Linköping University Post Print

Energy management practices in Swedish energy-intensive industries

Patrik Thollander and Mikael Ottosson

N.B.: When citing this work, cite the original article.

Original Publication:

Patrik Thollander and Mikael Ottosson, Energy management practices in Swedish energy-intensive industries, 2010, Journal of Cleaner Production, (18), 12, 1125-1133.

<http://dx.doi.org/10.1016/j.jclepro.2010.04.011>

Copyright: Elsevier Science B.V., Amsterdam.

<http://www.elsevier.com/>

Postprint available at: Linköping University Electronic Press

<http://urn.kb.se/resolve?urn=urn:nbn:se:liu:diva-58226>

Energy management practices in Swedish energy-intensive industries

Patrik Thollander^{a,*}, Mikael Ottosson^b

^a Department of Management and Engineering, Linköping University, SE-581 83
Linköping, Sweden

^b Department of Thematic Studies - Technology and Social Change, Linköping
University, SE-581 83 Linköping, Sweden

Received

Abstract

Previous studies point out a large (untapped) potential for energy efficiency in industry through the adoption of energy management practices. The aim of this paper is to describe and analyze energy management practices in two different Swedish energy-intensive industries: the pulp and paper industry and the foundry industry. The results show that one third of the studied mills and about two fifths of the studied foundries do not allocate energy costs by means of sub-metering, which probably contributes to reinforce the split incentive problem. Moreover, about one fifth of the mills and about half of the foundries lack a long-term energy strategy. The results also show that only about 40% and 25% respectively of the studied mills and foundries may be categorized as successful when it comes to energy management practices. If energy management is not fully prioritized even in energy-intensive industries – such as the studied foundry

* Corresponding author. Tel.: + 46-13-28 57 45; Fax: + 46-13-28 17 88
E-mail address: patrik.thollander@liu.se (P. Thollander), mikael.ottosson@liu.se (M. Ottosson).

and pulp- and paper industry it will, in all probability, not be prioritized in less energy-intensive industrial sectors or countries either, indicating a large untapped potential in regard to cleaner, more environmentally sound, production in the industrial sector.

Keywords: Energy management practices; energy efficiency gap; pulp and paper industry; foundry industry, split incentives, principal agent relationship, Information imperfections and asymmetries

1. Introduction

Industrial energy efficiency is becoming increasingly important from the point of view of both public economy and business. Governments have instituted several incentives to increase energy efficiency in industry, since this is one of the most promising means to reduce CO₂ emissions resulting from the use of fossil fuels [1]. From a business point of view, greater energy efficiency is of importance as it has direct economic benefits such as increased competitiveness and higher productivity [2-3]. Research, however, has shown that despite the existence of cost-effective energy efficiency measures in industry, these are not always implemented due to various barriers to energy efficiency such as split incentives, principal-agent relationships, and information imperfections and asymmetries [4-7]. The discrepancy between the optimal level of energy efficiency, assuming rational decision-makers, and the actual level of energy efficiency is called the energy efficiency gap [4].

For countries such as Sweden, being highly dependent on energy-intensive industries, the past decade has created new prerequisites. Between 2000 and 2006 Swedish industries' electricity prices almost doubled and oil prices rose by about 70%

[8-9]. This especially affected energy-intensive industries such as the pulp and paper, foundry, steel, and chemical industries, with their high energy costs. While non-energy-intensive industries have energy costs in relation to the added value of only a few per cent, energy-intensive industries like foundries are facing costs of 5-15% and energy-intensive process industries like pulp and paper mills are facing costs well beyond 20% [10-11]. Partly as a result of these energy price increases, the energy-intensive pulp and paper industry in Sweden is considering shutting down several mills [12]. For industry, there are two main means of coping with these new prerequisites: 1) supply side management, for example investment in new electricity production and negotiating lower prices with energy suppliers, and 2) demand side management, for example a greater focus on energy management. Recently, energy management has been the subject of considerably increased attention as regards policy formulation. For example, standards for energy management have been set both in the EU and in North and South America. A number of previous studies have been conducted in the area of energy audits [13-14], energy optimization [15-16], energy modelling [17-18], and energy audit programs in relation to the adoption of energy efficiency technologies [19-20]. Up until today however, research concerning actual energy management practices in industries with regard to strategic, organizational, and financial issues have been scarce, both regarding theoretical contributions and regarding empirical case studies. [21-24] constitute exceptions to this. This may seem surprising considering the development of energy prices described above and the substantial potential indicated for energy management (Cf. [24]) and implies a need for further research in this field. The aim of this paper is to describe and analyze energy management practices in two different Swedish energy intensive industries: the pulp and paper industry and the foundry industry. These two industries were chosen first and foremost for their energy intensity.

