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An interdisciplinary perspective on industrial energy efficiency

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ABSTRACT

This paper combines engineering and social science approaches to enhance our understanding of industrial energy efficiency and broaden our perspective on policy making in Europe. Sustainable development demands new strategies, solutions, and policy-making approaches. Numerous studies of energy efficiency potential state that cost-effective energy efficiency technologies in industry are not always implemented for various reasons, such as lack of information, procedural impediments, and routines not favoring energy efficiency. Another reason for the efficiency gap is the existence of particular values, unsupportive of energy efficiency, in the dominant networks of a branch of trade. Analysis indicates that different sectors of rather closed communities have established their own tacit knowledge, perceived truths, and routines concerning energy

efficiency measures. Actors in different industrial sectors highlight different barriers to energy efficiency and why cost-effective energy efficiency measures are not being implemented. The identified barriers can be problematized in relation to the social context to understand their existence and how to resolve them.

Keywords: Barriers, Energy efficiency, Social construct, Industry, Network

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1. Introduction

Global warming resulting from the use of fossil fuels is said to threaten the environment, and industrial energy efficiency is one of the most important ways to reduce this threat, as industry together with transportation is the highest energy-using sector in the world [1-2]. Approximately 30% of energy used in the EU-25 countries is related to industry. However, even in the most “technology optimistic” perspective, industrial energy use is projected to increase within 50 years [3]. How and when energy is used in industry determines society’s ability to create long-term sustainable energy systems. Generally, the end-users are also ultimately the ones who must pay for transforming or adapting the energy systems, which increases their importance as a key component of the system. However, shifting energy systems toward greater sustainability sometimes requires users to “transform” their behavior, values, and routines to conserve energy. This transformation can be facilitated by policy means and government initiatives such as taxation, standards,

subsidies, information campaigns, and energy guidance. EU and national governments aim, in various ways, to influence industrial energy use towards increased efficiency, and in this paper we discuss the premises on which industrial energy efficiency is based and on which government policy instruments are generally based and designed.

A number of previous studies have been conducted in the area of energy supply [3-6], energy end-use [7], metering, planning and modeling [1,4,8,9]. However, numerous studies of energy efficiency potential state that cost-effective energy efficiency technologies in industry often go unimplemented, due to various barriers. Previous studies have discussed the potential for industrial energy efficiency and the reasons why many energy efficiency measures are never implemented [4]. Explanations as to why companies do not adopt such measures include low present energy costs, lack of information, procedures and routines that do not favor energy efficiency, short-term payback rules, lack of funds, and energy costs comprising a relatively small part of company turnover [5,6,10]. At the same time, industrial energy efficiency can be expected to be shaped by social and commercial processes and built on knowledge, routines, institutions, and methods established in networks [7]. In this paper, we analyze industrial energy efficiency from a socio-technical perspective and discuss energy efficiency measures and behavior as negotiated in networks.

This paper combines engineering and social science approaches to enhance our understanding of industrial energy efficiency and thus broaden our perspective on related policy making in Europe. Sustainable development demands new strategies, solutions, and policy-making approaches. One way to

develop new strategies for industrial energy efficiency entails comparing different sectors and the practices established in them. Via this comparison, we can identify and visualize new opportunities and methods applicable in different sectors. The paper is unique in this way as, to the best of the authors' knowledge, no such approach has been used before. The focus is on improving energy efficiency in non-energy-intensive and small and medium-sized enterprises (SMEs), this due to extensive empirical studies on barriers, which gives a good starting point for discussing how to cross pollinate social and engineering sciences.

It should be noted that our aim is not to criticize previous theoretical approaches but rather to address that the traditional view of studying industrial energy efficiency and barriers may need to be reconsidered in order to meet the urgent need for efficient energy policies to be (re-) designed. After first presenting the theoretical baseline, we continue by addressing previous Swedish empirical work on the subject, and end by discussing the policy implications of how industrial energy efficiency might be addressed, using a combined engineering/social science approach.

