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Do energy efficiency networks help reduce barriers to energy efficiency? -A case study of a regional Swedish policy program for industrial SMEs

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ABSTRACT

Improved energy efficiency is one of the key elements to decouple energy-related emissions from economic growth. Since the energy management practices in small and medium-sized enterprises are underdeveloped, most of the energy efficiency potential is left untapped. Studies show that several barriers pertaining to economic, technological, and organizational systems lead to poor implementation rates of energy efficiency measures. An energy efficiency network is considered effective in overcoming these barriers and promoting energy management practices in small and medium-sized enterprises. This paper explores the role of energy efficiency networks, and specifically the role of its functions in overcoming the identified barriers from literature. This study was carried out as a multiple case study including 13 industrial small and medium-sized enterprises using semi-structured interviews with participants from companies in a Swedish regional energy efficiency network program. Results show that energy efficiency networks are effective in overcoming some of the barriers to energy efficiency implementation and that the present functions are effective in addressing some barriers faced by small and medium-sized enterprises, e.g., energy efficiency implementation barriers such as lack of time and resources. However, some barriers still remain as constraints for energy efficiency implementation, even after energy efficiency network participation.

1. Introduction

Energy efficiency (EE) improvement is one of the most important targets in the United Nations Sustainable Development Goals with the aim to double the global rate of improvement in EE by 2030 [1]. The International Energy Agency suggests EE as the most important step towards energy security, environmental protection, and economic growth [2]. However, as mentioned by the UN Environment Program, the present rate of improvement is not enough to meet the two-degree target by 2050 as stated in the Paris Climate Agreement [3]. In Sweden, the country is aiming to achieve carbon neutrality by 2045 [4]. One of the means to achieve such a goal is through EE. In Sweden, 36 % of all energy is used in industry [5], and 17 % of the total industrial energy was used by small and medium-sized enterprises (SMEs) [6].

To attain the EE targets, it is important to utilize the full EE potential that remains untapped as a result of the heterogeneity of the sector and a multitude of barriers. Studies on barriers to EE in Sweden and other EU countries [7–10] have explained this potential gap by barriers such as lack of time, other business priorities, lack of knowledge, lack of information, lack of staff, high investment, etc. Studies of barriers to EE among SMEs show ambiguous findings. An early study by Gruber and Brand [11] found that subsidized energy audits for German SMEs showed limited success, where many of the SMEs were not aware of the grant and also were hesitant to use it [11]. This contradicts in part a study by Trianni et al. [8] where major barriers were found to be economic and information-related. Trianni et al. also found that there was an apparent lack of interest in EE and other issues received higher priority.

In-house energy management systems and energy audits are the primary means to overcome barriers, work with improved EE and realize the EE potential [2]. The first important step in energy management is an energy audit. Research shows that energy audits help reduce barriers

Abbreviations: EE, Energy Efficiency; EEM, Energy Efficiency Measure; EEN, Energy Efficiency Network; LEEN, Learning Energy Efficiency Network; SME, Small and Medium-Sized Enterprise.

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to EE [13]. However, internal energy management is underdeveloped in small and medium-sized enterprises (SMEs) and non-energy-intensive industries [14,15], and only half of the viable measures suggested in an energy audit are implemented, i.e., an implementation rate of approximately 50 % [16]. Energy audits are also considered the first step in improving EE in SMEs, as an audit provides the information needed to eliminate informational barriers and helps to define the potential areas of improvements and savings [17]. Therefore, energy efficiency networks (EENs) are suggested as a complement to provide companies with the support needed to successfully work with energy management and implement energy efficiency measures (EEMs). Subsidized energy audits help SMEs to easily make use of the service from the network [18]. EENs have been shown to double the implementation rate by giving the SMEs the support and services needed to improve their EE [19].

EENs are networks of companies sharing common interests in EE. EENs are intended to overcome the barriers to EE and realize the energy-saving potential by knowledge sharing, capacity building, and exchanging experiences [20]. This helps the companies to deploy in-house energy management and view EEMs in a wider perspective with readily available information. The concept of EENs was initially started in Switzerland in the 1980s and since then has been transferred to different countries inside and outside Europe [18].

In Sweden, Paramonova et al. [21] reviewed existing networks and emphasized the need for qualitative and quantitative evaluation methods for industrial EENs. Furthermore, the study called for a common standard approach to both operation and evaluation of industrial EENs [21]. ENERGIG was the first scientifically grounded regional pilot EEN program in Sweden, funded by the European Regional Development Fund as well as regional partners. It was in operation from 2014 to 2019 with a total of 44 companies in seven networks [22].

EEN progress is made in three major phases: initiation, identification of savings potential, and monitoring and evaluating the results of EEN applications [18]. This study focuses on the third phase of EENs, which is monitoring and evaluating the performance of EENs in terms of their individual network functions. To the authors' awareness, there is a scarcity of studies on evaluation of EENs and the individual functions in regard to their impact on barriers to EE, which calls for developing a methodology for such studies. This paper aims to propose a methodology for process evaluation of EEN functions using EE barriers. Specifically, this paper provides preliminary insights in process evaluation, i.e., to what extent the individual EEN functions worked and how they have contributed to the performance of EENs, and the overall impact of EENs' individual functions in regard to reducing/overcoming barriers to EE. In previous evaluations of Swedish EENs where interviews have been conducted, the network coordinator's and participants' perception of the network operation have been the study focus [21,23]. The uniqueness of this preliminary study thus comes from using barriers to EE when evaluating the impact of the structured EEN program, which has not been done before. In this study, the system boundary is moved from the policy program to the level of the individual functions of the EEN program, see Fig. 1, which to the authors' awareness has not been seen in previous study of barriers and EEN programs before.

The proposed methodology can be used in future research to enhance knowledge of which barriers can be overcome in the various phases of an EEN. Furthermore, it can be used as guidance for other network operators to design their own evaluation methodology by using a similar approach.

2. Energy efficiency in SMEs

The EE potential may be seen as higher when utilizing both efficient technologies and energy management practices, according to Backlund et al. [24]. The difference between the theoretical potential and current EE is called the EE gap [25]. To understand how to close or reduce the EE gap, there should be an understanding of what motivates firms to be more energy efficient [26]. Solnørdal and Foss categorized the drivers to EE as economic, organizational, market drivers, policy instruments, and control drivers [26]. EEN or what is referred to academically as

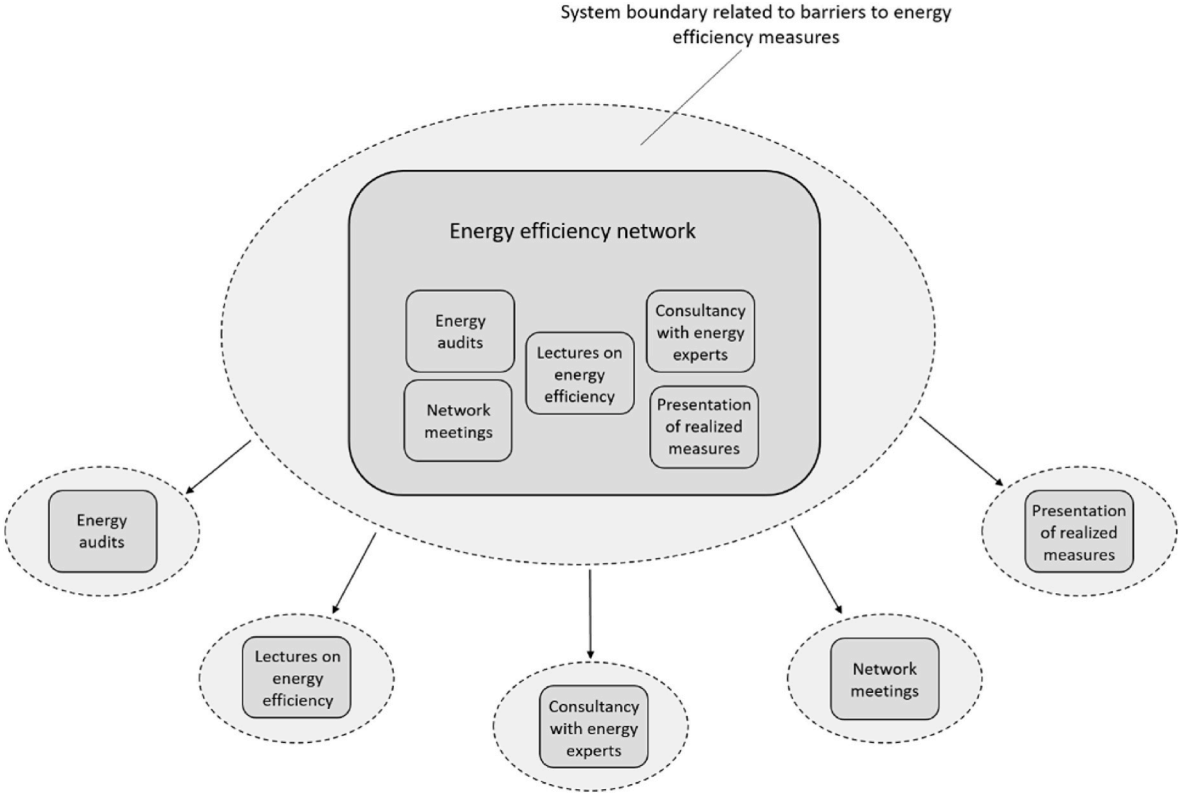

Fig. 1. System boundary when evaluating the network programs' impact on barriers.

networking is considered a valuable driver to EE due to the knowledge and trustworthy information on EE [26]. The other way of closing or reducing the EE gap is through overcoming barriers to EE [26]. The identification of barriers is thus important to enable, among other things, new policy measures to be adopted which speed up adoption of EEMs [27].