Moreover, while the pulp and paper industry consists primarily of large companies of 250 employees or more with continuous production of pulp and paper, the foundry industry mainly consists of small and medium-sized foundries with batch production. The choice to study two industries, and not one, thus gives the research results greater validity as the average number of employees, for example, differs widely. The two sectors together account for about half of Swedish industry's energy use and about 2% of the EU-25's industrial end use of energy [25].

The aim has been divided into four major research questions:

- What payoff criteria are used when investing in energy efficiency measures at the foundries/mills?
- Do the foundries/mills have an existing long-term energy strategy and if so, what period does it cover?
- How are energy costs allocated at the foundries/mills?
- How are various information sources for energy efficient technologies valued?

The reason for the first research question was the commonly cited principal-agent relationship or moral hazard problem, which leads to strict monitoring and control of the employees. For example, the mill/foundry uses strict payoff criteria set by the board or MD regarding energy efficiency investments, resulting in less incentive for energy managers to strive to find and implement energy efficiency investments [4]. Even though the pay-off method does not include an interest rate, it gives a clear indication of the studied companies' investment criteria for energy efficiency investments, which in turn gives an indication of the importance of the principal-agent relationship problem. A similar approach is found in [26]. As regards the second research question, previous

research has found that a long-term energy strategy is of outmost importance if energy management is to succeed, emphasizing the importance of studying this research question [24,27]. Regarding the third question, the commonly cited split incentive problem, due for example to inadequate allocation of energy costs at plant level, called for a study of how energy costs are actually allocated at companies with extensive energy costs. If a department's energy costs are not allocated on the basis of actual energy use, but instead, for example, per square metre or per number of employees, the department manager's commitment to saving energy will most likely be less ambitious. The company's energy management program will in all probability then be less effective as there are no incentives for middle management to focus on the issue. Instead, the major means to reduce energy costs for single departments lies in either 1) lowering the department's use of space, or 2) actually firing people. In energy-intensive industries, split incentives would be assumed to be of less importance with thorough sub-metering of boilers, furnaces, fans, pumps, etc. The fourth research question was chosen due to the fact that information imperfections and asymmetries are of major importance to study in regard to adoption of energy efficient technologies. It should be noted that the four research questions by no means claim to fully reflect the success or failure of energy management practices in the two studied sectors, but rather may be seen as indicators of the current status of energy management in these industries. Moreover, it should also be noted that the paper does not aim to evaluate energy management standards and practices but more on an aggregated level describe and analyze how energy management is carried out in two highly energy-intensive industries.

The paper contributes to reduce the scarcity of industrial energy management research by providing new knowledge on the current status of energy management practices in Swedish energy-intensive industry.

2. Energy management in industry¹

Previous research has shown that barriers to energy efficiency in the studied sectors such as cost and risk of production disruptions, lack of access to capital/budget funding, lack of time and other priorities, other priorities for capital investments, slim organization, and lack of sub-metering, play an important role in explaining why energy efficiency investments that are cost-effective are not implemented [25,28]. Energy management is a means to overcome barriers to energy efficiency. Research by [24] has shown that industries who adopt energy management practices may save up to 40% of their total energy use [24]. Both top management's wholehearted support and a strategic approach are of outmost importance if an energy management programme is to succeed. Some other important elements include an initial energy audit, senior management's support, monitoring of energy use, an energy policy, a programme for energy saving projects, and staff motivation and training [22-24]. It is important to note that the goals in an industrial energy management system are on a lower organizational level than business energy strategies. While a strategy deals with how company leaders try to establish a direction for the organization and includes pre-determined courses of action and goals, reducing energy use and energy costs using industrial energy management could be one of many goals within such a strategy [29]. Even though not explicitly covered in this paper but briefly touched upon in the discussion chapter, it should be

¹ It should be noted that energy management is focused on reducing the use of energy rather than reducing emissions of GHG, which is an element in climate change management [30-31]. Even though these two perspectives are related, this paper aims to study energy management practices. What effects the adoption of energy management practices has on reducing GHG emissions is an area for future research to explore.

noted that in regard to energy management, an increased focus on core business, which has been a strong trend within management and organization since the beginning of the 1990s [32], may prevent successful adoption of energy management practices as manufacturing companies today have fewer resources for non-core areas such as energy management, as also stated by [33].

