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# Energy management in Swedish pulp and paper industry – the daily grind that matters

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## Keywords

efficiency, pulp and paper industry, energy management system, competitiveness, EN 16001, ISO 50001

## Abstract

The Swedish pulp and paper industry (PPI) accounts for almost 50 percent of industrial final energy use. It is an energy-intensive industry and process optimization is seen as prerequisite to compete on the global market. This alone should motivate company boards and on-site organisations to put energy management high on the agenda. Definitely, from time to time, energy issues (e.g. fuel shifts, selling of generation capacity, and more lately increasing auto-produced electricity) have been managed with respect to the combined effects of policies and market forces. Yet, it was first after 2004 that the industry implemented energy management systems (EnMS), with particular focus on energy efficiency, and received certification according to the Swedish and later the European standard. This was required by the Programme for improving energy efficiency in energy-intensive industries (PFE), a five-year voluntary agreement in which some 100 companies reported gross annual electricity savings of 1.45 TWh, equal to 5 percent of base year consumption. This result highlights the potential role of an EnMS in raising awareness and facilitating investments. In this paper we analyse the case of the Swedish PPI; its relation to energy issues in previous periods and the formalised EnMS practices of recent years. We pose the questions: How are standardised EnMS structured and put into practice? What are there measurable effects and other discernible outcomes? The results are based on in-depth interviews with energy management coordinators at eight pulp

and paper mills. The experiences with EnMS are found to be predominantly positive. EnMS has changed organisational structures and created greater focus on energy efficiency, which has resulted in quantified energy savings. Considering that EnMS implementation and certification is at a pioneering stage and that the international ISO 50001 standard is currently being developed, these are important results for the future of EnMS in industry.

## Introduction

Close to a third of global energy use and almost 40 percent of the carbon dioxide emissions are attributable to the manufacturing industries (IEA, 2009). Energy efficiency improvement can be a means to several ends but from the business perspective held by industry representatives it serves foremost to gain competitive positions. This is not to say that energy efficiency is always prioritised across industry and this is important to consider for the achievement of societal goals like energy saving and climate mitigation targets. In fact, it is absolutely necessary for fulfilment that all sectors of society, not the least energy-intensive industries, make substantial contributions. Exploiting the full potential of energy efficiency improvement requires continuous and systematic attention. To facilitate such corporate management many national Energy Management System (EnMS) standards have evolved over the last decade.

In Sweden, a national EnMS standard was introduced with the voluntary agreement Programme for improving energy efficiency in energy-intensive industries (PFE) which is administrated by the Swedish Energy Agency (SEA). Since

2004, through its combination of incentives and obligations<sup>1</sup> PFE has stimulated some 100 energy-intensive<sup>2</sup> companies to implement and become certified for their use of EnMSs.<sup>3</sup> After 2009, when the first five-year programme period was concluded, PFE was cited as a success (SEA, 2011a). The companies reported 71 MEUR of investments into electricity savings measures that, in combination with many zero-cost measures, generated gross annual electricity savings of 1.45 TWh (i.e. almost 5 percent of their annual electricity demand). The average straight payback period of these measures was less than 1.5 years (SEA, 2011a). The cost for society has been estimated at a low 6.5 Euro per MWh of saved electricity, thus being clearly favourable compared to market electricity prices and cost of new generation capacity (Stenqvist & Nilsson, 2011). Considering that many PFE companies belong to truly energy-intensive sectors (e.g. pulp and paper, chemical industry, manufacture of basic metals) the observed results are rather intriguing and in contradiction to economic theory stating that the market place alone creates a high and persistent energy consciousness within energy-intensive firms. According to some scholars, the use of energy efficiency programmes to stimulate an attention-raising effect among energy-intensive firms is viewed unnecessary (Brännlund & Kriström, 2010). Their solution for an effective climate policy is rather a global tax or an emissions trading scheme to internalise the externality (i.e. carbon dioxide emissions). Also in practice on an EU policy level there are expectations on EU ETS and the Energy Taxation Directive to encourage take-up of remaining energy savings opportunities in energy-intensive firms (EC, 2011). The European Commission does, however, also recognise that some obstacles need to be addressed by other measures. For large companies the Commission plans to propose regular energy auditing to become mandatory and it also recommends Member States to incentivise the implementation of standardised energy management systems (EC, 2011).

Previous experiences from voluntary agreements that include obligations on energy management practices in energy-intensive firms show that these provide cost-effective energy savings beyond business-as-usual (Worrell et al., 2009). The Swedish PFE provides another example that allows us to challenge the hypothesis of adequate energy consciousness in energy-intensive firms and more specifically to analyse the potential contribution from standardised EnMS practices.

## PURPOSE AND RESEARCH QUESTIONS

Given the potential capacity of a standardised EnMS in raising awareness and facilitating energy efficiency improvement in energy-intensive firms (as well as other firms) it is important to study the practical implementation that makes such changes come about. In light of the development with many national EnMS standards being launched and now also consolidated into international standards it is of interest to study the response among industrial actors. Therefore, in this paper we present the case of standardised EnMS in the Swedish pulp and paper industry (PPI). The key questions being posed are: How is a standardised EnMS structured and activated? Which are the measurable effects and other discernible outcomes?

## OUTLINE

In a first section of this paper some basic concepts related to energy management are presented. Then, as a point of reference we present results from previous research on industrial energy management practices, with preference for its occurrence within the Swedish PPI. Next, based on conducted interviews we are able to present how the more formalised EnMS practices in recent years have materialised in eight studied pulp and paper mills. For the reflections on measurable effects from certified EnMS a quantitative assessment illustrates the size of electricity savings implemented as well as the development of absolute and specific electricity consumption at the mills. In a final section we conclude the overall results and reflect about possible implications for the future of EnMS implementation and certification according to international standard.