2.1. Energy efficiency networks

In Switzerland, EENs were introduced through which companies have established and collaborated through networks [20]. The first Swiss network "Energy Model Zurich" was established in Zurich as a collaboration to improve EE and savings [20]. This network aimed to help the private sector to reduce energy consumption and CO_2 emissions and achieved significant energy-saving potential in a few years [20]. Later, similar EENs were introduced in Germany [18]. A network of 30 pilot networks was initiated with the goal of establishing a management system in order to demonstrate the benefits of EENs, called the learning energy efficiency network (LEEN) [28]. By operating using LEEN standards, the project was extended to many other networks [18]. In an evaluation of the German "30 Pilot Networks," a majority of the participants said that their benefits from the network were high or very high, the time required was rather low, and that they gained contacts used outside of the network [28]. Despite this, experience from the German EENs shows that it is difficult to convince companies to participate in the network program and three to four working days are required to convince one company to join [29]. The trustworthiness of the EENs and of the recruiting person is of great importance. Personal contacts with the network operator/moderator or consulting engineer were reported as half of the reasons to join a network [29]. Chassein et al. evaluated regional EENs through a survey to investigate if EENs have a positive impact on participants, showing that the exchange of experiences was the component most appreciated by the network participants [30]. The joint targets of EE and CO_2 reductions were of importance in order to increase the priority of EE in the companies and convince top management to invest [31].

The functioning of LEEN networks passes through three phases: initiation phase, energy review phase, and network operation phase. During the initiation phase, the concept of LEEN is presented, with the completion of networks, and network agreements to pave the way for the official start of the networks. In the energy review phase, identification of savings potential, site inspection, and initial saving reports are set to reach the efficiency targets. The last phase is to monitor the result of LEEN networks through site inspections, lectures on energy efficiency topics, presentation of realized measures, and general exchange of experiences [18].

2.2. Swedish networks

The regional EEN policy program under study, ENERGIG, originates from Paramonova et al.'s [32] model for EENs and was quite similar to the German LEEN model with three phases: initiation, identification of savings potential, and monitoring and evaluation of results [18]. ENERGIG was the first scientifically grounded Swedish pilot EEN program with standard guidelines and clear targets that adapted insights from Sweden-specific research on barriers to EE in industrial SMEs. ENERGIG is based on planning activities to fulfill the goals of elevating EE [22]. The program serves as a form of indirect energy service provider that matches companies' demand and offers technical expertise as well as providing knowledge transfer to interested SMEs [22]. It is managed and monitored by experts for continuous feedback in order to ensure the monitoring of activities [22]. In a previous study on companies participating in the industrial EEN program, companies participating in ENERGIG showed a higher level of awareness of EE [33]. The companies presented a higher degree of improved EE than companies taking part in a stand-alone energy audit program. This indicates that the functions of the network program led to increased knowledge on how to effectively work with energy management practices. Furthermore, the study investigated non-energy benefits from the industrial EEN program ENERGIG and a stand-alone energy audit program [33].

Non-energy benefits are benefits from EE that are not directly linked to energy cost savings. Non-energy benefits can be at company level, e.g. increased production, increased competitiveness, improved work environment and reduced environmental impact, or at national level, e.g. new job opportunities [34]. While stand-alone energy audit programs led to non-energy benefits related to specific EEMs, e.g. improved air quality or reduced noise, participation in EEN also led to non-energy benefits related to the EE policy, such as improved company image and establishment of new contacts [33].

The major functions identified within an EEN program in general and the regional ENERGIG network in particular were energy audit, lectures on EE, consultancy with energy experts, network meetings for experience sharing and presentation of realized measures [35] as shown in Table 1.

The factors of mobilizing SMEs to participate in network functions are through free energy audits and no annual membership fee. Thus this differs from for example the LEEN. Yet another factor that differs is that LEEN often targets large companies while the regional energy EEN program under study targeted industrial SMEs. Also, software was deployed and used within the regional EEN program with an EEM database and another software for energy audit analysis [20]. The major stakeholders of the networks are the network administrator, network operator, participating SMEs, and technical expert(s) [22].

2.3. Barriers to energy efficiency

The full EE potential in companies is often not realized as a result of cost-efficient EEMs not being implemented. This is explained by a number of barriers to EE, i.e., factors hindering the implementation of measures [25,36,37]. Many studies have revolved around theoretical barriers as well as empirical investigations. There are different ways to categorize barriers to EE. One of the earlier major contributions in

Table 1
Major functions of ENERGIG network identified in literature [22,35].

Functions	Description of Functions
Energy audits	The initial step of the network process is conducting an energy audit. Participating companies are offered an on-site energy audit free of charge, conducted by an experienced auditor. They also have the option to conduct the energy audit themselves using an innovative software for auditing or have final-year engineering master's degree students do the energy audit.
Lectures on energy efficiency	Each network meeting includes a lecture on EE on a topic requested by the participating companies. The lecture is given by an expert in the specific field and includes both theoretical knowledge on EE but also information about the BAT in the field.
Consultancy with energy experts	There are technical experts involved in the network program available for consultancy with the companies. The network operators also work as a support for the companies to get in contact with the right person for their consultancy needs.
Network meetings for sharing experiences	Network meetings are held quarterly where participating companies meet and share experiences with each other. Each meeting concerns a predetermined topic, requested by the participants.
Presentation of realized measures	The network meetings are held at the company sites and include a study visit at the company hosting the meeting. During the study visit they present their processes and the measures of EE they have implemented and plan to implement. This function also includes sharing of data, documents and/or reports related to implemented measures, and EEMs derived from a unique database.

Europe to categorize barriers to EE was done by Sorrell et al. who categorized barriers to EE into behavioral, organizational, economic market failure and economic non-market failure [36]. In the taxonomy by Cagno et al. [37] barriers are categorized into external or internal barriers. Internal barriers are further divided into economic, behavioral, organizational or competence or awareness-related barriers. The literature related to barriers to EE improvements have been reviewed by e.g. Fleiter et al. [38], Johansson and Thollander [39] and Johansson et al. [40].

The main barriers impeding implementation of EEMs vary due to sector, company size, geographic location, production complexity, etc. Barriers to EE have mainly been studied from a European context [40]. In a European study by Trianni et al. [41], Swedish foundries perceived barriers higher than average, and small enterprises and enterprises with simpler production had a higher perception of barriers. For SMEs, barriers are perceived greater in the early part of the decision-making process, and especially barriers that are related to information and behavior [42]. More market innovative SMEs face barriers related to technology, external risks and lack of information as lower than less innovative firms [43]. Studying the real and perceived barriers in Italian SMEs showed that the main perceived barriers do not correspond to the main real barriers. The major perceived barriers were related to economic and information while the real barriers rather related to lack of interest or other priorities. However, the barriers varied with factors such as firm size, production complexity, energy expenditure, etc [8]. In a study of small food retail companies, four of the five highest ranked barriers were related to economic, and the main drivers were also related to economic [44]. Using a self-assessment questionnaire, data from 500 companies were analyzed and showed that lack of awareness and support from top management were major barriers in SMEs [45]. In a Swedish study of micro and small-sized companies that had participated in an energy program, the main barriers was found to be lack of time, other priorities and slim organization. The respondents also stated that the main benefit from the program was the obtained information [46]. In a previous study by Trianni et al. the relationship between EEMs and other production resources in Slovenian SMEs were explored. Both negative and positive effects on the production resources were carefully considered by the decision-makers when it comes to the willingness to adopt EEM, especially the ones closer to the production [47].

When considering barriers to technology-specific measures, measures related to compressed air and HVAC system showed higher barriers in regard to investment costs, trustworthy information and hidden costs, compared to lighting and motors EEMs. Also, small companies with lower complexity of production perceived the barriers higher [48]. In another study, major barriers to EE in compressed air systems were mainly related to investments and more specifically other priorities for capital investments, access to capital and lack of budget funding [49].

2.4. Networks' ability to overcome barriers

One of the main benefits of an EEN is as a means of reducing the barriers related to implementing EEMs. Previous studies claimed that EENs enable behavioral changes and could reduce barriers related to organizational issues and competence [19,32,52]. The three levels of barriers described by Paramonova are technological regime, technical systems, and socio-technical regime [35]. Barriers to the technical system include heterogeneity, hidden costs, and risk. The technological barriers include imperfect information, adverse selection and form of information. Socio-technical barriers include credibility and trust, values, inertia, bounded rationality, power and culture. The theoretical barriers can also be perceived as categories that include other barriers, e.g. the theoretical barrier "hidden costs" can be seen as a category including cost of production disruption, lack of time/other priorities, other priorities for capital investments, and cost of identifying opportunities and analyzing cost effectiveness [53]. "Imperfect information" as a theoretical barrier covers difficulty/cost of getting information, lack of staff awareness, lack of technical skills, and poor information quality regarding EE opportunities [53], while "risk" includes technical risks such as production disruption and possible poor performance equipment [53]. For each theoretical barrier, there is a potential positive effect from network participation [35]. However, this is a theoretical assumption and no previous studies have been done to evaluate the actual ability of the networks to overcome such barriers.

