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Industrial Energy Management

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Assessing and Fostering Industrial Energy Management through Energy Management Practic's Definition and Classification

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It was a long journey. It is true that “life is about what we make to happen”. Lots of things happened and changed in the time while I’v been involved with my PhD. Barring losing confidence so many times I’v lost count, getting stuck just as many times, moving from one place to the other, laptop crashing, needing to concentrate as much as possible, and pure frustration in general, but knowing and believing that I just had to do it in my own time and my own terms was the promising and motivating point.

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Aida Sa
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Assessing and Fostering Industrial Energy Management through Energy Management Practic's Definition and Classification

The work reported here is the PhD thesis of Aida Salimnezhadgharehziaeddini. The work consists of a collection of five papers focused on energy management (EnM) programs and practices and also determinant factors in which supporting the decision making process which lead to the implementation of EnM programs in Small, Medium and Large sized energy-intensive companies from different sectors. This introductory section has two objectives:

- It clarifies the theoretical and empirical background of the research project, and it presents the main problem addressed. These topics are discussed in the first part of this introductory section: "Background".

- It clarifies the overall objective of the research and it summarizes the aims, methods and findings of the five included papers, explaining the way in which the papers are aligned with respect to the overall objective of the research. These topics are discussed in the second part of this introductory section: "The research project".

This introductory section is followed by the five papers, which are the main results of the current thesis.

1. Part 1: Background

1.1. The importance of Energy Efficiency and Energy Management in industry

Potentials for energy efficiency (EE) activities, energy management (EnM) are huge due to the numerous inefficient energy-intensive and non-intensive industrial companies. A general estimation of the investment opportunity by International Finance Corporation (2011) exceeds 100 billion US dollars. Due to the strategic importance of EE, national policies are also favouring EnM programs within industrial companies (IFC 2011).

Despite the huge potential and favouring policies, the phenomenon that economically profitable EE investments are not being realized is called “energy-efficiency paradox” (Zhang

2003). It is also known as “energy efficiency gap” expressing the difference between the potential cost-effective EE investments and the actual investment level implemented (Brown, 2001; Levine et al., 1995; Golove and Eto, 1996; Jaffe and Stavins, 1994; Sanstad and Howarth,

1994. Goldman et al., 2005). Why is that always the case?. The existence of “energy efficiency paradox” or “energy efficiency gap” is exposed to discussion in terms of market failures and market barriers (Jaffe and Stavins, 1994; Goldman et al., 2005; Rohdin et al., 2007).

There is considerable potential for improving industrial EE both from technical and managerial point of view. Nevertheless, it has been addressed the numerous ‘barriers’ inhibit the adoption of such improvements, such as lack of information, shortage of trained and expertise personnel and limited access to capital. In particular, the adoption of such improvement programs may be associated with various ‘hidden costs’ that are difficult to capture within existing energy-economic models. But while there is a general debate on energy efficiency ‘gap’, both the policy options and continuous improvement within an organization to overcome this gap need to be identified and acted upon. Moreover, considerable debate over the most effective approach is highlighted. The most frequently announced barriers to end-use EE has been shown in figure1.

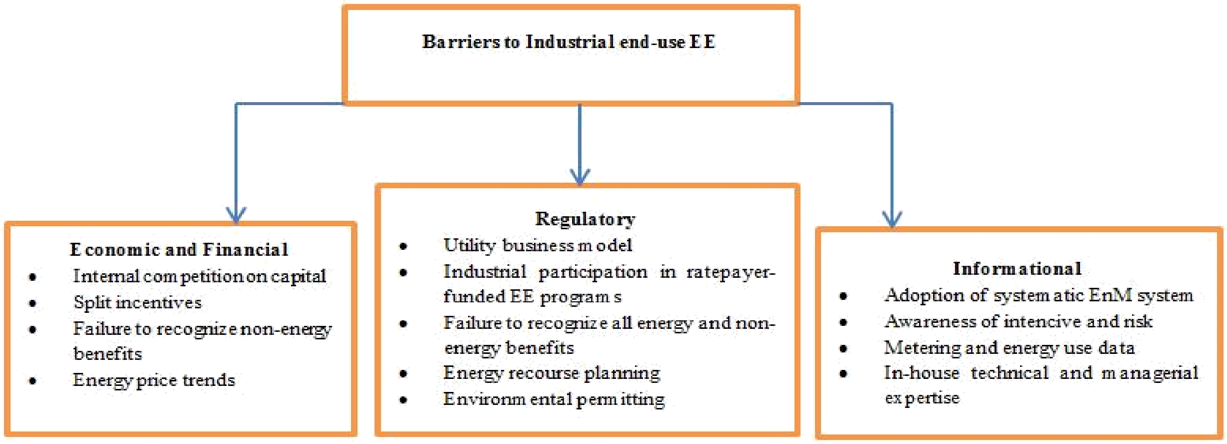


Figure 1. Barriers to industrial end-use EE

Nowadays, companies have to consider the efficient and smart use of energy and resources in manufacturing besides traditional performances to sustain their competitiveness in their respective industry. Thus, it became a must for manufacturing firms to put more efforts on in-depth analysis of energy and resource performance through their manufacturing processes and facilities. A comprehensive process design and plant optimization with a specific focus on EE is of paramount importance for this purpose. Currently, Potentials to improve EE are far from being exploited as mentioned by many scholars.

The concept of a barrier to EE is both confused and contested. Although the term is widely used, there is little consensus on how barriers should be understood, how important they are in different contexts, and how (if at all) they should be addressed.

Since industrial energy use accounts for roughly one third of global energy demand and that share is growing steadily, managing energy consumption is vital for manufacturers. However, nowadays companies have become more aware about the potentials of waste of energy and associated cost savings. Systematic energy management (EnM) is identified by practitioners and academics as one of the most effective approach to improve and sustain EE in industries. The reason can be explained through EnM systematic and program to equip companies with practices and procedures to continuously realize and capture the possible improvements and new opportunities. The most announced drivers to implement EnM within an organization can be categorized as follows in figure 2.

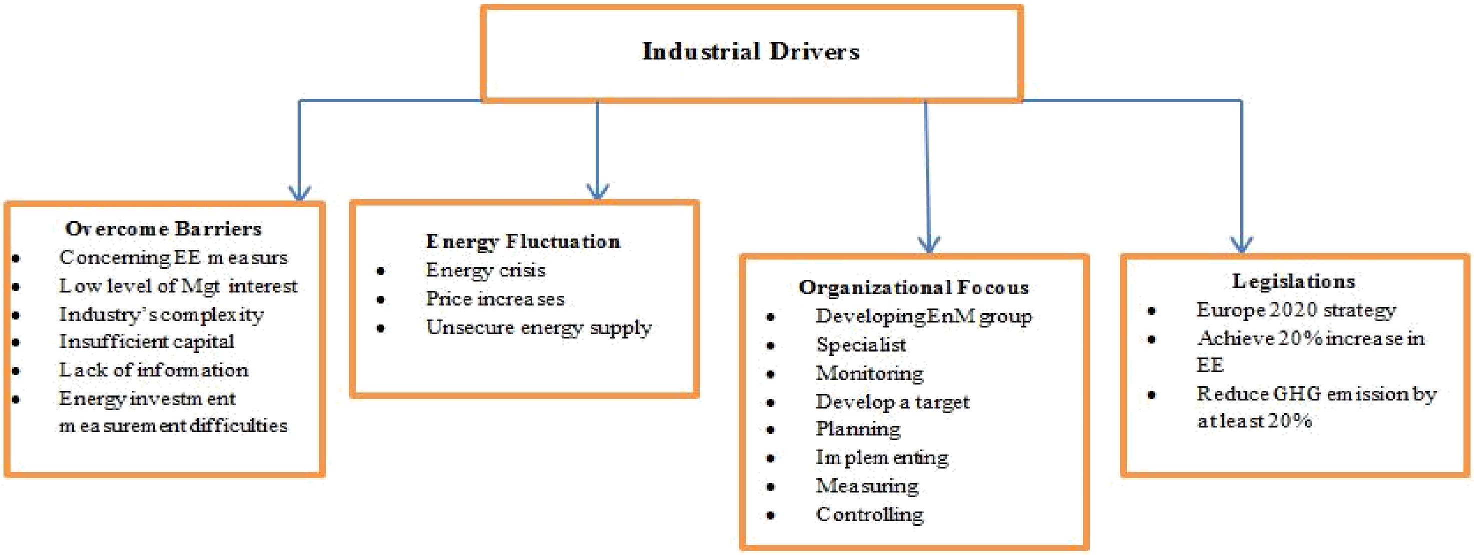


Figure 2. Industrial driver to adopt EnM

Although, there is a lot of evidences in the academic literature which approve the huge potential of EnM to improve the EE level of the company, still there is no cohesive definition about EnM and also, there is a huge gap about *how* exactly EnM could make the improvements within the companies. Moreover, studies concerning energy services in the industry have not been extensively exploited. There is no study on classification of energy management practices (EnMPs). Notably, energy policy measures for improved EE in industry is in need of clarifications in these regards, as policies involving EnM components forms the backbone of successful industrial energy policies, e.g. Voluntary Agreements (Rezessy and Bertoldi 2011; Price 2005; Cagno et al., 2015a). EnMPs are to be seen as more managerial actions, while others defined it as more technical and operational practices. The lack of single accepted definition for EnMPs causes imprecise understanding about EnMPs. As another result, no characterization which could characterize EnMPs' based on their target exists in the body of EnM literature. Theses gaps also cause failure in choosing proper EnM configuration through single industry's characteristics. In other word, the lack of a precise definition about EnMPs causes both technical and managerial failure towards improving companies' EE. If major improvements in EE are the target for a single industry, many different policy instruments and pre-steps can and must be taken. As for effective EnM it is pillar to work continuously, for better result it is necessary to establish policies which could support EnM programs properly and continuously. Even though an EnM system as such cannot be seen as national policy, EnM standards often comprise the backbone of Voluntary Agreements. According to Jelic´ et al. (2010) the comparison of national EnM standards illustrates that there is a lower agreement on some elements. Management commitment, strategic planning, purchasing and design are all those listed with low agreement level. Policy makers, engineers and scholars are in a position to think about not only what to install to improve EnM programs, but also how to implement these measures. Thus to converge an unanimously accepted strategy, close contact between practitioners, policy makers and scholars is the mainstay. Simultaneously, it causes not only to avoid any possible confusion in existing program when policy makers and scholars get in touch with the realness of the industry through the practitioners, but also to establish policies which support EnM program properly. Thus, regardless of any discipline which laws are relevant to, they constantly need to be revised by policy makers to innovate and inject new, necessary, and value added items to the existing program. In Figure 3 a presentation on how these four elements affect each other's failure and/or success is shown. Different definitions of a single concept not only cause inaccurate understanding about it, but also cause improper proceedings to obtain the desired results. The perspectives of management only or merely technical to the EnM concept has caused both mentioned problems in industries. However, EnMPs could be defined as *total continuous or frequent managerial and technical actions in a company which aim primarily to reduce energy costs or secure energy supply and secondary to reduce pollution* (Sa et al., 2015a) .Some authors believe that there is overlap between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure (Trianni et al., 2013). It is useful to list all EnMPs and group them based on where and how they improve the EE. Characterization of EnMP through the EnM definition can be a light to better understanding of what EnM is. Based on EnM literature, there are indications that EnMPs positively link to a top management support and ambitious, productivity, and firm's climate friendly R&D (Cagno et al., 2015b)