3. Swedish energy-intensive industries

Swedish industry comprises about 59,200 companies with an annual energy consumption of approximately 157 TWh; electricity accounts for about 56 TWh, biofuels 53 TWh, petroleum products 20 TWh, and coal and coke 17 TWh. In addition, about 5 TWh district heating and 6 TWh natural gas are used [9]. 58,600 of the companies are considered to be non-energy-intensive and the remaining 600 are considered to be energy-intensive, the majority being located in sectors related to pulp and paper, iron and steel, mining and chemicals. These account for about 75% of the aggregated Swedish industrial energy use [9].

3.1 Pulp and paper industry

More than 85% of Sweden's pulp and paper production is exported and the Swedish pulp and paper industry is the world's second largest overall exporter of paper, pulp and sawn timber [34]. The Swedish pulp and paper industry consists of approximately 60 mills, employs some 27,500 people and accounts for about 6% of the Swedish aggregated production value [9,34]. With about 50 TWh biomass, 23 TWh electricity and 7 TWh fossil fuels, the Swedish pulp and paper industry accounts for about 50% of Sweden's annual industrial energy use. Swedish chemical pulp mills also generate about 5 TWh electricity [35]. Since the 1970s the industry has gradually grown

less dependent on fossil fuels, partly due to energy efficiency improvements (the Swedish pulp and paper industry has a reputation as one of the most energy efficient in the world [35]) and partly due to increased use of electricity [9].

3.2 Foundry industry

With about 200 companies and about 7,000 employees the Swedish foundry industry had an aggregated turnover of 1.3 billion Euros in 2007 and produces some 195,000 tonnes of castings annually, of which 74% are iron castings, 19% non-ferrous castings and 7% steel castings [36-37]. Swedish production, giving rise to an annual energy use of about 1.2 TWh, is about 2% of the aggregated European production [37].

Fig. 1. Annual energy use in the various Swedish industries (based on [5]).

4. Method

This research was carried out as a multiple case study of the Swedish pulp and paper and foundry industries. Case study research is especially advantageous when ‘how’ or ‘why’ questions are asked about a contemporary set of events over which the

investigator has little or no control (Cf. [38]). The research was carried out using a questionnaire focused on energy management practices. The questionnaire was based upon both a literature survey and previous empirical research in the studied sectors [21-28]. Based on these previous studies, three issues of importance to energy management in industry were chosen as indicators, viz. the pay-back criteria for energy efficiency investments, the existence and duration of a long-term energy strategy, how the companies allocate their energy costs, and how various information sources for energy efficient technologies are valued. Long-term energy strategy refers to strategy on a business level. There might also be a corporate energy strategy on a higher organizational level, which also includes, for example, supply-related issues for the entire corporation.

In an attempt to categorize the studied industries, based on three of the chosen indicators, in terms of success or lack of success as regards energy management practices, three categories were chosen. This was inspired by [21]'s methodological approach. The first category comprised those mills and foundries that answered affirmatively to having pay-off periods for energy efficiency investments of two years or more, having an energy strategy of three years or longer and allocating energy costs based on sub-metering. The second category comprised organizations that answered affirmatively to two of the statements and the third category comprised the remainder of the mills and foundries.

The questionnaire was sent to 110 energy managers in autumn 2007. The aggregated response frequency was 50%: 69% for the pulp and paper industry and 34% for the foundry industry, which may be regarded as a high rate of response compared with similar studies (Cf. [39-40]). On average, the studied mills had around 450 employees and the foundries fewer than 40. The respondents in the pulp and paper

industry were taken from the Swedish Energy Agency's contact list for the Swedish long term agreements (LTA) programme PFE (Programme for improving energy efficiency in energy-intensive industries) and from the Swedish Forest Industry Federation, while the foundry industry respondents were taken from the Swerea/Swecast industry federation. Based on [38], both the industry federations and the Swedish Energy Agency were asked to review and comment on the final draft of the questionnaire before it was sent out to the respondents.

The PFE includes a number of mandatory elements such as the certification of an energy management system (EMS) according to the energy management standard. While the majority of the pulp and paper mills are participating in the PFE and thus have implemented an EMS, the majority of foundries neither participate in the PFE nor have a certified EMS. Based on this, questions concerning the PFE and EMS were omitted from the questionnaire.

