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# An energy efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments

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**Abstract** Despite the need for increased industrial energy efficiency, studies indicate that cost-effective energy efficiency measures are not always implemented, which is explained by the existence of barriers to energy efficiency. This paper investigates whether this holds for the Swedish pulp and paper industry, and if so, investigates the barriers inhibiting and the driving forces stressing cost-effective energy efficiency investments. By so, this case study covers about 2% of the EU-25 industrial end-use of energy. The overall results from a questionnaire show that there is an energy efficiency gap in the sector and that the largest barriers were technical risks such as risk of production disruptions, cost of production disruption/hassle/inconvenience, technology inappropriate at the mill, lack of time and other priorities, lack of access to capital, and slim organization. As regards the driving forces for energy efficiency, the highest ranked driving forces were cost reductions resulting from lower energy use, people with real ambition, long-term energy strategy, the threat of rising energy prices, the electricity certificate system, the PFE. The results show that many of the barriers and driving forces were not solely market-related, e.g., lack of time or other priorities, slim organization, other priorities for capital investments, lack of staff awareness, and long decision chains indicate that firm-specific barriers plays an important role. These barriers may not be overcome by market-related public policy instruments but is rather a consequence of how the energy issue is organized within the firms. The second and the third largest driving forces, people with real ambition and a long-term energy strategy further support this.

**Keywords** Energy efficiency · Pulp and paper industry · Barriers · Driving forces · Energy policies

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## Introduction

One of the main means of reducing the threat of increased global warming, caused by human use of fossil fuels, is to reduce the industrial use of energy (IPCC 2007)[1]. Studies of the implementation of cost-

[1] For an overview of the debate regarding energy efficiency and its impact, please see Geller and Attali (2005).

effective energy conservation measures[2] show that these are not always implemented because of the existence of barriers to energy efficiency, resulting in a so-called energy efficiency gap. According to mainstream economic theory, barriers related to market failures, e.g., imperfect information, split incentives, adverse selection, and principal–agent relationship, justify public policy intervention in the market (Jaffe and Stavins 1994). Moreover, barriers have shown to differ depending on regional and sector specific conditions (Sorrell et al. 2000), indicating a need for regional- and sector-specific studies to observe these barriers. To overcome the barriers, both organizational and behavioral factors such as, for example, the existence of a long-term energy strategy, people with real ambition, and public policies, e.g., the European trading scheme (ETS) and other country-specific instruments are important factors.

Sweden uses about 450 TWh energy annually, of which, 147 TWh is electricity (SEA 2007a). As such, the country is the sixth largest user of electricity per capita in the world, mainly explained by factors such as a large proportion of electricity-intensive industry, a high proportion of electric heating, and a history of low electricity prices due to significant quantities of cheap hydropower and nuclear power (SEA 2007b). About one third of all energy in Sweden, or about 156 TWh, 57 TWh of which is electricity, is used by industry. Energy-intensive industries in turn accounts for more than 70% of the industrial energy use. Of the energy-intensive industries, the pulp and paper industry accounts for nearly 50% of the annual industrial energy use which is about 2% of the EU-25 industrial energy use (SEA 2007a; Eurostat 2007). The Swedish pulp and paper industry's substantial energy use makes this sector particularly important to study in terms of barriers to and driving forces for energy efficiency. Research has a role to play in finding what barriers inhibit and what driving forces stress the implementation of cost-effective energy efficiency investments. The aim of this study was therefore to investigate different barriers to and driving forces for the implementation of cost-effective energy efficient measures in the Swedish pulp and paper industry. The research questions covered in this paper are:

- Is there an energy efficiency gap in the Swedish pulp and paper industry?

And if so:

- What are the barriers inhibiting the implementation of cost-effective energy efficiency measures in the Swedish pulp and paper industry?
- What are the driving forces stressing the implementation of cost-effective energy efficiency measures in the Swedish pulp and paper industry?

This paper, thus, provides important knowledge of the complex factors inhibiting and stressing the implementation of cost-effective energy efficiency investments by studying the largest energy intensive sector in one of the most energy-intensive countries in the world.

## The Swedish pulp and paper industry

In the Swedish pulp and paper industry, about 80% of the pulp and paper produced is exported. In 2005, Sweden was the third largest exporter of paper products and the fourth largest exporter of pulp in the world (SFI 2005). In related research in the Finnish pulp and paper industry during the late 1990s, an energy audit program within the sector revealed an economic savings potential of 10–15% for heat and fuels and 1–4% for electricity with an average payback period of 2 years (Hietaniemi and Ahtila 2007). In a report by Nilsson et al. (1996), it was stated that replacing worn pumps, downsizing oversized equipment, installing variable-speed drives, etc. for pumps greater than 50 kW could effectively reduce electricity use in the pulp and paper mills by up to 30% (Nilsson et al. 1996). In a Swedish case study of a chemical mill, it is stated that it is not unlikely that these energy efficiency potentials are valid for the studied mill (Klugman et al. 2007). Furthermore, other research indicates, at least technically, that potential also exists for further significant energy efficiency improvements in other areas, for example process heat integration (pinch) analysis (Wising et al. 2005; Bengtsson et al. 2001; Andersson et al. 2006; Holmberg and Gustavsson 2007; Möllersten et al. 2003; STFI 2003).

[2] A cost-effective energy conservation measure is defined as an investment which lowers the use of energy and which is considered cost-effective according to the Mill's investment criteria.