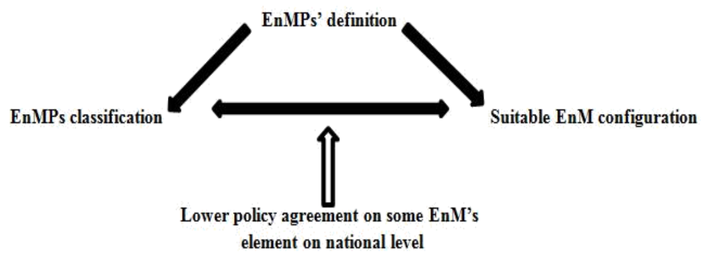


Figure3: EnMPs Gap Analysis (Sa et al., 2015b)

Therefore, according to the mentioned problems, this research intends to contribute to the companies and academia a better understanding on how to successfully integrate EnM into the manufacturing process.

2. Research Project

2.1 Background

Paradox or energy efficiency gap was first defined by Hirst and Brown (1990) meaning that profitable investments into improved EE is not realized in companies because of the barriers to EE (Decanio 1993 and 1998; Eichhammer, 2004; Cagno and Trianni 2013; Trianni et al., 2013; Brunke et al., 2014). A number of papers examined barriers to EE in the industry, some of the high-ranked for whole sizes being technical risks, lack of options to improve energy management practices (EnMPs) (Brunke et al., 2014) limited access to capital, lack of time or low priority given to EE by the top management, poor information quality and/or lack of information (Brunke et al., 2014) or high transaction costs (DeCanio and Watkins, 1998). Several studies have identified a low status of Energy Management (EnM) in industrial companies to be a barrier to EE (Rohdin et al., 2007; Thollander and Ottosson 2010). Implementing EnM can be a way to improve EE and to reduce the related CO2 emissions (Christoffersen et al., 2003; Kannan and Boie 2003) and overcome barriers to EE.

To improve EE in the industry through EnM programs, long term energy strategies, committed and skilled energy managers are both important factors in spurring improved EE in industrial firms. As several factors promote the efficient use of energy, barriers also exist. Energy management (EnM) addressed in several scientific papers as a robust and efficient means to overcome such barriers. The term EnM has been used differently in the academic literature, and still there is no adhesive definition (Schulze et al., 2015). What many definitions of EnM have in common is that they primarily concentrate on implementation of energy efficient technologies and replacing inefficient equipment. However, EnM also includes practices such as care, operation and maintenance of technology, to maintain an effective functioning. Continuous work and improvement practices are the first requirements for that (Gordic et al., 2010). The most recent theoretical and empirical researches about drivers and barriers respectively can be found in Cagno et al., 2013; Brunke et al., 2014 and Trianni and Cagno 2015. As regards the foundry sector the most recent comprehensive research about barriers can be found in Trianni et al., (2013) and for drivers look at Thollander et al., (2013). Meanwhile, previous policy researchers identified and classified a number of barriers to and drivers for EE in industries (DeCanio, 1993; de Groot, 2001; Sandberg and Soderstrom, 2003; Thollander and Ottosson 2008). Two of these barriers, namely organizational and behavioral barriers relate to the energy management practices (EnMPs) within the company. Because in general, the details of how an EnM program could make continuous improvement within the company have remained largely unexplored (Christoffersen et al., 2006; Kannan and Boie, 2003; Thollander et al., 2010). Organizational barriers relate to the unclear division of tasks and the lack of financial resources, time and skilled personnel (Sardianou, 2008). Personnel values and mindset is included in behavioral barriers (Lindgren Soroye and Nilsson, 2010; Stern, 1992).

The EE improvements through EnMPs in companies is addressed as an important but also challenging issue by policy researchers. A compounding of different policy measures has been introduced to influence industry, both directly and indirectly, including a mixture of voluntary and non-voluntary standards. This challenge, also, is due to a lack of clear understanding about EnMPs and also how these should be placed by organizations in order to improve EE. Guidelines and different standards on EnM emphasize the importance of monitoring, evaluating and enhancing energy performance at process and system levels. However, for better results managers need to assess their program to track the strength and weakness of the current energy plan. The reasons for this relate to the need of verifying and evaluating companies' energy strategy and the current situation of the adopted practices together with assessing companies' policy, organizing, training, performance measurement, communication and investment maturity level.

Moreover, implementing EnM is also difficult because of many misconceptions (e.g. Only big companies can do it, only plants with new equipment can do it, large capital budgets are required, we have no enough time and staff, we already do everything we can, and everybody manages energy) and the barriers which depends on the geographic location and industry's character itself (such as energy intensity and size)**.** Therefore, EnM programs with its huge potential for improved EE is still far from what it should be exploited in practice based on the adopted highest success levels (Sa et al., 2015). Those potentials have been untapped not only because of the mentioned barriers, but also because of lack of alignment between energy programs and company's total strategy or company's macroeconomic policy and also because of lack of transparency which accordingly increases the nature of risk. Within the last twenty years, by increasing energy prices and global energy crisis, EnM considerably developed as an industrial energy system support function. The former studies addressed its strategic and efficient role in improved energy system. Meanwhile, the number of empirical and theoretical studies increased about drivers for and barrier to the EE project implementation. However, EnM is not properly decided upon and/or not fully adopted, with all its potential, to help companies for improving their EE performance level. In macro perspective, there are two different perspectives in EE literature about investment decision making". A number of former researchers believe EE investments would decide upon if the financial analysis conforms the investment for a particular program (which is in line with finance theory). However, others emphasis on organizational energy culture, power relationship, managers mindset and characteristics of the investment itself. Strategic decision making literature did not provide a clear and applicable answer about what makes an investment strategic. However, some researchers in this field are described strategic decisions as follow:

Table1. Strategic investment descriptions

References	Description of strategic investment
Butler et al., 1991; Lu and Heard 1995; Schoemaker 1993	Decisions as vital importance.
Carr and Tomkins 1996	Decisions which have a significant effect on the organization as a whole.
Butler et al., 1991; Carr and Tomkins 1996; Cauwenbergh et al., 1996	Decisions which have a significant potential for improving corporate performance.
Cossette 2004	Strategic means important and not secondary issue.
Child 1972	Decisions which regarding the goals, domains, technologies and structure of a firm.
Dereumaux and Romelaer 2001	Decisions regarding a firm's development through products-market-technologies triplets

The definition provided by strategic process research are not comprehensive enough to understand the strategic character of investment decisions because the aspect of the scope and content of investments did not take into the account properly. Adopting a practice based on how it is aligned with an organization's strategy would not lead us to clear and proper selection and it would leave us in a vague situation. The reason for that is either the firm's strategy is not often identifiable or it does not exist (Cooremans 2011). Cooremans (2011) and Sa et al., (2015) in their paper emphasized on enhancing the understandings about the scope and/or the target of each practice or investment and make it more strategic and align with organization's total strategy. Moreover, it is important to analyze how a particular program enables a firm to strength its strategic position (Cooremans 2011). Therefore, in this way energy related issues would not seen as a secondary issue (which they normally seen) but a strategic issue.

Literature determines top management's support as a key and very important drivers to adopt any proposed EnM program. Payback time is another driver which gives priority or rejection for any proposed program. Thollander and Ottosson (2010) in an empirical investigation within the Swedish pulp and paper and foundry sector showed that companies apply a criterion of three years or less for EE's pay off. This result in an investigation which conducted in the developing countries across nine manufacturing sub sectors fell into 0.9 to 2.9 years (Alcorta et al., 2014). Pay off criterion differs through countries and time when we look at the what Gruber and Brand showed in 1991. In an empirical study in Germany with sample size of 500 of SMEs companies the average required payback criteria were about four years (Gruber and Brand, 1991). Since top management support in a variety of studies addressed as a fundamental and necessary affecting factor to implement a program, the need for investigation about managerial perspective is highlighted. Many believe that as long as a program is profitable the possibility of adopting a program would increase. However, it is not the case in every situation. Many EE practices which theoretically are profitable are not adopted in practice (Aflaki et al., 2013). Often it is due to lack of executing and valuing the project properly and improper definition (Schulze et al., 2015; Sa et al., 2015). Though it is sometimes due to uncertainty and its associated risk, lack of transparency and weaker understandable calculation (Sandberg and Soderstrom, 2003). Top management is positioned in a strategic level of a company and they make decisions about what is in line with company's total strategy. In other word, they are dealing with the core business. Energy is considered as a non-core business, non-strategic, but a secondary and peripheral issue (Sorrell et al., 2000). Moreover, since energy related costs in comparing with the company's total cost receives a small portion, thus energy related practices receive relatively small attention (Cooremans 2015).

Another important point which resulted in low levels of EnMPs adoption and/or decision making is due to the high level of EE investment risks in compare with the other projects. Neoclassical energy economists (like: Newell 2004; Soest and Bulte 2001) believe that the EE gap is not real because their energy-saving programs technically are energy efficient but no economically (due to hidden costs and return overestimations). Although being risky is the nature of making any decisions (due to uncertainty), but the level of the risk increases if it is more strategic. EE investment literature discussed very little in this regard. Apart from financial risk which raises from these investments, Sorrel et al., (2000) listed core business risk or technical risk linked to adoption of new technologies as a third important barrier to adoption and/or positive decision making regard to EE investments. Several strategic risks threaten a company when a decision is made (have a look on Cooremans 2011). However, the uncertainty of EE investment outcome leads to negative investment decision making in most of the time.