In order to avoid imbalanced results due to differences in size among the pulp and paper mills, the results have been split into two groups when categorizing successful energy management practices: one consisting of mills with more than 250 employees (71%) and one consisting of mills with fewer than 250 employees (29%).

It should be noted that when analyzing results from this study, a respondent's answers may include a degree of bias, e.g. personal opinions may affect his or her answers. Moreover, it should be noted that, for example, the respondents answering the questionnaire may be working in organizations which work more proactively with energy management than those who did not respond. Even though this should not be ignored, it is worth noting that the response rate in this study was considerably higher than in other studies in the industry (Cf. [40]) and that the collected questionnaires are

derived from different organizations of varying size and with different types of production. The black box of non-responders to a questionnaire should, however, always be taken into account when interpreting the results.

5. Energy management practices in Swedish energy-intensive industries

The following section outlines and analyses the results of the study, beginning with results regarding the industries' pay-back periods, followed by results regarding the existence and duration of a long-term energy strategy and the results regarding the allocation of energy costs. In the final part of the section, the companies are categorized in terms of successful energy management practices, and the industries' view on various information sources is presented.

5.1 Pay-off criteria

Several different ways of calculating potential energy efficiency investments exist, one of the most recognized and straightforward methods being the pay-off method. Results are outlined in Fig. 2 below.

Fig. 2. Payoff-criteria for energy efficiency investment shown as percentages of the total number of responses.

As can be seen from Fig. 2, most of the companies apply a pay-off criterion of 3 years or less for energy efficiency investments, which can be compared with a general pay-off period of 4.1 years in a study of German industries from 1991 [26]. It should be noted that it is often problematic to distinguish investments in energy efficiency from for example production related investments. This is due to the fact that an investment is in many cases related to both production efficiency and energy efficiency. Moreover, a discrepancy between operational and strategic measures should also be noted. Many of the energy efficiency investments related to the support processes, e.g. ventilation, space heating and lighting, have lower initial costs compared to heavily capital-

intensive production processes. This means that while the support process measures may be adopted on an operational level in the organizations, many of the heavily capital-intensive production process related investments are often related to strategic decision-making.

As stated in the introduction, strict investment criteria may be a result of a principal-agent relationship problem. It should, however, be noted that strict investment criteria may also be seen as a measure of the company's calculated risk. Results indicate that the principal-agent relationship might in general be of less importance in the studied sectors. Notably, though, 25% of the studied energy-intensive foundries lack investment criteria for energy efficiency investments, which may indicate an area for potential improvements concerning energy management practices.

5.2 Existence and duration of a long-term energy strategy

Previous research emphasises the great importance of a long-term energy strategy in successful energy management practices in industrial organizations; successful in terms of implemented energy efficiency measures, both technical and behavioural [22,24]. In previous research, the existence of a long-term energy strategy was one of the most highly ranked factors for promoting energy efficiency in the two studied sectors [25,28]. A long-term energy strategy should not be considered to be equivalent to an Energy Management System (EMS), which is adopted on a more operational level, lower down in the organization supporting the operation of energy management. Energy management, as stated previously, should have the support of top management and adopting a long-term energy strategy is an important means of emphasizing this. However, successful energy management practices could be facilitated by an EMS. Fig.

3 outlines the findings regarding the existence/non-existence and duration of a long-term energy strategy at the studied industries.

Fig. 3. Existence and duration of a long-term energy strategy.

As shown in Fig. 3, about one fifth of the studied pulp and paper mills lack a long-term energy strategy, and more than half of the foundries lack such a strategy, indicating that these industries do not consider energy management to be a core activity. Moreover, Fig. 3 also indicates that less than half of the studied pulp and paper mills, and less than 30% of the studied foundries have an energy strategy of at least five years. Adopting an energy strategy of one to three years and calling it “long-term” is of course questionable. Nevertheless, this shows that most of the companies either lack a strategy or have a strategy with regard to energy of three years or less, indicating areas for improvement with regard to energy management practices. One plausible explanation

for this might be an increased focus on core business that may result in fewer resources being allocated to non-core activities such as energy management.

Notably, basically all the studied pulp and paper mills are taking part in the Swedish LTA-programme, the PFE, which includes, among other things, certification of an EMS in accordance with the Swedish EMS standard. In fact, the pulp and paper industry represents about 70% of the energy use of the industries involved in the PFE. As the Swedish pulp and paper industry is a major user of energy, this may be seen as an interesting finding that indicates, based on previous research such as [22-23], an area with improvement potential in regard to reducing industrial energy end-use.

