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Barriers to and Driving Forces for Energy Efficiency in the Non-Energy Intensive Manufacturing Industry in Sweden

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Abstract

The manufacturing industry is facing tougher competition which increases the demand to implement cost-effective energy efficiency measures. However, studies have indicated that obvious cost-efficient measures are not always undertaken. This is explained by the existence of barriers to energy efficiency. The aim of this study is to investigate the existence and importance of different barriers to the implementation of energy efficiency measures in the Swedish non-energy intensive manufacturing industry. Results from this study highlight a number of factors that inhibit the degree of implementation, such as the *cost* and *risk* associated with *production disruptions*, *lack of time* and *other priorities*, *lack of sub-metering* in larger organizations, etc. The study also finds a number of drivers, such as the existence of *people with real ambition* and a *long-term energy strategy* at site level.

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1. Introduction

The manufacturing industry accounts for about 75% of the world's yearly coal consumption, 20% of global oil consumption, and 44% of the world's natural gas consumption. Furthermore, the manufacturing industry also uses 42% of all electricity produced [1]. Growing concern for global warming, which results from the use of fossil fuels, has led to the implementation of a number of policy instruments, e.g., CO₂ emissions trading. Current and future policy instruments may result in higher energy prices and thus further increase the demand for industrial energy efficiency [2]. Increased globalization and the opening up of domestic markets within the European Union will make the implementation of cost-efficient energy efficiency measures within industry even more necessary, especially for a country like Sweden where the industry currently enjoys one of the lowest electricity prices in Europe [3].

Despite this, studies show that cost-efficient energy conservation measures are not always implemented, implying the existence of an energy efficiency gap, explained by the existence of barriers to energy efficiency [4-12]. These barriers differ depending on regional and sector-specific conditions [4] which imply the need for regional and sector-specific studies in order to spot these barriers and be able to adopt effective public energy policies [13].

In Sweden, about one third of all energy is used by industry, while the non-energy intensive industry accounts for a third of the industrial energy used [14]. Numerous Swedish studies have dealt with the study of energy efficiency measures in the industry, and most have focused on the issue in the energy intensive sectors [14-21], while studies

of the non-energy intensive sector are scarce. There is thus a great need for research in this area.

While energy efficiency in Swedish industry is a well-penetrated scientific subject, especially within the energy intensive sector, studies investigating barriers to and driving forces for the implementation of energy efficiency measures are scarce. The aim of this study is to investigate the existence of different barriers to the implementation of energy efficiency measures in the non-energy intensive¹ manufacturing industry in Sweden, and the significance of the barriers. It also identifies a number of driving forces, even though this was initially not the main objective. Studies of barriers to and driving forces for energy efficiency are of the utmost importance in understanding the mechanisms of how energy efficient technologies are adopted in the industry. This paper thus presents unique results of barriers to and driving forces for the implementation of energy efficiency measures in the Swedish non-energy intensive industry.

2. Method and concerned industries

This study was carried out as a case study [22,23] using semi-structured interviews [24], due to the explorative nature of the study and the multiple sites investigated. The companies investigated had all participated in a project carried out about five years ago that offered public sponsored energy audits.² They were the largest non-energy intensive

¹ Non-energy intensive industry is defined here as companies whose energy costs do not exceed 2% of their turnover.

² Using the terminology of [8], the results from the industrial energy audits presented in [20] can be seen as the maximum hypothetical energy savings without economic constraints.

manufacturing companies in the municipality of Oskarshamn.³ The main criterion for selecting respondents at the companies was that they should be responsible for energy issues at their site. Contacts were initiated by phone, at which time interviews were also scheduled. This study was based on eight personal interviews at eight different companies and everyone who was approached agreed to participate. The companies in the study comprise two large and six medium-sized sites. A few details about the industries concerned are presented in Table 1.

Table 1. Company specific information for the investigated industries.