2.2. Objective of the thesis

Believing energy to be finite and nature as a place to live not only for the present generation, but for future generations increasingly leads us to use energy smarter and more efficiently. Industry, meanwhile, especially energy-intensive industries, as a major energy user receives relatively more attention. While according to an International Energy Agency report in 2007, industry in all sectors had made successful improvements, but still the Hirst and

Brown's claim in 1990 about the existence of the gap between the actual level of energy efficiency (EE) potential are remaining strong (International Energy Agency, 2012). According to IEA (2014), if current trends continue in the years to come, two-third of the economic potential to improve EE will remain untapped until 2035 (IEA, 2014). Though several researchers addressed barriers to implement EE measures, namely energy efficient technology's complexity (Fleiter et al., 2012a), and implementing EE measures are a challenge because of industry's complexity (industry's characteristic) (Schulze et al., 2015). Therefore, this challenge makes it difficult to generalize any success stories or programs. Researchers addressed energy management (EnM) as a tool for overcoming EE barriers. Energy management means to optimize one of the most complex and important managerial and technical creations that we know: the energy system. However, how an EnM could do more in detail such improvements are scarce. The reason for this can be addressed to several gaps regarding: lack of proper understanding about EnMPs, lack of information about scope and target of practices which results in poor EnM configuration and moreover, lack of understanding about effective driving factors which leads the positive investment decision making through top management.

These knowledge gaps are the starting point of the thesis. The thesis aims at increasing the effectiveness of the decision making process leading to the implementation of EnM in the manufacturing sector. Thus, the research questions can be stated as follows:

1. ***How Energy management practices can be defined?***
2. ***How energy management practices can be classified according to their scope and target?***
3. ***How to assess industrial energy management program?***
4. ***How to foster energy management program's implementation?***

2.3. Outline of the thesis

In order to have a clear idea about EnM literature a review of the literature has been performed, with a focus on the studies dealing with the EnM definition and its related programs and practices. The questions presented here as first and second research questions highlighted as a gap in the body of EnM literature. Therefore, paper 1, entitled “Industrial Energy Management Gap Analysis” has been carried out to analyze the importance level and correlation of identifying gaps to contribute better understanding about and implementation of EnM.

The research related to research question 1 and research question 2 is presented on paper 2, entitled “Classification of Industrial Energy Management Practices A case study of a Swedish foundry”. To provide a comprehensive definition for EnMPs and classification for EnM program the use of knowledge from both scientific literature and practitioners in the field of manufacturing has been carried out.

To develop an assessment model for the EnM program within manufacturing companies (Research question 3) and moreover to assess the most important promoting factors for improved energy efficiency a multiple case study of 10 Swedish foundry has been carried out. Research related to research question 3 is presented on paper 3, entitled “Assessing Industrial Energy Management Program – A Multiple case study of Swedish foundries”.

To address the relevant contextual factors which hindering (barriers) or fostering (drivers) the positive investment decision making, regarding EnM program implementation in manufacturing industry, (Research question 4), two parallel research processes have been followed for barriers and drivers. First, it has been necessary to develop a taxonomy of the drivers for and barriers to positive decision making within the organization. The research has been performed by means of an iterative process, and by incorporating the scientific literature and the practitioners’ knowledge. Moreover, is this regard, the results of paper 2 and paper 3 has been used to assess the exiting EnM programs in practice. Having developed a taxonomy of barriers and drivers for positive investment decision making in the process of EnM implementation, the relevant barriers and drivers have been identified by means of doing a multiple case study in all sizes and different sectors within 25 Swedish energy intensive manufacturing companies. The results are presented in the paper 4, entitled “Assessing the Driving Factors for Energy Management Program Adoption”.

Although EnM improvements through policy makers is not within the scope of current research, paper 5 entiteled “Introducing Passive House Concept to Industries” aims to inject a new idea into the EnM guidelines. Also, it attempts to introduce self-sufficient industries through passive house concept with special focus on industrial facility design (see Table 2).

Table 2. List of the papers

Paper 1	Sa A, Thollander P, Cagno E (2015) Industrial Energy Management Gap Analysis. Innov Ener Res 4: 122. doi:10.4172/ier.1000122 Published in Innovative Energy & Research Journal 2015.
Paper 2	Sa, A., Paramonova, S., Thollander, P., & Cagno, E. (2015). Classification of Industrial Energy Management Practices: A case study of a Swedish Foundry. *Energy Procedia*, *75*, 2581-2588. Preliminary version has been presented at ICAE 2015 conference. Second, extended version has been published in Energy Procedia 2015. Full version to be submitted to Applied Energy Journal.
Paper 3	Sa, A., Thollander, P., & Cagno, E. (2015). Assessing Industrial Energy Management Program – A Multiple case study of Swedish foundries. Preliminary version has been presented in the Global Cleaner Production Conference 2015. Spain. The full version has been submitted to the Cleaner Production Journal.
Paper 4	Sa, A., Thollander, P., & Cagno, E. (2015). Assessing the Driving Factors for Energy Management Program Adoption Has been submitted to the Renewable & Sustainable Energy Review’s Journal.
Paper 5	SA, A., THOLLANDER, P., & CAGNO, E. Introducing Passive House Concept to Industries. Preliminary version has been presented in WSEAS conference 2015 and published.

2.4 Paper1: Industrial Energy Management Gap Analysis

2.4.1 Aim

To address the existing gap in the body of energy management literature.

2.4.2 Method

Literature review has been carried on barriers to and drivers for energy efficiency, energy management literature and successful implementation criteria.

2.4.3 Result

Different definitions of a single concept not only cause inaccurate understanding about it, but also cause improper proceedings to obtain the desired results. The perspectives of management only or merely technical to the EnM concept has caused both mentioned problems in industries. However, EnMPs could be defined as total continuous or frequent managerial and technical actions in a company which aim primarily to reduce the energy costs or to secure the energy supply and secondary to reduce the pollution (Sa et al., 2015). Some authors believe that there is overlap between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure (Trianni et al., 2013). It is useful to list all EnMPs and group them based on where and how they improve the EE. Classification of EnMP through the EnM definition can be a light to better understanding of what EnM is.

Based on EnM literature, there are indications that EnMPs positively link to a top management support and ambitious, productivity, and firm's climate friendly R&D (Cagno et al., 2015b). Meanwhile companies' characteristics like energy intensity and size have a direct impact on energy practices. After all, even if there would have existed top management ambitious, in most of the cases two stumbling blocks are exist: 1) there is no energy manager by definition within the company and/or 2) since energy is not considered as a core business and strategic but mostly a secondary issue therefore it receives relatively little attention. Top managements are positioned in a strategic level of any organization. Since top management support is a key to EnM's program success, energy manager should make the EE investments more strategic. The more strategic an investment the more opportunity it has to acquire the contest. While integrating energy and operations approaches erases the line between process energy services and ancillary energy services and spreads out the doors to strategic analysis, linking the operations and energy analyzes could bring better results from the EE improvement point of view. An investment is strategic if it contributes to create, maintain, or develop a sustainable competitive advantages (Cooresman 2011). To build a competitive advantage, making a balance between internal resources and external factors through resource allocation is essential (Johnsson et al., 1999). Turner (2007) has a very strategic view towards energy within the industry. Turner determined and clustered five energy related strategies for a single industry, which are: reliability, efficiency, low cost/no cost, funding, and awareness and practices which could maintain the targets are identified. Grouping energy related practices through their targets could make the situation more clear for the top managers to realize by performing which practices they could arrive at what kind of resolutions not only from the EE improvement point of perspective, but also from a strategic point of opinion.

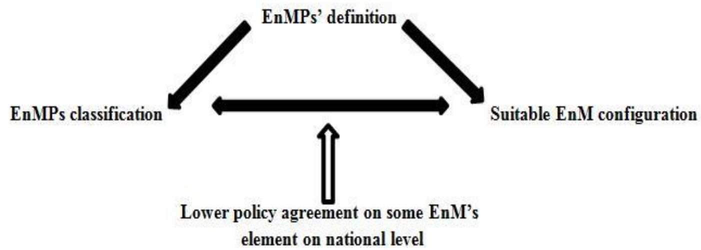


Figure 1. EnM Gap analysis

2.4.4 Conclusion

EnM is a robust tool to improve the EE in industries and its main task is to reduce costs for the provision of energy in buildings and facilities without compromising the manufacturing processes. However, it needs some clarifications in regards to definitions, which points towards a direction on how to reach overall sustainability, not just to work in accordance with continuous improvements, this in order to inject into the current and future EnM policy programs for improved impacts. Although the requirements for industrial facilities, in turn, can differ, how EnMPs are defined helps to clear understanding about the in-house EnM program and choosing proper EnM configuration based on industry's characterization and overall objectives.

2.5 Paper 2:Classification of Industrial Energy Management Practices A case study of a Swedish foundry

2.5.1 Aim

Despite the importance of EnM, there is no precise and unanimous definition for energy management practices. Moreover, very few papers investigate energy efficiency opportunities and/or energy management practices in the foundry industry. This paper aims to identify, classify and characterize energy management practices through their definition, with respect to energy efficiency, that could take place in a foundry industry.

2.5.2 Method

Literature review and a single case study, a foundry, which is conducted between 2009 and 2014, are applied in answering the research questions. The chosen case is defined as one of the most energy-efficient foundry in relation to improved EE. The choice of methodology was also supported by our access to rich and comprehensive empirical sources. Also, the choice of context is grounded in the industry's international orientation and exposure to the issues of EnM. In addition, a certain level of industry representativeness in a chosen sector was considered for this study, for example, market share, sales volume, and international expertise. The primary form of data collection was a series of interviews with senior management and an EnM staff. Based on the perspective of the research questioned posed in this study, we look at the company's in-house EnM program from the perspective of Turner (2007) and its main components. In addition to the interview, frequent site visits and document research (industry statistics, annual reports, media, industry association data, and government environmental regulation reports) to examine and cross-checking qualitative data are conducted to increase research validity (Yin 2008). In the following section, the case of a Swedish foundry is analyzed from EnM point of view.

2.5.3 Results

Some authors consider an EnMP as a technical procedure while other believes it is more managerial. However, we define EnMPs as total continuous or frequent managerial and technical actions in a company which aim primarily to reduce energy cost or secure energy supply supply and secondary to reduce pollution. Some authors believe that there is overlapping between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure. It is useful to list all EnMPs and group them based on where and how they improve the EE. Characterization of EnMP through the EnM definition can be a light to better understand what EnM is. Turner (2007) clustered EnM strategies into five dimensions: Reliability, Efficiency, Low cost/No cost, Funding, and Awareness. In this study we try to group EnMPs in these five dimensions, inspired by Turner (2007).

