-defined by the authors but interpreted by each respondent, with their specific company in mind.

Economic barriers come after the organizational ones, as there is a moderate interest in energy management investments within the studied SMEs, as shown in Section 4.1. Lack of access to capital and lack of budget funds set aside for energy management require better financial planning to invest in energy management matters. When the usefulness of energy management does not outweigh the costs, it is important not to perceive energy management only on the monetary level and neglect the other benefits behind it, such as the environmental impact and green corporate image. Reduced barriers of energy management can have an impact on the reduction in emissions, waste, and improved production, operation and maintenance and better work environment [86]. If energy management is considered in terms beyond direct costs and/or savings, it may be more motivating to adopt for the SMEs. For SMEs to adopt and work on energy management, they have to overcome/reduce their economic barriers since overcoming these barriers might directly or indirectly reduce other types of barriers.

For knowledge-related barriers, the SMEs lack information and skills on energy management, and most likely, there is a lack of training and communication regarding energy efficiency for the majority of SMEs, as presented in Section 4.1. Training can increase the level of competence of employees in large companies. It has the potential to increase knowledge in all trained areas related to energy management, as presented in a study by Karcher and Jochem [36]. In contrast, SMEs are still struggling to make their employees sufficiently competent through training, knowledge experience, and education on energy management. The barriers are characterized by lack of awareness about energy management among staff and a lack of internal and/or expert competence. As discussed earlier, if SMEs hire a specialized person in energy management, they would not only overcome barriers such as slim organization but the lack of internal expert competence and lack of staff awareness regarding energy management as well. Such experts can conduct the required energy management work and teach the other employees, so everyone can be a change agent when it comes to energy matters. However, hiring such a person might not be economically convincing to SMEs, as explained by Kannan and Boie, since the benefits of energy management work might not be enough to cover the position [28]. The ability to overcome or reduce barriers highly depends on the SMEs' motivation and commitment because it is a long-term and continuous process. From the result of this study, organizational barriers seem to be most important for the SMEs to overcome and should therefore be prioritized.

For the drivers of energy management, the results show similarities to those for the barriers. Organizational drivers represent five of the top ten drivers of energy management in SMEs. In other words, organizational drivers of energy management can motivate SMEs to improve in different aspects when it comes to the adoption of energy management improvements. SMEs can have contact with energy efficiency network participants if they belong to any network and they can network outside the company. Networks could work as a hybrid of in-house and outsourced energy management for the company. Commitment from top management is an important factor that drives SMEs to adopt/improve energy management in their organizations. This driver has been found in other studies [69,87]. Schulze recommended involving top management in energy management work [32]. Improved working conditions, as well as environmental, quality, and other management systems, are also important drivers that encourage SMEs in improving their energy management work. In general, energy management should be perceived beyond improved energy efficiency since it results in non-energy benefits [86].

Economic drivers are the second motivation for SMEs to be involved in energy management since they have benefits such as reduced production waste, reduced costs, and reduced maintenance. Two of these drivers are among the top three drivers, which shows how SMEs prioritize economic drivers, although they are not the majority among the top ten drivers.

Finally, knowledge-related drivers are the third category that motivates SMEs towards energy management. For example, people with real ambition can encourage the workers to do what is best for the company while also ensuring that energy efficiency is prioritized and integrated into daily operations and routines. If energy management is considered important, there is more likely to be motivation to practice it. Knowledge of daily operations is a driver that gives the employees the confidence to improve the way they practice things. If SMEs want to prioritize one of these categories, it would be recommended to prioritize the organizational drivers.

From anticipating barriers to, and drivers of, energy management in SMEs, it can be said that, from the top ten drivers and barriers, organizational aspects seem to be most important, followed by barriers/drivers related to economics and knowledge as the second and third category, respectively. The top three barriers are all organizational, but two of the top three drivers are economic, and one is organizational. This is an important point to take into account for practitioners and policy makers. It means economic drivers cause high motivation for SMEs to be involved in energy management. It is important to design policies in a way that corresponds to lowering/reducing barriers and enhancing drivers to target the specific need of the sector group.

In this study, the drivers and barriers were categorized using the same three categories: organizational, knowledge, and economic. For some barriers and drivers, there could be an overlap between categories, and in those cases, they were placed in the category they were considered to mainly belong to. This proposed method on how to study barriers and drivers to energy management in SMEs is suggested to be conducted in more studies and for other contexts. Studying barriers and drivers for SMEs in different contexts allows for comparison and increases the understanding of the relation between a driver/barrier and the specific context, which is valuable knowledge when designing efficient policies.

As for the driver, new contacts with companies/suppliers/customers, it is applicable to the specific companies in this study since they have all been part of an energy efficiency network, either national or regional. This driver may not be valid for all SMEs that have not participated in a similar program. The fact that all companies participate or have participated in an energy efficiency network may also have caused them to be more mature and aware of energy efficiency and energy management activities compared to SMEs that have not participated in similar programs. Therefore, the results related to the maturity of energy management in SMEs may be slightly overestimated in comparison to the general SME.