Company	#1	#2	#3	#4	#5	#6	#7	#8
Employees	65	2,100	65	425	85	160	125	115
Pay-back criteria[year]	3	1	<10	3	3	1	3	3-5
EMS	No	Yes	No	Yes	No	Yes	No	Yes
Outsourcing of facilities (internal or external)	No	No	No	No	No	Yes	No	Yes
ESCOs	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type of goods	Contracting	Trucks	Veneer	Batteries	Candles	Transformers	Envelopes	Office chairs
Size	M ¹	L ²	M ¹	L ²	M ¹	M ¹	M ¹	M ¹

¹ Medium-sized; ² Large

The interviews were divided into two parts: first, an interview where each respondent was asked to describe his or her view of barriers (and driving forces) to energy efficiency, followed by a session where the respondents was asked to fill out a questionnaire covering various aspects of the subject. Every interview was taped entirely and took about an hour to complete.

³ The municipality of Oskarshamn, part of the Kalmar County, has some 26,500 inhabitants and is located at the Baltic Sea in the southeast of Sweden. The annual industrial production value of Oskarshamn represents about 0.4% of the national industrial value for Sweden. The Gross National Product for the county as a whole is 89, for Oskarshamn it is 138 compared to the national index of 100 [25].

It should be noted that when quantifying barriers, drivers, and information sources large simplifications are made. The quantified results contain several perspectives of the issue other than a single score on a ranking. This must be kept in mind when drawing conclusions from these types of studies. The respondent's answers must also be added to parameters which must be seen as somewhat uncertain. However, there is a difficulty gaining this type of information any differently, wherefore full confidence must be put in the respondent's answers.

3. Barriers to energy efficiency

A barrier is defined as “a postulated mechanism that inhibits investment in technologies that are both energy efficient and (apparently) economically efficient” [4]. The barriers in this study are presented in Table 2, and include behavioral, organizational, and economic barriers [4-12]. It should be noted, however, that the classification of barriers is not unambiguous [9].

4. Analysis

The second part of the interview consisted of a questionnaire with a number of questions covering the topic of barriers to energy efficiency. The respondents verified the existence of an energy efficiency gap. In order to rank the results from the questionnaire

Table 2. Classification of barriers to energy efficiency (Based on [4]).

Theoretical framework	Theoretical Barrier	Comment
Economic Non- market failure	Heterogeneity [8]	A technology or measure may be cost-efficient in general, but not in all cases.
	Hidden costs [8]	Examples of hidden costs are overhead costs, cost of collecting and analyzing information, production disruptions, inconvenience etc.
	Access to capital [8]	Limited access to capital may prevent energy efficiency measures from being implemented.
	Risk [8]	Risk aversion may be the reason why energy efficiency measures are constrained by short pay-back criteria.
Economic Market failure	Imperfect information [26]	Lack of information may lead to cost-effective energy efficiency measures opportunities being missed.
	Split incentives [8]	If a person or department cannot gain benefits from energy efficiency investment it is likely that implementation will be of less interest.
	Adverse selection [8]	If suppliers know more about the energy performance of goods than purchasers, the purchasers may select goods on the basis of visible aspects such as price.
	Principal-agent relationships [8]	Strict monitoring and control by the principal, since he or she cannot see that what the agent is doing may result in energy efficiency measures being ignored.
Behavioral	Bounded rationality [27]	Instead of being based on perfect information, decisions are made by rule of thumb.
	Form of information [12]	Research has shown that the form of information is critical. Information should be specific, vivid, simple, and personal to increase its chances of being accepted.
	Credibility and trust [12]	The information source should be credible and trustworthy in order to successfully deliver information regarding energy efficiency measures. If these factors are lacking this will result in inefficient choices.
	Inertia [12]	Individuals who are opponents to change within an organization may result in overlooking energy efficiency measures that are cost-efficient
	Values [28]	Efficiency improvements are most likely to be successful if there are individuals with real ambition, preferably represented by a key individual within top management.
Organizational	Power [4]	Low status of energy management may lead to lower priority of energy issues within organizations.
	Culture [4]	Organizations may encourage energy efficiency investments by developing a culture characterized by environmental values.

the questions were rated: 2 points if the respondent considered the question to be “often important,” 1 point for “sometimes important” and 0 points for “rarely important.” In 12 of the 20 questions, one or several of the respondents claimed that the stated barrier was of major importance in explaining the existence of an energy efficiency gap at their company. These barriers are presented in Table 3. In the table, as in the rest of this paper, the barriers expressed by the respondents have been classified into the theoretical barriers

presented in the chapter *Barriers to energy efficiency*. It should be noted that this classification has its faults as many of the barriers expressed by the respondents fit into more than one theoretical barrier [9].