## Background and concepts

### DEFINING ENERGY MANAGEMENT

The concept of energy management is defined by Capehart et al. (2008) as:

*The efficient and effective use of energy to maximize profits (minimize costs) and enhance competitive positions.*

While pointing out the objective of energy management this definition does not describe the procedures that constitute energy management. Certainly, for any profit-seeking organization, and especially one where the cost share for energy products is significant, this objective of energy management should be inherent in the business. This, however, does not ensure that appropriate energy management procedures are practiced. On the contrary, the existence of energy efficiency gaps indicates that such are often absent across sectors of energy end-users (Jaffe & Stavins, 1994). In Sweden, the energy saving potential in some energy-intensive sectors<sup>4</sup> has been estimated at 10 percent by the year 2016. This means that a forecasted increase in industrial energy demand can be avoided through a more efficient energy use (SOU 2008:110, 2008, p. 215). The estimate is conservative since it only takes into account savings from technical measures and not behavioural changes (i.e. O&M), the latter being central in EnMS practices. Moreover, the un-

1. Participants are exempted from the EU minimum tax on electricity of 0.5 Euro per MWh. In return, each company is required to: conduct an energy audit and analysis; identify and invest in profitable electricity saving measures; implement and certify an EnMS; introduce routines for energy efficient procurement and project planning; report their progress to the SEA.

2. According to the definition of the EU Energy Taxation Directive (2003/96/EC) a company is energy-intensive if: (1) purchases of energy products and electricity amount to at least 3 percent of the production value and/or (2) the energy-, carbon dioxide- and sulphur tax on energy products and electricity used by the company amount to at least 0.5 percent of the added value. PFE companies belong to the following industrial sectors: pulp and paper; chemical products: steel and metal; mining and quarrying; mineral products: saw mills and manufacture of wood products; manufacture of food products.

3. Initially according to the Swedish SS 62 77 50 and then according to the European EN16001 standard.

4. The sectors of: iron and steel, pulp and paper, refineries and petrochemicals.

derlying assumptions on energy prices levels from 2005 and onwards has been greatly exceeded by actual developments. Energy efficiency improvement should therefore have become even more attractive than expected.

The emphasis on efficient energy use as the means to maximize shareholder value is an important one to make. It can certainly be imagined a firm in which the increased energy use enables higher production levels and thus improved profits. However, if the increased production capacity has deficient energy performance the same firm will become more exposed to increasing energy prices and the shrinking profit margins that follow. In situations with low market demand or increasing energy prices the poorly performing production capacity ought to be suspended first. At stake here is to keep a constant focus on maintenance and further improvement to attain energy efficient production processes and auxiliary systems that will allow the company to minimize its energy use per unit of output (monetary or physical) and thereby uphold a competitive position.

In one or the other way energy related issues is always being managed but with an EnMS that prioritizes the efficiency aspect, the company can avoid the risk that other objectives take overhand. Moreover, even if there is a clear focus on energy efficiency, as with everything else, management can be poor. With an EnMS an industrial company is helped to structure and incorporate its energy management ambitions into the daily operations. The basic principles are the same as for other types of management systems, e.g. environmental management systems like ISO 14001. Following the cyclic “Plan-Do-Check-Act” approach, as depicted in Figure 1, the company shall: establish goals and procedures that correspond to the energy policy and requirements of relevant stakeholders (plan); implement the necessary procedures (do); monitor the manufacturing processes with regards to the policy, the significant energy aspects and specified targets and also report the results (check); take actions to continuously improve the performance of the processes (act) (SIS, 2003).

A proper EnMS implementation requires documentation and activation of an organisational structure including the work planning to identify tasks and responsibilities (SIS, 2003). Internal revisions should be conducted regularly to make sure that work keep up with requirements set by the standard document and the energy policy. External revisions performed by an accredited auditor can give further recognition as the company receives a certification according to the standard. It is evident from at least ten national EnMS standards released over the last decade, from Denmark in 2001 to China in 2009, that there are prospect for EnMSs to facilitate industrial energy efficiency improvement (Kahlenborn, 2010). The European EN 16001 was released in 2009 and there is ongoing work to conclude the international ISO 50001 in 2011. By time the numerous national standards are likely to be phased out in favour for the internationally agreed documents. In the Swedish PFE, for example, EN 16001 substitutes for SS 62 77 50 since 2009, and when the ISO 50001 is available it will probably succeed.

#### ENERGY AND THE PULP AND PAPER INDUSTRY

The energy use in the PPI varies considerably depending on the production process. There are many different pulping processes but the two main routes are mechanical and chemical. In