Strategy	Programs	Applied practices in reference case
Reliability	Maintenance program	Develop preventive maintenance plan by installing different class A, B, C alarm system for leaking or any other imperfection Develop connected system to prevent energy losses Develop maintenance program for each 3years
	Modernization	Sensor installment for weather adjustment Establish weather station in order to control humidity, wind direction and sun influence
	Operations	Establish borehole storage Heat exchangers Establish heat recovery system Establish sorption cooling technology Integrate LCC to procurement strategy
	Training	
	Contingency planning	Frequency convertor system for ventilation Frequency reduction for ovens and switch off the washers for about 15-20 min when electric load is about 11MW which brings 2MW energy use reduction Establish solar collector system and collecting about 35MWh per year Establish solar shelters Establish energy production system Collect volatiles and burn them to produce heat Take care of solvents burning heat in the foundry
Efficiency	Plant property evaluation	Develop a plan for updating inefficient equipment
	Measurement	24hours measurement for electricity in total and specifically for the furnaces, machinery area, water consumption and heat consumption Develop daily, monthly and annually reporting system for electricity, water and heat consumption Develop energy report for each working area, sub metering, like: electric motors department Develop EE index (energy use/ tonnage produced) then set EnM goal Develop annual evaluation program in terms of production rate and energy consumption Develop idling report (for monitoring idling drifts) Establish permanent instrumentation for energy measurement

	Control	Control by portable equipment in order to investigate possible energy reduction opportunities CO, CO2 and VOC controlling sensor in working area VSD control for fan's speed depending on air quality in working area CO control sensor in foundry connected to VSD for process ventilation CO2 control sensor in public area connected to VSD for ventilation Internet based controlling and monitoring system Waste water treatment control Heat recovery system connected to control system
	Energy organizational efficiency	
Low cost/ No cost	Alternatives for energy sources	
	Negotiation	Receive 40% government support for 1.5 years to install PVs to produce electricity Purchase green energy, biomass
	Time of use	Load management, use delays for some equipment Establish an electrical demand control system (in one sunny day it saves 5MWh)
	Elimination	Investigate areas which have significant energy losses Eliminate excessive heating demand
Funding	Stabilize funding	Identify and prioritize future projects based on improved energy efficiency and pay off (less than 3years)
	Return saving to customer	
	Short term funding	Receive 30% government support for a test program for verification of energy saving by borehole storage
	Economic analysis training	
Awareness	Training	Set a goal of 20 kWh/m2 electric demand for heating and ventilation through borehole storage Have high green policy Set goals for electricity, water and heating Avoid public water procurement for cooling in 2016 Improve electric efficiency by 5% till 2015 Decrease heating demand from 5GWh in 2012 to 2.5 GWh by 2015 Inform staff since eight years back about the importance of climate change Train staff to eliminate insignificant and unnecessary energy usages and minimize idling losses Displays to visualize energy trends
	Communication	Form a network of energy committee between maintenance (the energy manager is in the maintenance group) and environment departments, machinery area and production line Involving in research program by Elforsk organization for electric demand reduction Networking with foundry organization and Scania once a year Established close network contact with Volvo's energy management Publicize energy activities, e.g. seminars
	Behavior modification	
	Program evaluation	

2.5.4 Conclusion

Industrial companies strive for profit, and promoting EE can at times be difficult and not so prioritized. Because many different policy instruments and pre-steps can and must be used if major improvements in EE are to take the place moving industry towards improved sustainability, the results of this paper aimed to propose a comprehensive definition for EnMPs. Moreover, by characterizing EnMPs, the paper attempt to improve understanding of in-house EnM programs. Based on a literature review, there are indications that EnMPs are positively related to a top management support and ambitious, productivity, and firm's climate friendly R&D. However, large organizations often have some difficulties over SMEs in ensuring effective EnM. In larger organizations, lines of communication are generally wider, organizational structures are complex enough, and access to a top management is rather difficult. All of these characteristics can be real disadvantages for effective EnM for large companies, especially for foundry industries which have more complex production process than, for example, non-energy intensive companies where the major energy use is found in the support processes. However, the same as what is running in the current studied reference case, proper meeting schedule between the energy group's members can be one means of overcoming the mentioned problems. Other tools for EnM success in large industries could be a centralized focus and energy manager's high desire to save energy and the environment, as also found in Brunke et al. (2014). The energy manager's background is another important aspect which has had a direct impact on the EnM success at the studied company. Besides all these mentioned factors, there are drivers which motivate energy managers to improve EE in industries.

2.6 Paper 3: Assessing Industrial Energy Management Program – A Multiple case study of Swedish foundries

2.6.1 Aim

Guidelines and different standards on EnM emphasize the importance of monitoring, evaluating and enhancing energy performance at process and system levels. However, for better results managers need to assess their program to track the strength and weakness of the current energy plan. The reasons for this relate to the need of verifying and evaluating companies' energy strategy and the current situation of the adopted practices together with assessing companies' policy, organizing, training, performance measurement, communication and investment maturity level. Therefore, the aim of this paper is to:

1) Present the structure of the energy strategy and related practices. The strategic plan deals not only with technical aspect but also with the funding, communication, education, and behavior modification aspect of EnM program. According to Turner (2007), developing a strategic plan with related practice items is the last but the most important step in an organization's EnM program development, and unfortunately is where many stop.

Table 1. EnM strategies, programs and related practices (inspired from Turner 2007)

Strategy	Program and related Practices	Codes
Reliability	Maintenance Program Modernization Operations Training Contingency Planning	R1 R2 R3 R4 R5
Efficiency	Plant property evaluation Measurement Control Energy Organizational efficiency	E1 E2 E3 E4
Low cost	Negotiation Load Management Elimination	L1 L2 L3
Funding	Stabilize funding Return savings to the customer Short term funding Economic analysis training	F1 F2 F3 F4
Awareness	Training Communication Behavior modification Program evaluation	A1 A2 A3 A4

2) Assess industrie's EnM program and maturity level, according to EnM matrix (Carbon Trust 2011) which is presented in table 2. EnM matrix gives a clear picture about strength and weakness of industries' EnM program across six areas (policy, organization, training, performance measurement, communication and investment) of EE measures at site level.

Table 2. EnM matrix (inspired from Carbon Trust 2011)

Level	Policy	Organizing	Training	Performance measurement	Communicating	Investment
4	Energy policy action plan and regular review have an active commitment of top management	Fully integrated into the management structure with clear accountability for energy consumption	Appropriate and comprehensive staff training tailored to identified needs, with evaluation	Comprehensive performance measurement against targets with effective management reporting	Extensive communication of energy issues within and outside organizations	Resources routinely committed to energy efficiency in support business objectives
3	Formal policy, but not active commitment from top	Clear line management accountability for consumption and responsibility for improvements	Energy training targeted at major users following training need analysis	Weekly performance measurement for each process, unit or building	Regular staff briefings, performance reporting and energy promotion	Some appraisal criteria used as for other cost reduction projects
2	Unadopted policy	Some delegation of responsibility, but line management and authority unclear	Ad-hoc internal training for selected people as required	Monthly monitoring by fuel type	Some use of company communication mechanisms to promote energy efficiency	Low or medium cost measures considered if short payback period
1	Unwritten set of guidelines	Informal mainly focused on energy supply	Technical staff occasionally attends specialist courses	Invoice checking only	Ad-hoc, informal contacts used to promote energy efficiency	Only low or no-cost measures taken
0	No explicit energy policy	No delegation or responsibility for managing energy	No energy related staff training provided	Nomeasurement of energy costs of consumption	No communication or promotion of energy issues	No investment in improving energy efficiency

3) Identify and understand the nature of all those promoting factors which promote foundries to continue the EE improvement more than other promoting factors (table 7).

2.6.2 Method

Considering the research aim described above and the nature of the study, this study was carried out as a multiple case studies of 10 Swedish foundries. Case study research is especially advantageous when “how” or “why” questions are being posed (Yin, 1994). The case studies were chosen in small, medium-sized and large companies. The study was carried out using semi-structured interviews conducted between August and November of 2014. In each case normally two persons, one from top management and the other from the energy group of the company, were interviewed (for approximately two hours) about the EnMPs, EnM program, the company’s energy-related targets and motivating factors. The content of the interviews enabled the researchers to identify the practices adopted in each case. Thollander and Ottosson (2008) classified EE drivers for pulp and paper industry into market related (M1 to M3), policy instruments (P1 to P15), and behavioral and organizational (O1 to O10) driving forces. In this study the same classification has been chosen to identify which drivers among all the others promote continuous improvement of EE within Swedish foundries. During the interviews the energy manager and/or companies' energy manager representative were asked to mark and rate factors found in Table 7, which represented EE promoting factors for improved EE on a scale of 0: not important at all to four: strongly important. The maturity matrix (Table 2) is also developed to assess the current state of the EnM program of each foundry. The matrix consists of six themes from policy through investment, where users could rate their EnM program on a scale of 0: not important at all to four: strongly important. The matrix enables a conversation around EnM that reflects a wider set of subjects than just technology (the default solution for many). It tells the aspect of organizing, training, investment, communication and performance measurement. This tool is also a powerful way of understanding where barriers might exist in an organization.

In addition to the interview, extensive document research (industry statistics, annual reports, and government environmental regulation reports) to examine and cross-check qualitative data is done to increase research validity (Yin, 2002).

Finally the ordinary least squares (OLS) model (always with p-value of (* $p<0.10$, ** $p<0.05$, *** $p<0.01$)) is used to find the correlation between EnM program and EnMPs adoption. Also, it is used to present the correlation of EnM program and the level of each aspect of EnM matrix.

2.6.3 Results

There are opportunities for EE improvement in all areas of a single foundry like melting, molding, ventilation, compressed air, lighting and HVAC. However, according to a current investigation, melting is the biggest area for improvements (Jarza 2011). Melting alone accounts for almost 50% of a company's total energy end-use (Thollander et al., 2015). In all cases, electricity was the main energy carrier and in some cases district heating was used to cover the heating needs. LPG devotes a small part of energy carrier of the 10 studied foundries which is used to preheat the ladles. Table 3 shows in detail the practices identified within selected foundries and their strategic role through EE improvement, according to Turner's (2007) energy strategy classification. Also, the number of companies which chose the referenced practices in their energy program is presented (see Table 3).