The Swedish pulp and paper industry accounts for about 50% of the aggregated domestic industrial energy use, has some 60 mills, employs some 27,500 people, and counts for about 6% of the Swedish aggregated production value (Swedish Forest Industry 2005; SEA 2007a). In the production of pulp, there are three basic types: mechanical, chemical, and chemical–mechanical pulp production. While the chemical pulp process mainly uses biomass as primary energy source, the mechanical pulp process uses more electricity.

The sector uses about 50 TWh biomass, 22.5 TWh electricity, and 7.3 TWh fossil fuels. Since the 1970, the sector has gradually grown less dependent on fossil fuels due to increased energy efficiency, while the use of electricity has increased (SCB 2006). It should also be noted that the chemical pulp mills generate about 5 TWh electricity through the use of back pressure (SFI 2007).

The sector is characterized by heavy capital-intensive production investments; a paper machine, for example, costs about 200–500 million USD to install. Furthermore, the manufacturing of paper is carried out at a speed of about 100 km/h (Laestadius 1998). In addition, production disruptions are very costly, and the few planned stops in the continuous production processes make any change in the process a high-risk project.

## Method

Previous research indicates that barriers to energy efficiency may be better understood using ideas from not only mainstream economic theory but also, e.g., organizational economics (Sorrell et al. 2000). It is therefore important to use a systems approach incorporating ideas from different scientific disciplines when studying the complex factors inhibiting investments in energy-efficient technologies[3]. According to Churchman (1968), "A systems approach begins when first you see the world through the eyes of another", i.e., when a problem is illuminated from several perspectives. In this study of barriers, a well-developed theoretical framework was used derived mainly from economic literature. But, as stated by Sorrell et al. (2000), it is useful to incorporate ideas from other areas as well. As regards the driving forces, there are few Swedish studies dealing explicitly with the issue, and the three existing studies derived their factors from in-depth interviews (Rohdin and Thollander 2006b) and a workshop with representatives from the sector (Rohdin et al. 2007), resulting in a limited number of driving forces studied, and related mainly to matters within the firm such as people with real ambition and the existence of a long-term energy strategy. In this study, an effort was therefore made to try to expand the driving forces investigated incorporating the current Swedish energy policies affecting the case studied, potential public policies, as well as other external and internal driving forces derived from the scientific literature such as international competition, environmental pressure from non-governmental organizations (NGOs), i.e., not only empirically derived as was the case with the previous Swedish studies on the subject. By studying both barriers to and driving forces for energy efficiency, this paper presents unique results as regards such barriers and driving forces, as well as a methodological development incorporating an enlarged number of driving forces in relation to previous studies of driving forces for energy efficiency. A number of studies exist concerning barriers to energy efficiency (e.g., Sorrell et al. 2000; Schleich and Gruber 2007), but to our awareness, no study has previously been published that uses such a wide approach and also includes a number of the most important driving forces for energy efficiency related to the sector. By studying an expanded number of driving forces, it is also possible to answer the question of whether organizational and behavioral factors play such an important role as has been stated in previous industrial Swedish research on the subject.

A dense degree of research has emphasized the hypothetical and technical energy efficiency potential within the Swedish pulp and paper industry, e.g., Wising et al. (2005), Bengtsson et al. (2001), Andersson et al. (2006), and Klugman et al. (2007). To our awareness, no published study has yet emphasized the reasons for non-adoption of energy efficiency measures that are cost-effective in accordance with the company's own payoff criteria and that therefore should be implemented. This paper, thus, investigates barriers to energy efficiency investments

[3] Like Schleich and Gruber (2007), this paper investigates energy-efficient investments in general and does not focus on a single technology.

with technologies available on the market today which are cost-effective from the company's point of view. Examples of such investments include both production processes and generic processes such as pumps, fans, and other motor drives where many of the improvement measures concern, for example, load controls and proper adjustments of processes (SEA 2007c).

Inspired by Yin (1994), the research questions were answered by means of a questionnaire centering on barriers to and driving forces for energy efficiency. The questionnaire also included questions about the respondent's view of whether there exist cost-effective energy efficiency measures at their mill that had not been undertaken, the mill's investment criteria, as well as questions regarding the usefulness of different information sources concerning energy efficiency technologies. When presenting the results in this paper, the questions were translated from Swedish to English.

The barrier part of the questionnaire was originally developed and empirically tested by Sorrell et al. (2000), while the part regarding driving forces was developed through a literature review of related articles including de Groot et al. (2001), del Rio González (2005), Rohdin and Thollander (2006a), Rohdin et al. (2007), Johansson et al. (2007), and Ottosson and Peterson (2007). Again inspired by Yin (1994), the questionnaire was reviewed by staff at the Swedish Forest Industries and the Swedish Energy Agency as well as by senior colleagues before being sent out. The questionnaire was sent to 59 mills in autumn 2007 and was intended to be answered by energy managers or people in charge of energy issues. The reason for submitting the questionnaire to this category was that these people have knowledge of the industrial process at the mill – and therefore, potential cost-effective energy efficiency investments – as well as factors inhibiting and stressing their implementation. Furthermore, these people are often in charge of the mill's energy purchasing and contact with Swedish authorities. This implies that they are the ones who are most likely to be able to answer questions regarding market- and public-policy-related issues accurately. The response rate was 40 replies or 68%, which may be considered high compared to similar studies, e.g., Velthuijsen (1995) and de Groot et al. (2001). To avoid imbalanced results between different types of mills, the results were initially split into two groups: one which consisted of mechanical mills and the other chemical mills. No major differences were evident between the groups and the aggregated results from the questionnaire. The results were therefore not categorized into different groups when outlined in this paper.