2. Energy policy decision-making and barriers to energy efficiency

Energy policy decision-making is often based upon mainstream economic theory relying upon fundamental axioms such as perfect information, zero transaction costs etc. One categorization within mainstream economic theory is that between market failures/imperfections and market barriers as the former may justify public policy intervention if passing a cost-benefit analysis. Brown [11] writes:

the existence of market failures and barriers that inhibit socially optimal levels of investment in energy efficiency is the primary reason for considering public policy interventions. In many instances, feasible, low cost policies can be implemented that either eliminate or compensate for market imperfections and barriers, enabling markets to operate more efficiently to the benefit of society. In other instances, policies may not be feasible; they may not fully eliminate the targeted barrier or imperfection; or they may do so at costs that exceed the benefits [11].

A number of market failures or market imperfections exist such as incomplete markets, imperfect competition, and information imperfections and asymmetries. Among these, the market failures imperfect information and asymmetric information are of interest when studying industrial energy end-use efficiency [4]. Asymmetric information may in turn be classified into split incentives, principal-agent relationship, and adverse selection [9]. In summary, barriers to energy efficiency which may be classified as market failures or market imperfections may lead to policy adoption, while so called market barriers, which may be classified as any barrier which accounts for the energy efficiency gap, may not promote policy adoption. The classification of barriers thus has strong implications in regard to if, how, and when, a policy is to be adopted.

Growing concern about global warming has led the EU to implement several policy instruments, such as the EU Emission Trading Scheme (ETS) and the European Energy End-Use Efficiency and Energy Services Directive (ESD), according to which each Member State is obliged to formulate and design a

National Energy Efficiency Action Plan (NEEAP). The ESD went into effect in 2006, and proposes reducing energy use by 9% in each Member State by the ninth year of Directive implementation by ameliorating market imperfections and eliminating market barriers to energy efficiency [8]. Specifically, the ESD will accomplish this by:

- a) providing necessary indicative targets as well as the mechanisms, incentives, and institutional, financial, and legal frameworks needed to remove existing market barriers and imperfections (market failures) that impede the efficient end use of energy and
- b) creating the conditions for developing and promoting an energy service market and for delivering other energy efficiency improvement measures to end consumers [8].

In this way, the EU is going a step further than traditional economic policies based on mainstream economic theory, as the Directive's aim is both to eliminate market imperfection and eliminate market barriers [8]. The ESD promotes, among other matters, efforts to find feasible energy end-use policy initiatives directed toward SMEs in a national context:

In order to enable final consumers to make better informed decisions as regards their individual energy consumption, they should be provided with a reasonable amount of information thereon and with other relevant information, such as information on available energy efficiency improvement measures [8].

One criticism of energy policies and programs is that technological advances and rising energy prices will cause energy efficiency measures to be

implemented in any case, even without government intervention [12]. Yet another argument is that factors opposing the implementation of energy-efficient technologies do not represent market failure or market imperfection barriers but simply market barriers [13]. These arguments are related to mainstream economic policy, which relies greatly on the market and market restructuring in seeking to improve energy efficiency [9]. This means that, for public intervention to be implemented, the factors inhibiting the adoption of energy efficiency technologies must be categorized as market failures or market imperfections, of which there are four broad types: incomplete markets, imperfect competition, imperfect information, and information asymmetry.

Discussion of the energy efficiency gap builds on the assumption that there are technologies, methods, or processes that may reduce energy use in an industry, but that barriers hinder their implementation. If industrial actors would only act rationally, this gap would not exist. To explain this gap, different kinds of barriers to energy efficiency have been identified, including lack of information, knowledge, time, and funding. However, the empirical barriers identified in various studies are difficult to classify as market failure or non-market-failure barriers [14].

One criticism of this barrier approach is that it leads to reductionism in research. If a science, technology, and society (STS) approach is instead applied, the energy efficiency gap may be better understood in a social and institutional context.