There are no similar studies on barriers and drivers to energy management in SMEs, which is why all comparison of results has been with the only similar study of the pulp and paper industry in Sweden. However, none of the companies in this study belong to the energy-intensive sectors pulp and paper, iron and steel, cement, chemical, petrochemicals, or aluminum. As known from previous research on barriers and drivers to energy efficiency, the energy-intensive sectors have other preconditions and face different challenges compared to the non-energy intensive sector [88], and the results from the studies are, therefore, not completely comparable.

6. Conclusions

The aim of this exploratory study was to identify major barriers to, and drivers of, energy management in industrial SMEs. The paper adds to the array of papers undertaking case study research about energy efficiency and its barriers and drivers. To the authors' knowledge, this paper is the first to make an attempt to study barriers to, and drivers for, energy management in SMEs, which, unlike previous research about energy efficiency, also involves the managerial aspects. With that said, the paper concerns a limited number of SMEs studied, for which reason one of the main contributions from the paper, apart from the preliminary novel findings regarding barriers to and drivers for energy management among industrial SMEs, is a methodological approach that previously has only been explored once before, in a study of the Swedish pulp and paper industry [25].

The top four most important barriers to energy management are lack of time/other priorities, non-energy related working tasks are prioritized higher, slim organization, and lack of internal expert competences, which are all, but one, categorized as organizational barriers, and the last one is knowledge-related. This shows that the organizational barriers are of high importance to SMEs, as are knowledge-related barriers. The finding related to organizational barriers strengthens previous research about barriers to energy efficiency where these types of barriers also have been ranked high among SMEs [54]. Related to the knowledge barrier, this finding relates to the study by Solnørdal and Thyholdt [67], where improved energy efficiency and eco innovation was found to be stronger among Norwegian companies that have staff with higher educations. One major conclusion from this paper is that in order to reduce the energy efficiency gap, SMEs are in need for increased knowledge of energy efficiency internally, and participation in an energy efficiency network is not fully sufficient.

In conclusion, in line with an array of previous research, energy management among the studied SMEs seems to not be so mature, which, in turn, shows a still large untapped potential in the societal aim to reduce the energy efficiency gap. Notably, the studied SMEs all took part in an energy management capacity building program in the form of energy efficiency network participation but nevertheless showed large areas for improvements related to energy management. This leads to the conclusion that even SMEs participating in energy management capacity building programs, in the form of energy efficiency networks, still show major areas for improved maturity levels in relation to energy management, which does not only relate to knowledge barriers.

The top four most important drivers for energy management are reduce production waste, participation in energy efficiency networks, cost reduction from lower energy use, and commitment from top management. Two of the four highest ranked drivers are of economic nature and two are organizational. This finding, that the reduction in waste and participation in networks are strong drivers for an SME to engage in energy management practices, are, to the authors' awareness, new. One conclusion from this is that participation in energy efficiency network policy programs is a key policy means to improve energy efficiency among industrial SMEs, which confirms previous findings that collaborations with competitors increases the energy efficiency innovation [67]. The other two ranked drivers, management commitment and reduced costs, have been found to be high ranked in other driver-related studies related to energy efficiency [66].

A fourth conclusion is that it is important, in studies on barriers and drivers, to include energy management as our results show that, in part, different findings are found. We strongly advocate further studies, both case study research and surveys, to be undertaken with this research design.

From a societal perspective, since energy efficiency network programs currently form the most advanced form of policy means for enhancing or supporting energy management among SMEs, yet another conclusion is that, even with the most advanced policy programs available tackling energy efficiency and climate change mitigation, there will still be a large untapped potential for improved energy management and improved energy efficiency among industrial SMEs.

The novelty of this preliminary study comes from ranking the drivers of, and barriers to, energy management in industrial SMEs, which is something that has not been done before. This preliminary study is based on the results of 14 responses and is not generalizable for all groups of SMEs.

However, there are two major limitations in this study. First, the studied companies belong to energy management capacity building programs in the form of energy efficiency networks, which makes the results difficult to generalize beyond the scope of SMEs that participate in energy efficiency network programs. Second, the number of studied SMEs in this case study is fairly low. This leads us to the conclusion that more studies are needed, both to improve the method further and to strengthen the findings. It is therefore suggested that future research is conducted for other contexts (other geographical areas, more SMEs, additional drivers or barriers in the questionnaire), in order to provide further insights on how to reduce barriers and enhance drivers in relation to energy management, and, in such a study, also include SMEs that have not participated in energy efficiency networks. Previous studies of barriers to, and drivers for, energy efficiency have shown that the major barriers and drivers vary due to factors such as size, geographic location, etc. (e.g., [54]). Indications exist when comparing this papers findings to findings by Lawrence et al. [25]. Therefore, we suggest that future studies are conducted for context beyond this case study, e.g., other geographic locations, specific sectors, etc.

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