In addition, the administrative practices companies adopt for energy improvement are also directly linked with the barriers to EEM [14]. Method governance creates methods and routines supporting those who undertake actions later through standardization and continuous improvements. Correspondingly, in result governance, a key person participates in EEN and executes in a result-oriented way [14]. It is important to understand the style of governance companies adopt while participating in EEN.

3. Methodology

This preliminary study was carried out as a multiple case study inspired by Yin [54], using an exploratory approach meaning that data is collected prior to formulation of any hypothesis. Thirteen industrial SMEs, located in Sweden, were included in the multiple case study. The study is qualitative research, based on process evaluation, i.e., to what extent individual EEN functions are performing and what their impact is on the barriers to EE. The developed preliminary methodology for this evaluation was to use both literature review of EE barriers and information from semi-structured interviews for further analysis. The importance of using such methodology to evaluate the impact on various barriers for the different major functions within an EEN program, is that it may provide enhanced knowledge on which specific functions may trigger enhanced uptake of EEM. Furthermore, it can be used in future evaluation of other approaches that are supposed to overcome barriers to EE as well as evaluating future functions of EEN programs. The methodology consists of an interview guide with context-specific barriers to EE, which were analyzed further.

3.1. Barriers

In this study 14 barriers to improved EE were deduced from scientific literature regarding barriers in industrial SMEs in Sweden. The collected studies [10,36,53,55,57,58] were in the period between 2000 and 2010. The studies were all read carefully to identify the barriers to EE that are suitable for the study. The challenge of selecting the barriers studies led to the creation of the inclusion criteria that are shown in Table 2. All the studies went through the inclusion criteria and it was decided to choose the studies that cover barriers to EE in industrial SMEs [53,58] since the respondents of this study consists of SMEs mainly.

The selection of the individual barriers was based on screening these studies and comparison of the barriers in the studies. Nine of the barriers that are considered in this study were found in the studies by Thollander and Rohdin [53] and Thollander et al. [58]. The other five common

Table 2
Inclusion criteria for the selected studies of barriers.

Issue	Inclusion Criteria
Publication type	Published articles
Language	English
Availability	Available online as full text
Time period	2000–2010
Country	Sweden
Firm size	SMEs
Research discipline	Industrial energy management
Level of analysis	Company level, process level, technology level, equipment level
Relevance	Article presenting barriers to energy efficiency

barriers were taken from the study by Thollander et al. [58]. It can be seen that the majority of the collected barriers to EE in this study are of high relevance to all sectors in Sweden [52]. Table 3 shows the 14 barriers to EE that are considered in this study.

If this method to be used to evaluate the reduction of barriers to EE in other industrial SMEs, it is recommended to revise the inclusion criteria to take the specific context of the study into consideration. Johansson et al. concluded from a review that barriers to EE in industrial SMEs vary with factors like: firm size, sector, production complexity and geographic location [40].

3.2. Interviews

Similar to a study by Andersson and Thollander [59], semi-structured interviews were used to evaluate the functions of EEN. The total number of the industries that participated in the Swedish EEN program was 44. The interviews were conducted with representatives from 13 industrial SMEs that had participated in the EEN program ENERGIG. The majority of the questions in the interview guide were of a structured character and were answered using a Likert scale. A five-point scale was used for process evaluation to indicate how far the individual functions of EEN have succeeded while a three-point scale was used to indicate the impact of EEN on overcoming the barriers to EE, if it has a high, neutral or low impact. The reason why a five-point Likert scale was not used in both cases is the fact that the study does not derive any benefit from more diverse impact.

The interview guide also included open-ended questions about the EEMs implemented, issues faced during the EEN program period, experiences from EEN participation, EE targets and cost savings. These questions were asked to understand the level of participation and activeness in implementing EEMs. The respondents were mainly chief executive officers of the companies. In all interviews, a brief overview of the purpose of the study was given in the beginning. The participants were asked to rank the parameters in the Likert scale given for each question, apart from the open-ended questions.

During the interviews, interactions were made between the interviewers and the interviewees while answering the interview guide. The reason for that was to understand further why they ranked the ability of certain function to overcome a specific barrier with a specific number. The interaction was not possible in all questions that sometimes highly depends on the flexibility of interviewees. The interviews were recorded, partially transcribed and coded by using Nvivo software. The questions were coded per barrier to EE inspired by Thollander et al. [60]. For each barrier, the collected information is subtitled as company 1, company 2, etc. In which each company number refers to a specific interviewee in a separate sheet. For each company, different amount of information was gathered to represent what the companies' state as "can/cannot overcome barriers to EE" and other feedback. The amount of information varies between companies since some companies where generous and more explaining than others. Some companies gave reflections regarding certain function and/or barriers to EE and stated their satisfaction about the performance of the network and their future plans regarding joining a new network or similar programs. Other companies were straight to the point while answering the interview guide with no further explanations.

It should be noted that the secondary data can also be coded per function. However, it was not of high interest to the authors since the Likert scale questions were designed to understand the ability of EEN functions to overcome barriers to EE. Therefore, the authors decided to code the secondary data per barrier instead of function to be complementary to the Likert scales questions.

Table 3
Barriers to energy efficiency used in the interview guide, [53,58].

Barriers to Energy Efficiency	References
Lack of time/other priorities	[53,58]
Access to capital	[53,58]
Cost of production disruption/inconvenience	[53,58]
Lack of budget funding for energy-efficient technologies	[58]
Difficulty/cost of getting information on the energy use of purchased equipment	[53,58]
Other priorities for capital investments	[53,58]
Lack of technical skills	[53,58]
Low priority is given to energy management	[58]
Lack of staff awareness	[53,58]
Technical risks such as potential production disruption	[53,58]
Slim organization	[58]
Energy objectives not integrated into operation, maintenance or purchasing procedures	[58]
Poor information quality regarding energy efficiency opportunities	[58]
Cost of identifying opportunities, analyzing cost effectiveness and tendering	[53,58]

3.3. Analysis

The major analysis was the evaluation of data of a qualitative nature that was obtained from the respondents. For evaluating the qualitative nature of the research, there seems to be a lack of standard operating procedures, which complicates evaluation of policy programs and results from this study [61]. A Likert scale was used in this study for ranking the barriers. The parameters were ranked from high to low based on the percentage of respondents that ranked the impact of the specific parameter as 4 or 5 on the five-point scale and 2 or 3 on the three-point scale. A minor analysis was done using the interquartile range (i.e., difference in dispersion among the respondents regarding their opinion on the importance). After interquartile range was done, parameters were ranked from low to high similar to a method that was used in a previous qualitative study by Brunke et al. [62]. In this study, the interquartile doesn't play a central role in the analysis but merely represent the dispersion in answers among participants as shown in the figures attached in Appendix A. An important note is that the number of companies studied was too low to be statistically representative and therefore the results cannot be used for any statistical generalization. Due to the exploratory approach in this study, the results may still be of interest as it is, to the authors' awareness, the first preliminary study to evaluate EENs using barriers to EE.

The secondary data were reviewed into a matrix of barriers and functions. The data were analyzed from all companies to give a comprehensive understanding that is complementary to the Likert scales answers. The matrix is shown in Table 4. This matrix was used to analyze the impact of functions to reduce barriers to EE. Simultaneously, this matrix was used to analyze to what extent the barriers can be reduced and by which functions. It should be noted here that this matrix was not used to support the process evaluation as the secondary data were straightforward so the Likert scale analysis were used merely for this purpose.

4. Process evaluation and analysis

The evaluation of results is based on the semi-structured interviews conducted with 13 industrial SMEs. The results from the interviews were analyzed using the ranking of the stated barriers from the interview guide. The first part of the result presentation consists of the respondents' perception of different processes of EEN, i.e., how essential they are for the efficient operation of EEN. The second part of the result presentation consists of the evaluation of the impact of the individual functions on the barriers. The ranking of the barriers is based on how many of the respondents answered that the function had an impact on the reduction of the barrier. Detailed results can be found in Appendix A.

4.1. Process evaluation

Results showed that the respondents perceived the energy audit as

Table 4
The matrix of analyzing secondary data.

	Energy audits	Lectures on energy efficiency	Consultancy with energy experts	Network meetings for sharing experiences	Presentation of realized measures
Lack of time/other priorities					
Access to capital					
Cost of production disruption/inconvenience					
Lack of budget funding for energy-efficient technologies					
Difficulty/cost of getting information on the energy use of purchased equipment					
Other priorities for capital investments					
Lack of technical skills					
Low priority is given to energy management					
Lack of staff awareness					
Technical risks such as potential production disruption					
Slim organization					
Energy objectives not integrated into operation, maintenance or purchasing procedures					
Poor information quality regarding energy efficiency opportunities					
Cost of identifying opportunities, analyzing cost effectiveness and tendering					

the most important function of the EEN, with all the respondents agreeing about this, and no other function was given the same importance as the audits. The lectures on energy efficiency function were ranked as the second most important function of the EEN. Consultancy with energy experts was ranked as the third most important function for EEN in order to meet the objective of the network. A majority of the respondents agreed that the presentation of realized EEMs derived from a unique EEM database and network meetings for experience sharing were also important functions of the EEN. Hence, all five functions were perceived as important for the EEN by more than half of the respondents. The ranked list is shown in Table 5.

4.2. Impact on barriers

The respondents ranked the barrier "lack of technical skill" as the top-ranked barrier reduced by participating in EEN, with all respondents answering that this barrier was reduced by the EEN. The results further show that both barriers "poor information quality" and "difficulty/cost of getting information" were ranked high as reduced by the EEN, followed by "lack of staff awareness," "lack of time/other priorities," "other priorities for capital investments," "cost of identifying opportunities, analyzing cost effectiveness, and tendering" and "low priority is given to energy management." The ranked list is shown in Table 6.