3. European industrial energy efficiency in a social context: theoretical background

As stated in the introduction, industrial energy efficiency is an important means of reducing the threat of global warming [1] as industry is a major energy user [2]. Almeida's research [15] on the energy-efficient motor market in France represents an approach to examining the slow diffusion of apparently cost-effective energy efficiency measures, complementing the dominant view, represented, for example, by Schleich and Gruber [16], of barriers to energy efficiency. Barrier models describe the non-implementation of cost-effective energy efficiency investments and specify three pertinent features of the non-implementation: the objective obstacle, the subject hindered, and the action hindered [14]. The methodological questions to ask when formulating a barrier model are: What is the obstacle, whom does it affect, and what aspect of energy conservation does it affect? [14]. Barriers to energy efficiency may be divided into three broad categories, namely, economic, organizational, and behavioral barriers (see Table 1).

[Table 1]

Commonly cited barriers to energy efficiency include various information imperfections and asymmetries (e.g., split incentives), principal-agent relationships, and adverse selection. These barriers may be classified as market failure barriers, while other barriers, such as heterogeneity, risk, lack of access to capital, and hidden costs, may be seen as rational barriers and are not classified as market failure barriers. However, there is considerable dispute regarding the perception of barriers. While some researchers claim that most barriers are solely reflections of "normal" markets, others claim this is not so

[13]. The research tradition in which industrial barriers are discussed and the concept developed has been problematized by Shove:

Technical change is a one-way process of technology transfer, and ... social obstacles or non technical barriers impede technological progress. What is missing is an appreciation of the social contexts of energy saving action and of the socially situated character of technical knowledge. As we shall see, reinstatement of these missing elements has knock-on consequences for the rest of the conventional package, so much so that the whole tidy edifice begins to crumble.
[17:1108]

Shove criticizes a tendency in research to focus on individual decision-makers as if they make decisions in a vacuum, regardless of social and institutional context [17]. Studies by STS researchers, for example, those of Callon [18], Bijker [19], and Shove [17], emphasize that decisions concerning how we use energy and implement energy efficiency measures are made in social contexts. Practitioners identify and make energy-related decisions in various networks and contexts, according to Shove:

What qualifies as a reliable, cost effective, worthwhile energy saving measure in one socio-cultural domain might count for nothing in another. [17:1109]

Nelson and Winter [20] identified already in the 80's technological regimes as important because the constraint the pattern of innovation emerging in an industry. A 'technological regime' defines a pattern of solution to selected

technological problems. Technological regimes refer to cognitive routines that are shared in a community of engineers and that guides their R&D activities.

The technological regime is the rule-set embedded in:

“engineering practices, production process technologies, product characteristics, skills and procedures, ways of handling relevant artifacts and persons, ways of defining problems; all of them embedded in institutions and infrastructures” [21, pp 443].

It highlights that engineers, and other persons involved in technology use and adoption, act in a social context of social structures, regulations and norms. Technical regimes are broaden down to socio-technical regimes by including institutional and market aspects needed to make the technical regime work. A socio-technical regime is characterized by the set of rules that guide technical design, as well as rules that shape market development such as user preferences and rules for regulating these markets [22]. The use of socio-technical regimes also implies the existence of different regimes and that it exist connection and mutual dependency between them. In a company different social groups can be distinguished with their own special features. Actors within these groups share aims, values, problem agendas, professional journals etc. But rules are not just linked within regimes but also between regimes, and regimes influence each other and that is why socio-technical regimes are a better concept to explain this [23].

According to such a perspective, energy efficiency thus also depends on social relationships and discussion, negotiations, and agreements developed in actor networks. One outcome of this perspective is that energy-saving measures

in one socio-cultural domain may be useless in another (see e.g [7]). Experiences, routines, and habits established and negotiated in a particular network will then determine what energy efficiency measures will be implemented. These negotiated agreements can thus serve as both possibilities and constraints.