The respondents were gained from the Swedish Energy Agency's contact list for the Swedish long term agreements (LTA) program PFE (program for improving energy efficiency in energy-intensive industries) as well as from the sector organization, the Swedish Forest industry. They were asked to rank different barriers to and driving forces for energy efficiency in the questionnaire as follows: one point if the respondent considered the factor to be often important, half a point for sometimes important, and zero points for rarely important. As stated in related articles, one should be aware that in the analysis following from these quantifications, large simplifications were made, as the quantified results contain several more perspectives of the issue than merely a single ranking score (Rohdin et al. 2007). Furthermore, it must also be kept in mind when drawing conclusions from these types of studies that the respondent's answers may include a degree of bias. Personal opinions, for example, may affect the respondent's answers to some questions. On the other hand, these people will most likely still act according to these opinions.

It should also be noted that the classification of barriers to energy efficiency are not entirely accurate representations. As Weber (1997) states: *it is empirically impossible to find the 'true' reason behind energy-conserving action which has not been taken* (Weber 1997). As all theoretical frameworks of complex real-world phenomena involving people and organizations, the theory should rather be seen as an analytical tool. This should be kept in mind when analyzing the empirical findings outlined in the result sections where many of the barriers expressed by the respondents fit into more than one theoretical barrier.

## 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" (Sorrell et al. 2000). Major papers cited regarding barriers to energy efficiency include Jaffe and Stavins (1994) who define market barriers as any factors that may account for the existence of the energy efficiency gap. A market failure, on the other hand, refers to a condition where the effective allocation of goods and services by the market are violated, which might justify a public policy intervention (Jaffe and Stavins 1994). Using the theoretical perspectives outlined below, it should be noted that an empirically identified barrier may include economic, organizational, and behavioral aspects. In this study, barriers were categorized into market-related barriers as well as organizational and behavioral-related barriers.

### Market-related barriers

Heterogeneity, hidden costs, lack of access to capital, and risks are barriers which may be categorized as non-market failures, i.e., these barriers exist although the market is functioning (Jaffe and Stavins 1994). Heterogeneity is associated with the fact that even if a given technology is cost-effective on average, it will most probably not be so for some firms. Heterogeneity holds in particular for production processes where firms are often specialized in one type of goods and where an energy efficiency measure is then difficult to implement in another firm. Although very similar goods are produced, small deviances in the products such as different size and shape inhibit the measure's being undertaken in another firm (Jaffe and Stavins 1994). Hidden costs are a wider definition of the more commonly cited transaction costs (Ostertag 1999). Hidden costs refer, for example, to the costs associated with an investment that are not reflected in commonly used investment calculations, e.g., the payback method, which causes the hidden cost to be neglected in the investment calculation. Another barrier which may prohibit investments in energy efficiency technologies, even if the investment is cost-effective, is lack of access to capital. Risk is another commonly cited barrier where investments in energy efficiency technologies are not undertaken due to different types of risk (Jaffe and Stavins 1994).

Split incentives, principal–agent relationship, and imperfect information are commonly cited market failures (Jaffe and Stavins 1994). Split incentives are a condition where two parties have different incentives for their actions. A commonly cited example is the landlord–tenant relationship where the latter is not interested in energy efficiency if the energy costs are not included in the rental cost (Brown 2001). The principal–agent problem arises due to lack of trust between two parties at different levels within society or a business organization. For example, the owner, who may not be as well informed about the site-specific criteria for energy efficiency investments, may demand short payback rates/high hurdle rates on energy efficiency investments due to his or her distrust in the executive's ability to carry out such investments. This may prevent cost-effective energy efficiency investments being undertaken (DeCanio 1993; Jaffe and Stavins 1994). Yet another commonly cited market failure is imperfect information which relates to insufficient information about the energy performance of different technologies and its potential savings. Imperfect information is argued to lead to suboptimal decisions based on uncertain information, leading to underinvestment in energy efficiency (Sorrell et al. 2000).

### Behavioral and organizational-related barriers

In addition to explanations of the energy efficiency gap derived from economic literature, there are also behavioral and organizational barriers to energy efficiency. The term bounded rationality may be used to explain the energy efficiency gap. In short, this means that an organization, as well as individuals, to some extent, do not act on the basis of complete information but rather make decisions by rule of thumb, leading to the non-take-up of energy efficiency investments (Stern and Aronsson 1984). Moreover, the form of information given is of importance. People are more likely to act on information if it is specific and presented in a vivid and personalized manner and comes from a person who is related to the receiver (Stern and Aronsson 1984). The latter is closely related to credibility and trust in the information provider. It is important that a firm implementing an energy efficiency technology can rely on the party providing the information (Stern and Aronsson 1984). Another barrier is values, but according to Sorrell et al. (2000), these explain the take-up of energy efficiency investments rather than the non-take-up of the latter. Closely related to this is culture, where an organization may encourage energy efficiency investments by developing a culture characterized by environmental values. Lack of power for the person or department in charge of the energy issue is yet another cited barrier to energy efficiency (Sorrell et al. 2000).