The impact on reducing the barriers has also been studied at the function level.

4.2.1. Energy audit

Energy audit is the first function to be evaluated in terms of impact and the ranked list is shown in Table 7. According to the respondents, the barrier "lack of technical skills" is the top barrier reduced by the energy audit. This is followed by the barriers "lack of time/other priorities" and "access to capital" which are also highly ranked as reduced by the energy audit. Furthermore, energy audits have the potential to reduce the barriers "difficulty/cost of getting information on the energy use of purchased equipment," "poor information regarding energy efficiency opportunities," "lack of staff awareness," and "low priority is given to energy management."

Table 5
The result of the functions' importance for the EEN.

Rank	Function
1	Energy Audits
2	Lectures on energy efficiency
3	Consultancy with energy experts
4	Presentation of realized measures
5	Network meetings for sharing experiences

Table 6
Barriers ranked based on perception of reduction by "EEN".

Rank	Function
1	Lack of technical skills
2	Poor information quality regarding energy efficiency opportunities
3	Difficulty/cost of getting information on the energy use of purchased equipment
4	Lack of staff awareness
5	Lack of time/other priorities
6	Other priorities for capital investments
7	Cost of identifying opportunities, analyzing cost effectiveness and tendering
8	Low priority is given to energy management
9	Lack of budget funding for energy-efficient technologies
10	Energy objectives not integrated into operation, maintenance or purchasing procedures
11	Slim organization
12	Cost of production disruption/inconvenience
13	Access to capital
14	Technical risks such as potential production disruption

Table 7
Barriers ranked based on the perceived reduction by "Energy Audit".

Rank	Function
1	Lack of technical skills
2	Lack of time/other priorities
3	Access to capital
4	Difficulty/cost of getting information on the energy use of purchased equipment
5	Poor information quality regarding energy efficiency opportunities
6	Lack of staff awareness
7	Low priority is given to energy management
8	Lack of budget funding for energy-efficient technologies
9	Cost of identifying opportunities, analyzing cost effectiveness and tendering
10	Energy objectives not integrated into operation, maintenance or purchasing procedures
11	Other priorities for capital investments
12	Slim organization
13	Cost of production disruption/inconvenience
14	Technical risks such as potential production disruption

4.2.2. Lectures on energy efficiency

The impact of the function "lecture on energy efficiency" on the various barriers to EE is shown in Table 8. The respondents agreed that lectures on efficiency are mostly effective on the barrier "lack of technical skills" and "poor information quality regarding energy efficiency opportunity." The results show that the barriers "cost of identifying opportunities, analyzing cost effectiveness and tendering" and "lack of time/other priorities" were reduced due to the lectures on energy efficiency. This function has the ability to reduce the barrier "difficulty/cost of getting information on the energy use of purchased equipment" as this is ranked fifth as a barrier reduced by the lectures on energy efficiency.

4.2.3. Consultancy with energy expert

"Consultancy with energy expert" is the third function of EENs evaluated and the impact on the reduction of barriers is shown in the ranked list in Table 9. Consultancy with energy expert has the highest impact on the barriers "lack of technical skills" and "poor information quality regarding energy efficiency opportunities" respectively. The barriers "lack of time/other priorities," "difficulty/cost of getting information on the energy use of purchased equipment" and "cost of identifying opportunities, analyzing cost effectiveness and tendering" are also ranked among the top five barriers reduced by the consultancy with energy experts.

4.2.4. Network meetings and experience sharing

The function "network meeting and experience sharing" has the highest impact on the barriers "poor information quality regarding energy efficiency opportunity," "lack of technical skills" and "lack of time/other priorities." Furthermore, according to the respondents, it also has an impact on the barrier "access to capital" and "cost of identifying opportunities, analyzing cost effectiveness and tendering." The ranked list of reduced barriers is shown in Table 10.

4.2.5. Presentation of realized measures

As for the function "presentation of realized measures," four of the 14 barriers were reduced for more than half of the respondents. These barriers were "lack of time/other priorities," "poor information quality regarding energy efficiency opportunities," "lack of technical skills" and difficulty/cost of getting information on the energy use of purchased equipment," ranked in the same order. The ranked list of reduced barriers is shown in Table 11.

5. Interview results and analysis

This preliminary study has qualitatively evaluated the impact of the EEN and its individual functions on barriers, providing a holistic view.

Table 8
Barriers ranked based on the perceived reduction by "Lectures on Energy Efficiency".

Rank	Function
1	Lack of technical skills
2	Poor information quality regarding energy efficiency opportunities
3	Cost of identifying opportunities, analyzing cost effectiveness and tendering
4	Lack of time/other priorities
5	Difficulty/cost of getting information on the energy use of purchased equipment
6	Other priorities for capital investments
7	Access to capital
8	Low priority is given to energy management
9	Energy objectives not integrated into operation, maintenance or purchasing procedures
10	Lack of staff awareness
11	Lack of budget funding for energy-efficient technologies
12	Cost of production disruption/inconvenience
13	Slim organization
14	Technical risks such as potential production disruption

Table 9
Barriers ranked based on the perceived reduction by "Consultancy with Energy Experts".

Rank	Function
1	Lack of technical skills
2	Poor information quality regarding energy efficiency opportunities
3	Lack of time/other priorities
4	Difficulty/cost of getting information on the energy use of purchased equipment
5	Cost of identifying opportunities, analyzing cost effectiveness and tendering
6	Lack of staff awareness
7	Other priorities for capital investments
8	Access to capital
9	Energy objectives not integrated into operation, maintenance or purchasing procedures
10	Low priority is given to energy management
11	Lack of budget funding for energy-efficient technologies
12	Slim organization
13	Cost of production disruption/inconvenience
14	Technical risks such as potential production disruption

Table 10
Barriers ranked based on the perceived reduction by "Consultancy with Energy Experts".

Rank	Function
1	Poor information quality regarding energy efficiency opportunities
2	Lack of technical skills
3	Lack of time/other priorities
4	Access to capital
5	Cost of identifying opportunities, analyzing cost effectiveness and tendering
6	Lack of staff awareness
7	Other priorities for capital investments
8	Energy objectives not integrated into operation, maintenance or purchasing procedures
9	Low priority is given to energy management
10	Difficulty/cost of getting information on the energy use of purchased equipment
11	Lack of budget funding for energy-efficient technologies
12	Technical risks such as potential production disruption
13	Cost of production disruption/inconvenience
14	Slim organization

Table 11
Barriers ranked based on the perceived reduction by "Presentation of Realized Measures".

Rank	Function
1	Lack of time/other priorities
2	Poor information quality regarding energy efficiency opportunities
3	Lack of technical skills
4	Difficulty/cost of getting information on the energy use of purchased equipment
5	Access to capital
6	Low priority is given to energy management
7	Cost of identifying opportunities, analyzing cost effectiveness and tendering
8	Other priorities for capital investments
9	Energy objectives not integrated into operation, maintenance or purchasing procedures
10	Lack of budget funding for energy-efficient technologies
11	Lack of staff awareness
12	Technical risks such as potential production disruption
13	Slim organization
14	Cost of production disruption/inconvenience

Available literature on the impact of EEN on barriers is theoretical in nature. In this way, this study stands out from previous contributions which can be used to improve the EEN standard evaluation procedures, for future research and policy design, as well as for EEN operations. In this section, the results will be analyzed and discussed in three distinct parts: analysis of each function's importance, impact of EEN and its functions on EE barriers, and recommendations.

5.1. Analysis of functions

The results show that all functions are important for successful and effective operation of a regional EEN policy program, and the most important perceived function was the energy audit. This confirms the finding of a previous study by Cagno et al. that energy audits can help in overcoming barriers to EE in the industry [26]. This result is comparable with the results of other studies [35] as the energy audit supplies correct information to eliminate informational barriers and also defines potential areas of improvement and savings potential [17]. Subsidized energy audits help SMEs to easily take advantage of the service from the EENs [18]. The result of this study is also in line with a previous evaluation of EE in industry [63] as the lectures on energy efficiency and consultancy with energy experts provide support in reducing knowledge gaps regarding both the existing savings potential in the company and existing financial support programs for investments in EE [63].

Even though some results obtained in this preliminary study are similar to previous literature results, the qualitative analysis shows slight disagreement among the participants, especially for the functions "presentation of realized measures" and "network meetings and experience sharing." According to some of the respondents, these functions were not useful due to different energy-using processes for each participating company and that EEMs were implemented prior to the network participation and due to this they could not learn so much from the other companies, i.e., it was both due to heterogeneity of the participants and also due to the different energy management maturity levels among the participating firms. This in turn may be of general interest beyond the scope of this study as the initiation of one single EEN should include a screening of the maturity of the firms as well as their major energy-using processes. If there is no match in any of these two factors among the planned EEN participants, it may be important to point that out to the planned EEN participants before initiation of the EEN. Also, some of the respondents had the opinion that in the lectures on energy efficiency the specific information presented was not useful for the company. This factor may in part be related to the one discussed above, namely energy management maturity and heterogeneity of the firms.

5.2. Analysis of the impact of functions with regards to reduced barriers

In the analysis below, a barrier is considered to be reduced by the function if more than half of the respondents think the function has an impact on the barrier, i.e., they rank the function's impact on the barrier as 2 or 3 on the Likert scale. In Appendix A, details related to the impact on the barriers are found.