Focusing on social negotiations and agreements helps explain why energy efficiency technologies are rejected or adopted in different sectors. It also directs attention to the fact that technology diffusion too is social in character and to the idea that differentiating between technical and non-technical barriers is an analytical construct that could lead to important aspects being overlooked or at least oversimplified in analysis. The barrier approach could benefit from, for example, in-depth studies of what energy efficiency discourse is like in a company, i.e., how employees talk about energy efficiency and how the discourse relates to environmental issues and cost allocations in regard to energy efficiency measures. Below we will discuss how identified barriers could then be problematized in relation to the social context, enabling a deepened understanding that could in turn lead to new ways to overcome specific barriers.

4. Barriers identified in earlier studies of Swedish SMEs

Several studies have empirically examined barriers to energy efficiency, for example, Gruber and Brand [24], Sorrell et al. [4], Brown [11], de Groot et al. [25], Schleich [26], Schleich and Gruber [27], and Sardianou [28]. An overview of empirical barriers to energy efficiency identified by Swedish studies is presented in Table 2 [29–31].

[Table 2]

Table 2 shows the greatest barriers to energy efficiency identified in the examined Swedish studies, which examined industries in Oskarshamn, Sweden, SMEs on the Swedish Highland, and Swedish foundries. Naturally, there are many similarities between these studies. For example, technical risks and lack of time are highly ranked in two of three studies; as a main interest is determining general patterns of barriers to be targeted by policy makers, these could be a focus. We would like to highlight the differences between the spotted barriers and discuss the explanations for them and their implications for policy making.

Notably, among the industries in Oskarshamn the risk of production disruption was considered the greatest barrier to implementing energy-efficient technologies, while this was ranked fourth by the studied Highland SMEs. Among the Highland SMEs, lack of time was deemed the greatest barrier, while the Oskarshamn industries ranked that barrier second and the Swedish foundries ranked it only eleventh. For the Swedish foundries, lack of capital was the largest barrier, while the Oskarshamn industries ranked this ninth and the Highland SMEs ranked it third.

Among the studied Swedish foundries, technical risks, such as potential production disruption, were ranked second, while these were ranked low, i.e., eleventh place, by the Highland SMEs. Other priorities were ranked second among the Highland SMEs and Oskarshamn industries, but ranked only fifth by the Swedish foundries. The difficulty and cost of obtaining information about the energy consumption of purchased equipment was considered the third

greatest barrier among Oskarshamn industries, fourth for the foundries and seventh for the Highland SMEs.

5. Barriers in a socio-technical network perspective

Focusing barriers in industry in the perspective of the existence of competing social networks could throw new light on why energy efficient technology is not implemented, even if it can be both economically and technologically rational for the industry to do so. Decisions concerning how we use energy and energy efficiency measures are made in social contexts [32].

As we saw above we can identify different barriers and also establish that there are differences between sectors regarding what barriers are perceived as most important. Why this is so and how we can understand these differences remain however undetermined. To analyze energy efficiency and related technologies as embedded in and shaped by social processes and negotiated in networks, can contribute to explain differences in how barriers are valued by the actors, and it is possible to problematize the grounds on which these barriers exist. The barriers mentioned by the industrial actors will partly reflect traditions, value structures, and rumors that the actors seldom have tried to verify or refute, because it is values embedded in actor's practice. When Swedish foundries claim that lack of access to capital is their greatest barrier, one may ask why they have greater problems finding capital than do SMEs in Oskarshamn. And why is lack of time a significant barrier among Oskarshamn industries and Highland SMEs but not among the Swedish foundries? One explanation are of course that the foundry industry may indeed have a harder time than do other sectors finding investment capital for energy efficiency

measures, and that energy efficiency technologies in this sector may be more capital intensive. But part of the explanation is also that the empirical findings reflect routinely accepted answers that can easily be challenged. To start challenge these established values is vital for improved energy efficiency in industry. This can be done by visualize differences in how barriers are perceived in different sectors to start a reflection among the actors on this. Another way is to visualize existing priorities in industry that lead to that obvious profitable measures are not implemented. In the following section, examples from three system levels, the company level, the industry level, and the energy policy decision-making level, are presented.

