Energy management in Swedish pulp and paper industry – benchmarking and non-energy benefits

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Keywords
energy management, non-energy benefits (NEBs), benchmarking, pulp and paper industry, energy performance benchmarking

Abstract
Manufacturing industry has a large energy efficiency potential, yet to be utilized, known as the energy efficiency gap. This gap exists due to barriers that hinder industrial companies from making energy efficiency investments. Research also shows that the gap is even larger if energy management practices are included as well. One type of energy management practice for industrial companies is energy performance benchmarking, which deals with several organisational applications. For example, energy performance benchmarking can be used to compare a company's degree of energy efficiency to its peers. A benchmarking approach can also be adopted on different levels of aggregation, including sector, site, and process level. Furthermore, continuous work with energy management also entails additional benefits beyond the energy effects, known as non-energy benefits. In an energy management context, these benefits might for instance be organisational or informational in nature. The aim of this paper is to study these aspects of energy management – benchmarking and non-energy benefits – within the Swedish pulp and paper industry.

These aspects of energy management have not, to the authors' knowledge, been extensively investigated. The adopted method for data collection is a mixed method approach, where a questionnaire was sent to all operating pulp and paper mills in Sweden, and semi-structured interviews were carried out at six mills. The findings in this study show that the most common benchmarking method in the Swedish pulp and paper mills is external benchmarking within a company group. The benchmarking method with the highest perceived value for a mill's energy management, however, is historical benchmarking of energy use. Furthermore, the pulp and paper mills have perceived a number of non-energy benefits from energy management practices, where top management's interest in energy efficiency issues increasing more than expected was perceived as the most substantial.

Introduction
Globally, the industrial sector accounts for about one-third of total energy end-use (IEA, 2015). The share in Sweden is even larger; approximately 40 % of energy end-use in the country originates from industry, mainly from the energy-intensive sectors: pulp and paper, iron and steel, and the chemical sector (SEA, 2015). The pulp and paper sector accounts for about half of the total industrial energy end-use in Sweden (SEA, 2015). Swedish industry, in particular the pulp and paper industry (PPI), relies on electricity and biofuels as primary energy carriers (SEA, 2015). Therefore, for companies belonging to the Swedish PPI, improved energy efficiency and reduced electricity use are important means to improve overall efficiency and stay competitive. However, even if energy efficiency in these companies has been prioritized and contributed to improvements in energy use as well as in environmental and economic aspects, there still seems to exist a potential for greater energy efficiency. The potential is due to the fact that the theoretical level of existing cost-effective energy efficiency measures is not equal to the realized level. This difference is known as the energy efficiency

gap (e.g. Hirst and Brown, 1990). This gap exists due to industrial companies facing barriers that hinder them from making energy efficiency investments. In a study of the Swedish PPI the existence of this gap has been confirmed, but the magnitude of the energy efficiency potential was not explored (Thollander and Ottosson, 2008). The prevailing situation has not yet been investigated, although previous studies have shown that this gap is even larger if energy management practices are considered as well (Backlund et al., 2012). Recent studies by Paramonova et al. (2015) showed that at least 35 % of the total energy efficiency potential in large Swedish energy-intensive companies was devoted to energy management procedures. In a later study of Swedish industrial companies, Sa et al. (2017) found major barriers to positive decisions on energy management activities: access to capital; time and expertise; awareness and uncertainty; practice characteristics; risk; and industry's complexity. Sa et al. (2017) further argues that these factors can also act positively, as drivers for energy management activities within a company. Hence, to fully deploy the industrial energy efficiency potential, barriers to cost-effective energy efficiency technology measures and barriers to energy management procedures both have to be overcome. Energy management therefore constitutes important opportunities to further reduce energy use and improve energy efficiency in industrial companies.

In their review of energy management literature, Schulze et al. (2016) observed that energy management, as a concept, was defined and interpreted in different ways, and identified five key areas: strategy/planning, implementation/operation, controlling, organisation, and culture. The controlling area is, according to Schulze et al. (2016), divided into energy accounting, performance measurement and benchmarking, of which benchmarking, and energy performance benchmarking in particular, can be applied to compare a company's degree of energy efficiency with its peers. A benchmarking approach can be adopted on different levels of aggregation, including sector, site, and process level.

The area of energy management that constitutes implementing and operation is divided by Schulze et al. (2016) into energy audits, energy efficiency measures/activities and investment decisions. Previous research shows that implementation of industrial energy efficiency measures can yield additional effects (benefits) beyond the energy savings, so-called non-energy benefits (NEBs). However, possible NEBs of having implemented energy management activities and continuously working with energy management procedures have not been widely studied to the authors' knowledge.

The aim of this paper is to study these aspects of energy management within the Swedish PPI, with focus on the following research questions:

- How is energy performance benchmarking operationalized in the Swedish PPI?
- How are NEBs considered in energy management activities within the Swedish PPI?