Results show that some barriers are sufficiently overcome by EEN functions while others are not overcome by any of the EEN functions. The functions that are the most effective in reducing barriers were "energy audit" and "lectures on energy efficiency." This is in line with the results of the perceived importance of the individual functions, where the energy audit and lectures on energy efficiency were ranked as the two most important functions in the EEN, see Table 3. These two functions are also the two functions that have an impact on most barriers. The results were analyzed into three sections: barriers reduced by all functions, barriers reduced by some functions and barriers not reduced by any of the functions, which are elaborated in the following sections.

5.2.1. Barriers reduced by all functions

The evaluation of the EEN and its functions showed that EENs and related functions are highly effective in overcoming some of the commonly seen EE barriers in industrial SMEs. "Lack of technical skills," "lack of time/other priorities" and "poor information quality regarding energy efficiency opportunities" are ranked as the top three barriers that have been successfully reduced by all the EEN functions. A previous study [35] validates that "lack of technical skills" could be reduced by working with auditors, experts and consultancy besides experience-sharing practices between managers. In order to perform EE practices on a daily basis, SMEs suffer from "lack of time/other priorities" as a decisive barrier. By participating in an EEN, the companies can outsource some of their energy management functions to their administration [35].

In terms of "poor information quality regarding energy efficiency opportunities," a previous study [35] shows that the participation in EEN may help through the exchange of information either in network meetings or consultancy sessions, or through peer meetings with other companies, which reduces the tendency of inappropriate decision-making regarding EEMs [35]. It confirms the findings of this study and one of the interviewed participants claimed that:

Information is problematic, but the participation in EEN helped to learn new information about EEMs and I favored the network meetings to overcome this barrier because one can ask for specific information for what they need.

5.2.2. Barriers reduced by some functions

In fact, the results show that some of the barriers can be reduced by some functions of the EEN while they cannot be overcome by others. For example, "difficulty/cost of getting information on the energy use of purchased equipment" is one barrier that was overcome by all EEN functions except "network meetings and experience sharing." An energy audit specifies what to change while lectures provide knowledge on what equipment is on the market and at what price [35]. "Network meetings and experience sharing" do not seem to successfully satisfy the SMEs to overcome this barrier. A reason for this could be the fact that "network meetings and experience sharing" regarding equipment is not sufficient for the SMEs due to the fact that they have different equipment and processes and this information from peers is not necessarily useful for their specific industry.

The barrier "access to capital" was reduced by all functions except for "consultancy with energy experts" and "presentation of realized measures." Due to the exploratory nature of this study, and the fact that to the author's awareness no previous study has carried out a similar preliminary study, it is not possible to confirm the effectiveness of these functions in overcoming the barrier. However, one of the interviewed respondents stated that:

> "Presentations of realized measures" is merely about the changes in processes but not much about how to get access to capital while changing the processes, while "consultancy with energy experts" regards the help we get on technical or organizational changes.

The barrier "cost of identifying opportunities" was successfully overcome by all EEN functions except "network meetings and experience sharing" and "presentation of realized measures." According to the previous study by Paramonova [35], such cost of opportunities can be reduced or avoided by means of energy audits that provide detailed information about the possible changes of measures with the possible investment cost [35]. Also, consultancy with energy experts reduces the knowledge gap regarding the potential of financial support and the potential of savings [63]. Meanwhile, "presentation of realized measures" and "network meetings and experience sharing" have low impact on this barrier in SMEs.

Both barriers "other priorities for capital investment" and "low priority is given to energy management" seem to be overcome only by lectures on energy efficiency. Again, no previous study justifies the reason behind the inability of the rest of the functions to overcome these barriers. The previous study [35] justifies not prioritizing EEMs for capital investment due to low interest in EE investments as this is not a part of the industrial core competences, since these investments save costs but do not generate any revenue [35]. Therefore, an energy audit did not help to prioritize capital investments although they are subsidized by the Swedish Energy Audit Program for SMEs [35]. This

complies with the findings of this study in which one participant claimed that:

> There are other priorities for investments comparing to energy investments which is the last thing you would think about.

By being part of EEN, the function "lectures on energy efficiency" helped to prioritize both energy management and capital investment for EEMs in SMEs. This finding confirms the claim of one of the interviewed company representatives, who said that:

> Energy management has higher priority after being involved in EEN

Both barriers "lack of staff awareness" and "lack of budget funding energy-efficient technologies" can be reduced only by the "energy audit" function. Regarding the ability of audits to reduce the barrier "lack of budget funding energy efficient technologies," it can be justified that audits cover annual energy consumption, price of each energy carrier, and the proposed EEMs for different processes and equipment [35]. Regarding staff awareness, SMEs do not have a high number of staff, and since they can be the same persons who do the measures for audits and discuss it with an expert from the network, that could have led to the increased awareness. The results confirmed the claim of one respondent that:

> Staff awareness about energy efficiency has increased within the company, especially on the managerial level compared to the production staff.

It can be justified due to the changes in the organizational values and culture of EE practices due to the knowledge gained from an energy audit [35].

5.2.3. Barriers not reduced by any of the functions

Even though this study shows that the EEN and EEN functions are successful in overcoming several of the barriers, there are some barriers on which respondents perceived EEN and the individual functions to have little or no impact. These barriers are "cost of production disruption," "energy objective not integrated into operation, maintenance or purchasing procedures," "slim organization" and "technical risks." This part of the study shows different results compared with the available theoretical study [35], which explained that the experience-sharing within the EEN can influence the abovementioned barriers. Increased awareness and knowledge gained through EEN should address problems of "slim organization," "split incentives" and "lack of awareness" [35]. "Cost of production disruption" is also claimed as a barrier EENs can overcome through sharing experiences, lectures, and consultancy with energy experts. However, the results of this study do not support these arguments and rather show that these barriers remain after network participation [35].

During the interviews, it was observed that the companies run their energy management by result governance. The major problem associated with this is the lack of continuity when the key person leaves. This will likely affect the experience-sharing and knowledge-sharing in the company and the EEN. The result-oriented approach of participating is most likely one of the main reasons why the EEN and its functions did not impact these barriers. Method governance is another form of energy management [14]. Method governance, unlike result governance, builds structural and long-term improvements in group culture.

5.3. Recommendations

In general, applying standardized functions for companies with a common base helps the EEN operators to compare the performance of the companies and identify the reasons behind not achieving expected results. Barriers vary due to geographic location, sector, size of company, production complexity, etc., meaning that each network of companies might have different types of barriers to implementation of EE. This evaluation of a network program in Sweden shows that some functions are better at overcoming certain barriers, so an initial investigation of barriers of participating companies in the network at the initiation phase along with an energy audit is recommended. Thereafter, the functions of the network can be designed, or additional functions can be added in order to overcome the network-specific barriers. These functions can either be applicable to the whole network or company-specific that serve certain SMEs based on their motivation and results.

According to the interviewed respondents, current EEN functions have failed in overcoming the barriers "slim organization," "technical risks," "cost of production disruption" and "energy objective is not integrated into operation, maintenance or purchasing procedure." In order to fully or partially overcome these barriers, it is recommended to further enhance existing EEN functions or add new functions designed deliberately to overcome these barriers. Modifications of current functions can also be made to include elements needed by SMEs with the support of expertise in the field.

Both "other priorities for capital investment" and "low priority is given to energy management" need effort in improving functions like consultancy with energy experts, network meetings for experience sharing and presentation of realized measures. Unexpectedly, these functions do not seem to provide enough motivation for SMEs to prioritize the energy management or capital investment for efficiency measures. It is recommended to modify the content and discuss it with SMEs to investigate the impact of changed content on improvements. "Lack of staff awareness" seems to require effort to be fully overcome. It is advisable to frequently engage staff in efficiency lectures, network meetings for experience sharing, consultancy with energy experts and presentation of realized measures. It is important to engage staff and not only focus on the managerial level for organizational change. This is also important to ensure that knowledge and experience are preserved within the company if key persons leave the company.

Barriers like "difficulty/cost of information on new equipment," "access to capital," "cost of identifying opportunities" and "lack of budget funding for EE technologies" have a mixed tendency of being overcome by EEN functions. It is recommended to design a function that corresponds to their economic nature. EEN functions serve more as information-based guidelines, which are hard to apply to economic concerns like cost of information or opportunities, access to capital or lack of budget. It is advisable not to neglect the economic factor by EEN to ensure smooth performance of overcoming such barriers and tapping EE potential. It is recommended to develop a financial tool which analyzes the savings potential from energy audit of participants and link it to the cost of implementation from market prices. This financial tool facilitates finding investment cost, internal return on investment, and net present value. This tool should also be able to include non-energy benefits obtained from improved EE (reduced maintenance cost, etc.). This will encourage participants to allocate the budget and capital for EE. Even though the study is conducted in a Swedish context, it is suggested that similar studies with a similar methodology should be conducted of EEN programs in other regions. It is also suggested to review the existing research on barriers in that specific region before conducting such a study, to include the major barriers for that specific sector and/or region in the study. This is important as studies have shown that barriers can vary greatly [55].

The results shown in this paper may be seen as preliminary and may have high uncertainty based on the state of the participants. From the interviews, it was evident that the involvement of different companies in the EEN was different. Taken that no similar company participates in the same level in the network, the impact of some activities may thus be have a minor impact for some companies. The study included interquartile range in the result to show the differences in opinion among the participants to know the uncertainty in each result. That is, if the interquartile is high, the opinions of the respondents vary over the Likert scale. The number of participants in the study is too low to conduct any statistical analysis, hence repetitive future studies with more

respondents included from different networks is suggested.