Table 3. Rank of the major barriers derived from the questionnaire.

Rank (Points)	Barrier	Comments	Main theoretical barrier
1 (12)	Cost of production disruption/hassle/inconvenience	5 out of 8 respondents considered the cost of production disruption a major barrier to energy efficiency.	Hidden costs
2 (12)	Lack of time or other priorities	Lack of time was something that the interviewees often perceived to be a large barrier.	Hidden costs
3 (11)	Cost of obtaining information about the energy consumption of purchased equipment	Half of the respondents considered this to be a large barrier to energy efficiency, especially if the information comes from equipment suppliers.	Imperfect information
4 (11)	Technical risk such as risk of production disruptions	The risk of production disruptions was considered a barrier by half of the respondents.	Risk
5 (11)	Other priorities for capital investments	Generally, production-related investments had a higher priority among the studied companies than investments in energy efficient technology.	Hidden costs
6 (10)	Technology is inappropriate at this site	This was considered a large barrier by 2 of the respondents.	Heterogeneity
7 (9)	Lack of staff awareness	Staffs are not aware of or do not pay attention to energy efficiency and its potential.	Imperfect information
8 (9)	Lack of technical skills	Some of the respondents felt that lack of technical skills within their organization constitutes a barrier to energy efficiency.	Imperfect information
9 (9)	Access to capital	Access to capital may constitute a barrier. However, the respondents claimed that it is not a major barrier as long as the investment criteria are fulfilled.	Access to capital
10 (8)	Poor information quality regarding energy efficiency opportunities	Even though energy audits had been carried out, 6 out of 8 respondents considered this to be a barrier to energy efficiency. Only 2 considered it to be a major barrier, however.	Imperfect information
11 (8)	Possible poor performance of equipment	6 out of 8 considered this to be a barrier, 2 considered it to be large.	Risk
12 (7)	Cost of identifying opportunities, analyzing cost-effectiveness and tendering	This was considered a substantial barrier by 2 of the respondents.	Hidden costs

4.1 Economic non- market failures

Heterogeneity was considered to be a barrier of major importance by two of the respondents. This may be used as an explanatory variable for some technologies in some specific cases, although it does not explain sufficiently well the low adoption of energy efficiency technologies at the studied companies.

All the respondents claimed that production-related issues have higher priority than energy-related issues. The cost of production disruptions was also found to be a major barrier to energy efficiency. Furthermore, all the respondents considered lack of time to be a barrier, especially concerning the search for energy efficiency measures. However, the cost of identifying opportunities, analyzing cost-effectiveness, and tendering was not regarded as a barrier of great magnitude by most of the respondents.

The respondents all assumed that energy prices would increase in the future. The respondents thus, did not consider the risk connected to declining energy prices when implementing measures to be a barrier, but rather a driving force for energy efficiency. From the questionnaire it may be concluded that the respondents did not consider business and market uncertainties to be a barrier of importance. Technical risk such as the risk of production disruptions was considered to be a major barrier by half of the respondents. The risk of possible poor performance of equipment was considered to be a barrier by most of the respondents.

Other studies have found that limited access to capital may constitute a substantial barrier to energy efficiency [4,5]. In this study, however, limited access to capital was, with one exception, not considered a major barrier. This may partly be explained by the

fact that several of the companies in the study are successful businesses. Although limited access to capital was not considered a significant barrier in this study, it is however a prerequisite for carrying out investments.

Hidden costs are found to be an important barrier and may be used as an explanatory variable to the short pay-back periods (see table 1) as these short pay-back periods might be a rough way to compensate for the hidden costs.

4.2 Economic market failures

During the interviews a picture evolved that showed the larger companies as more mechanistic, with strict investment criteria consisting of short pay-back terms (1-3 years), and the medium-sized companies as more organic, where investments are carried out in a less formalized fashion. This may be classified as a principal-agent relationship, which is a form of asymmetric information. An executive at one of the large organizations explained that investments are only viable if they pay back fast enough to make the investment not show up in the annual report, i.e. within a year. In the study, two out of three of the companies with a clearly stated long-term strategy regarding energy related issues, had implemented more than the companies that lacked such a strategy. A long-term strategy may therefore represent a driving force in overcoming strict investment monitoring.