5.3 Allocation of energy costs

In many organizations and in particular those with multiple departments and divisions, inadequate allocation of energy costs may lead to slack energy management [27]. As stated in the introduction, if the energy costs are allocated per square metre, there is no incentive for a department or division manager to pay attention to the issue as there is nothing for him or her to gain. The implementation of a cost-efficient energy efficiency measure does not produce any additional benefit for the individual department. In an ownership situation where another company is in charge of, or even owns, the company's facilities, the allocation is again of utmost importance, if the split incentive problem is to be minimized. A monitoring system using sub-metering at plant level is one of the major prerequisites for proper energy cost allocation, and successful energy management adoption. However, research shows that it is not always installed in manufacturing companies and even where it exists it is not always used for proper energy cost allocation [27]. Other, less appropriate, means are used instead. Fig. 4 shows how energy costs are allocated by the studied industries.

Fig. 4. Allocation of energy costs.

As expected, Fig. 4 shows that the majority allocate energy costs using sub-metering. However, about one fifth of the studied mills and about one third of the studied foundries do not allocate energy costs at all, and at about one tenth of the studied industries, energy costs are allocated per square metre and per number of employees respectively. This indicates that the split incentive problem may still be of importance, even among the studied energy-intensive industries.

5.4 Categorization of successful energy management practices

Fig. 5 shows the results of our attempt to categorize the studied industries in terms of success and lack of success as regards energy management practices.

Fig. 5. Categorization of energy management practices. The first category includes those companies that answered affirmatively to having pay-off periods for energy efficiency investments of two years or more, having an energy strategy of three years or longer, and allocating energy costs based on sub-metering. The second category comprises companies that answered affirmatively to two of the above outlined statements, and the third category comprises the remaining companies.

As can be seen from Fig. 5, about 40% of the studied pulp and paper mills and 25% of the studied foundries may be considered successful, using the three indicators. When comparing the results among the pulp and paper mills in terms of number of employees, more than or fewer than 250 employees, it was found that there was no difference in relation to number of employees between the successful mills in terms of energy management practices. However, among the mills with less successful energy management practices, there was a considerably larger amount of mills with less than

250 employees in category three, while the opposite is true for category two. The use of indicators is a very rough means of making such a categorization but it nevertheless gives an indication that a potential for improvement seems to exist as regards energy management practices in the studied industries.

5.5 Information sources

As stated in the introduction information imperfections and asymmetries may play a crucial role in the adoption or non-adoption of energy efficiency measures at plant level. Fig. 6 shows the respondents' ranking of various information sources.

Fig. 6.

Ranking of different sources of information, 1 p for 'excellent', 0.75 p for 'good', 0.50 p for 'average' and 0.25 p for 'not good'.

As seen in Fig. 6, the highest ranked information sources are colleagues within the company and colleagues within the sector. The high ranking of colleagues within the sector and within the company indicates that new energy efficiency technologies may face a barrier in regard to the diffusion of information. Moreover, consultants, conferences and seminars, and the industry federation were also high-ranked among foundries. This indicates that information regarding, in particular, new energy efficiency technologies, could be assumed to be more effectively diffused among foundries than among the pulp and paper industry. Comparing the results with previous research conducted in German industries indicates both similarities and differences. Ranking of written information sources was ranked highly in both the German study and by Swedish pulp and paper mills [26]. An interesting difference is that industry federations were ranked relatively low by both the German industries and the Swedish pulp and paper mills, while it was ranked highly by Swedish foundries [26].

Discussion

Already in 2000, before large energy price increases affecting Swedish industry had taken place [8], the energy-intensive Swedish industries faced high energy costs and thus had great incentives to prioritize the energy issue [11]. However, even though substantial incentives existed, and in fact have amplified as energy prices have increased, the results presented in this paper show that potential still exists to improve energy management practices in the studied industries.

Results regarding allocation of energy costs show that a considerable number of the studied foundries/mills do not allocate energy costs based on sub-metering, most likely contributing to reinforce the split incentives problem. Moreover, results regarding the existence and length of a long-term energy strategy indicate that among energy

intensive industries, energy management does not seem to be a highly prioritized issue for a considerable proportion of the industrial population. Results regarding the studied organizations' pay-off criteria indicates that the principal-agent relationship barrier leading to strict monitoring and control of the implementation of cost-efficient energy efficiency measures, seems to be of less importance in the studied industries.