6. Conclusions

Realizing the EE potential among industrial SMEs is a challenge and EENs can greatly enhance EEM deployment if carried out successfully. Research on barriers to and drivers for EE among industrial SMEs has been studied over the years showing ambiguous findings [8,11]. However, so far research about which major barriers can be overcome by EENs and its various activities has not been done. Such studies are of utmost importance as industrial SMEs often require some form of public support (such as energy audits or EENs) for overcoming barriers as they have limited resources and time [40]. The process evaluation undertaken in this study showed that the energy audit was the most favorable function among EEN participants, followed by lectures on energy efficiency, consultancy with energy experts, presentation of realized measures and network meetings for experience sharing. This supports previous research showing that energy audits help remove barriers [13] but also that an EEN can serve an SME in actually making them carry out an energy audit as early findings by Gruber and Brand [11] showed that SMEs were reluctant to do so even when the audit was subsidized. The result of this study shows that EEN cannot overcome all the major barriers with present conditions. The network seems to be effective against some barriers whereas only partially effective against some other barriers. There are still a few barriers which remain as such even after the EEN. This in turn underlines the importance of additional policy means such as investment subsidies to be complemented by SME policy programs including energy audit policy programs and EEN policy programs, to even further overcome barriers not fully addressed by the EEN functions.

In general, this preliminary study has shown the major barriers that may be overcome by an EEN, thus enabling future EEN programs to be more efficiently designed. Even though previous research shows that studies on barriers and SMEs show ambiguous results (e.g. Trianni et al. [8] and Gruber and Brand [11]), the methodology addressed in this study may serve EEN policy program officers in undertaking process evaluation of their particular program.

One major limitation of the study's preliminary finding is that it has been based on a low number of respondents, which makes it hard to generalize it for other regions and countries. However, the proposed methodology has been shown to be suitable in evaluating the EEN program in this study for which reason it is suggested to be applied also in future case studies.

The proposed methodology for this study is unique to the author's awareness due to using barriers to EE when evaluating the functions of an EEN program, which to the author's awareness has not been done before. The only former study in the field is the study by Schleich [13] who found that energy audits help reduce barriers to EE. Specific to EENs, this methodology can be used for future process evaluations in case of adding new functions or modifying the current ones. It is recommended to apply formative process evaluation while the program is operating to assess the performance of the various functions. In general, this methodology can also be used to evaluate other EE policy programs aiming to improve EE. Further research is also suggested scaling up this study in a national or international context using a survey. When doing so, it is also recommend, as barriers may differ between regions/countries studied, that barriers to EE preferably is investigated carefully before the final design of the survey, i.e. adopting the proposed methodology to suit the targeted program participants. Further, it is also of importance to carefully address that the functions in such a survey are similar in the sample, e.g. energy audits can be carried out based on different standards or even on different energy audit levels.

Future research on EEN programs can investigate the gap between network operators and participants' perception of the EEN. Future researchers should also investigate different policy tools for improved standardization and development of EEN programs. Preferably, there should also be an ongoing evaluation during the EEN process and guidelines on modifications of the functions in order to ensure that SMEs are helped to overcome the common barriers they face.

Credit author statement

I am Noor Jalo declare that all authors worked together on all parts together since data collection till the revision of the submitted article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A

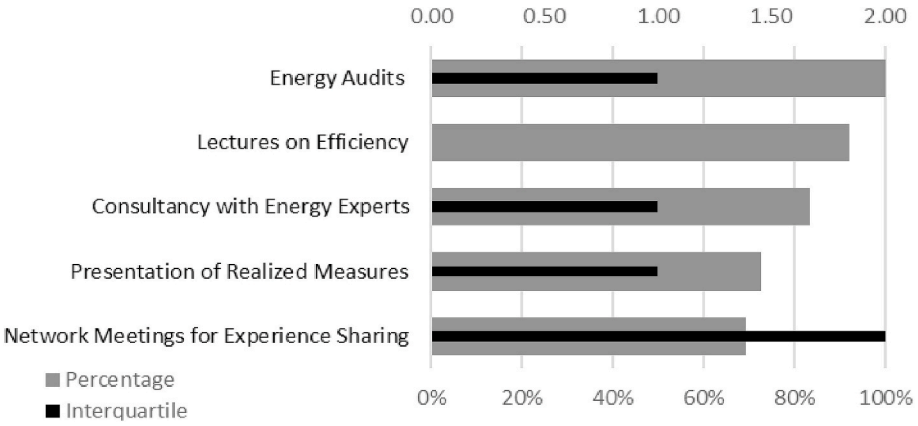

Fig. A1. Ranking of EEN functions on overall effectiveness of EEN.

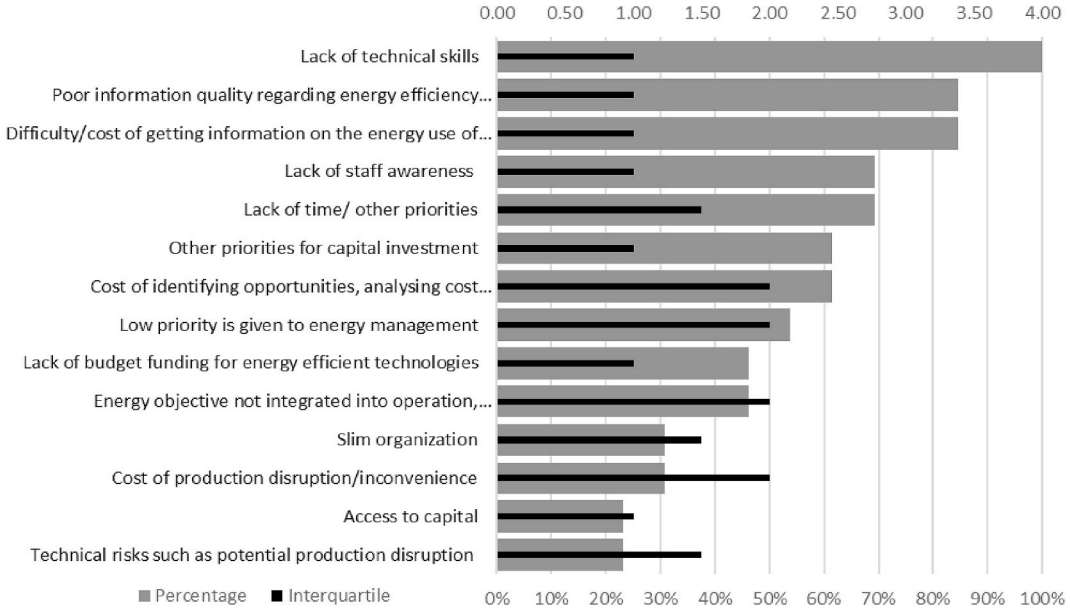

Fig. A2. Barriers ranked based on perception of reduction by "EEN.

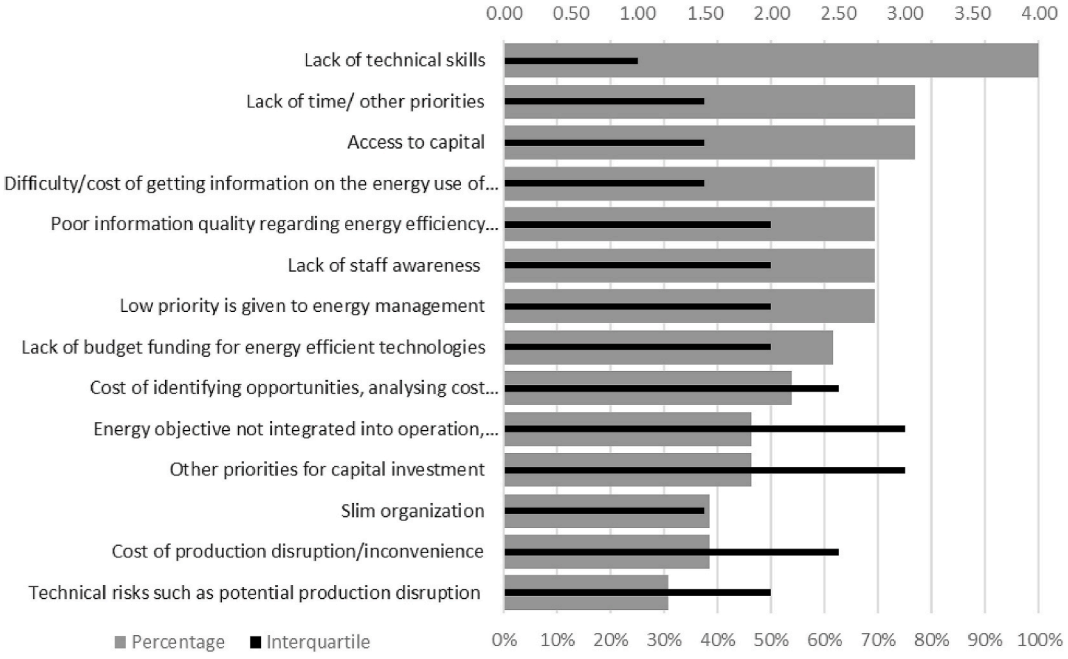

Fig. A3. Barriers ranked based on perceived reduction by "Energy Audit" within an EEN.