Therefore, this study seeks to explore how information on energy performance benchmarking and NEBs can contribute to energy management practices in the Swedish PPI.

The remainder of this paper starts with a background of energy management in general, energy management in the PPI and in particular in the Swedish PPI. The background section also introduces the concepts of benchmarking and NEBs. This is followed by a description of the applied method, and presentation of the findings. The paper ends with a concluding discussion.

Background

ENERGY MANAGEMENT

Energy management as a concept has been described and interpreted in various ways (Schulze et al. 2016). In their review of energy management literature Schulze et al. (2016) found that the definition of energy management varied depending on the scope and to what degree and level (strategic, operational or tactical) energy management was integrated in the company (cf. Abdelaziz et al., 2011; Bunse et al., 2011; Kannan and Boie, 2003). However, Schulze et al. (2016) identified that the elements of industrial energy management could be structured into five key areas: strategy/planning, implementation/operation, controlling, organisation, and culture. The area of strategy and planning included strategy and policy for energy, operational energy planning and strategic energy risk management. Furthermore, Schulze et al. (2016) divide the implementation and operation area of energy management into energy audits, energy efficiency measures/activities and investment decisions. The controlling area, according to Schulze et al. (2016), constitutes energy accounting, performance measurement and benchmarking, whereas organisation consists of energy manager, integration, and standardization. The last area, culture, includes education and training, staff motivation and internal communication. Based on their review results, Schulze et al. (2016) propose to define energy management as follows: 'Energy management comprises the systematic activities, procedures and routines within an industrial company including the elements strategy/planning, implementation/operation, controlling, organization and culture and involving both production and support processes, which aim to continuously reduce the company's energy consumption and related energy costs'. Energy management is sometimes used in the same sense as energy management systems, but the terms are not the same. Energy management, as described above, basically refers to companies' strategic and continuous procedures on energy issues, while an energy management system comprises the tools for energy management (Thollander and Palm, 2013).

Schulze et al. (2016) breaks down energy management even further into smaller constituents, or as denoted by the authors, 1st Order Concepts, in which benchmarking and NEBs are included. This paper, as stated in the introduction, will focus on benchmarking and NEBs in relation to energy management, which means a particular focus on two of Schulze et al.'s (2016) dimensions of energy management: implementation/operation and controlling. The first dimension includes the concept of NEBs and the latter covers the area of benchmarking. These topics will be introduced and further described below.

ENERGY MANAGEMENT IN THE SWEDISH PULP AND PAPER INDUSTRY

In 2016, the Swedish PPI produced 3.9 million tons of pulp and 10.1 million tons of paper of which nearly 90 % was exported to other European countries (SFI, 2016a). Together with the production from the Swedish lumber mills, this makes Sweden the third largest exporter of pulp, paper and other wood products in the world (SFI, 2016b). The industry sector in Sweden accounted for 140 TWh, or 38 % of total energy end-use in 2016, with half of the industrial energy end-use from the Swedish PPI (SEA, 2017). The fact that production in this sector is energy-intensive makes the pulp and paper mills an interesting population to study regarding how these companies work with energy efficiency issues, e.g. how energy management is integrated in the mills. Moreover, many of the pulp and paper mills in Sweden have participated in a policy program for improving energy efficiency in energy-intensive industries (PFE), in which the companies were required to work in a structured way with energy management activities.

Thollander and Ottosson (2008) concluded that, except for cost reductions due to energy savings, people with real ambition (e.g. a committed energy manager) and long-term strategy were the highest ranked driving forces for energy efficiency in the Swedish PPI. The authors stress that these factors are important since these elements indicate a need for energy management procedures in a company. Further, the findings of the study also revealed that many of the barriers found to implementing cost-effective energy efficiency measures in the Swedish PPI were related to how energy issues are organised within the companies, for instance, lack of time or other priorities, slim organisation, other priorities for capital investments, lack of staff awareness and long decision chains. This, together with the drivers discussed above, addresses the importance of working with energy management in pulp and paper mills in order to improve energy efficiency in this sector. Furthermore, energy management might lead to several energy efficiency measures of, for instance, behavioural and organisational nature and these measures are often low-cost measures with attractive payback periods (Paramonova et al., 2015).

ENERGY EFFICIENCY BENCHMARKING

A basic principle of energy efficiency benchmarking is to compare the performance of a pre-defined system to a reference system (Ke et al., 2013). One motivation to carry out benchmarking is to raise awareness of energy performance and find areas of potential energy efficiency improvement. As benchmarking is a controlling element in an energy management framework, it can provide feedback for the energy strategy and energy target setting (Schulze et al., 2016). This applies both to policy design as well as to companies and company groups, making benchmarking programs valuable for both policy makers and business leaders (Boyd, 2016). Energy efficiency benchmarking can be carried out on different levels of detail, e.g. single pieces of equipment or entire countries, depending on its purpose. The standard on energy efficiency benchmarking (EN 16231) provides a methodology to collect and analyse energy data, and how to compare the energy efficiency within or between entities (Swedish Standards Institute, 2012). Benchmarking is carried out either internally or externally. An example of internal benchmarking is to compare an energy end-use process to itself using a reference value from an earlier point in time (Peterson and Belt, 2009). A comparison of an energy end-use process to best available technology (BAT) or to an industrial company's peers is considered external benchmarking.