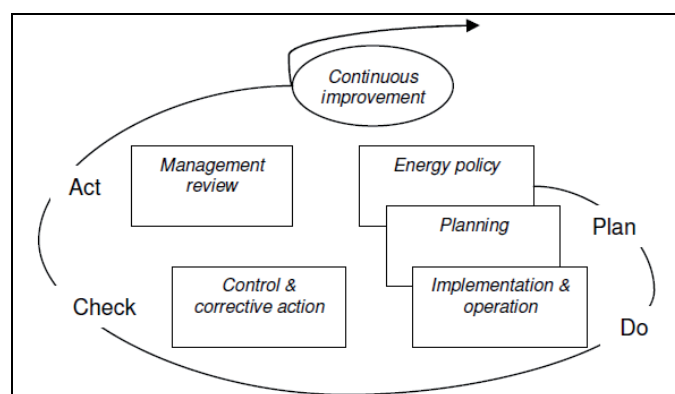


Figure 1. The PDCA approach of a standardised EnMS. Source: SIS (2003)

electricity-intensive mechanical pulping, wood chips are processed in large grinders and nearly all the wood ends up in the pulp which is used for paper such as newsprint. In an integrated mill the heat is recovered from the mechanical pulping process and the steam produced is used for drying the paper and other processes. Chemical pulping is used to produce stronger high quality fibres and involves dissolving the lignin in a chemical cooking process. About half of the wood ends up in the spent pulping liquor that is concentrated in evaporators. The resulting black liquor is combusted in chemical recovery boilers and the bark component can also be combusted in separate boilers. The high pressure steam produced is used for CHP generation, enough to meet all the steam and electricity demands of a modern chemical pulp mill. In 2008, the Swedish PPI consisted of 56 mills. Their fuel use was 218 PJ of which 94 percent was bio-energy, mainly in the form of black liquor. The total electricity demand amounted to 22 TWh<sup>5</sup> of which back pressure turbines auto-produced 6 TWh, equal to 25 percent of the demand. (SFIF, 2011)

Energy is clearly an integral part of the energy-intensive PPI. Management of energy issues has thus been important to respond to changes in relative energy prices and various environmental and energy policies. In the 1970s, the dramatic increase in oil prices set off a fuel switch in the PPI from oil to biomass and partly electricity. The oil substitution, which is still ongoing, has later also been motivated by the Swedish carbon tax that was introduced in 1991 and more recently the EU ETS that was introduced in 2005. Fossil fuels now account for only 6 percent (2008) of the fuel consumption in the PPI (SFIF, 2011), which aims to phase out all fossil fuels from the production processes by 2020. The introduction of the Swedish carbon tax also created a market for wood fuels and the forest industry (i.e. subsidiaries within the PPI groups) started to deliver wood chips, pellets and other fuels on a large scale to outside buyers, in particular the district heating sector. Over the past decades there has also been a steady growth in the number of pulp and paper mills that deliver waste heat to neighbouring district heating systems. In 2007, 22 pulp and paper mills delivered 1495 GWh of heat to district heating systems (Wiberg, 2007).

5. To put this in perspective it is equal to 16 percent of Sweden's electricity demand (SEA, 2009).



Another, more recent, development in the PPI is the great interest in electricity-related investments. There have been substantial investments in process-integrated electricity production and many companies have announced ambitious investment plans for wind power. These investments, which are described in Ericsson et al. (2011), represent a fundamental trend break to the 1990s and early 2000s, during which the PPI divested many of its off-site power assets (hydropower and nuclear power). According to Ericsson et al. (2011) this reorientation follows from policy driven changes in the underlying economic conditions in the sector, in particular the increase in electricity prices and expectations of permanently higher electricity prices in the future. Since the early 2000s, the PPI has faced increasing electricity prices following the electricity market reform and the introduction of the EU ETS. The reorientation has, however, also been driven by the opportunities created by the Swedish quota obligation scheme with tradable renewable electricity certificates (TRECs) that was introduced in 2003 (Ibid). The additional income from sales of TRECs has greatly improved the profitability of investments in biomass-based CHP.

#### EXPERIENCES IN ENERGY MANAGEMENT

The previous section showed that for the last decades the PPI has been heavily involved in strategic considerations and decision making concerning the supply of different energy carriers. More related to the concept of energy management is that apart from driving investments in new power assets increasing electricity price has become a trigger for increased focus on energy efficient production processes. Due to the historical low electricity prices that created a competitive advantage to the PPI and Swedish industry in general, the issue has become more acute in the post 2000 period than before (Trygg & Karlsson, 2005).

A relevant study is Thollander and Ottosson (2010) that examines, based on a questionnaire sent out in 2007, some aspects of energy management practices in the Swedish PPI. At that time the industry had been participating in PFE for two years and had just received certification for their EnMSs. Aspects considered by Thollander and Ottosson (2010) were: the strictness on payback criteria for energy efficiency investments; the existence of long-term energy strategies; and procedures on energy cost allocation. These indicators were then used to categorize how successful the mills were in their energy management practices. On a rather rough three grade scale 40 percent out of 40 responding mills were categorized as successful. Hence, there seems to be some potential for improvement. Nevertheless, all the mills did receive EnMS certification from authorised third-party auditors. Since the three aspects used by Thollander and Ottosson (2010) to judge success are not explicitly mentioned in the Swedish EnMS standard this does not appear contradicting. Questions can be raised about how EnMS practices are best evaluated in addition to the stamp of approval issued by external auditors. Therefore, in this point of time when the same mills have applied their EnMSs for another four years as required by the PFE participation, it is motivated to complement previous studies to describe the current status of EnMS practices in Swedish PPI.

## Methodology and empirical base

#### THE RESEARCH METHODOLOGY

A main objective for introducing a standardised EnMS is to facilitate a management around energy efficiency so to enhance the competitive position of the firm. In this regard a measurable energy efficiency improvement that is assumed to be cost-cutting at the plant or company level can be viewed as one, though not the only, indicator of successful EnMS practices. A specific technical measure such as replacement of an industrial motor of poor efficiency with one of higher efficiency class generates instant electricity savings that depending on various conditions may persist to deliver annual savings for several consecutive years (CEN, 2007). Technical measures alone does little, however, to arrange an organisation for giving preference to energy efficiency and making it a core value for enhanced competitiveness and so shifting the mindset of management and staff. Yet being difficult to measure there should be large potential for such changes to influence energy efficient decision making and behaviour in the longer run (e.g. in terms of procurement procedures). The measurable impact in terms of energy efficiency improvement may arise long after such organisational changes are undertaken.