5.1 The company level

One example from a Swedish foundry showed how closed communities could be opened up using our approach, namely, requiring the inclusion of energy performance figures in the company's annual report [33]. By stating, for example, the extent of cost-effective potential measures available at a company in the annual report, as well as other relevant energy figures, the sometimes rather isolated company board would receive a figure capturing the company's energy efficiency potential, which may be seen as a type of restricted capital.

We need to start looking for these imbedded values and knowledge to be able to challenge these. A start for doing this is mapping these industrial regimes and find out existing knowledge on energy efficiency, what information that is dispersed, by whom and how it differ between companies and industrial sectors.

5.2 The industry level

On an industry level, introducing and building regimes and networks focusing on energy efficiency and how to reduce the energy efficiency gap could

be a way to challenge established routines and establish new ones. One example from that, also derived from the Swedish foundry industry, are networks or clusters being set up where energy controller meet and discuss their approach to common problems faced within that sector. For example, up until 2009, air heat recovery from the cast cooling system, have been shown difficult to find solutions to. Several foundries have tried but for various reasons failed. Now, one company has implemented the industry's first needle battery, a solution which has been shown to work out fine. This success story is now being spread, throughout this network, so that other foundries, when facing an opportunity to invest in the foundry cast cooling system, may consider this energy efficient solution.

5.3 The energy policy decision-making level

Sweden has, unlike the other Scandinavian countries Denmark, Finland and Norway, lacked a national energy program for industrial SMEs for 20 years [31]. One of the main reasons for this may be found in a strict attempt to base energy policy-making on mainstream economic theory. The Swedish Ministry of Enterprise, energy and communications in 2001 stated that:

a public resource affecting politics can therefore be motivated by indentifying and try to eliminate these so called market imperfections.energy policies should be of general character and not be targeted towards one single technology. [34].

Notably, the EU, in the ESD from 2006, stated that the aim of the directive was to: ...to remove existing market barriers and imperfections (market failures) that impede the efficient end use of energy... [8]. This directive, in turn led to

the implementation of a Swedish industrial energy program towards SMEs where the authorities took a wider approach also incorporating market barriers [35,36]. In other words, the approach, previously held by the Swedish authorities, may be one explanatory variable to why Sweden have not had a national energy program towards industrial SMEs the past 20 years. When the EU through the ESD [8], and later the Swedish authorities [35] instead took a wider approach, deviating from mainstream economic theory incorporating not solely market imperfections but also market barriers, to reducing energy use, an energy program for industrial SMEs was the outcome.

6. Social networks discussed in earlier studies

Previous studies have touched on existing social networks and their significance for energy efficiency when the focus has been on information dissemination and on what actors are cited by representatives of these industries as most important when they seek energy efficiency information (cf. Stern et al. [37]). Here we discuss the empirical findings of Swedish studies regarding networks perceptions of various information sources. The company's networks are mainly consisting of people within their own sector and the technological regime in foundries does not include actors from for example pulp and paper industry. If we look at the sources of information about energy efficiency that these regimes use, then we can see that colleagues within the sector is highly ranked, see table 3.

[Table 3]

Among the Oskarshamn industries and Swedish foundries, colleagues in the same company and sector were the most important informants, while for the Highland SMEs, the actor category most often mentioned was consultants. Among Oskarshamn industries and Swedish foundries, consultants were ranked second and third most important, respectively. In general, oral information seems more important than written information and various networks such as colleagues are highly ranked sources of information.