The selection of system boundaries and energy performance indicators is important to enable relevant benchmarking. A simple indicator of energy efficiency comparisons is the ratio between energy input and unit of production (e.g. ton pulp), often referred to as specific energy end-use[1] (SEC). This type of indicator is commonly used in benchmarking studies of energy efficiency where a process-specific approach is applied, in the paper industry (Laurijssen et al., 2013) as well as other industries (e.g. Spiering et al., 2015; Worrell and Price, 2006; Xu et al., 2009).

However, SEC in its simplest form is influenced by effects of structural differences in an industry which need to be accounted for (Phylipsen et al., 1997). These effects include the mix of processes and mix of products, both of which have to be considered in the PPI. Regarding mix of processes, a continuous digester for instance is generally more efficient regarding thermal heat use than a batch digester, but the same end product is possible. Regarding mix of products, the share of different paper qualities produced in a mill affects the amount of energy use. Thus, if SEC is used as a performance indicator, these factors need to be normalized in order to enable a comparison between pulp and paper mills. On a less aggregated level (e.g. process level), structural differences are less prevalent (Phylipsen et al., 1997). Still, even if similar processes are compared the end product has to be accounted for, since e.g. high-quality pulp needs longer digesting than a lower quality pulp.

NON-ENERGY BENEFITS

The implementation of energy efficiency measures in industrial companies plays an important role in improving industrial energy efficiency and cutting energy costs. In addition to saving energy and reducing energy costs, the implementation of energy efficiency improvement measures has also been shown to give other effects which can be beneficial for an industrial company. These additional effects are known as non-energy benefits (NEBs) and have been observed at different levels in industrial companies. Finman and Laitner (2001) and Worrell et al. (2003) divide observed NEBs in a company according to where in the company the benefits have been perceived: production, operation and maintenance, working environment, waste and emissions. This shows the diversity of the possible NEBs that can arise as a consequence of implemented energy efficiency improvement measures. Moreover, this also addresses the potential extra values that implemented energy efficiency measures might add in the various parts of a company. As described above, energy management encompasses several key areas. Schulze at al. (2016) include these types of NEBs as one of the concepts in the Implementation/Operation area. Hence, NEBs of implemented energy efficiency measures are included as one of several constituents that build energy management. However, to the authors' knowledge, possible additional effects of energy management have not been addressed in a comprehensive way in previous studies.

Björkman et al. (2016) describe additional benefits of a Swedish energy efficiency program (PFE), a policy instrument for improving industrial energy efficiency in energy-intensive

1. The term is more commonly referred to as *specific energy consumption*, but in accordance with the first law of thermodynamics, the term energy use is applied in this paper.

companies that ran from 2004 to 2014. The program required involved companies to implement energy management practices as well as an energy management system. In addition to the energy efficiency measures that were realized by the participating companies, energy management systems were implemented by all companies. The system integration required the following components: persons officially dedicated to the energy efficiency work within the company, increased number of targets and follow-up in sustainability reports, education and training done by key competence staff as well as all other staff, increased internal and external communication for feedback and customer relations, and setting up and monitoring an increased number of key performance indicators. All these components could be considered as elements of energy management. In the evaluation of the program the participants stated several additional beneficial effects related to planning and control, capital budgeting, human resources, and energy culture. Benefits stated by the companies were, for instance: energy efficiency received substantially higher management attention; easier to get access to internal investment capital for energy efficiency investments; lowered the perceived risk to introduce new solutions; education and training programs were performed; increased awareness in the companies' organisations of energy efficiency issues; energy efficiency became a part of the daily agenda with increasing awareness of its importance; energy cost reductions and other cost reductions; and participating companies were taking multiple energy benefits into account when making energy efficiency investment decisions.

Method

As this study seeks to investigate how energy performance benchmarking is operationalized and how NEBs are considered within the Swedish PPI, a quantitative approach was adopted using a questionnaire for data collection. The questionnaire contained a number of questions to elucidate to what degree different levels and types of benchmarking activities are conducted. In addition, a number of statements of Likert-type scale ranging from 'do not agree at all' (1) to 'fully agree' (5) were included to analyse the perceived value of benchmarking practices and 'no change at all' (1) to 'substantial change' (7)[2] to analyse the perceived existence of NEBs for decision-making activities in pulp and paper mills' energy management. A Likert-type scale is a commonly used measurement when investigating attitudes of a certain theme (Bryman, 2008).