Based on this reflection we argue that multiple indicators must be used to describe the status and judge the success of EnMS practices. Since these are the intentions of this paper, the empirical base is both of a qualitative and quantitative nature. This dual approach is found necessary to obtain answers to the key questions posed in the introduction. Qualitative, and partly quantitative, data was gathered by the means of site visits including interviews with appointed energy management representatives at eight different mills. These in-depth and semi-structured interviews concerned issues on EnMS structure and activation at the mills. The answers from respondents provided enough material to frame five headlines that, inspired by literature (e.g. Capehart et al., 2008), highlights key issues on how an EnMS is structured and put into practice. The results from the interviews are presented under the following headlines: Energy management coordinator; Management and staff commitment; Energy cost allocation; Monitoring and reporting; and Training.

#### THE INTERVIEWED FIRMS

The empirical base of this paper originates from eight pulp and paper mills of varying size, type and geographic location. The selection of mills was done according to a few criteria. All respondents should participate in PFE that requires companies to implement and certify EnMSs. From 2005 to 2009 PFE has engaged about 100 energy-intensive firms and in total some 250 industrial sites in different industrial sectors. This study is focusing on the pulp and paper industry, which in Sweden covers about 45 companies and almost 60 mills.<sup>6</sup> At a conference arranged for PFE companies one author of this paper attended and established contact with representatives from several mills. After some correspondence the representatives of the eight mills, being presented in Table 1, accepted to be respondents.

6. It is common in the PPI that each mill operates as a separate business unit with an individual company registration number.

Data was collected during site visits that included interviews with appointed persons and shorter round tours at the production site. All visits, that lasted between one and three hours, were made over a period from February to June 2010.

#### QUANTITATIVE DATA SOURCES

For the eight mills, in order to enable interpretations of measurable effects from EnMS practices, the following data has been compiled and analyzed: electricity consumption; specific electricity consumption; and reported electricity savings during the course of PFE. The focus on electricity is due to the accessibility of such data. The requirement on EnMS implementation was introduced with PFE that in particular targets electricity savings in its substitution for the EU minimum tax on electricity (Stenqvist & Nilsson, 2011). For this reason the companies have only been obliged to identify and report their electricity savings measures to the SEA which in turn has provided this data (SEA, 2011b). Other energy savings measures (i.e. heat and fuels) have also been implemented under the guidance of the EnMS as made evident by the voluntarily reporting made by some companies.

The data on absolute and specific electricity consumption has been compiled from publicly available data provided by the Swedish Forest Industries Federation (SFIF, 2011). Its member companies from the entire PPI annually reports physical production as well as energy and emission related figures. The analysed time period (2005-2009) equals the period during which standardised EnMSs have existed at the mills.

### Energy management practices at the mills

#### ENERGY MANAGEMENT COORDINATOR

To implement, develop and activate the EnMS a competent employee needs to be appointed with responsibility for coordination and thus become the Energy Management Coordinator (EnMC) at the company or industrial plant (Capehart et al., 2008). At all the mills there were one employee in such position and he or she was also among the persons being interviewed. Though their job titles varied (e.g. process engineer, energy manager, energy management coordinator etc.) it became clear as they described their work tasks that they were in the EnMC position at the mill. Coordination in the multi-divisional structure common for a pulp and paper mill involves work planning, communication and following up the progress. Internal communication was conducted with appointed staff members and also, though less frequently, with management representatives, i.e. production manager, energy manager, the manager of the mill. External communication involved the EnMC reporting to authorities according to regulations on energy and environmental matters. Common for all mills was that the EnMCs were not solely occupied with work on energy management as they all had multiple tasks to handle. A substantial part of their work, however, equalling about 25 percent of full-time, was devoted to EnMS activities.

#### MANAGEMENT AND STAFF COMMITMENT

The commitment from management is considered crucial for successful EnMS operation (Capehart et al., 2008). For some mills the EnMS was represented by a person in the top

Table 1. The interviewed mills.

Mill	No. of employees	Prod. [kt] p=pulp / pp=paper	Electricity use [GWh]
◆	355	p: 380	284
■	720	p: 170, pp: 335	504
▲	150	p: 30, pp: 55	67
×	950	p: 555, pp: 600	820
✖	900	p: 625, pp: 830	2036
●	190	p: 40, pp: 30	88
+	870	p: 600, pp: 495	718
-	400	p: 403	486

*Data from 2008 or 2009. Source: SFIF (2011)*

management group who was also the signatory of the energy policy. In other mills the EnMC, though not being member of management, was the appointed management representative. In any case, the interviews with the EnMCs confirmed that top management was supportive in the work for energy efficiency improvement. The participation in PFE was an important incentive in this regard. Mills that belonged to larger company groups with strong production bases in Sweden were often involved in group-wide activities about energy efficiency to exchange experiences and knowledge build-up.

Given the complexity of a pulp and paper mill, i.e. production processes that involve people with advanced technology and are fuelled with different energy carriers through an infrastructure of conversion and distribution technologies, the EnMC cannot independently keep control over the entire EnMS domain. Also, given the number of staff in these large size plants, often between 500 and 1000 employees plus some contracted personnel, it is impossible for a sole EnMC to directly communicate and engage with the entire work force. For energy management practices to spread across the mill staff in various positions and with different competences will have to be engaged to support the EnMC.