## Driving forces for energy efficiency

A driving force might be seen as the opposite of a barrier, in other words, different types of factors that stress investments in technologies that are both energy-efficient and cost-effective. As mentioned above, market failures may justify public policy intervention in the market (Jaffe and Stavins 1994). Previous empirical research related to this paper has shown the importance not only of public policies but also of organizational and behavioral driving forces as well as external driving forces for implementing cost-effective energy-efficient technologies. In this paper, the driving forces were categorized into different types, namely market-related driving forces, current and potential energy policies, as well as organizational and behavioral factors.

### Market-related driving forces

A firm being a utility-maximizing unit tries to minimize its costs and in relation to energy tries to achieve cost reductions resulting from lower energy use. One market-related driving force is, thus, cost reductions resulting from lower energy use (de Groot et al. 2001; del Rio Gonzàlez 2005). Other market-related factors stressing the implementation of cost-effective energy efficiency measures include the threat of rising energy prices and international competition, derived from Rohdin and Thollander (2006a, b). Moreover, energy service companies (ESCOs) and third party financing are other possible means of lowering the use of energy (EC 2006).

### Policy instruments affecting the Swedish energy-intensive industry

Apart from the ETS, there are a number of country-specific instruments that are of importance. In Sweden today, there exist several different policy instruments which directly or indirectly affect energy costs and the implementation of energy efficiency measures. The Swedish industry is faced with a carbon tax of approximately 21 euros/ton $CO_2$ as well as an electricity tax of 0.55 euros/MWh. Moreover, Swedish energy suppliers are obliged to purchase electricity certificates corresponding to a certain proportion of the electricity that they sell, known as their quota obligation (SEA 2007d). The electricity certificate system (ECS) is a market-based support system intended to increase cost-effective electricity production from renewable sources, supporting electricity produced from solar power, wind power, hydropower, CHP plants with biofuels, and peat combustion. The Swedish state gives the producers of renewable electricity a certificate for each MWh of renewable electricity that they produce, affecting all renewable electricity suppliers including the Swedish pulp and paper industry. The certificate can be sold, and therefore, provides additional revenue for the energy supplier in addition to that from the sale of electricity.

The previously presented electricity tax, which represented an adaptation to the European Union's energy tax directive, led the Swedish government to introduce an industrial energy efficiency program, an LTA approach named PFE with the aim of achieving greater energy efficiency in the Swedish energy-intensive industry. The program began in December 2005 and will last for a first period of 5 years where companies may join the program any time during this period. Within the first 2 years, the company must undertake an energy audit which should result in a number of energy efficiency measures that can be implemented over the rest of the period. The program also includes the implementation of an energy management system, the introduction of standardized routines for purchasing and planning, resulting in energy-efficient technologies, energy systems, and plants. Industrial companies that join the program and fulfill the requirements will receive a 100% return of the electricity tax paid, which constitutes an exception to the European Union's energy tax directive (Ottosson and Peterson 2007; Johansson et al. 2007). It should be noted that the program only includes electricity.

In addition to the previously mentioned policies, Swedish industry is also affected by the Swedish environmental code. The Swedish environmental code came into force in 1988 and cites, among other things, energy efficiency as a key aspect. One issue, for example, is that the best available technology should be used taking cost in relation to benefits into consideration. Energy efficiency requirements have recently come further to the fore when the environmental permits are processed. The authorities, thus, have the possibility to enhance energy efficiency measures and activities through the code when issuing a permit as well as through the supervision procedure. It should be noted that although legal grounds exist, this instrument is quite slow and has not yet been widely practiced (Johansson et al. 2007).

### Potential energy policies

Other studies, as well as the European end-use efficiency and energy service directive (EC 2006), have cited a number of energy policies which are not currently in use in the Swedish pulp and paper industry. These include investment subsidies for energy efficiency technologies (Farla and Blok 1995), offering detailed support from energy experts when implementing energy efficiency investments (Rohdin and Thollander 2006b), publicly financed energy audits by energy consultant/sector organizations, etc. (Anderson and Newell 2004), and beneficial loans for energy efficiency investments (EC 2006).

Apart from these, two other sector-specific policies might be networks within the sector and information and support through sector organizations, in this case, the Swedish forest industry (Rohdin and Thollander 2006b).

### Behavioral and organizational-related driving forces

As mentioned above, market failures may justify public policy intervention in the market (Jaffe and Stavins 1994). Previous empirical research related to this paper has shown the importance of not only public policies but also both behavioral and organizational-related driving forces for implementing cost-effective energy efficient technologies. de Groot et al. (2001) found, for example, that green image of corporation was an important driving force in a Dutch study. In another related study, this time of the Spanish pulp and paper industry, conducted by del Rio Gonzàlez (2005), the author outlines a number of factors, both behavioral and organizational, that affect the implementation of proactive environmental technologies such as personal commitment of managers. Other cited drivers include people with real ambition, which is closely linked to personal commitment of managers, long-term energy strategy, environmental management systems (EMS), (Rohdin et al. 2007), and improved working conditions (Masurel 2007).

## Empirical results: barriers to energy efficiency

With one exception, the respondents agreed that there exist cost-effective energy efficiency measures at their mill, confirming the first research question. The existence of an energy efficiency gap implies the second and third research questions to be examined: what are the barriers inhibiting the implementation of cost-effective energy efficiency measures, and what are the incentives stressing the implementation of cost-effective energy efficiency measures in the Swedish pulp and paper industry? The overall results of barriers to energy efficiency are presented in Fig. 1.