When colleagues are used as a source of information, existing behaviors, perceptions, and norms concerning energy efficiency tend to prevail: most of the information circulating will likely be of a kind acceptable in the company and sector. From earlier research on socio-technical regimes we know that more innovative ideas and suggestions that challenge existing energy efficiency values and habits are more likely to be introduced from outside the dominate regime [38]. New technologies and new ideas have problems to break through because of established regimes that are deep-rooted. Path-breaking transitions are hard to achieve. One way for novelties to be used is when existing regimes are replaced, which does not however, occur that often. Another way is to contribute to changes in practices and routines of existing regime actors [21,22] which can be done through for example, seminars and conferences. Actors from different companies and sectors, i.e., different regimes, meet in seminars and conferences and discuss energy efficiency from different perspectives—a source of new influences on a company.

When consultants are used as information sources, the company is limited to their views on energy efficiency and expertise in the energy area. Individual consultants are often experts on particular aspects of energy and have

established procedures for determining what aspects of a company's energy use that should be the focus. Energy consultants often simply provide advice or information about possible energy efficiency measures, but do not follow up the implementation. Such an approach makes a rather limited contribution to the introduction of new ideas or innovative efficiency measures in a company, and may inhibit the diffusion of energy-efficient technologies.

What are needed are new forms of discussions, new alternatives, that challenge existing regimes, and to try new approaches by letting different social networks learn from each other. That would enable discussion of whether the barriers in each sector can be overcome by bridging and by elucidating any prejudices, bad habits, or thoughtless routines that may affect the various activities in the sector.

We already possess knowledge of how to improve energy efficiency; the problem lies in disseminating it, and an important part of that is letting actors learn from each other. This indicates a need to enhance communication between the established and more or less closed social networks in different sectors. Letting actors cross traditional communication boundaries and actively stimulating new social arrangements, involving actors from different sectors who can share their good examples with each other, should perhaps be more prioritized by both researchers and policy makers.

7. Concluding discussion

It should be noted that the applied STS-approach may or may not be a sufficient approach in dealing with these issues. However, it does provide a

start, though not a basis, of a timing topic of aiming at achieving effective energy policy instruments beyond the traditional approach.

Problems of industrial energy efficiency are multifaceted, one obvious problem being that energy-efficient technologies do not diffuse satisfactorily. It is clear that, in theory, there is an “efficiency gap” between technical-economic potential for improved energy efficiency and what is implemented in practice. Shove [17] states that if we acted as rational consumers the gap would not exist; the fact is it does exist, so it is time to approach this problem with new tools. This paper has demonstrated that different sectors constitute more or less closed communities that have established their own tacit knowledge, truths, and routines concerning energy efficiency measures. Actors from different sectors emphasize different barriers to energy efficiency and different reasons why cost-efficient energy efficiency measures are not implemented. Building on these studies of energy efficiency barriers by including questions about how companies perceive sustainability, costs, and comfort, how they act in practical situations, and what attitudes, norms, and routines determine their actions, would indeed be of interest. Then it would be possible to relate energy use and energy efficiency culture to social practices in companies. Identified barriers could then also be problematized in relation to socio-technical regime context.

Understanding that there are technical, social, and organizational reasons why optimal energy efficiency measures are not being implemented by industrial companies would have positive consequences for policy development. Common policy instruments such as taxation and subsidies could arguably be combined with information and discussion across established professions and sectors. For example, creating actor networks crossing established sector

boundaries would challenge established norms and routines. Moreover, by realizing the importance of the social construction of technological development and the spread of energy-efficient technologies, other policy instruments would become relevant, such as networks regarding energy services and energy efficiency. Then, purely economic incentives would perhaps prove not to be the most efficient policy instruments. Instead, it may be workshops, seminars, energy clusters or other open networks in which established norms, routines, and tacit knowledge are highlighted and challenged.