It was clear from the visited mills that all EnMCs had certain contact persons within the organisation. Most often the EnMC had appointed contacts at each important production step which in an integrated pulp and paper mill typically includes the following divisions: wood preparation and debarking; pulping; bleaching; paper making (often by multiple paper machines). In three of the mills these contacts were referred to as division-level EnMCs which clearly indicates their connection to the EnMS. In other mills, without making this designation, it was an agreed task of process engineers to report to the overhead EnMC whenever needed (e.g. in case of deviation from normal operation).

The EnMS teamwork can be organised in different ways, but Capehart et al., (2008) recommends a structure with one technical committee and one steering committee. The former consist of people with strong technical background that can assist the EnMC and division-level staff in specific situations and also keep the organisation updated on the advancement of energy efficient solutions. The role of the steering committee

should be to assist the EnMC in guiding the EnMS activities and raise awareness at division-level. None of the interviewed mills had established two distinct committees. Instead, in all the mills there were at least one and sometimes several energy management groups of mixed composition. In practice the basic function appears to be the same. A group typically consisted of the EnMC, division-level process engineers and technical experts enrolled from the maintenance as well as from the project department. They met regularly a few times per year in order to evaluate the list of proposed energy efficiency measures and prepare decisions on implementation.

To quantify the total staff involvement, the EnMCs were asked to estimate the number of employees directly involved in work related to the EnMS and energy efficiency improvement, either from time to time or on a more regular basis. The estimates varied from 6 to 50 persons, which depending on the size of the mill corresponds to between 2 and 5.5 percent of the entire staff.

### ENERGY COST ALLOCATION

A common barrier to energy efficiency is the split incentive situation that arises when end users are not held accountable for the costs of their energy use. In a manufacturing industry this occurs when energy costs are accounted for as part of the general overhead, which will give less incentive for a division in the plant to reduce its energy use. To overcome the potential split incentive barrier, the plant's energy use should be sub-metered to enable cost allocation based on the actual consumption of each division or important process that constitutes a cost centre. In their study Thollander and Ottosson (2010) examined the status of energy cost allocation in the Swedish PPI and concluded that: 66 percent made energy cost allocation based on sub-metering; 8 percent based on square meters; and 5 percent based on number of employees. The remaining 21 percent made no allocation at all.

The interviews confirmed that sub-metering and related energy cost allocation, as well as energy revenue allocation (e.g. some divisions supply others with steam) can be a complex issue in a pulp and paper mill, which is probably the case also for other heavy process industries. On the basis of their production processes all the mills are organised into divisions and in all but one mill each division also represents a cost centre. A category of five mills claimed to be allocating energy costs based on the actual usage controlled by adequate sub-metering systems for electricity and steam, consisting sometimes of up to 80 metering points. Some of these mills could also express the specific consumption of different fuel types (e.g. bio-energy, fuel oil, and diesel) down to division-level. These five mills were rather content with their sub-metering system but could anyway express some difficulties concerning the precision of the electricity metering as some processes were simultaneously fed from several low voltage switchgears. This was a greater concern for a second category of two mills. Their number of switchgears was insufficient for doing an electricity cost allocation based on constant sub-metering. Instead the energy invoice was approximately allocated to the division level by the help of periodic use of portable metering equipment. Improvement of the metering system was planned by one of these mills. One mill was organised as a single cost centre. It was anyhow divided into larger production processes and equipped with an adequate sub-me-

tering system to monitor the specific energy consumption of each such process. This represents an interesting case where the information on process level energy consumption is accessible and visible to staff and management, while the economic incentives for division level energy efficiency improvement are not as apparent.

A special case for several mills was compressed air, an energy carrier often regarded as a common resource. Hence, the cost allocation to the divisions needs to be done by some other means than a consumption based rate. It is stated by at least three mills that the common ownership of the compressed air system, with the maintenance department being responsible for service, makes it difficult for staff at the division level to identify measures on this equipment. These mills also stated they have implemented none, or only a few, measures related to compressors or sealing of air leakage.

### MONITORING AND REPORTING

In addition to cost allocation it can be discussed how a sub-metering system can support monitoring of specific energy consumption and the assessment of the production's energy performance. With a capacity to gather substantial amount of energy related data it is also of interest how such data is being transferred and reported internally, and perhaps externally, to stimulate energy efficiency improvement. Moreover, whenever an energy efficiency improvement measure is implemented, the EnMS should make sure that energy savings are estimated and verified in an appropriate manner.

Five mills had automatic meter reading to assimilate real-time data from the metering devices (mainly for electricity and steam) and transfer it to a database accessible via the companies' intranet. Depending on the size of these mills the number of meters, for electricity and steam consumption, varied between 20 and 80. The energy consumption data was combined with physical production data to provide the specific consumption of different energy carriers (e.g. kWh/ADMt<sup>7</sup>). Continuous monitoring was used to confirm that acceptable levels were maintained. At one of the mills there was an alarm being triggered upon significant deviation. This called for a prompt reaction from the responsible process engineer to find an explanation and possible solution to the abnormality. Another mill mentioned a procedure of reporting eventual deviations at daily meeting and shift changes to facilitate a follow-up on such information. Several mills mentioned that data on specific consumption was used to keep track on processes identified as significant energy aspects by the EnMS. The electricity-intensive thermo mechanical pulping process provided one example where sub-metering data was used to compare the performance of refiners and make evident, for example, a need for replacing refiner plates. At all mills the EnMCs compiled reports to make annual comparisons of the specific energy consumption for different energy carriers. This was done on the plant level and, whenever sub-metering allowed for it, at the division or process level. Two of the mills mentioned that this was done even on a monthly basis.