Table 3. Adopted EnMPs by 10 foundries (A to J represents 1 to 10 foundries)

Practices	A	B	C	D	E	F	G	H	I	J	Sum
R1	X	X	-	X	-	-	X	-	X	X	10
R2	X	X	X	X	X	X	X	X	X	X	
R3	X	-	-	-	-	-	X	X	X	X	
R4	-	-	-	-	-	-	-	-	-	-	
R5	X	X	X	X	X	X	X	X	X	X	
E1	X	-	-	-	X	-	X	-	-	-	3
E2	X	-	-	-	-	-	X	-	-	-	
E3	X	-	-	-	-	-	-	-	-	-	
E4	-	-	-	-	-	-	-	-	-	-	
L1	-	-	-	-	-	-	-	-	-	-	2
L2	X	-	-	-	-	-	X	-	-	-	
L3	X	-	-	-	-	-	X	-	-	-	
F1	-	-	-	-	-	-	X	-	-	-	1
F2	-	-	-	-	-	-	-	-	-	-	
F3	-	-	-	-	-	-	-	-	-	-	
F4	-	-	-	-	-	-	-	-	-	-	
A1	X	-	-	-	-	-	-	-	-	-	2
A2	X	-	-	-	-	-	-	-	-	-	
A3	-	-	-	-	-	-	-	-	-	-	
A4	X	-	-	-	-	-	X	-	X	-	
Sum	**12**	**3**	**2**	**3**	**3**	**2**	**10**	**3**	**5**	**4**	

According to the results of the assessment model (table 4) only two foundries in large size positioned their EnM maturity level relatively in 4 and 3 and all the others is positioned in a mode of 2 and average maturity level for all 10 foundries fell in a mode of 2.3. A comparison between table 3 and 4 illustrates the results of table 4. Where ever there is no EnMPs the maturity level decreases. The main weakness for all foundries, except company A, respectively devotes to training, performance measurement, energy policy action plan, investment. Given that huge emphasis in literature on the influential role of energy efficiency service provider companies on improved EE, between all studied cases only two foundries of large size addressed ESCOs, only in small part, in their entire EnM program (the reasons in most of the cases are: lack of trust, lack of information and complexity of the industry itself). In almost all cases it was observed that lack of metrics when projects are implemented hampers the next implementation. Moreover, without top management support and interest energy saving investment decision making would not decide upon.

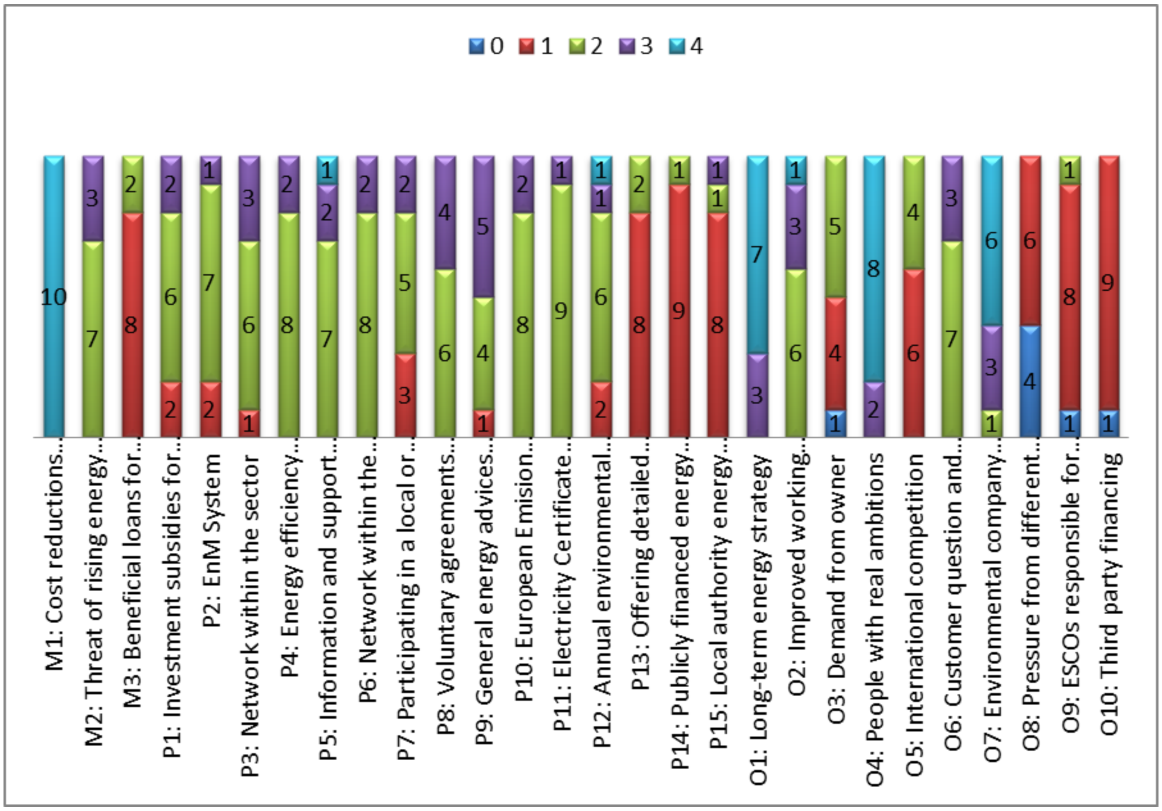
Table 4. EnM assessment model results

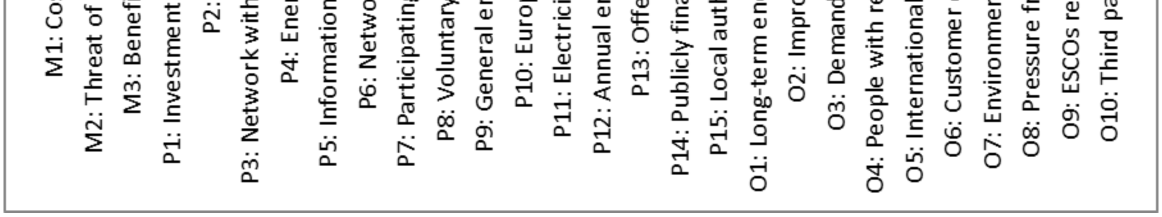
Size	L	SM	SM	L	SM	SM	L	L	L	SM
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Policy	4	1	1	3	1	1	4	1	2	1
Organization	4	2	2	3	2	2	3	2	2	2
Training	2	0	0	0	0	0	0	0	0	0
Performance measurement	4	0	2	2	0	0	4	2	2	2
Communication	4	2	2	2	2	2	3	2	1	2
Investment	3	2	2	2	2	2	3	2	2	2
Average	Tends to 4	Tends to 2	Tends to 2	2	Tends to 2	Tends to 2	Tends to 3	Tends to 2	Tends to 2	Tends to 2

Results (see table7) show that the most important driver for the adoption of EnMPs is cost reduction resulting from lower energy use. Because it has a mode of 4 (strongly important) from all 10 foundries. People with real ambition with a mode of 4 from 8 foundries is the second important promoting factor which is also has almost same importance level in Venmas (2014) and Thollander and Ottosson (2008) study. On the contrary, third party financing together with a publicly financed energy audit by a technical consultant with a mode of 1 (not important) from 9 companies has the lowest level of importance to promote EE between study cases.

Table 7 shows that there are promoting factors from different perspectives, such as market related (M1 to M3), policy related (P1 to P15), and organizational and behavioral related (O1 to O10), which push and motivate industries more and more to adopt EnMPs to continue the EE improvements. Table 7, shows in detail the EE promoting factors.

Table 7: EE promoting factors (inspired from Thollander and Ottosson (2008) and Brunke et al., (2014))





2.6.4 Conclusion

To successfully implement an EnM program, standards are providing proper statements in order to specify WHAT to do. But HOW to do them in detail is something which is left out of the single industrial company to decide. In this paper, we tried to deliver a clearer picture about the current situation, from an energy perspective, of Swedish foundries and identify aspects missing in the companies energy strategy plan and why. Lack of proper EnM programs by definition within an in-house energy program caused the poor level of EnMPs to be spread and also a generally low maturity level. The investigation has shown that more than half of the studied cases lack a long term energy strategy, sub-metering system, and proper EnM control system. Also, lack of information and trust to ESCOs through companies' EE improvement program is highlighted among selected Swedish foundries. Comparisons with previous literature and the result of current study showed that drivers with a high EE promoting level sometimes are acting as barriers.

In conclusion, the assessment made in this study showed that the real level of EnM program in Swedish foundry is far from what it should be, based on the adopted highest success levels, and the choice of evaluation method applied in the conducted research. Therefore, this paper concludes that the sustainability target would be hard to achieve if managers will not be committed enough to develop a proper and comprehensive EnM program in their agenda. Moreover, it would be difficult to achieve if managers do not tie energy targets to the companies' overall target and/or strategy.

2.7 Paper 4: Assessing the Driving Factors for Energy Management Program Adoption

2.7.1 Aim

This paper aims to understand the main driving factors which lead organizations to adopt or not adopt a particular program (always with respect to energy management). Moreover, it aims to express the impact of those driving forces of implementing a successful energy management program which could contribute better understandings about suitable EnM configuration. The investigation has been conducted as a multiple case study involving 15 manufacturing companies in different sectors and sizes located in Sweden. After analyzing the minimum required steps to establish energy management, assessing the practices adoption according to their energy strategy and moreover, through assessing energy management maturity level, we found a low level of risk (which raises from lack of certainty and awareness) and program's alignment to the core business as prominent driving factors for all sizes which foster the positive investment decision making through top management. On the contrary, industries complexity for large manufacturing companies and access to the capital for small and medium companies plays a main barrier to adopt those programs.

2.7.2 Method

The case studies were chosen in small, medium and large size from different industrial sectors. The study was carried out using semi-structured interviews conducted between August 2014 and November 2014. In each case normally two persons, one from top management and the other from the energy group of the company, were interviewed (in approximately two hours) about the EnMPs, EnM program, companies' energy related targets and motivating factors. The content of the interviews enabled the researchers to identify the adopted practices in each case.

According to the EnM literature, there are eleven minimum steps (presented in Table1) which is required to be taken for implementing EnM. During the interview energy manager of each cases asked about how they considered these eleven steps in the legend of: fully considered=2, partially considered, and not considered=0. The content of interview about EnM program and related practices which has been adopted so far within the company enabled researchers to understand about adopted practices status. In APPENDIX A, energy strategy classification, inspired from Turner (2007) has been shown. Moreover, the level of adoption for each practice in legend of: fully considered=2, partially considered, and not considered=0 has been marked.