Notably, basically all the studied pulp and paper mills are taking part in the Swedish LTA, PFE, which demands, among other things, certification of an EMS according to an EMS standard. If this lack of strategy at a considerable proportion of the mills is a result of a plausible improvement potential in the formulation of future LTAs and whether the EMS-standard should include an element regarding a long-term energy strategy, are questions for future research to answer. The results should nevertheless be of importance both for industrial federations and for policy-makers designing future energy policies for industry on EU, national, and sector levels.

Relating the findings from the categorization of successful energy management practices to a similar study of Danish mainly non-energy-intensive, manufacturing industries shows that only between approximately 3% and 14% of these industries were categorized as successful [21]. It should be noted that the cited study used other indicators in order to evaluate successful energy management practices and a full comparison is therefore not unambiguous.

As regards the importance of various information sources, the high ranking of colleagues within the sector and within the company indicates that new energy efficiency technologies may be inhibited or at least face a lag in regard to the diffusion of information. Moreover, comparing the findings regarding information sources with [26] indicates that industry federations, for example, were ranked relatively low by both

the German industries and the Swedish pulp and paper mills while they were ranked highly by Swedish foundries.

Comparing [21] with the results from the present study, the adoption of energy management practices in energy-intensive industries seems to be higher than in non-energy-intensive industries. Moreover, the difference between the pulp and paper industry and the foundry industry shown in Fig. 5 indicates that the degree of adoption of energy management practices may also be affected by energy intensity and the size of the organization. The studied mills are not only more energy-intensive than the foundry industry, but also mainly comprise larger organizations, with an average of around 450 employees, compared to the studied foundries with an average of fewer than 40 employees.

Another feasible theory that might explain the results presented in this study, i.e. why energy management is not fully prioritized by a significant number of the studied companies, is the organizational focus on core business [32]. As previously illustrated by [33], several reports from both the USA and Sweden indicate that manufacturing companies, energy-intensive and non-energy intensive, today have fewer resources for non-core activities such as operation of energy facilities. This is due to the fact that the companies are increasingly focusing their efforts on their core businesses activities [33,35,41]. This means that even though the energy-intensive industries, and especially the pulp and paper industry, have energy costs in relation to the added value of well beyond 20 per cent, energy management and energy-related business activities may not qualify as core business, and will therefore not be strategically prioritized [33].

Considering this paper's results in relation to the impact of a strong focus on core business; it may be considered that the energy efficiency gap, i.e. the discrepancy between the business-as-usual level and the optimal energy efficiency potential, may be

fully rational in relation to the core business notion. If an extensive focus is put on core business activities, it would be assumed that the organization's "non-core" activities such as energy management would face restrictions in terms of resource allocation.

However, in order to fully analyze if this holds for the industries studied in this paper, complementary studies where interviews are conducted with several energy managers, MDs and CEOs, would need to be undertaken. The empirical findings from the questionnaire therefore call for future research in this context, possibly applying a more in-depth method than a questionnaire.

Conclusions

Based on the research results presented in this paper, even among energy-intensive industries, energy management does not seem to be fully prioritized at all the companies – around 40% of the mills and 25% of the foundries may be considered successful in terms of energy management. Moreover, the degree of adoption of energy management practices seems to increase with the size of the company and in particular increase with energy intensity. [21]'s research among Danish manufacturers seems to confirm the latter statement. Furthermore, the split incentive barrier was found to be of importance in the studied industries, the principal-agent relationship barrier was found to be of less importance, and information imperfections and asymmetries was shown to exist.

It should be noted that the priority of energy management is not solely related to energy intensity. The findings presented in this paper may in similar studies in other countries and other industrial sectors be affected by for example energy prices, national public policy instruments, organizational culture and corporate and business strategies. Despite these recognized limitations, the results presented here may be generalized

beyond the actual scope of the research. If energy management is not fully prioritized even in energy-intensive industries – the pulp and paper industry being one of the most energy-intensive in the world and Sweden being one of the most energy-intensive countries in the world - it will in all probability not be prioritized in less energy-intensive industrial sectors or countries either. This indicates a large untapped potential with regard to achieving cleaner and more environmentally sound production in different industrial sectors.

Acknowledgments

The work has been carried out under the auspices of the Energy System Programme, which is financed by the Swedish Energy Agency. We kindly thank the respondents at the studied organizations for giving freely of their time to answer the questionnaire. Finally, we would like to express our appreciation to the three anonymous referees whose useful comments have improved the quality of this paper considerably. The usual disclaimer applies.