Due to their participation in PFE, all mills are required to identify and implement electricity savings measures with a

7. ADMt stand for air-dried metric tonnes of pulp.



payback period of less than three years. In their reports to the SEA they also have to estimate the size of achieved savings. For answering to this but also driven by internal company demands the mills had developed methods to assure evaluation of their measures. To some extent such methods was practiced also before the EnMS, but most mills claimed they had made advancements. In a survey of the whole PFE collective, 80 percent of the PFE participants claim that the EnMS has introduced new methods for monitoring energy use that have been valuable for the energy efficiency improvement (Hörnsten & Selberg, 2007).

The interviewed mills described their methodologies applied for evaluating electricity savings as a combination of engineering estimates using on-site data and direct metering of the end-use load. For energy efficiency measures on motors, portable metering equipment has been used to meter the electricity consumption during a couple of days before implementation. After the installation the equipment has been metered again and the difference in load has been multiplied by the normalised annual hours of operation. The result constitutes the annual electricity savings. When direct metering has not been feasible the electricity savings have been estimated based solely on theoretical calculations. Sometimes this is the preferable method (i.e. being more accurate) as can be the case for pumping equipment with an intermittent operation.

#### TRAINING

Training is another aspect and requirement of a standardised EnMS. Staff in different divisions and with specific work tasks will have diverse opportunities to influence the energy performance of the manufacturing processes. Supportive training may be essential if this is to be realised in the best possible way. As part of the EnMS it should be identified what type of training that is needed and for what staff. Since energy efficiency improvement can be achieved from different angles (e.g. operation & maintenance, procurement, project planning etc.) several target groups may benefit from training. Since organisations are changing (e.g. staff is being replaced) and technical systems are being altered (e.g. new technology is being installed) training needs to be given continually.

The interviews gave diverse answers concerning the training that had been conducted since the EnMSs had been introduced. A distinction should be made between actual training sessions and dissemination of information. To the former category belongs both examples on broad training or lecturing targeting awareness raising among all employees, but also more specialized training for certain operators of equipment. At all mills the EnMCs had spread the information to all employees about the existence of an EnMS to facilitate energy efficiency improvement. This action cannot be considered training but rather a call for everyone to be aware and support the work. At these occasions, the staff have been encouraged to identify and give own proposals on energy efficiency measures.

At two of the mills all employees, more than being informed, had received a few hours lecture on energy and environmental issues of importance to the mill. Included in these sessions were facts about policies at the national (e.g. PFE, environmental regulations etc.) as well as the international (e.g. EU-ETS) level, and how these affect the activities and business. These broad training sessions were intended to build an understanding among the staff for the energy related goals formulated by

the organisation. The aim was to stimulate staff to become more cooperative and take personal responsibility for improved energy efficiency, for example, by being alert on the operation and condition of equipment (e.g. to avoid unnecessary idle running). The Swedish EnMS standard state that the need for training should be identified and satisfied among employees in positions to influence the significant energy aspects. Several respondents expected international EnMS standards to make more explicit specifications and could thus foresee that efforts for training and awareness-raising would need to be improved in the future compared to current practices.

At five mills it was mentioned that they offered specialised training for staff with larger influence on the energy performance of manufacturing processes. Courses were held in optimised operation of the most energy demanding equipment such as pumps and boilers. A few mills pointed out that such training was carried out also before the EnMS implementation. On the other hand, at some mills it was claimed that the role of operators had become more autonomous over the last years. On the basis of their educational and practical skills they are expected to steer their work according to best practice.

#### Quantified electricity savings

After five years participation in PFE (i.e. 2005-2009), companies were required to report their achieved electricity savings from different categories of measures. The main category includes technical and other operation and maintenance (O&M) measures. Some measures were identified through the required energy auditing activities that were undertaken in the first two years of PFE. Other measures were identified thereafter as a result of the EnMS practices that received certification in the second year of the programme. Technical measures typically involve replacing or improving certain equipment, which in the PPI often relates to pumping systems. There are also many examples of zero-cost measures like shutting down unnecessary equipment and improving operation practices. Another category of measures are the routines for energy efficient procurement and project planning that PFE requires. The purpose is that companies should acknowledge the life cycle cost (LCC) in its procurement and investment decisions and possibly give preference to energy efficient alternatives (SEA, 2006). Procurement routines should be applied to electrical equipment (e.g. motors, pumps and fans) that is using more than 30 MWh per year. Project planning routines should guide the investment decision in case of larger renovations at the production site. These kinds of assessments were partly new to the mills when they entered PFE, but eventually have become integrated in their EnMS practices. For the interviewed mills Table 2 shows the size of reported annual electricity savings from the different categories. The total of reported annual electricity savings for a mill is commonly around three percent, though the sample's high and low deviates quite much.