### Market-related barriers

The largest barrier expressed by the respondents was technical risk such as risk of production disruptions. Risk was also stated as the seventh largest barrier, risk of poor performance of purchased equipment.

The second largest barrier found was cost of production disruptions/hassle/inconvenience which, according to Ostertag (1999), may be related to the theory of hidden costs. In a related study of the second year evaluation of the Swedish program for energy-intensive industries (SEA 2007c), one of the respondents stated that energy efficiency improvements often involve stopping the plant, and it was not certain that a stop could be achieved each year at the plant. This is due to the fact that a stop in the continuous pulp and paper production entails significant costs. Costs and risks related to a stop in the production process are thereby stated as the two main barriers within this sector. Heterogeneity, expressed as the opinion that the technology is inappropriate at the mill, is stated as the third largest barrier according to the respondents. As shown in Fig. 1, the three main barriers to energy efficiency in the Swedish pulp and paper industry, as well as the fifth largest barrier, lack of access to capital, are all more or less part of the category of economic non-market failures.

Lack of time or other priorities was found to be the fourth largest barrier. Whether this barrier is related to the theory of hidden cost or not is an area open for

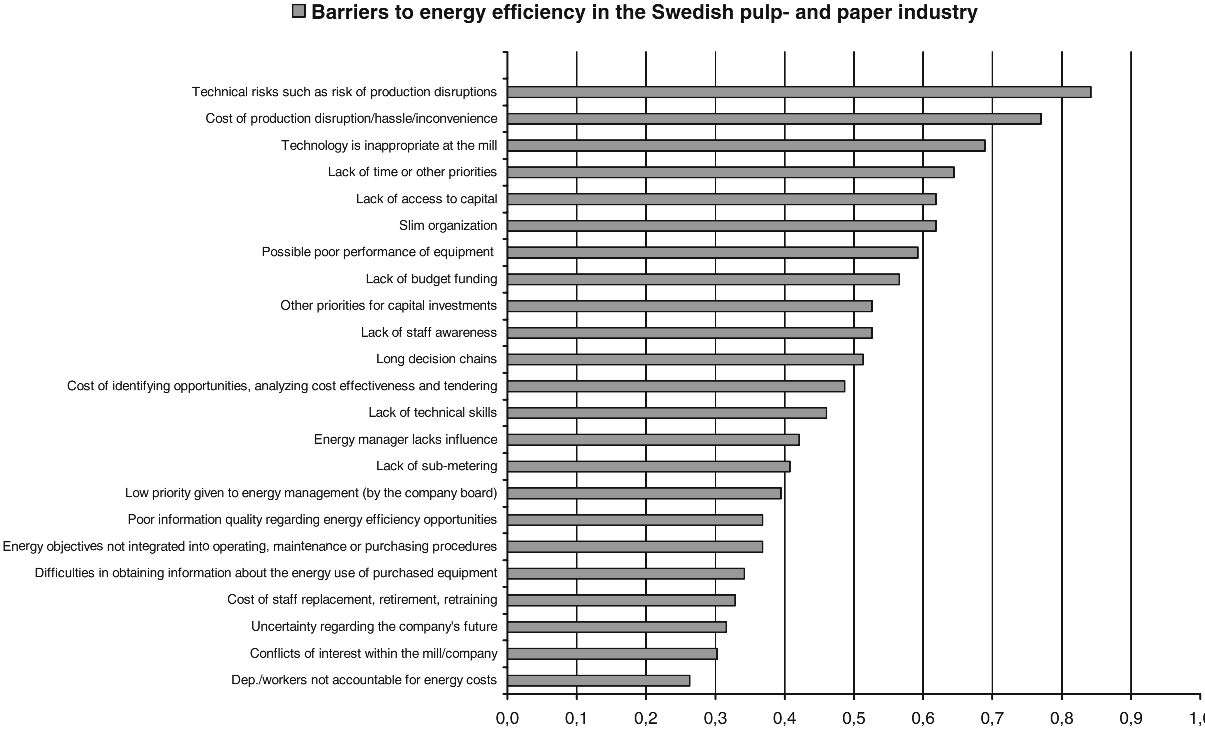


**Fig. 1** Ranked results from the questionnaire. The barriers were rated as follows: 1 point if the respondent considered the question to be "often important", half a point for "sometimes important", and zero points for "rarely important"

discussion. Rohdin and Thollander (2006a) categorized lack of time or other priorities as a hidden cost in the Swedish non-energy-intensive industry. However, in the energy-intensive Swedish pulp and paper industry, this argument might not hold, as energy costs are a large portion of the overall production costs with one or more people working full time with energy management activities. In that sense, this barrier is more closely related to concept of bounded rationality, which, in ,turn indicates that energy efficiency is not prioritized. The consecutive barrier, slim organization further supports this.

In related research of the non-energy-intensive Swedish manufacturing industry, lack of sub-metering was found to be a problem when investing in energy efficiency technologies (Rohdin and Thollander 2006a). Lack of sub-metering may in turn lead to a split incentive, as departments and workers are not responsible for the cost of energy. Studying the Swedish pulp and paper industry, these factors did not seem to be of major importance. Department/workers not accountable for energy costs were the lowest ranked barrier in the study, and lack of sub-metering was also among the lower ranked barriers.