References

- [1] IPCC, 2007. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Summary for Policymakers. Retrieved October 8, 2007, from: <http://www.ipcc.ch/SPM0405 07.pdf>
- [2] Worrell, E., Laitner, J., Ruth, M., Finman, H., 2003. Productivity benefits of industrial energy efficiency measures. *Energy*: 28(12):1081-98.

[3] Hirst, E., Brown, M., A., 1990. Closing the efficiency gap: barriers to the efficient use of energy. *Resources, Conservation and Recycling*;3(4):267-81.

[4] Jaffe, A.B., Stavins, R.N., 1994. The energy efficiency gap: what does it mean? *Energy Policy*;22(10):60-71.

[5] Shi, H., Peng, S.Z., Liu, Y., Zhong, P., 2008. Barriers to the implementation of cleaner production in Chinese SMEs: government, industry and expert stakeholders' perspectives. *Journal of Cleaner Production*;16(7):842-52.

[6] Painuly, J. P., Park, H., Lee, M.-K., Noh, J., 2003. Promoting energy efficiency financing and ESCOs in developing countries: mechanisms and barriers. *Journal of Cleaner Production*;11(6):659-65.

[7] Sardianou, E., 2008. Barriers to industrial energy efficiency investments in Greece. *Journal of Cleaner Production*;16(13):1416-23.

[8] Johansson, B., Modig, G., Nilsson, L.J., 2007. Policy instruments and industrial responses - experiences from Sweden. In: *Proceedings of the 2007 ECEEE summer study "Saving energy - just do it"*; Panel 7:1413-21.

[9] SEA (Swedish Energy Agency), 2008. *Energy in Sweden 2007*. Swedish Energy Agency Publication Department, Eskilstuna.

[10] SFA (Swedish Foundry Association), 2004. Specialist support for Scandinavian foundries. Swedish Foundry Association, Jönköping. [in Swedish]

[11] SEA (Swedish Energy Agency), 2000. Energianvändning inom industrin [Energy use in industry]. Swedish Energy Agency Publication Department, Eskilstuna. [in Swedish].

[12] DI (Dagens Industri) 2008. Rottneros slår igen Utansjö bruk. [Rottneros to close Utansjö mill]. Retrieved, October 16, 2009, from Dagens Industri's website: <http://di.se/Nyheter/?page=/Avdelningar/Artikel.aspx%3FO%3DRSS%26ArticleId%3D2008%255C01%255C09%255C264479>.

[13] Klugman, S., Karlsson, M., Moshfegh, B., 2007. A Scandinavian chemical wood pulp mill. Part 1. Energy audit aiming at efficiency measures. *Applied Energy*;84(3):326-39.

[14] Thollander, P., Karlsson, M., Söderström, M., Creutz, D., 2005. Reducing industrial energy costs through energy efficiency measures in a liberalized European electricity market—case study of a Swedish iron foundry. *Applied Energy*;81(2):115–26.

[15] Klugman, S., Karlsson, M., Moshfegh, B., 2009. A Swedish integrated pulp and paper mill-Energy optimization and local heat cooperation. *Energy Policy*;37(7):2514-24.

[16] Cai, Y.P., Huang, G.H., Yang, Z.F., Tan, Q. Identification of optimal strategies for energy management systems planning under multiple uncertainties. *Applied Energy*;86(4):480-95.

[17] Kissock, J.K., Eger, C., 2008. Measuring industrial energy savings. *Applied Energy*;85(5):347-61.

[18] Costa, A., Paris, J., Towers, M., Browne, T., 2007. Economics of trigeneration in a kraft pulp mill for enhanced energy efficiency and reduced GHG emissions. *Energy*;32(4):474-81.

[19] Anderson, S.T., Newell, R.G., 2004. Information programs for technology adoption: the case of energy-efficiency audits. *Resource and Energy Economics*;26(1):27–50.

[20] Harris, J., Anderson, J., Shafron, W., 2000. Investment in energy efficiency: a survey of Australian firms. *Energy Policy*;28(12):867-876.

[21] Christoffersen, L.B., Larsen, A., Togeby, M., 2006. Empirical analysis of energy management in Danish industry. *Journal of Cleaner Production*;14(5):516-26.