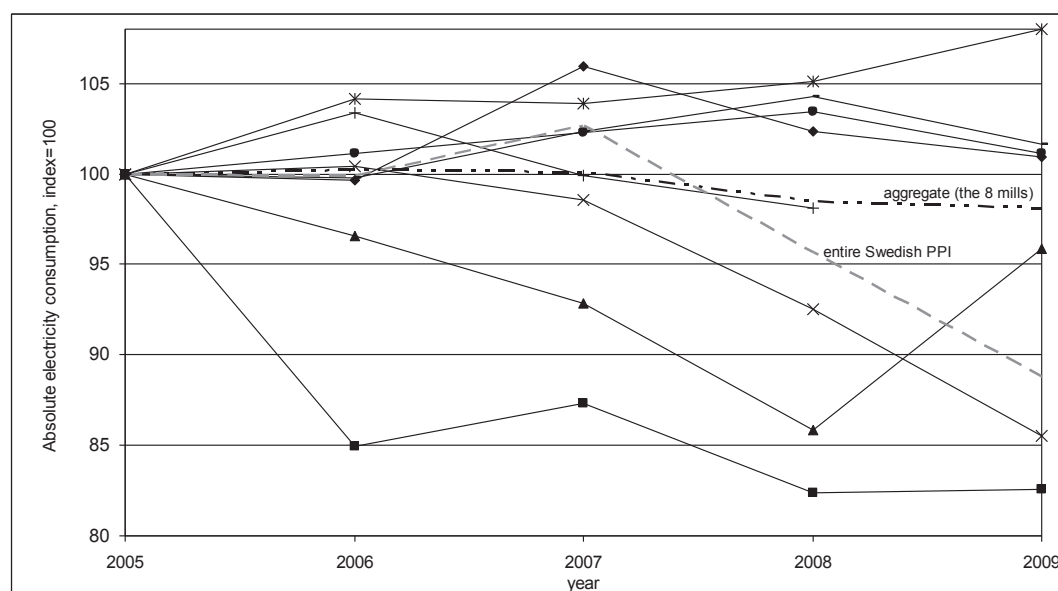
Figure 2 displays, for the eight mills, the absolute electricity consumption over the period 2005-2009. Four mills have decreased their electricity consumption, of which two with a substantial amount of about 15 percent. On the other hand, the other four mills have increased their electricity consumption, of which one with about 8 percent. The aggregated result for the eight mills shows a moderate decrease compared to the aggreg-



Table 2. The mill's reported annual electricity savings under PFE.

Mill	Categories of reported annual electricity savings			Sum of annual elec. savings	
	Technical and O&M measures [MWh]	Procurement routines [MWh]	Project planning routines [MWh]	[MWh]	Relation to 2004 elec. demand [%]
◆	6571	8	1787	8366	2.9
■	26016	554	270	26840	4.4
▲	8044	63	5	8112	8.6
×	32384	380	390	33154	3.5
✱	57701	794	1509	60004	3.2
●	1115	100	63	1278	1.5
+	26710	300	2500	29510	4.0
-	11887	199	377	1763	2.7
<b>Sum</b>	170 428	2398	6901	179 727	3.5 (3.85 in average %)

Source: SEA (2011b)



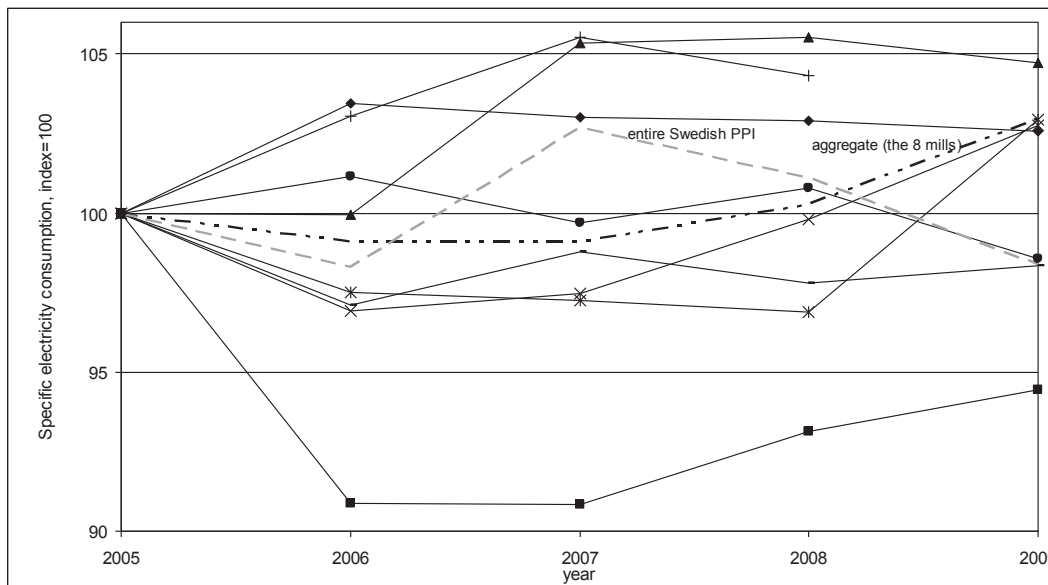
Source: SFIF (2011)

Figure 2. Electricity consumption for the eight mills (2005–2009).

gate for the entire Swedish PPI, which decreased its electricity consumption by 10 percent over the period. With regards to the figures in Table 2 there is no general consistency between the size of reported annual electricity savings and the development of absolute electricity consumption. This can be due to several reasons since different conditions influence the energy consumption of an industrial plant, the most evident being production volume, production mix and weather conditions. During 2008 and 2009, for example, many mills experienced low production volumes following the global recession. Also, depending on production mix and periodic variations in energy markets a mill may favour one fuel input over another, for example, to increase steam production from an electric boiler. Varying conditions like these will cause annual energy savings to differ from pre-estimated values. In their engineering estimated values the mills have commonly normalised the annual

hours of operation, but the fact that equipment run on variable loads may be more difficult to adjust for.