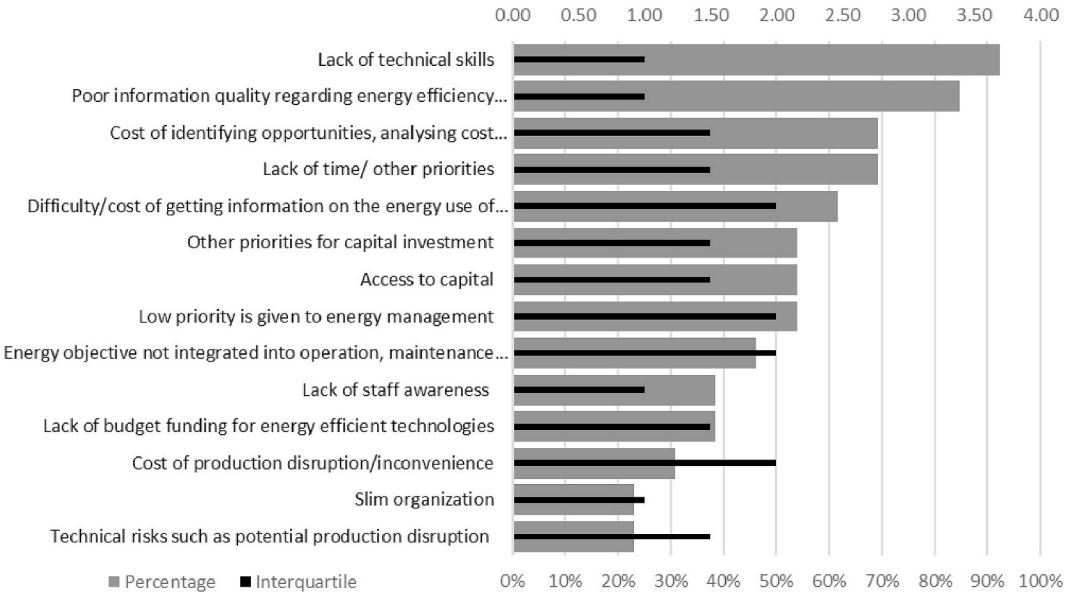

Fig. A4. Barriers ranked based on the perceived reduction by "Lectures on Energy Efficiency".

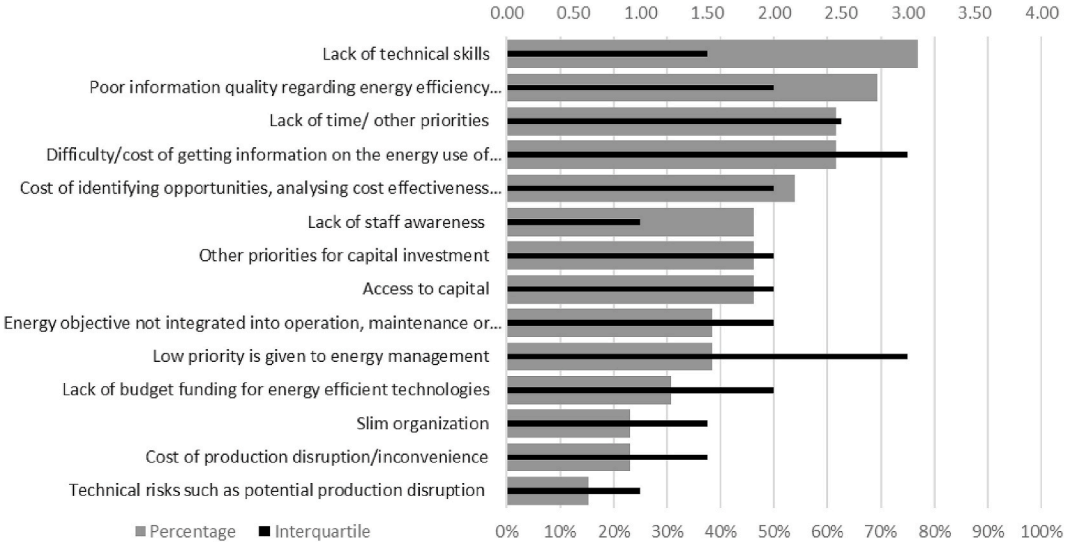

Fig. A5. Barriers ranked based on the perceived reduction by "Consultancy with Energy Experts".

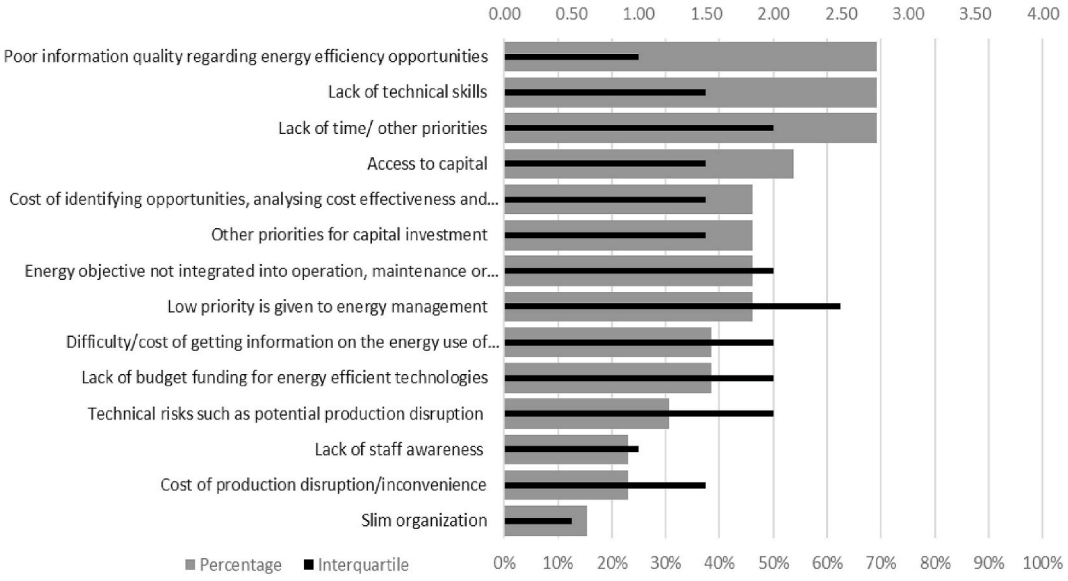

Fig. A6. Barriers ranked based on the perceived reduction by "Network Meetings & Experience Sharing".

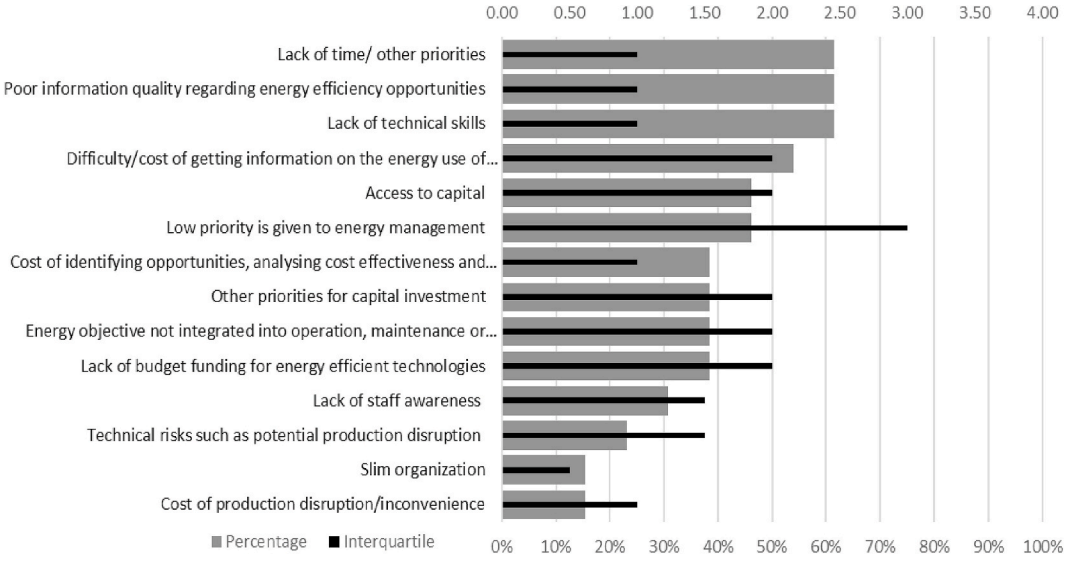

Fig. A7. Barriers ranked based on perceived reduction by "Presentation of Realized Measures".

References

[1] United Nations. Sustainable development goals"," [online]. Available: https://www.un.org/development/desa/disabilities/envision2030-goal7.html. [Accessed 13 February 2020]. Accessed.

[2] International Energy Agency. Tracking industrial energy efficiency and CO2 emissions. Paris: International Energy Agency (IEA); 2007.

[3] UNEP DTU Partnership. Overcoming barriers to investing in energy efficiency. New York and Geneva: United Nations Publication; 2017.

[4] European Parliament News. What is carbon neutrality and how can it be achieved by 2050?. European Parliament, 10 March 2020. [Online]. Available: https://www.europarl.europa.eu/news/en/headlines/society/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050. [Accessed 10 March 2020]. Accessed.

[5] Kanchiralla FM, Jalo N, Johnsson S, Thollander P, Andersson M. Energy end-use categorization and performance indicators for energy management in the engineering industry. Energies 2020;13(2):369.

[6] Thollander P, Kimura O, Realini A, Maggiore S, Rohde C, Helgerud H-E, Cosgrove J, Johansson I. A review of energy efficiency policies for small and medium-sized manufacturing enterprises from around the world. ACEEE 2019 summer study on energy efficiency in industry. Portland: Oregon; 2019.