The PPI in Sweden consists of 50 mills, divided into 10 pulp mills, 13 paper mills, and 27 integrated pulp and paper mills. Thirty-seven of the mills are part of a larger company group with at least two mills located in Sweden. The remaining mills are either not part of a company group or the sole mill in Sweden in a company group. Each mill was contacted prior to sending the questionnaire, where the mills themselves decided who was most suitable to respond (someone with energy responsibilities, such as an energy coordinator or similar). While the energy coordinators at the mills were encouraged to respond to the questionnaire in a structured phone interview, they also had the choice to respond by filling out the questions themselves, in order to increase the response rate. To ensure that each respondent understood the context to which the questions referred, a definition of energy management was included in the questionnaire. In total, 28 complete responses were received, resulting in a response rate of 56 %. In comparison to similar studies, this could be considered high (cf. Brunke et al., 2014; Thollander and Ottosson, 2008).

In benchmarking practices, the reference value to which an entity is benchmarked can be determined either through a historical benchmark by comparing the performance of an entity to itself at an earlier point in time, comparing processes from multiple facilities within the same company, or by comparing with an industrial benchmark obtained from e.g. equipment manufacturers or experts in the field (Peterson and Belt, 2009). To cover different methods of benchmarking, respondents of the questionnaire filled in whether they conducted any of the following: (1) internal benchmarking of historical energy use; (2) external benchmarking of energy use with companies in the same company group; (3) external benchmarking of energy use with companies outside the company group; and (4) external benchmarking with best available technology (BAT). The same four categories were used to determine their perceived value of the types of benchmarking using a Likert-type scale. Furthermore, the benchmarking boundary can vary from comparing unit processes to an entire organisation (Swedish Standards Institute, 2012). Thus, the respondents also categorized the aggregated level in which their benchmarking were conducted, distributed on: (1) single piece of equipment's energy use; (2) energy use of a single process; (3) entire mill's energy use; or (4) another level of detail (to be specified). For the questions regarding types of and level of benchmarking, the respondents were allowed to fill in multiple responses.

In parallel with the quantitative data collection, interviews were carried out at six pulp and paper mills, to distinguish in-depth benefits and challenges regarding benchmarking practices. While it is difficult to compare quantitative data with qualitative data, the likelihood of data alignment increases if e.g. the interview and questionnaire items are similar, data collection is conducted during the same period of time, and participants belong to the same context (Harris and Brown, 2010). A total of 11 interviews were conducted, divided among six different mills, following a semi-structured approach (Kvale and Brinkmann, 2009). Similar to the questionnaire respondents, the interviewees had responsibility for energy issues in the company; seven of the interviewees were energy coordinator, energy engineer or similar, and the remaining four had a management position. The mills represented three different company groups, and consisted of both pulp mills and integrated pulp and paper mills. The qualitative data primarily serve to achieve a better understanding of pulp and paper mills' development and application of energy performance benchmarking practices.

Previous studies have shown various NEBs perceived at different levels in a company as a consequence of industrial energy efficiency measures (e.g. IEA, 2012; Nehler and Rasmussen, 2016; Worrell et al., 2003). However, NEBs of energy management activities and procedures have not been subject to such investigation. Björkman et al. (2016) have described additional effects that were perceived by companies participating in the Swedish Program for Improving Energy Efficiency in Energy

2. Questions about benchmarking and NEBs were designed to be in different parts of the questionnaire. Therefore, different Likert scales for benchmarking and NEBs have been applied.

Intensive Industries (PFE). The PFE required the participating companies to work with energy efficiency issues in a structured manner which also included implementation of an energy management system. These findings formed the basis for which benefits to include in the questionnaire. The following additional effects were tested: top management's and the organisation's interest in energy efficiency issues; energy performance measurement and evaluation; access to investment capital; additional/new personnel categories involved in energy efficiency issues; and employees' knowledge of energy efficiency. These effects could be considered to be parts of the energy management procedures and not additional effects. To avoid that, the questions aimed to investigate if these additional effects have changed more than expected to be able to count these effects as benefits.

Since one part of energy management comprises implementation of energy efficiency measures (e.g. Schulze et al., 2016), a few of the previously described NEBs, i.e., NEBs of implemented energy efficiency measures, were also included in the questionnaire and tested among the respondents. The selection of the NEBs aimed at covering various categories of NEBs. The following NEBs were tested: improved external environment; cost reductions beyond energy cost reductions; improved corporate image; increased productivity, and improved work environment. Hence, the NEB part of the questionnaire included a total of 13 questions about benefits.