In three of the companies, the facilities were owned by another company; either by one within the group or by a completely different company. The ESCOs (Energy

Service Companies) owned the technical installations within the building—i.e., lighting, ventilation and compressed air—and were also responsible for investments in this equipment, while the companies that rented their facilities were obliged to pay for the cost of energy. All respondents with this type of ownership claimed this to be a major barrier to energy efficiency, as the ESCOs lack incentives to reduce energy costs. Furthermore, this type of ownership also constitutes a legal problem when the company renting the facility wants to invest in energy efficient equipment in order to reduce costs. When asked who is to implement energy efficiency measures at a site one executive answered: “This is a huge problem, and I do not know who should investigate this further.” The same executive went on to explain that the cost had increased as a result of this type of ownership: “It was much cheaper when we owned them (the facilities) ourselves.” This also represents a principal-agent relationship problem.

ESCOs were also used for maintenance and to identify possible efficiency measures regarding ventilation at all but one of the studied companies. This may be seen as a way of trying to overcome these barriers. Many of the respondents, however, claimed that the use of ESCOs is a problem, since they feel that the ESCO business concept includes a split incentive. This is also stated in a thesis covering ESCOs in Sweden and Great Britain. It was concluded that “The supply of Energy Efficiency Services does not result in a more efficient use of energy – neither from the viewpoint of public economics nor from the viewpoint of business economics” [29,30]. There are, however, positive aspects to this as well. One positive aspect is that the medium-sized companies in the study gained help to obtain information regarding energy efficiency measures for the support installations, i.e., lighting, ventilation, and compressed air.

According to these respondents, less information would be gained about possible efficiency measures for these installations without the ESCOs. Another form of asymmetric information, adverse selection, has not been found to represent a major barrier to energy efficiency in this study.

One of the major barriers found was imperfect information, despite the fact that the investigated industries had had energy audits carried out at their sites during the previous five years. Three of the respondents clearly stated that these energy audits had been a prerequisite in subsequent initiatives regarding energy efficiency.

One barrier to energy efficiency, especially in companies that consist of several departments, may be that a particular department does not receive any of the profit from an efficiency measure [4]. The respondents at the larger companies in the study stated that a prerequisite for allocating the profit from an energy efficiency investment is equipment that can measure the change. The studied companies have either had the energy cost distributed evenly per square meter, per machine group, or not at all.

With one exception, the companies in the study had not had sub-metering of energy at their sites, which resulted in problems when quantifying energy savings. This makes it especially difficult for the larger companies, with strict investment criteria, since an energy efficiency measure cannot be quantified in terms of reduced cost. This was stated by one executive as: "...the largest problem with implementing energy efficiency measures, is the fact that I have hardly any metering equipment ... I would prefer to have more sub-metering in order to better motivate an investment." Lack of sub-metering, which may be seen as a form of imperfect information, has been found to be a barrier to energy efficiency.

The respondents in the medium-sized companies claimed that lack of sub-metering is a minor problem, which may be explained by the fact that these companies have more diffused investment policies. Sub-metering in order to quantify energy savings has thus been shown to be important for companies with strict investment policies. The only company with sub-metering (electricity users exceeding 50 kW) had implemented many energy efficiency measures. The importance of sub-metering, expressed by the respondents, may also be explained by strict monitoring and control derived from a principal-agent relationship.

Minor barriers included in imperfect information were lack of information regarding energy performance of equipment, poor information quality regarding energy efficiency opportunities, and lack of staff awareness and technical skills.

A technology lock-in was detected in the studied companies, resulting in considerable electricity consumption. It was stated clearly by the respondents, especially in terms of investing in complex production machinery, that there were only a small number of suppliers (two or less), which implies a market oligopoly. According to the respondents, these suppliers market only product machinery that uses compressed air, which in the opinion of the respondents is less energy efficient than equivalent electrically powered equipment. The respondents explained that they had no possibility to influence these suppliers. This can be classified as a form of imperfect competition and may thus represent a market failure.

4.3 *Behavioural barriers*

Bounded rationality was identified at the medium-sized companies with private owners, as decisions were made without formal investment criteria. This was not considered a large barrier to energy efficiency; rather the opposite. The executive director at the company with the highest implementation rate in the study said: “We do not work with this (investment criteria); we implement the things we believe in.” This executive explained that his environmental values and his concern for the company’s long-term survival (threatened by increased competition and a presumed increase in future energy prices) were key drivers to implementing energy efficient technology at his site.