The empirical findings, however, may indicate that a principal–agent relationship problem exists in the form of slim organization, constituting the sixth largest barrier in this study. Furthermore, barriers such as energy manager lacks influence, and low priority given to energy management, however, are ranked lower. On the other hand, the slightly higher ranked barriers, lack of budget funding and long decision chains may indicate the existence of split incentives and a principal–agent relationship. This is due to the fact that lack of budget funding and long decision chains may show that energy efficiency investments, however, are not receiving full support from the company board.

Previous research has often stated imperfect information to be a barrier of major importance justifying, for example, industrial energy information programs (Howarth and Andersson 1993; Jaffe and Stavins 1994; Hirst and Brown 1990). However, this was not the case in this study; barriers such as difficulties in obtaining correct information about the energy use of purchased equipment and poor information quality regarding energy efficiency opportunities were ranked considerably low.

### Behavioral and organizational-related barriers

In this study, it could be stated that investments in energy efficiency technologies are in general faced with formal investment criteria, indicating that investments are not made by rule of thumb. Only three of 40 respondents stated that investment criteria were lacking. Form of information was not identified as a barrier of major importance; poor information qualities regarding energy efficiency opportunities as well as difficulty in obtaining information about the energy use of purchased equipment were ranked low. Related to this is the credibility of and trust in the information source. When the respondents were asked to rank the usefulness of different sources of information, colleagues at the mill/company and colleagues in the sector were the highest ranked information sources, indicating that these are the most credible and trustworthy. This may be explained by the fact that the sector is characterized by a highly complex production process where specific knowledge of the process is required in order for the information to be accepted (Laestadius 1998). The individuality of every pulp and paper mill and the high rank of colleagues within the mill/sector, thus, make general information dissemination quite complex.

It is seen from Fig. 1 that apart from the previously discussed lack of time or other priorities and slim organization, there are a number of barriers related to behavioral and organizational factors. These include lack of budget funding, other priorities for capital investments, lack of staff awareness, long decision chains, and energy manager lacks influence. Among these, especially the first four barriers, are high to medium-ranked. This indicates that values, power, and culture may be stated to be barriers of importance in this sector.

In summary, the largest barriers in the sector could be categorized as non-market failures, although the fourth and sixth largest barriers, lack of time or other priorities and slim organization indicate the existence of split incentives and a principal–agent relationship. However, there are a number of barriers such as other priorities for capital investments, lack of staff awareness, and long decision chains which may indicate that behavioral and organizational factors also play an important role.

## Driving forces for energy efficiency

### Market-related driving forces

Naturally, the highest ranked driving force, according to the respondents, was cost reductions resulting from lower energy use, as shown in Fig. 2. Whether this could be seen as a driving force for energy efficiency investments is, however, open to discussion; one might argue that it is rather a prerequisite for the long-term survival of a firm. The fourth largest driving force for energy efficiency was the threat of rising energy prices. The sector, being one of the most energy-intensive industries, is of course highly vulnerable to such increases. However, it should be noted that rising energy prices on the other hand could also be advantageous, in particular for the chemical pulp mills which produce electricity using back pressure.

Among other market-related driving forces, medium-ranked by the respondents, one could note international competition. Third party financing and ESCOs responsible for operation and maintenance of the buildings are instruments for change according to the European energy end-use efficiency and energy services directive, but was the lowest ranked driving forces among all the factors investigated in this study (EC 2006). Another study by the energy-intensive Swedish foundry industry also found that third party financing was ranked low, indicating that this driving force may be of insignificant importance for energy-intensive industries (Rohdin et al. 2007).

### Policy instruments affecting the Swedish energy-intensive industry

The two highest ranked public policy instruments were the ECS and the PFE where ECS was ranked the higher of the two. As mentioned above, the Swedish state, through the market-based ECS, gives producers of renewable electricity a certificate for each MWh produced. This has increased the benefits of investing in new turbines in the chemical pulp mills due to the fact that they produce biomass-generated electricity through back pressure. The ECS leading to lowered