Results

ENERGY PERFORMANCE BENCHMARKING

The questionnaire results regarding what benchmarking methods are practiced by mills and the methods' perceived values are shown in Figure 1 and Figure 2, respectively. As evident from Figure 1, only a small share of the mills in the Swedish PPI do not practice energy performance benchmarking at all. Many of the pulp and paper mills practiced two or more benchmarking methods. External benchmarking within a company group was the most practiced method where no additional method was adopted, but for mills to complement it with other methods was even more common. Two or more benchmarking methods were used by 61 % of the mills.

For individual benchmarking methods practiced in Figure 1, the most common methods were external benchmarking within a company group (64 %) and internal benchmarking (54 %). At the same time, internal benchmarking was perceived as the most valuable by a large margin (Figure 2). Of the mills that practiced internal historical benchmarking, 80 % considered this type of benchmarking valuable to a high degree (highest value). This could imply a learning-by-doing pathway, where the value of internal benchmarking is realized after it has been practiced. At the same time, 33 % of the mills that did not practice internal benchmarking also considered it valuable to a high degree. In total, only one of all responding mills considered it not particularly helpful. Thus, it is possible that, while a majority of the pulp and paper mills perceive internal benchmarking as useful, they do not prioritize resources for this, considering other energy management activities more important.

Furthermore, while external benchmarking of other mills within the company group was the most common method, it was only perceived as the second most valuable benchmarking method in the PPI (Figure 2). The reason this is also the most practiced benchmarking method could be an effect of larger collaboration projects initiated by company group management, where energy comparison is one of multiple purposes. Additionally, data confidentiality is not an issue when the data is shared within a company group, which facilitates that benchmarking method in particular in contrast to other external methods. This might in turn be one explanation for the low number of companies conducting benchmarking with mills outside the company group. An external benchmarking outside the company group might also limit the possibilities of a continuous discussion regarding differences in the results due to competitive reasons.

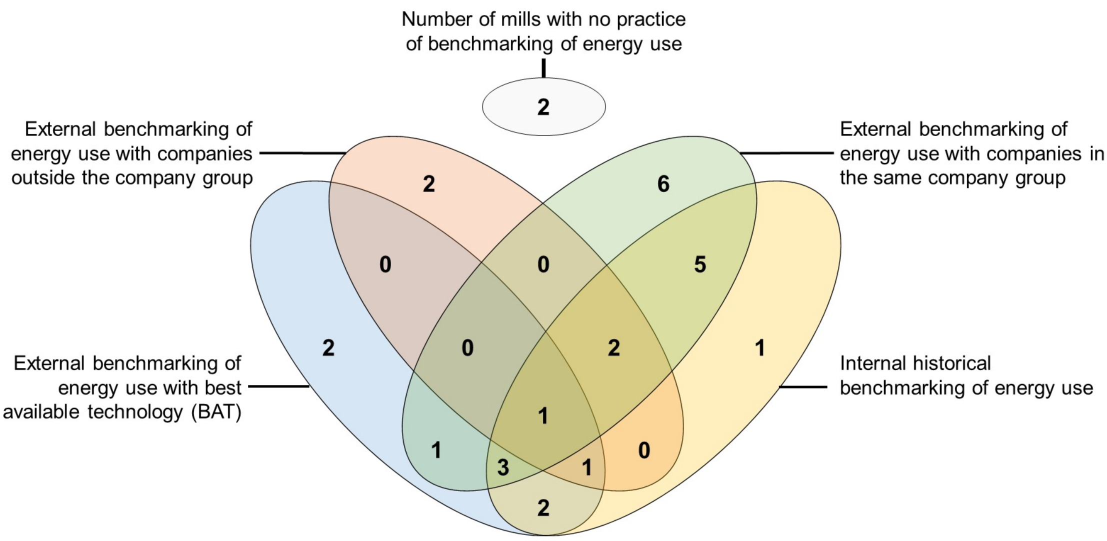

Figure 1. Venn diagram of methods of energy performance benchmarking practiced by pulp and paper mills, as shown by responses to the questionnaire (n=28).

The fact that benchmarking practices are more relevant on a process level is reflected in Figure 3. Benchmarking on single processes' energy use is carried out by 71 % of the pulp and paper mills. In addition, many mills combined benchmarking practice of processes with benchmarking of energy use of equipment as well as the entire mill. This combination was the second most common (Figure 3). Also, only one non-integrated paper mill practiced benchmarking on the process level. Two of the paper mills carried out benchmarking on another level, one of which was in-depth analysis of electricity use, however without specifying exactly how. For integrated pulp and paper mills, all except two conducted benchmarking on the process level.

The issue of differences in mill characteristics in a plant level benchmark was also recurrently mentioned by interviewees. In this regard, the respondent mills seem to prefer a less aggregated benchmark. If SEC is used as a performance indicator in the benchmark, a more detailed level of comparison generally reduces the effect of differencing factors such as process mix, since similar processes can be compared. However, due to the complex and intertwined processes in the PPI, as well as the mix of end products, these factors are still prevalent. This was also evidenced during interviews. Table 1 presents the main factors for benefits and challenges regarding benchmarking of energy performance, as derived from the interviews.