[7] Cango E, Trianni A, Worrel E, Miggiano F, Abeleen C. Barriers and drivers for energy efficiency: different perspectives from an exploratory study in The Netherlands. Energy Convers Manag 2015;102:26–38.

[8] Trianni A, Cagno E, Worrell E, Pugliese G. Empirical investigation of energy efficiency barriers in Italian manufacturing SMEs. Energy 2013;49(C):444–58.

[9] Sorrell S, Mallett A, Nye S. Barriers to industrial energy efficiency: a literature review. 2011. Vienna.

[10] Rohdin P, Thollander P, Solding P. Barriers to and drivers for energy efficiency in the Swedish foundry industry. Energy Pol 2007;35(1):672–7.

[11] Gruber E, Brand M. Promoting energy conservation in small and medium-sized companies. Energy Pol 1991;19(3):279–87.

[13] Schleich J. Do energy audits help reduce barriers to energy efficiency? An empirical analysis for Germany. Int J Energy Technol Pol 2004;2(3):226–39.

[14] Thollander P, Palm J. Improving energy efficiency in industrial energy systems: an interdisciplinary perspective on barriers, energy audits, energy management, policies, and programs. Springer; 2013.

[15] Moshfegh B. Competitive, climate neutral and competitive Gävleborg 2050. 2014.

[16] Anderson ST, Newell RG. Information programs for technology adoption: the case of energy-efficiency audits. Resour Energy Econ 2004;26(1):27–50.

[17] Paramonova S, Thollander P. Ex-post impact and process evaluation of the Swedish energy audit policy programme for small and medium-sized enterprises. J Clean Prod 2016;135:932–49.

[18] Schlomann B, McCullough A, Gerdes J. Energy efficiency networks. Pol Brief 2016.

[19] Koewener D, Jochem E, Mai M, Mielicke U. Energy efficiency networks for companies – concept, achievements and prospects. Eur Counc Energy Eff Econ 2011.

[20] OECD/IPEEC. Energy Efficiency Networks: towards good practices and guidelines for effective policies to stimulate energy efficiency. 2017.

[21] Paramonova S, Backlund S, Thollander P. Swedish energy networks among industrial SMEs. Eur Counc Energy Eff Econ 2014.

[22] Johansson I, Stenqvist C, Thollander P. Energy efficiency networks for SMEs - program theory and ongoing. In: In international energy policy & programme evaluation conference, Bangkok, Thailand; 2017.

[23] Paramonova S, Thollander P. Energy-efficiency networks for SMEs: learning from the Swedish experience. Renew Sustain Energy Rev 2016;65:295–307.

[24] Backlund S, Thollander P, Palm J, Ottosson M. Extending the energy efficiency gap. Energy Pol 2012;51:392–6.

[25] Jaffe A, Stavins RN. The energy-efficient gap: what does it mean? Energy Pol 1994;22(10):804–10.

[26] Solnørdal M, Foss L. Closing the energy efficiency gap—a systematic review of empirical articles on drivers to energy efficiency in manufacturing firms. Energies 2018;11(3):518.

[27] Hasan MASM, Trianni A. A review of energy management assessment models for industrial energy efficiency. Energies 2020;13(21):5713.

[28] Rohde C, Mielicke U, Nabitz L, Köwener D. Learning energy efficiency networks -evidence based experiences from learning energy efficiency networks - evidence based experiences from Germany. ACEEE summer study on energy efficiency in industry. 2015.

[29] Durand A, Jochem E, Joest S, Quezada A, Roser A, Chassein E. Energy efficiency networks: lessons learned from Germany. Eur Counc Energy Eff Econ 2018.

[30] Chassein E, Durand A, Gerspacher A, Jochem E, Roser A. Evaluation of regional learning energy efficiency networks - generation, audits, targeting, and network operation. IREES 2018.

[31] Jochem E, Gruber E. Local learning-networks on energy efficiency in industry - successful initiative in Germany. Appl Energy 2007;84(7–8):806–16.

[32] Paramonova S, Ivner J, Thollander P. Outsourcing industrial energy management - industrial energy efficiency networks provided as an energy service. Nova Publisher; 2014.

[33] Johansson I, Thollander P. Non-energy benefits in energy audit and energy efficiency network policy programs for industrial SMEs. In: In proceedings of the ECEEE summer study; 2019.

[34] Nehler T, Thollander P, Dahlgren M, Ottosson M. Including non-energy benefits in investment calculations in industry – empirical findings from Sweden. ECEEE Indus Summer Study Proceed 2014:711–9.

[35] Paramonova S. Re-viewing industrial energy-efficiency improvement using a widened system boundary. Sweden: Linkoping; 2016.

[36] Sorrell S, Schleich J, Scott S, Scott S, O'Malley E, Trace F, Böde U, Köwener D, Mannsbart W, Ostertag K, Radgen P. Reducing barriers to energy efficiency in private and public organisations. 2000.

[37] Cagno E, Worrell E, Trianni A, Pugliese G. A novel approach for barriers to industrial energy efficiency. Renew Sustain Energy Rev 2012;19(C):290–308.

[38] Fleiter T, Worrell E, Eichhammer W. Barriers to energy efficiency in industrial bottom-up energy. Renew Sustain Energy Rev 2011;15:3099–111.

[39] Johansson M, Thollander P. A review of barriers to and driving forces for improved energy efficiency in Swedish industry – recommendations for successful in-house energy management. Renew Sustain Energy Rev 2018;82:618–28.

[40] Johansson I, Mardan N, Cornelis E, Kimura O, Thollander P. Designing policies and programmes for improved energy efficiency in industrial SMEs. Energies 2019;12(7):1338.

[41] Trianni A, Cagno E, Thollander P, Backlund S. Barriers to industrial energy efficiency in foundries: a European comparison. J Clean Prod 2013;40:161–76.

[42] Trianni A, Cagno E, Farné S. Barriers, drivers and decision-making process for industrial energy efficiency: a broad study among manufacturing small and medium-sized enterprises. Appl Energy 2016;162:1537–51.
[43] Trianni A, Cagno E, Worrell E. Innovation and adoption of energy efficient technologies: an exploratory analysis of Italian primary metal manufacturing SMEs. Energy Pol 2013;61:430–40.
[44] Dixon-O'Mara C, Ryan L. Energy efficiency in the food retail sector: barriers, drivers and acceptable policies. Energy Eff 2018;11:445–64.
[45] Viesi D, Pozzar F, Federici A, Crema L, Mahbub MS. Energy efficiency and sustainability assessment of about 500 small and medium-sized enterprises in Central Europe region. Energy Pol 2017;105(C):363–74.
[46] Backman F. Barriers to energy efficiency in Swedish non-energy-intensive micro- and small-sized enterprises-A case study of a local energy program. Energies 2017; 10(1):100.
[47] A. Trianni, E. Cagno, J. Dolsak and N. Hrovatin, "Implementing energy efficiency measures: do other production resources matter? A broad study in Slovenian manufacturing small and medium-sized enterprises," J Clean Prod, vol. 287, 2020.
[48] Cagno E, Trianni A. Evaluating the barriers to specific industrial energy efficiency measures: an exploratory study in small and medium-sized enterprises. J Clean Prod 2014;82:70–83.
[49] Nehler T, Parra R, Thollander P. Implementation of energy efficiency measures in compressed air systems: barriers, drivers and non-energy benefits. Energy Eff 2018; 11:1281–302.
[52] Johansson MT, Thollander P. A review of barriers to and driving forces for improved energy efficiency in Swedish industry– Recommendations for successful in-house energy management. Renew Sustain Energy Rev 2017;82:618–28.
[53] Rohdin P, Thollander P. Barriers to and driving forces for energy efficiency in the non-energy intensive manufacturing industry in Sweden. Energy 2006;31(12): 1836–44.
[54] Yin RK. Case study research: design and methods. Can J Progr Eval 2009;24(3): 221–2.
[55] Sorrell S, O'Malley E, Schleich J, Scott S. The economics of energy efficiency: barriers to cost-effective investment. Cheltenham, UK: Edward Elgar Publishing; 2004.
[57] Thollander P, Palm J. An interdisciplinary perspective on industrial energy efficiency. Appl Energy 2010;87(10):3255–61.
[58] Thollander P, Rohdin P, Danestig M. Energy policies for increased industrial energy efficiency: evaluation of a local energy programme for manufacturing SMEs. Energy Pol 2007;35(11):5774–83.
[59] Andersson E, Thollander P. Key performance indicators for energy management in the Swedish pulp and paper industry. Energy Strat Rev 2019;24:229–35.
[60] Thollander P, Svensson IL, Trygg L. Analyzing variables for district heating collaborations between energy utilities. Energy 2010;35(9):3649–56.
[61] Pratt MG. Fitting oval pegs into round holes: tensions in evaluating and publishing qualitative research in top-tier north American journals. Organ Res Methods 2008; 11(3):481–509.
[62] Brunke J-C, Johansson M, Thollander P. Empirical investigation of barriers and drivers to the adoption of energy conservation measures, energy management practices and energy services in the Swedish iron and steel industry. J Clean Prod 2014;84:509–25.
[63] Odyssee-Mure, Odyssee-mureeu. Energy efficiency trends and policies in industry: review of energy efficiency trends and policies in the industry sector in the EU, [online]. Available: https://www.odyssee-mure.eu/publications/br/energy-efficiency-in-industry.html. [Accessed 3 March 2020]. Accessed.