[22] McKane, A., Williams, R., Perry, W., T, L., 2007. Setting the Standard for Industrial Energy Efficiency Retrieved, December 9, 2009, from: <http://industrial-energy.lbl.gov/node/399>

[23] Worrell, E., Bernstein, L., Roy, J., Price, L., Harnisch, J., 2009. Industrial energy efficiency and climate change mitigation. *Energy Efficiency*;2:109-23.

[24] Caffal, C., 1996. Energy management in industry. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). Analysis Series 17. Sittard, The Netherlands.

[25] Thollander, P., Ottosson, M., 2008. An energy efficient Swedish pulp and paper industry – exploring barriers to and driving forces for cost-effective energy efficiency investments. *Energy Efficiency*;1(1):21-34.

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

[27] Rohdin, P., Thollander, P., 2006. Barriers to and Driving Forces for Energy Efficiency in the Non-energy Intensive Manufacturing Industry in Sweden. *Energy*;31(12):1836-44.

[28] Rohdin, P., Thollander, P., Solding, P., 2007. Barriers to and drivers for energy efficiency in the Swedish foundry industry. *Energy Policy*;35(1):672-77.

[29] Mintzberg, H., 1987. The Strategy Concept II: Another Look at Why Organizations Need Strategies. *California Management Review*;30:25-32.

[30] Möllersten, K., Yan, J., Moreira, J.R., 2003. Potential market niches for biomass energy with CO₂ capture and storage-Opportunities for energy supply with negative CO₂ emissions *Biomass and Bioenergy*;25(3):273-85.

[31] Möllersten, K., Gao, L., Yan, J., Obersteiner, M., 2004. Efficient energy systems with CO₂ capture and storage from renewable biomass in pulp and paper mills. *Renewable Energy*;29(9), Pages 1583-98.

[32] Markides, C. C. (1992). Consequences of corporate refocusing: Ex ante evidence. *Academy of Management Journal*;35(2):398–12.

[33] Möllersten, K., Yan, J., & Westermarck, M., 2003. Potential and cost-effectiveness of CO₂ reductions through energy measures in Swedish pulp and paper mills. *Energy*;28(7):691–10.

[34] SFIF (Swedish Forest Industry Federation), 2009. The Swedish forest industries - Facts and figures 2008. Retrieved, December 16, 2009, from the Swedish Forest Industry Federation's website:

<http://www.forestindustries.se/LitiumDokument20/GetDocument.asp?archive=3&directory=1399&document=10101>.

[35] Nilsson, L., Larson, E., Gilbreath, K., Gupta, A., 1996. Energy efficiency and the pulp and paper industry, Report Energy Efficiency number IE962. Washington, DC: American Council for an Energy-Efficient Economy.

[36] Swerea SWECAST, 2007. 2006 - ett nytt rekordår för de svenska gjuterierna - Gjuteribranschen fortsatt het [2006 – A new record year for Swedish foundries – The foundry industry is still hot]. Retrieved January 19, 2007, from: [http://www.gjuteri foreningen.se/aktuellt/pressrelease0703.pdf](http://www.gjuteriforeningen.se/aktuellt/pressrelease0703.pdf) [in Swedish].

[37] CAEF (The European Foundry Association), 2006. The European Foundry Industry 2005, CAEF, Düsseldorf, Germany.

[38] Yin, R.K., 1994. Case Study Research: Design and Method. Applied Social Research Methods, vol. 5. Sage, London.

[39] Velthuijsen, J.W., 1995. Determinants of investments in energy conservation, Dissertation, Rijksuniversiteit.

[40] de Groot, H., Verhoef, E., Nijkamp, P., 2001. Energy saving by firms: decision-making, barriers and policies. *Energy Economics*;23(6):717-40.

[41] Greenbaum, P.J., 2001. Spending money elsewhere. *Pulp & Paper Canada*;102(2):11-14.

About the authors

Patrik Thollander is an assistant professor at the Division of Energy Systems at Linköping University in Sweden and within the graduate school Energy Systems Programme. His research interests include among other things energy efficiency in industry, the Swedish foundry industry, industrial energy end-use policy design, barriers and driving forces, industrial energy system optimization using MILP, and industrial energy management and programmes.

Mikael Ottosson is a PhD candidate at the Department of Thematic Studies - Technology and Social Change at Linköping University in Sweden and within the graduate school Energy Systems Programme. His PhD project analyses how the Swedish forest industry has responded to the major changes affecting its two strategic key resources, the forests and electricity, over the 1989-2009 period. His research interests include the forest industry, energy efficiency in industry, strategic management, organization theory, economic sociology, and science and technology studies (STS).