A few recurrently mentioned benefits of energy performance benchmarking are that it triggers motivation for action and creates awareness of whether process operations are reasonably in line with others in terms of energy use. A comparison, especially between similar process steps in the production lines, with follow-up questions of why values differ, might lead to identification of measures that can benefit the entire process operation. Additionally, one interviewee mentioned that the mill got actual results (benefits) from benchmarking practices together with mills inside the company group.

An interviewee in one company mentioned that the energy manager on company group level analysed energy end-use processes for all mills, and identified common challenges and possible solutions. Benchmarking of energy use was a natural part of the concept. In its initial stages, however, it became evident that each mill had its own understanding and system bounda-

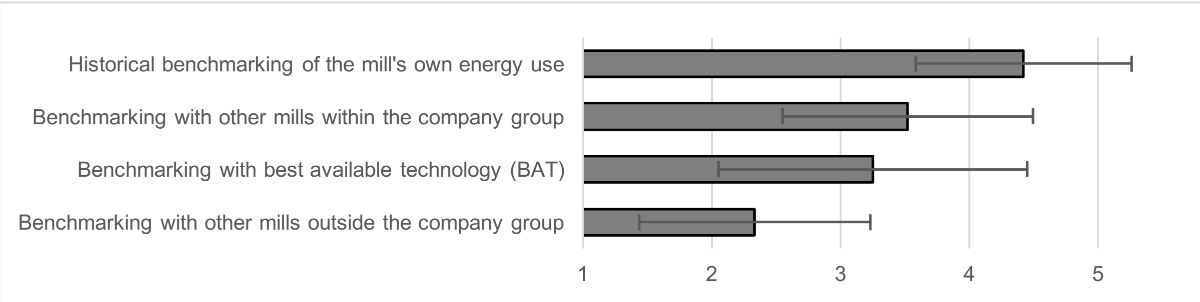

Figure 2. The pulp and paper mills' perceived value of different benchmarking methods, as shown by responses to the questionnaire, using a Likert-type scale ranging from 1 (not relevant at all) to 5 (relevant to a high degree). The standard deviation is also shown.

Figure 3. Venn diagram of number of pulp and paper mills practicing different levels of detailed energy performance benchmarking, as shown by responses to the questionnaire.

Table 1. Main factors identified for benefits and challenges experienced related to benchmarking practices, as derived from the interviews. Note that the interviews were conducted in Swedish, and the quotes have been translated into English.

Benefits experienced from benchmarking of energy use	
Main factors	**Quotes**
Creates incentives for further investigations	'You have to start contemplate why it appears the way it does'
	'Greatest benefit is when you come down to a detailed level, chain of "why"-questions'.
A positioning toward peers	'It is always good to know where you stand in comparison to competitors […] and that is a driver for everyone, I believe'.
	'Is it in-line with the rest of the world?'
Difficulties experienced with benchmarking of energy use	
Main factors	**Quotes**
Heterogeneity	'We absolutely do not want people to start comparing different things without understanding why it appears like it does'.
	'Every mill is unique in its set of processes'.
	'If you do not know how the numbers are derived, they [the numbers] do not say anything. You have to go into detail to be able to say something'.
Different taxonomies	'We all used our own terminology […] and it was incomparable'
Process integrations	'A mill is often so integrated, so it is hard'.
	'We may have chosen to integrate differently internally than what a reference [mill] has'.