Table 1. Minimum required steps to establish the EnM

References	Required steps	Code
Turner 2007; Thollander and Ottosson 2010; Abdelaziz et al., 2011	Long-term strategic planning	S1
Turner 2007	Energy practices by allocating responsibilities and tasks	S2
Turner 2007; McKane et al., 2007; Abdelaziz et al., 2011	Establish energy management team by energy manager	S3
McKane et al., 2007	Developing procurement policies	S4
Turner 2007; Thollander and Ottosson 2010, Abdelaziz et al., 2011	Conducting initial energy audit	S5
Turner 2007; Christofersen et al., 2006; Thollander and Ottosson 2010; Abdelaziz et al., 2011; Ates and Durakbasa, 2012.	Implement energy-saving projects	S6
Turner 2007; McKane et al., 2007	Monitoring the project's progress	S7
Turner 2007; Thollander and Ottosson 2010	Monitor energy use by main energy user equipments	S8
Turner 2007; McKane et al., 2007; Abdelaziz et al., 2011	Develop report documentation	S9
Turner 2007; Thollander Ottosson, 2010	Top management support	S10
Turner 2007	Awareness and training	S11

The maturity matrix (APENDIX B) is also developed to assess the current state of EnM program of each company. The matrix consists of six themes from policy through investment, which user could rate their EnM program on a scale of 0: not important at all to four: strongly important. The matrix enables a conversation around EnM that reflects a wider set of subjects other than just technology (the default solution for many). It tells the aspect of organizing, training, investment, communication and performance measurement. This tool is also a powerful way of understanding where barriers might exist in an organization. Understanding the Industrial EnM Model enables us to design an effective energy cost reduction program and offer services that best match to a company’s specific needs according to where they are in the overall EE maturity process.

2.7.3 Results

All finding through minimum requirement for establishing EnM, EnMPs and EnM assessment can be summarized into the following taxonomy:

Table 2.Taxonomy of barriers and drivers for EnM program investment decision-making

Barriers	Comments
Access to capital	A commonly cited barrier to implementing EE projects is lack of access to capital. This might be more relevant for the smaller companies which have low capability in terms of capital investment.
Time and expertise	Time, resources and skilled persons are essential to identify opportunities for cost-saving targets and implement the threats
Awareness and uncertainty	Lack of information about energy use trends, lack of benchmarking with best practice in same sector and lack of proper training are the most pronounced elements which increase uncertainty and decrease awareness between practitioners.
Practice characteristics	Transparency regarding scope, target, and moreover the link to the core business build the characteristics of a particular practice.
Risk	Disruption of a production line, overestimation about turnover, higher investment demand for EE projects in comparison with other type of investment and uncertainty about payback time horizon are the topics of EE-related risk felt regarding time, cost and quality.
Industry's complexity	Characteristic of an industry through its process and operation line even between same sectors are different and makes an industry, mostly in large-sized companies, a complex place.

Having classified the relevant barriers within each study according to our taxonomy, we recorded the number of times that each of these barriers was mentioned within the sample of studies, thereby allowing a quantitative picture to be provided of the results. Although this is a crude procedure, the results provide some indication of the relative importance of each barrier in preventing cost-effective improvements and investment decision making process in industrial EnM program. The results are summarized in Figure 1.

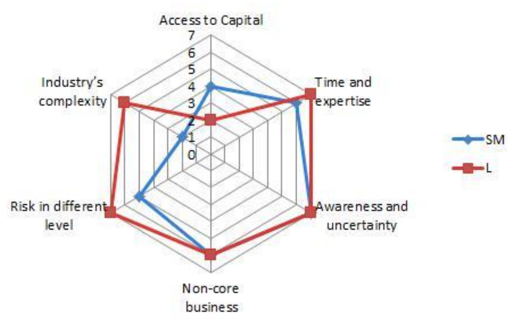


Figure 1. Simple count of the number of mentions of specific barriers to EnM investment decision making within the sample of studies

While all six of the barriers in our taxonomy appeared in the sample, the two that appeared most prominently were non-core business character of the programs and awareness and uncertainty which cause relatively high perception of risk. Therefore, increasing the strategic characteristic of the programs which leads higher alignment to the core business strategy of the organization and decreasing the perception of risk which raises from uncertainty and lack of enough information can be highlighted as two main positive driving factors which foster the adoption rate for EnM program.

The various arguments are discussed here about how an investment would be adopted from top management as a strategic management level. Therefore, according to alternative EE investments literature and what energy manager in 14 studied cases we obtained, contrary to what EE literature, if EnMPs are not adopted does not mean that they do not receive support from top management, but it means that they are not strategic enough. The influence of the strategic character of investment in the decision making process and its result (a positive, negative or no-decision), an this same influence on the capital budgeting tools used, as well as on financial requirements for profitability (pay off criterion).

Another important aspect of positive decision making is risk reduction. Energy managers need to reduce EnM program’s risk and uncertainty through risk management, which consist of: identify the risk, identify the person in charge and allocating responsibility through planning and resourcing and then evaluating again. Risk reduction improves the transparency and certainty and moreover, it brings value to the company. According to all these arguments, this paper suggests following framework for EnM program which can be fit for all manufacturing types. Energy manager needs to perfectly interpret and identify companies total strategy and capacity in order to implement an energy strategy which is aligned with the company's core business. Moreover, the need for “plan, Organize, implement and control” in each step of EnM program is highlighted to improve the transparency and reduce associated risks in each step as much as possible to improve the certainty level. To set the energy strategy, energy manager always needs to align the program with core business and adopt programs which are more strategic to improve positive investment decision makings. Last but not least, beside all determining factors, character of energy manager is the most important element to have a successful energy strategy. S/he not only need to be experienced enough in the field, being a professional project manager is another strong characteristic for energy manager. Any energy program can be seen as a project which needs to be completed in proper quality, cost and time always in aligning with companies total strategy and capacity. The more alignment with core business, more possibility to receive positive decision making from top management.

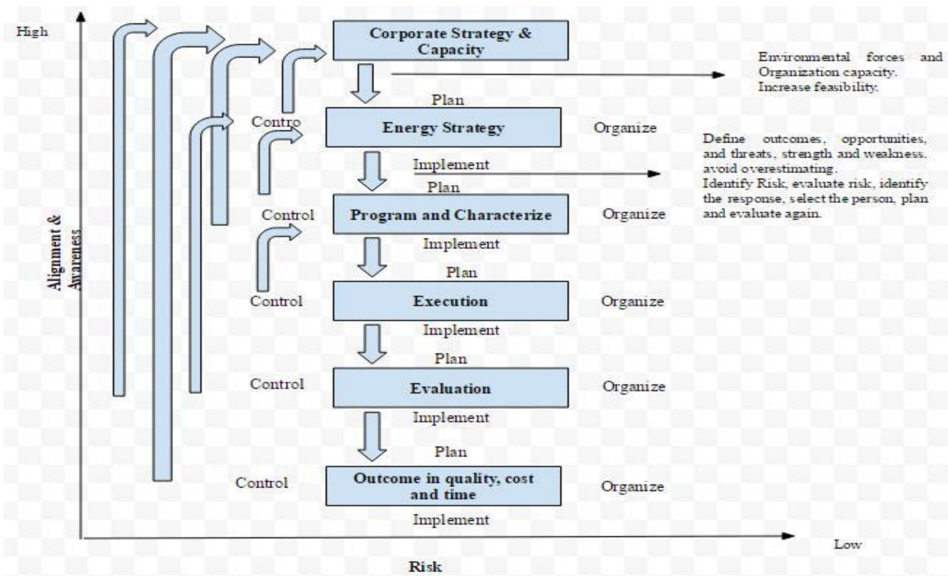


Figure 2. Contribution of the result on implementing successful EnM

2.7.4 Conclusion

EnM through its systematic programs and more in detail through its practices characterized as an industrial energy system support function. However, EnMPs is not properly implemented and/or not fully adopted in practice, with all its potential, to help companies for improving their EnM maturity level and, as a consequence, to enhance the energy system. Considering two macro level perspective regarding energy investment adoption criteria this paper assessed EnM programs from A to Z to understand better the existing barriers and drivers for energy related decision making criteria. After assessment of minimum required steps for establishing EnM program, adopted practices according to their scope and target and finally assessing the maturity level of EnM programs, current study developed a taxonomy about the barriers for EnM program adoption. Moreover, two of listed barriers appeared most prominent were non-corebusiness character of the programs and awareness and uncertainty which cause relatively high perception of risk. According to the result in the first step, finally this study tried to deliver a contribution about the impact of the main driving forces of positive investment decision making on implementing successful EnM program.

2.8 Paper 5: Is Passive House Concept Applicable to Self-Sufficient Industry?

2.81. Aim

The aim of this study is, by the 28 introduction of the concept of self-sufficient industries through passive house concept, an 29 attempt to further develop guidelines on the success of in-house energy management 30 programs.

2.8.2 Method

Based on the perspective of introducing self-sufficient industry, we look at Xylem's EnM program. 38 The site in Emmaboda of 110000 m2 has around 1200 employees and a manufacturing capacity of 140000 pumps and 2500 mixers and is considered a large energy intensive manufacturing industry in 1 Sweden. Companies' characteristics like energy intensity and size have a direct impact on energy 2 activities [14, 15]. Since 1998, Xylem is working continuously to improve energy efficiency with EnM 3 department. Xylem won the Swedish Foundry Association's energy prize in 2006 [16] as well as were 4 nominated to Sustainable Energy Europe & ManagEnergy Awards 2014 for the project "High 5 Temperature Borehole Thermal Energy Storage at Xylem" [17]. Programs and EnMPs which are 6 running in Xylem day by day make them more and more self-sufficient industry from energy supply 7 point of view.