In non-manufacturing firms, for example, if it is questioned whether the perceived risk of process interruption might be overestimated, this hindrance to improving energy efficiency could perhaps be avoided. Discussing the social construction of these barriers in social networks and regimes enables researchers to take industrial energy efficiency research a step further. Researchers may also facilitate and encourage the formation of networks across sectors and traditional professional boundaries.

It is important to approach barriers from a new perspective, using non-traditional analytical tools that can contribute new understandings or questions as to why a particular barrier is perceived as important in a company. Analyzing a company's culture and existing networks, that is, understanding the context in which energy efficiency goals and measures are discussed, is important in order to take industrial energy efficiency a step further.

In this paper, we have demonstrated that simply *perceiving* a barrier may itself serve as a barrier to implementing cost-effective energy efficiency measures in industry. One example is the argument that all barriers fit into the category of non-market-failure barriers, leading to the non-adoption of energy

policies and programs. Here, the EU has taken a step forward by focusing not only on market failures and imperfections, but also on market barriers in its Energy End-Use Efficiency and Energy Services Directive, enabling the adoption of energy policies that were previously difficult to adopt. The perception of barriers, as outlined by social science researchers, should not be neglected and should be emphasized in future research into building a more energy-efficient economy.

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Table 1

Perspectives on barriers (based on [4]).

Perspective	Examples	Actors	Theory
Economic	Imperfect information, asymmetric information, hidden costs, risk	Individuals and organizations conceived of as rational and utility maximizing	Neo-classical economics
Behavioral	Inability to process information, form of information, trust, inertia	Individuals conceived of as boundedly rational, having non- financial motives and a variety of social influences	Transaction cost economics, psychology, decision theory
Organizational	Energy managers lack power and influence; organizational culture leads to neglect of energy/ environmental issues	Organizations conceived of as social systems influenced by goals, routines, culture, power structures, etc.	Organizational theory

Table 2

Barriers identified in earlier studies of Swedish industry (based on [29–31]).

	Oskarshamn companies	Swedish foundries	Swedish Highland SMEs
1	Cost of production disruption/inconvenience	Access to capital	Lack of time or other priorities
2	Lack of time or other priorities	Technical risks, such as potential production disruption	Other capital investment priorities
3	Difficulty/cost of obtaining information on the energy use of purchased equipment	Lack of budget funding	Access to capital
4	Technical risks, such as potential production disruption	Difficulty/cost of obtaining information on the energy use of purchased equipment	Cost of production disruption/inconvenience
5	Other capital investment priorities	Other capital investment priorities	Lack of budget funding
6	Technology is inappropriate for the site	Possible poor performance of equipment	Lack of sub-metering
7	Lack of staff awareness	Lack of sub-metering	Difficulty/cost of obtaining information on the energy use of purchased equipment
8	Lack of technical skills	Poor information quality regarding energy	Lack of technical skills

efficiency opportunities			
9	Access to capital	Cost of identifying opportunities, analyzing cost-effectiveness, and tendering	Low priority given to energy management
10	Poor information quality regarding energy efficiency opportunities	Low priority given to energy management	Lack of staff awareness
11	Possible poor performance of equipment	Lack of time or other priorities	Technical risks, such as potential production disruption
12	Cost of identifying opportunities, analyzing cost-effectiveness, and tendering	Technology is inappropriate for the site	Slim organization

Table 3

Perceptions of various information sources among the studied industries

(based on [29–31]).

	Oskarshamn companies	Swedish foundries	Swedish Highland SMEs
1	Colleagues in the company	Colleagues in the sector	Consultants
2	Consultants	Staff at the Swedish Foundry Association	Government-sponsored energy audits
3	Conferences and seminars	Consultants	Colleagues in the company
4	Product information from suppliers	Colleagues in the company	Colleagues in the sector
5	Information from power companies	Conferences and seminars	Conferences and seminars
6	Colleagues in the sector	Written sources of information, such as journals	Product information from suppliers
7	Written sources of information, such as journals	Government-sponsored energy audits	Information from power companies