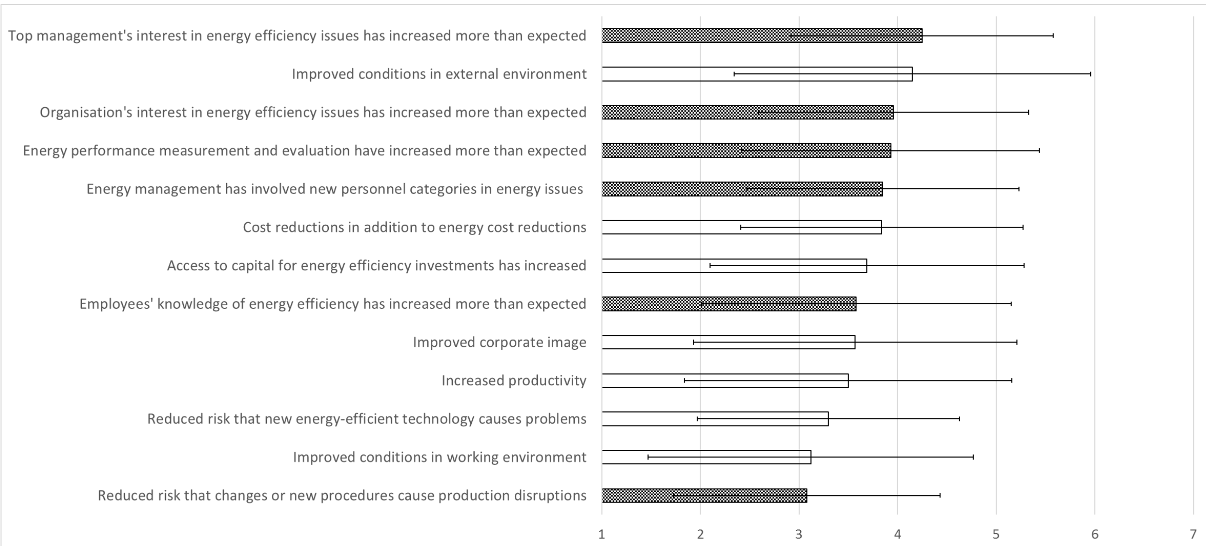

Figure 4. Perceived NEBs by the pulp and paper mills, using a Likert-type scale ranging from 1 (no change at all) to 7 (substantial change). Dotted: energy management NEBs, white: classic NEBs.

ries of certain steps. Knowledge of the processes by users was consequently required to understand causes behind differences. Due to every mill being unique in its production line and due to small differences in taxonomies used it is difficult to reach an 'apples-to-apples' comparison. Commonly mentioned difficulties of benchmarking regarded the heterogeneity, different taxonomies used, and how processes are integrated with each other.

Other ways to work with benchmarking were also carried out, one example being a model with theoretical performance indicators (best theoretical values) for energy end-use processes, which was used as reference mill to compare with. Being in its initial stage, this implied difficulty of making the mill's figures comparable with the theoretical best figures, but to some degree served as input to the energy management strategy.

As regards the level of detail of benchmarking, most interviewees proposed that a process-level approach is the most suitable when carrying out external benchmarking. This corresponds well with this also being the most commonly practiced level of benchmark, as shown in Figure 3.

NON-ENERGY BENEFITS OF ENERGY MANAGEMENT

The overall results, as displayed in Figure 4, showed that the mean value for the investigated NEBs ranged from just above 3 to slightly more than 4. These findings show that the mills have perceived positive changes for all the benefits studied due to their work with energy management practices.

The results show that the highest ranked benefit by the studied mills was increased interest in energy efficiency issues by top management, while increased interest in energy efficiency issues in the organisations in general was ranked number three. Moreover, the benefit that energy management has involved new groups of personnel in energy issues was valued as number five. Hence, there seems to be an increased interest in energy efficiency issues on different levels within the organisations and these organisational effects seem to be viewed as benefits of the pulp and paper mills' work with energy management. The second highest NEB stated by the pulp and paper mills was that conditions in the external environment have improved as a result of energy management. Due to pulp and paper mills being in various ways restricted and affected by environmental regulations, some of which are related to energy and energy efficiency improvements in particular, this might have influenced their opinions. For instance, it could imply a higher awareness of the additional effects energy efficiency might have on the external environment. Furthermore, the respondents who filled out the questionnaire were typically responsible for energy issues within the mills. However, their roles were sometimes combined with environmental responsibilities in the company, which could have contributed to a particular focus and awareness of environmental benefits in relation to energy management. An increase of energy performance measurement and evaluation due to energy management work was ranked number four by the pulp and paper mills. Furthermore, NEBs related to financial issues were also ranked relatively high, i.e., cost reductions beyond energy savings and increased access to capital for energy efficiency investments. These are also NEBs that have been perceived in relation to implemented energy efficiency measures, i.e., this relates to Schulze et al.'s (2016) dimension Implementation/Operation.

The results indicate slightly higher values for the energy management NEBs (dotted bars) as compared to the values for the classic NEBs (white bars). Hence, the mills have perceived classic NEBs, i.e., benefits due to implementation of energy efficiency measures, but also, to a slightly higher degree, NEBs of working with energy management procedures. It should be noted that the answers given varied among the mills, i.e., there was a spread to which extent the benefits have been perceived. This can be seen by the relatively large standard deviations given in Figure 4. Some of the mills have therefore not seen changes in these effects at all, whereas some mills stated changes to a high extent. The deviations might for instance be explained by the degree of implementation of energy management in the mills or if some dimension of the mills' energy management is more prominent than other dimensions. The spread might also be affected by the respondents' opinions of what is and what is not a benefit. For instance, some of the NEBs studied could have been considered part of energy management procedures by some respondents.

The results address a certain focus on two of the dimensions of Schulze et al.'s (2016) model in particular: organisation and culture. For instance, involvement and support by top management and the integration of energy efficiency issues in the organisation might have involved and motivated new staff in working with energy efficiency issues as a consequence of working with energy management.