2.8.3 Results and Discusion

EnM is a robust tool to improve EE in industries and its main task is to reduce costs for provision of energy in buildings and facilities without compromising work processes. However, it needs some defined standards to inject into the EnM programs for better results. The self-sufficient and/or passive industries concept can be designed and developed to promote leadership in this important area, .i.e. it point towards a direction on how to reach overall sustainability, not only aim for continuous improvements using the PDCA-cycle. The requirements for industrial facilities, in turn, can differ. In this paper it has not been the attempt to set the standards or criteria for passive industrial facilities, however, it has been emphasised to make some suggestions based on best-known example found among industries. A suggestion can be trying to define the optimal value for heat demand for a specific industrial sector (HD) as well as energy use (EU) by electric appliances. To define HD and EU it is necessary to measure heat demand for a particular company, kWh/m2 (HDi), average heat demand for a particular sector, kWh/m2 (aveHD), energy use (by electrical appliances) for a particular company, kWh/m2 (EUi) and average energy use (by electrical appliances) for a particular sector, kWh/m2 (aveEU) [19]. However, based on the characteristics of any industrial company requirements would be different. For instance, open foundries and close foundries are differing in insulation. Therefore, important parameters should be characterized when passive industries are defining. For improved EE results it is pillar to work continuously and properly. Even small modifications in EnMPs might bring sound improvements. Innovation sometimes does not come from expected places. Thus low-carbon and/or EE solutions can be expected to emerge from all parts of economy – not just the established “energy” or “environment” sectors, both of which can be hidebound by traditional ways of thinking. And real progress can be made when a series of innovations link together and set off a chain reaction. We need to think of innovation as “tipping points” and create policies that support them. Therefore, introducing passive industries and/or self-sufficient industries, this paper attempts to highlight more and more the importance of facilities’ EE improvement not only in design, but also in construction. The PH concept has 19 or 20 kWh/ m2 , year for external heating supply. The average in Swedish industry is 250kWh/ m2, year for heating. Xylem is down to 27 kWh/ m2, year by injecting almost PH requirements into its EnM program and practices. Moreover, the major part that has made Xylem so successful is not focusing on components but on the whole system. They have for example done very little in terms of insulation but extremely much on excess heat utilization using heat pumps etc. This may be seen as remarkable. An industrial company with 110 000 m2 of heated area have reached near the PH requirements. Xylem developed an almost proper EnM program to enhance its EE level; however, there is some vacant room to improve it even further. As it was mentioned, Xylem’s will to become self-sufficient from the perspective of energy supply is very similar to the PH concept. One major means for industrial companies could be modifying industrial buildings from EE point of view through facility management same as what has been developed by a PH concept for residential buildings [3]. From an energy point of view, the higher efficiency is always better. When one tries to add PH concept to EnM programs for industries the idea is to minimize heating, electricity, and cooling inputs. Therefore, based on the characteristics of the company insulation and other PH’s criteria would vary. So, from this perspective more is not always better and values should be set for industrial building envelopes. The criteria and requirements which are identified for PH are applicable in industrial facilities as well. However, when designing these criteria one should pay attention to the production rate of particular industrial facility. Since Xylem has improved the areas in regard to ventilation, heat recovery and installed various control system, it would have a huge potential to include PH requirements in its EnM programs. However, all proposed standards such as building insulation, ventilation, heat recovery, and air tightness need to redefine and recalculate to be fit for industrial facilities. As we know huge amount of heat is recoverable in the production processes. Proper window installation in proper size and well insulated windows consequently lowers energy demand, heat recovery and lightning. Since defining proper means for all mentioned criteria requires simulation model for several cases which are not in the scope of current paper and are therefore suggested as an area for future work.

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Paper 1

Industrial Energy Management Gap Analysis

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Commentary Open Access

Industrial Energy Management Gap Analysis

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Keywords: Energy management; Practices; Industry; Energy efficiency

Introduction

Improved energy efficiency (EE) is recognized as an essential strategy in energy and climate change mitigation policies (IPCC, 2014). Greater competition, unpredictable energy markets and control on greenhouse gas emissions, drives manufacturing industries to manage their energy demand carefully and use it efficiently. Energy management (EnM) as a cost reduction and risk protection strategy against the unpredictable energy market is a robust tool and support function which helps industries to improve their EE level. However, since energy cost in comparison with total production costs in manufacturing companies has the small portion consequently it receives little attention. Previous studies of improving industrial EE through EnM have been conducted in energy auditing [1] optimizing industrial energy systems [2], manufacturing simulation [3], energy system modeling, Kissock et al [4], energy efficienct technologies [5-7] and barriers to EE in energy-intensive companies and non-energy-intensive companies [8,9]. One of the foremost means of improving industrial EE is through the use of Voluntary Programs or Long-Term Agreements. Mentioned means have played role in EnM standard through combination of energy management practices (EnMPs) and energy assessment and energy assessment/ energy auditing [10]. However, still there is no single accepted definition for EnMPs [11]. Also, research concerning EnMPs has so far been scarce. Moreover, studies concerning energy services in the industry have not been extensively exploited. There is no study on classification of EnMPs. Notably, energy policy measures for improved EE in industry is in need of clarifications in these regards, as policies involving EnM components forms the backbone of successful industrial energy policies, e.g. Voluntary Agreements, see, e.g. [12-14]. Therefore, the current paper intends to deliver how important is to focus on mentioned four gaps in industrial EnM related literature and policy.

Analysis

EnMPs are to be seen as more managerial actions, while others can be defined as technical and operational practices. The lack of single accepted definition for EnMPs causes imprecise understanding about EnMPs. As another result, no classification which could classify EnMPs' based on their target exists in EnM literature. It also causes failure in choosing proper EnM configuration through single industry's characteristics. In other word, the lack of a precise definition about EnMPs causes both technical and managerial failure towards improving companies' EE. If major improvements in EE are the target for a single industry, many different policy instruments and pre-steps can and must be taken. As for effective EnM it is pillar to work continuously, for better result it is necessary to establish policies which could support EnM programs properly and continuously. Even though an EnM system as such cannot be seen as national policy, EnM standards often comprise the backbone of Voluntary Agreements. According to Jelic´ et al [15] comparison of national EnM standards, there is lower agreement on some elements. Management commitment, strategic planning, purchasing and design are all those listed with low agreement level. Policy makers, engineers and scholars are in a position to think about not only what to install to improve EnM programs, but also to how to implement these measures. Thus to converge an unanimously accepted strategy, close contact between practitioners, policy makers and scholars is the mainstay. Simultaneously, it causes not only to avoid any possible confusion in existing program when policy makers and scholars get in touch with the realness of the industry through the practitioners, but also to establish policies which support EnM program properly. Thus, regardless of any discipline which laws are relevant to, they constantly need to be revised by policy makers to innovate and inject new, necessary, and value added items to the existing program. In Figure 1 a presentation on how these four elements affect each other's failure and/or success is seen.

Different definitions of a single concept not only cause inaccurate understanding about it, but also cause improper proceedings to obtain the desired results. The perspectives of management only or merely technical to the EnM concept has caused both mentioned problems in industries. However, EnMPs could be defined as total continuous or frequent managerial and technical actions in a company which aim primarily to reduce the energy costs or to secure the energy supply and secondary to reduce the pollution [16]. Some authors believe that there is overlap between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure [17]. It is useful to list all EnMPs and group them based on where and how they improve the EE. Classification of EnMP through the EnM definition can be a light to better understanding of what EnM is.

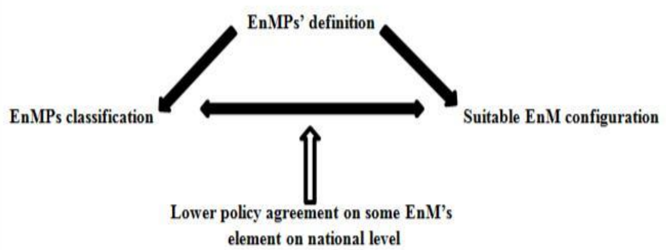

Figure 1: EnMPs gap analysis.

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Based on EnM literature, there are indications that EnMPs positively link to a top management support and ambitious, productivity, and firm's climate friendly R&D [18]. Meanwhile companies' characteristics like energy intensity and size have a direct impact on energy practices. After all, even if there would have existed top management ambitious, in most of the cases two stumbling blocks are exist: 1) there is no energy manager by definition within the company and/or 2) since energy is not considered as a core business and strategic but mostly a secondary issue therefore it receives relatively little attention. Top managements are positioned in a strategic level of any organization. Since top management support is a key to EnM's program success, energy manager should make the EE investments more strategic. The more strategic an investment the more opportunity it has to acquire the contest. While integrating energy and operations approaches erases the line between process energy services and ancillary energy services and spreads out the doors to strategic analysis, linking the operations and energy analyzes could bring better results from the EE improvement point of view. An investment is strategic if it contributes to create, maintain, or develop a sustainable competitive advantages [19]. To build a competitive advantage, making a balance between internal resources and external factors through resource allocation is essential [20].

Turner [21] has a very strategic view towards energy within the industry. Turner determined and clustered five energy related strategies for a single industry, which are: reliability, efficiency, low cost/no cost, funding, and awareness and practices which could maintain the targets are identified. Grouping energy related practices through their targets could make the situation more clear for the top managers to realize by performing which practices they could arrive at what kind of resolutions not only from the EE improvement point of perspective, but also from a strategic point of opinion.

Conclusion

EnM is a robust tool to improve the EE in industries and its main task is to reduce costs for the provision of energy in buildings and facilities without compromising the manufacturing processes. However, it needs some clarifications in regards to definitions, which points towards a direction on how to reach overall sustainability, not just to work in accordance with continuous improvements, this in order to inject into the current and future EnM policy programs for improved impacts. Although the requirements for industrial facilities, in turn, can differ, how EnMPs are defined helps to clear understanding about the in-house EnM program and choosing proper EnM configuration based on industry's characterization and overall objectives.

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Paper 2
Full Version
Classification of Industrial Energy Management Practices - A case study of a Swedish foundry

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Classification of Industrial Energy Management Practices
A case study of a Swedish foundry

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Abstract

Environmental concerns, stricter legislation and inflated energy costs, together yield improved energy efficiency (EE) as an important pillar in every industrial sector. Mindful of this challenge, energy management (EnM) and its related practices deemed to be one of the major instruments to improve EE within manufacturing companies. Despite the importance of this issue, there is no precise and unanimous definition for energy management practices (EnMPs). Moreover, very few papers investigate EE opportunities and/or EnMPs in foundry industry. The aim of this paper is to: 1) identify, classify and characterize EnMPs through its definition, with respect to EE, that could take place in a foundry industry; 2) address deficiencies in existing EnMPs and suggest further improvements.