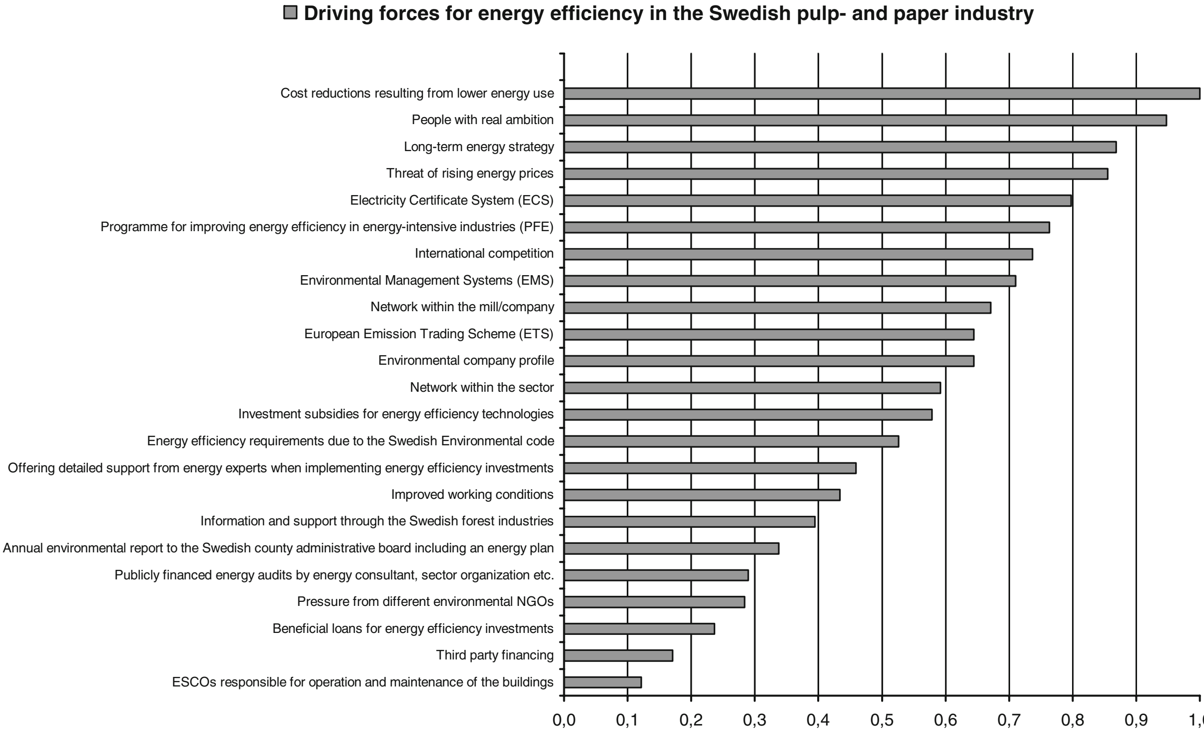


**Fig. 2** Ranked results from the questionnaire. The driving forces were rated as follows: 1 point if the respondent considered the question to be “often important”, half a point for “sometimes important”, and zero points for “rarely important”

payback periods for investments in new turbines has, thus, been regarded as valuable by the respondents.

As regards PFE, the program was also considered an important means of increasing investments in energy efficiency measures. However, while the ECS provides support for measures concerning the supply side, the PFE emphasized end-use measures. The high ranking of the PFE, leading to electricity savings within the Swedish pulp and paper industry of about 490 GWh (SEA 2007c; Ottosson and Petersson 2007) over a 5-year period indicates that although the program has only been running for 2 years, it has been well accepted among the respondents. Viewing the ranking of different information sources reveals that the Swedish Energy Agency is medium-ranked, indicating that the agency are considered trustworthy by the sector. Consequently, not only are the ECS and the PFE considered valuable, but also the authority governing the policies.

The third highest ranked public policy instrument was the ETS. One plausible explanation for the medium rank of ETS is the fact that the scheme has included an excessive amount of trading permits, and thus, has not affected the Swedish energy-intensive industry to any great degree. In a report by the Swedish Energy Agency, this is assumed to be the case even in the next ETS period, 2008–2012, (SEA 2007e). The results, both from this study and the one previously cited, indicate that the ETS will probably not affect the implementation of cost-effective energy efficiency investments to a great degree. This will most likely be the case unless the number of permits is restricted to a greater extent than is currently the case.

Interest has increased in recent years in involving energy efficiency within the Swedish County Administrative boards based on the Swedish environmental code (Johansson et al. 2007). However, energy efficiency requirements due to the Swedish environmental code were only medium-ranked among the respondents. Furthermore, the demand for an annual environmental report to the Swedish county administrative board including an energy plan was ranked extremely low, lowest of all the public policy instruments included in this study. Moreover, one respondent even stated in the questionnaire that the demand for energy efficiency requirements due to Swedish environmental code is driving development in the wrong direction and may even obstruct energy efficiency.

### Potential energy policies

A number of potential future public energy policies were also ranked by the respondents. The medium-ranked driving force, investment subsidies for energy efficiency technologies, was the highest of these, followed in descending order by detailed support from energy experts when implementing energy efficiency investments, publicly financed energy audits by energy consultant/sector organization, etc., and beneficial loans for energy efficiency investments. Notably, none of these potential policies were ranked high by the respondents. However, publicly financed energy audits by consultants, for instance, are a successful public policy instrument as regards the pulp and paper industry in Finland (Hietaniemi and Ahtila 2007).

### Behavioral and organizational-related driving forces

The second highest ranked driving force was people with real ambition, which means an energy manager within the organization (or a person in charge of energy issues) with a real desire to push energy efficiency issues. Interestingly, this is closely related to the values of a certain person and, as also stated by Sorrell et al. (2000), values may rather be seen as a driving force than a barrier to energy efficiency. Moreover, the investigated sector, being very much focused on productivity, makes an energy manager with real ambition particularly important if the energy efficiency questions were to be put on the agenda.

According to the respondents, the third largest driving force was the need for a long-term energy strategy. Previous research in other Swedish industrial sectors has shown this driving force and people with real ambition to be the highest ranked driving forces for energy efficiency (Rohdin and Thollander 2006a; Rohdin et al. 2007; Thollander et al. 2007). This shows that although the type of energy efficiency measures differs between the sectors, internal factors such as the two stated above seem to be of general importance. EMS, network within the mills/company, environmental company profile, and network within the sector were all medium-ranked. In a paper by Masurel (2007), it was argued that improved working conditions are the most important driving force for implementing environmental measures in SMEs. According to the results from this study, this was not the case in the energy-intensive Swedish pulp and paper industry, possibly due to the fact that measures in the sectors differ widely. While energy efficiency measures in SMEs are more related to the generic processes, measures within the pulp and paper industry are more related to the production processes. Pressure from NGOs was a high-ranked driving force in the study of the Spanish pulp and paper industry conducted by del Rio González (2005), while in this study, this driving force was one of the lowest ranked.