Concluding discussion

In this paper, it is found that the benchmarking method used most often in the Swedish pulp and paper industry (PPI) is external benchmarking within a company group, followed by internal historical benchmark. Internal benchmarking is in turn regarded by questionnaire respondents as the most valuable benchmarking method. To date, not every Swedish pulp and paper mill systematically carries out this benchmarking method, but only a small share does not practice any benchmarking at all. The results show that the mills who conduct energy performance benchmarking also find it more valuable, which indicates that those who have experience of benchmarking have also discovered its benefits in their energy management work. It is important to note that the cause-effect of this finding is not determined, as it might also show that those who perceive benchmarking as valuable are those who choose to practice it. Still, the usefulness of energy performance benchmarking in industrial energy management has also been emphasized in other research studies (cf. Boyd, 2016; Worrell and Price, 2006; Xu et al., 2009).

As regards the level of detail of benchmarking, respondents in both the interviews and the questionnaire mentioned that a process-level approach potentially delivers the most useful information to the mills' energy management. Such an approach provides an indication of how a mill stands toward its peers, and might create incentives for further investigation. However, process-based energy benchmarking is complex due to integration of processes in PPI, and further complicated by the companies' use of different taxonomies of processes. In addition, the interviewees in this study also emphasize that benchmarking practitioners need a certain level of knowledge regarding energy end-use processes in order to understand differences in performance and to identify actual areas of improvement possibilities. Earlier research expresses this as well (Ke et al., 2013; Laurijssen et al., 2013).

To incorporate successful energy performance benchmarking in the PPI, the identified challenges need to be addressed. As for the diversity of taxonomies used for energy end-use processes, future studies should strive for a joint categorization of energy end-use processes with associated key performance indicators. Furthermore, the performance indicators need to consider deviating factors, i.e., mix of end products, mix of processes etc., in order to reach an apples-to-apples comparison.

Non-energy benefits (NEBs) as a concept has previously addressed the additional effects of implemented energy efficiency measures and how these benefits can contribute to investment decisions (e.g. Pye and McKane, 2000). The results of this study indicate that the studied pulp and paper mills have perceived NEBs not only of implemented energy efficiency measures but also as a consequence of systematically working with energy efficiency issues, i.e. by energy management procedures and activities. The main NEBs among the studied mills were that the interest in energy efficiency issues has increased due to energy management activities, both top management's interest and the interest within the whole organisation, followed by improved conditions in the external environment and increased energy measurement performance and evaluation. The dimensions of energy management include various activities, which possibly could generate NEBs of various types and hence be perceived at different levels and areas within an industrial company. This could be addressed in future studies by investigating how NEBs are perceived at various levels in a company.

The benefits of energy management covered most dimensions of Schulze et al.'s (2016) model of energy management with emphasis on the benefits related to organisation and culture since these were among the highest valued by the mills. Additional effects such as improved external environment and increased performance measurement and evaluation were also perceived as benefits to a higher extent as well as non-energy cost reductions and increased access to capital for energy efficiency investments. These benefits are included under implementation/operation and controlling, two other dimensions in the model of Schulze et al. (2016). However, despite being different dimensions of energy management, some effects are probably interrelated to a greater or lesser extent. For instance, increased support by top management regarding energy efficiency issues might increase the access to capital for energy efficiency investments and might also increase the awareness of energy efficiency issues in all organisational areas within a company.

Previous studies on NEBs have focused on additional benefits of energy efficiency measures. Hence, this study contributes novel findings which put NEBs in a wider perspective; i.e., the relation between NEBs and energy management activities within a company. Since the results of this study indicate that working continuously and in a structured manner with energy efficiency issues, i.e. energy management, leads to additional effects beyond the energy effects, awareness of these benefits might be a way to overcome the barriers to energy efficiency pointed out, for instance, by Thollander and Ottosson (2008) and Sa et al. (2017), and also act as possible drivers to energy efficiency. The main NEBs perceived by the mills in this study were related to organisation, culture, external environment, energy performance measurements and cost reductions beyond energy savings. Benefits of an organisational character might reduce organisational and cultural barriers to energy management procedures, while the financial and economic benefits of energy management might be means to overcome financial barriers to energy efficiency investments.

Since energy performance benchmarking is a type of energy management practice, the NEBs which could be experienced related to this practice are the energy management NEBs. However, since benchmarking is one of many energy management practices, it is difficult to unravel the specific NEBs related to benchmarking, as the perceived energy management NEBs in this study originate from all of the mills' energy management activities. However, as benchmarking practices firstly relate to the area of controlling in the framework by Schulze et al. (2016), it will probably result in NEBs connected to that area, such as 'Energy performance measurement and evaluation have increased more than expected'.

The aspects of benchmarking and NEBs in relation to energy management in the PPI have scarcely been studied. Hence, this paper provides an important initial step to visualize the value of more work with these aspects of energy management within the pulp and paper mills. While the results are set in a context of the PPI, it may also be valuable for other manufacturing industries as well.

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Acknowledgements

We kindly thank the respondents for giving freely of their time to answer the questions.