Studies have shown that information should be specific, personal, vivid, and simple in order to increase its chances of being accepted [4,28]. All the respondents claimed that the information given by the energy audit reports was acceptable, although some felt that the reports lacked simplicity as the measures proposed in general contained no pay-back calculations or investment plans of the proposed measures.

One notable result from the interviews was that in one case, the conductor of the energy audit had been perceived as rude by the company representatives, a situation which unfortunately led to a head-on collision between the parties, and the company omitted the result from the energy audit as a result. With this one exception, the respondents claimed to trust the people who conducted the energy audits. When asked to rank the sources of information, the respondents said they considered information obtained through colleagues (either within the firm or in their industry) and information

from consultants to be more creditable than information obtained at seminars and conferences, or from power suppliers or journals.

Inertia, which can be seen as people resisting change, was not found to be a major explanatory variable for the energy efficiency gap. One driving force in particular that was shown to have an effect on the implementation rate was the existence of people with real ambition within the organization. The respondents from the two companies in the study that had been successful in adopting energy efficiency measures said that the key driving forces were people with real ambition and a long term strategy. At one of the companies, this was all in the form of one single person, the executive director with clearly stated environmental values, while at the other; it was a combination of two ambitious people, a worker and an executive.

4.4 Organizational barriers

Other studies have identified the low status of energy management as a barrier to energy efficiency [4]. This study, however, found no evidence that this was a barrier of major importance.

In relation to its size, Sweden is currently the country with the most EMS (Environmental Management Systems) certifications in the world. EMS is often regarded as a driving force for environmental efficiency [30,31]. Four companies in the study were ISO 14001 certified. At three of these, no energy efficiency measures had been undertaken. At the fourth, energy efficiency measures had been undertaken, but

according to the respondent the implementation of measures had very little to do with whether the company was certified or not. The existence of an EMS did not therefore seem to influence the rate of implementation of energy efficiency measures in the studied companies.

5. Concluding discussion

In [13] it is concluded that: “little is known about the adoption of energy technologies and management practices in non-energy intensive sectors... further research is needed in this area. We need to identify and understand the barriers that are preventing the adoption of energy efficient technologies and management practices in the non-energy intensive sector” [13]. This paper has added some pieces to the puzzle of understanding barriers to energy efficiency in the non-energy intensive sector, but again, further work is still very much needed.

The major barriers to energy efficiency found in this study were: *Cost/risk of production disruption/hassle/inconvenience; Lack of time or other priorities; Cost of obtaining information on the energy consumption of purchased equipment; Other priorities for capital investments; Lack of sub-metering; and Split incentives with ESCOs.*

It has been shown that long-term strategic company energy policies to phase out less energy efficient equipment are important for success at site level. Increasing energy prices were also found to be a driving force for energy efficiency. The need for people

with real ambition has also been highlighted as a key driver for energy efficiency. These persons should also have the authority to influence investment decisions. In the company with the highest implementation rate, these drivers were all found in the same person, but this does not necessarily always have to be the case. However, one conclusion that may seem remarkable is that Environmental Management Systems did not seem to have influenced the implementation rate of energy efficiency measures at the studied sites.

One of the main challenges when implementing programs of rational use of energy is to overcome the existing barriers to energy efficiency. One major problem in this respect is that the available information is insufficient and – in some informational situations – incorrect, i.e. more information is needed in order to formulate adequate policy instruments [10]. This paper has identified a number of barriers that may justify public policy intervention, namely: *Lack of sub-metering (for large companies); Split incentives/principal-agent relationship connected to the use of ESCOs; Lack of information regarding energy performance of equipment; poor information quality regarding energy efficiency opportunities; and Lack of staff awareness*. The study has also identified a market oligopoly in the complex production machinery market, which also raises the question of a need for public policy intervention to reduce imperfect competition. Whether and how these market barriers should be addressed is a topic for policy makers.

Further studies of barriers to and drivers for energy efficiency will be needed in the non-energy intensive, as well as in other, sectors in order to understand the complex mechanisms of energy efficiency implementations and to successfully formulate and adopt energy policy instruments within the European Union.

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