In summary, apart from cost reductions resulting from lower energy use, the behavioral and organizational-related driving forces, people with real ambition, and long-term energy strategy were the largest barriers found. Among the public policy instruments, the ECS and the PFE were ranked fifth and sixth among all the driving forces investigated.

## Concluding discussion

As previously stated, the respondents fully agreed, with one exception, that cost-effective energy efficiency measures exist at their mill, confirming the first research question, i.e., an energy efficiency gap exists in the Swedish pulp and paper industry. How large the potential for further energy efficiency improvements is, was beyond the scope of this paper and was therefore not investigated. However, an energy audit program for the Finnish pulp and paper industry during the late 1990s emphasized economic saving potentials of 10–15% for heat and fuels and 1–4% for electricity, with an average payback period of 2 years (Hietaniemi and Ahtila 2007). Consequently, similar measures could be assumed to exist even within the Swedish sector. As regards electricity, results from the Swedish LTA program, PFE, also indicate this, with electricity savings of 490 GWh over a 5-year period (SEA 2007c; Ottosson and Peterson 2007).

The existence of an energy efficiency gap implied the second and third research questions to be examined: what are the barriers inhibiting the implementation of cost-effective energy efficiency measures, and what are the driving forces stressing the implementation of cost-effective energy efficiency measures in the Swedish pulp and paper industry? Studies of which barriers prevent energy efficiency investments from being undertaken are of utmost importance, as such studies enable authorities to launch accurate energy policies more precisely. By reducing the magnitude of these types of barriers, overall reduced energy use and positive environmental effects could be achieved as well as a more effective allocation of goods and services.

As regards barriers to energy efficiency in the Swedish pulp and paper industry, it was found that the largest barriers were technical risks such as risk of production disruptions, cost of production disruption/hassle/inconvenience, technology inappropriate at the mill, lack of time and other priorities, lack of access to capital, and slim organization. Among these, the majority could be related to market barriers. The three largest barriers are most likely related to non-market failures. However, lack of time and other priorities as well as slim organization are more difficult to weave into a theoretical classification. What the latter two barriers does point out, however, is that energy efficiency, for various reasons, is not a very highly prioritized issue within the organizations.

As regards the driving forces, apart from cost reductions resulting from lowered energy use, the two highest ranked driving forces were people with real ambition and long-term energy strategy. In related Swedish research, these two barriers have been the highest ranked as well, indicating that from the company's point of view, the strongest drivers have to do with internal organizational matters. Moreover, while people with real ambition, which theoretically may be related to personal values, was the largest driving force according to the respondents, values was not identified as a barrier of major importance. This strongly supports the widened systems approach used in this study incorporating both barriers and driving forces. Moreover, the fact that people with real ambition and long-term energy strategy are the major driving forces may be of strong relevance for policy makers in formulating policies which may positively affect matters within organizations. These findings may also be of importance for the industry as a whole. From the energy managers' point of view, not only in the energy-intensive Swedish pulp and paper industry but also in other Swedish industrial sectors, people with real ambition are of utmost importance, addressing a need for energy management activities directed in encouraging staff within the organizations. In line with this is energy management, which is backed up by a long-term energy strategy.

Highly ranked among the driving forces were also the public policies, the ECS, and the PFE which are based on a voluntary approach. If a mill wants to invest in a new turbine receiving subsidiaries from the ECS or join the PFE, involving for example the criteria of adopting an energy plan, is up to the mill. The results from the questionnaire, thus, show that public policies based on voluntary actions from the mills are much higher ranked than the policies that are based on laws and regulations. In summary, this strongly indicates that LTAs and other voluntary public policy approaches are more important driving forces, or at least have a stronger legitimacy, than administrative policies such as requirements based on the Swedish environmental code. One conclusion from this, more generally stated, is that when designing public energy policies directed at energy-intensive industries, it is important that the policies consists of not only market-based approaches as also concluded by Bertoldi et al. (2003). Moreover, related research on barriers to energy efficiency has found that barriers differ among sectors and regions, indicating that energy policies should be diversified to reduce the magnitude of different sector- and regional-specific barriers (Sorrell et al. 2000).

This study has shown that within the Swedish pulp and paper industry there exist a number of barriers to and driving forces for energy efficiency which are not solely market-related. For example, lack of time or other priorities, slim organization, other priorities for capital investments, lack of staff awareness, and long decision chains indicate that firm-specific barriers play an important role. These barriers may not be overcome by market-related public policy instruments such as the ETS. Instead, these barriers are rather a consequence of how the energy issue is organized within the firms and has to do with factors such as values, culture, and power. This is further indicated by the fact that the second and third largest driving forces were people with real ambition and the existence of a long-term energy strategy within the firm. Further research on how to reduce the behavioral and organizational barriers within the firms is therefore of utmost importance.

This study has, by exploring different barriers to and driving forces for energy efficiency in the

Swedish pulp and paper industry, contributed to important knowledge of the complex factors inhibiting and stressing the implementation of cost-effective energy efficiency investments. The results from this case study aimed at the largest energy intensive sector in one of the most energy-intensive countries in the world has thereby covered about 2% of the EU-25 industrial end-use of energy.

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