In order to take account of physical output Figure 3 displays, for the eight mills, the specific electricity consumption (SEC) over the period 2005–2009. The physical output of each mill is defined as the annually produced tonnes of market pulp and final paper products. Three mills have decreased their SEC while five mills have experienced an increase. For some mills it might be a disappointment that despite hard work with electricity efficiency improvement under PFE, their SEC is increasing. The period 2008–2009 has been exceptional, though, due to the low production volumes at many mills. Because of the idling losses such situations tend to drive up the SEC. This is noticeable for three mills and since these are large size mills this has also shaped the aggregated result.



Source: SFIF (2011)

Figure 3. Specific electricity consumption for the eight mills (2005–2009).

In their EnMS the mills can of course formulate SEC-targets based on different base and target years. Some mentioned 2003 and 2010 respectively and hence their prospects for target achievement could be much better than made evident by Figure 3. For some mills it has not been an EnMS target to reduce specific electricity consumption. Therefore it is possible that other EnMS targets like the reduction of specific fuel oil consumption may result in a shift to electricity.

### Conclusions

The interviews exposed some differences in how the mills had structured their EnMS practices. Though the standard document provides a common guideline, there is no uniform model for how an EnMS is realised in an organisation. Still, each mill has received certification from an authorised third-party auditor. This explains the underlying idea of management systems, that objectives are set by management to reflect the ambition level with respect to context and challenges (e.g. cost structure, demand from customers and other stakeholders, physical infrastructure, previous experience, and perception about the future).

All mills had an appointed person, an EnMC, being responsible (though only at part-time) for coordinating the EnMS activities. By arranging and chairing regular meetings with division-level staff the EnMC has a central role in structuring the EnMS. The mills with appointed division-level EnMCs have further enhanced this structure. This way of embedding the EnMS throughout the organisation is reasonable, not the least in large multi-divisional mills, where each division represents a cost centre and thus have to take decisions about implementation of energy savings measures. Support from the main EnMC and technical expertise from maintenance and project departments is provided by the EnMS framework.

The allocation of staff and resources to support the EnMS is a management issue. The fact that a quite a share of the work

force (between 2 and 5.5 percent) has been directly involved in EnMS activities shows that mill management have been committed to the task. It is difficult to state an optimal level of staff involvement. As a minimum, all employees should be aware of the existence of the EnMS and whom to direct for related issues. As a guideline for a large process industry that plans to implement a standardised EnMS, an effective operation will require direct (though at a moderate part-time) engagement from 3-5 percent of the work force.

Inadequate energy cost allocation could provide a barrier to improving division-level energy efficiency improvement. The issue is closely connected to the issue of sub-metering that enables more precise energy cost allocation. A few mills lacked the satisfactory infrastructure and it should be an EnMS objective to make improvements on this area. Mills with advanced sub-metering systems have the advantage of being able to set specific targets on process levels and continuously monitor the progress of such energy aspects. For the majority of mills the practices on monitoring and reporting energy savings have improved since the introduction of the EnMS. It remains a challenge how to further improve these practices, for example, in the case of compressed air systems which is viewed as a common resource and therefore attracts less attention at the division-level.

The training of staff is an EnMS activity that has been treated differently by the mills but overall it has not been highly prioritised. Improvements could be made to identify the actual target groups for specialised training. Especially the routines on procurement and project planning that to some extent introduced new ways of thinking in the mills could be areas to address. This would involve procurement and project departments more heavily in the EnMS and could probably be motivated for keeping pace with the advancements of energy efficient technologies.

The Swedish as well as the European standard does not include any explicit specifications about issues concerning en-

ergy efficient project planning and/or procurement. For the mills these requirements were introduced as part of PFE and the results show that these routines were able to attain sizeable amounts of energy savings at some mills, though less at other. In the forthcoming ISO 50001 the need for evaluating energy performance in the design of new or renovated facilities as well as for procurement of equipment and services will become highlighted. The mills are thus prepared for a transition to the international standard. For a complete newcomer that plan to implement an EnMS according to the international standard the introduction of design and procurement routines will likely become challenging though potentially rewarding.

Reported annual electricity savings shows that the EnMS practices have resulted in actual savings, commonly about 3 percent compared to the electricity demand of the base year. Yet, when studying how absolute and specific electricity consumption was developing over the period 2005-2009, the impact from these measures was not always evident. This analysis is partly disturbed by the low production volumes in 2008-2009. A more complete picture of how energy intensity has developed in the PPI would require an analysis of the primary energy use. Also, the delimited five-year period is too short to deduce any real trends in electricity intensity. A comprehensive top-down study could be performed to examine the energy intensity over a longer time period. With a decomposition approach it could be estimated to what extent that energy efficiency improvement has influenced the development.

Since the European standard was published in 2009 and the international ISO 50001 will become available in 2011, the short-term future will tell if standardised EnMS is to be introduced by companies on a global scale. Though it might seem rational for companies to do so, they may not actually adopt EnMS on its own merit. This means that government's executive agencies within the framework of energy policy implementation will need to consider whether or not to incentivise an uptake of EnMS in different industrial sectors. In countries where national EnMS standards have already been developed, the dissemination has often been facilitated through voluntary or long term agreement on energy efficiency. The Swedish PFE provides one example on how to combine a moderate financial incentive with regulations to promote a rich set of attention raising activities including EnMS. Apart from the cost-effective savings achieved, an important result is that 100 companies and 250 industrial sites now have certified EnMSs. Some of these can provide good practice examples for other companies to follow.

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