Keywords: *energy management, practices, foundry*

1. Introduction

Improved energy efficiency (EE) is recognized as an essential strategy in energy and climate change mitigation policies (IPCC, 2014). However, the benefits of using energy more efficiently include not only greenhouse gas (GHG) emissions reductions, but also reducing investments in energy infrastructures, lower fossil fuel dependency, increased competitiveness and improved consumer welfare. Improved EE becomes necessary for manufacturing industry, particularly, since it is historically one of the greatest energy users and carbon emitters in the world. The manufacturing sector is responsible for about one third of the primary energy use and for 38% of the CO_2 emissions globally (IEA 2008a; EIA 2013). The foundry sector is considered to be one of the most energy-intensive sectors in Sweden together with pulp and paper, steel and chemical industries and thus requires attention (Thollander & Ottosson, 2010). 5-15% of the added value is allocated to energy costs in foundries in Europe

(Thollander & Ottosson, 2010). For sustainable and smart foundries and manufacturing industry in general, improved EE is therefore of a great importance (Thollander et al., 2013).

Even though improved EE becomes of an increased importance for manufacturing industries, a number of barriers exist which inhibits deployment of the potential for improved EE. Examples in the literature and in the world of practice show that although the manufactur-ing sector has made continuous improvements in EE, the techno-economical potential is not yet fully exploited (EC, 2010; hamer, 2004; Enkvist et al., 2007; IEA, 2008b; IEA, 2009; Mundaca, 2008). This paradox or energy efficiency gap was first defined by Hirst and Brown (1990) meaning that profitable investments into improved energy efficiency is not realized in companies because of the barriers to EE (DeCanio, 1993, 1998; De Groot et al., 2001; Eichhammer, 2004; Jaffe and Stavins, 1994; Paton, 2001; Cagno & Triani, 2013; Triani et al., 2013; Cagno et al 2014; Brunke et al., 2014;). A number of papers examined barriers to EE in industry, some of the high-ranked for whole sizes being technical risks, lack of options to improve EnMPs (Brunke et al.,2014) limited access to capital, lack of time or low priority given to EE by the management (Eichhammer, 2004; Cagno & Triani, 2013; Brunke et al., 2014), poor information quality and/or lack of information (Sardianou, 2008; Brunke et al., 2014) or high transaction costs (DeCanio and Watkins, 1998).

Several studies have identified a low status of EnM in industrial companies to be a barrier to EE (SPRU, 2000; Rohdin and Thollander, 2006; Thollander and Ottosson, 2010). Implementing EnM can be a way to improve EE and to reduce the related CO_2 emissions (Christoffersen et al., 2006; Kannan and Boie, 2003) and overcome barriers to EE.

O'Callaghan and Probert (1977) define 'Energy Management' as addressing "resources, as well as the supply, conversion and utilization of energy". EnM practices (EnMPs) thus help to improve EE in industries by a systematized and continuous way of dealing with energy related aspects. However, despite of quite big attempts to classify EnMPs for improving EE in manufacturing industries there is still a room for improvements. Foundries are one of the most energy-intensive industries and thus require extensive attention to how they manage energy usage on sites. Previous research in the field of EnM in the foundry industry has revealed that a number of barriers inhibit the adoption of more energy efficient technologies, e.g. lack of budget funding and other priorities for capital investments (Trianni, 2012). Similar findings were shown in a Swedish study of barriers in the sector (Rohdin et al., 2007). One of the foremost means of overcoming barriers to energy efficiency is for a company to work with

EnM. Previous research in the field of EnM has shown that there are a number of measures that may be implemented in, e.g. the operations and maintenance of a company, that have very low or no pay-back times (Cafall, 1996). These measures are often not related to investments in technology, but are rather an issue how energy is managed (Caffal, 1996). However, very little attention has been paid to how EnM in the foundry industry is actually carried out. To bridge this gap, the current study by emphasizing the role of EnM in improving EE in foundries aims to answer the following questions:

1) How are EnMPs defined in the academic literature?
2) How are EnMPs classified and characterized?

To answer the first question a literature review was done classifying different definitions by different researchers. A single case study, a foundry, is applied in answering the second research question.

2. Literature Review

Foundries are one of the most energy-intensive industries and thus require extensive attention to how they manage energy usage on sites. For the foundry industries same as other industries EE can be seen from two perspectives as Thollander (2010) addressed: 1) supply side management, for instance investment in new electricity production and negotiating lower prices with energy suppliers, and 2) demand side management, such as a greater focus on EnM. A number of studies have been conducted to evaluate EnM capability to improve industries EE in the area of energy audit (Klugman et al., 2007; Thollander et al., 2005), energy optimization (Klugman et al., 2009; Cai et al., 2009; Thollander et al., 2009), drivers and barriers (Brunke et al., 2014; Thollander et al., 2013), manufacturing simulation (Solding et al., 2009), energy management (Thollander and Ottosson, 2010). Up until today however, research concerning EnMPs characterization have been scarce. Moreover, no study has so far been published about a case study in the foundry industry about best practices of EnM.

The main energy using activities within foundries are melting and holding furnaces, ventilation and compressed air system, as well as other support processes (in form of motor equipment, lighting, etc.) and molding and core making (Singh, 1999). Thus, focusing on these activities it is possible to significantly improve EE and increase revenues and profit margins.

Melting and holding requires 35% or more of total energy supply and implies all the steps from heating the charge to melting it and superheating to a tapping temperature (Singh, 1999). However the need for melting and holding depends partly on the process efficiency, e.g. increasing the yield, and thus can be decreased by improving the process (Thollander et al., 2005). This can be done not only by means of changing equipment to more energy efficient but also by proper alignment of charge, preheating, optimizing the process time and other management activities depending on the operators (Singh, 1999). Also, since a lot of foundry processes require compressed air (molding and core machines, sand mixers, grinders) (Singh, 1999) it is important to assure the efficiency of compressed air production. Main suggestions can be choosing an optimal air pressure, sealing air leakages, using optimal electric motors, etc. Furnaces are another area for improvements where a lot of savings can be achieved by changing to more efficient furnaces (from traditional furnaces to thermax heating system) (Singh, 1999). However, additional improvements can be made by minimizing heat losses by means of temperature controllers, more efficient operation of the furnaces for example (Thollander and Palm, 2012). One purely managerial action is to implement a routine charging the furnace directly after it is being emptied. This may reduce electricity use for induction furnaces with 10 % (Thollander and Palm, 2012) Additional energy efficiency improvements can be achieved by improvements in the support processes which are similar to other industries and comprising efficient energy motors, installation of frequency converters, efficient lighting and occupancy sensors, etc.

The areas for improvements can be defined by adopting an in-house EnM program (supported by an energy audit) or outsource EnM programs for energy service providers. EnMPs in the form of the efficient running of equipment and processes can be as important as investment in EE technologies and processes. Another important aspect of an in-house EnM program is the installation of a control system enabling monitoring of energy usage on the site as well as good housekeeping of energy using equipment (Thollander and Palm, 2012).

O'Callaghan & Probert (1977) defined EnM as all elements from procurement to sales of products, "monitoring, measuring, recording, analyzing, critically examining, controlling and redirecting energy and material flows through systems" in order to minimize energy use. However, a support of top management as well as adoption of a long-term energy strategy can be intrinsic for EnM to be established in a company (Thollander et al., 2013). In order to improve EE and support industrial companies (especially support process intensive ones (Sorrell, 2007)), EnM can partly or fully be outsourced to an energy service companies (ESCOs) having knowledge and experience and providing Third Party Financing and Energy Performance Contracting (Möllersten, 2001; Thollander et al., 2013).

An international study of foundries detected a low level of implementing energy audit in foundries (Thollander et al., 2013). The study showed also a long-term energy strategy to be not so common for foundries in Sweden and a number of countries which in turn, implies lack of EnMPs in general. As for the outsourcing of EnM to ESCOs this was also not very much developed practice among the studied foundries. All this highlights a big discrepancy between actual and possible adoption of EnMPs in foundries which is supported by another study conducted in 2010 and stating the potential for EE improvement in foundries to be 25% (Thollander & Ottosson, 2010). This thus leaves a room for further improvements for finding EE potential as well as implementing EE actions in the form of both technological improvements and management.

3. Methodology

As it mentioned before literature review carried on to answer first research question and a single case study, a foundry, is applied in answering the second research question. The chosen case is defined as one of the most energy-efficient foundry in relation to improved EE (Thollander et al., 2010). A single case study, which is conducted between 2009 and 2014, is analyzed in this research. Comparing the chosen case study's KPI (key Performance Indicator) in terms of energy use per tons of good castings with data from the six foundries presented in Thollander et al., (2005) reveals that the chosen case can be classified as one of the most energy-efficient examples in the field of foundries. The choice of methodology was also supported by our access to rich and comprehensive empirical sources. Also, the choice of context is grounded in the industry's international orientation and exposure to the issues of EnM. In addition, a certain level of industry representativeness in a chosen sector was considered for this study, for example, market share, sales volume, and international expertise. The primary form of data collection was a series of interviews with senior management and an EnM staff. Based on the perspective of the research questioned posed in this study, we look at the company's in-house EnM program from the perspective of Turner (2007) and its main components. In addition to the interview, frequent site visits and documents research (industry statistics, annual reports, media, industry association data, government environmental regulation reports) to examine and cross-checking qualitative data are conducted to increase research validity (Yin, 2002). In the following section, the case of a Swedish foundry is analyzed from EnM point of view.

3.1 Foundry under study

In this chapter a case study of Xylem Water Solutions Manufacturing AB is presented. This is a pump producing company with a manufacturing unit located in Emmaboda, Sweden. The reason for choosing this company was the recognition of this company being highly involved in energy related questions which is also approved by the fact that they won the Swedish Foundry Association's energy prize in 2006 (Thollander et al., 2010) as well as were nominated to Sustainable Energy Europe & ManagEnergy Awards 2014 for the project "High Temperature Borehole Thermal Energy Storage at Xylem" (EUSEW, 2014). The site in Emmaboda has around 1,200 employees and a manufacturing capacity of 140,000 pumps and 2,500 mixers and is considered a large energy intensive manufacturing industry in Sweden. The area of the plant is 110,000 m2 including a foundry, six manufacturing workshop halls and an administration building (Abrahamsson, E. & Milesson, J., 2013). The workshops are employed for producing of electrical motors, drainage pumps, waste water pumps and mixers (Abrahamsson, E. & Milesson, J., 2013). Xylem has been working actively with energy matters since 1997 but nevertheless, this is still a big foundry which uses a lot of energy.

3.1.2 Energy system in Xylem

In 2013 the electricity consumption was 43 GWh and the use of district heating was 4.5 GWh, see figure1 (Rydell, 2014).

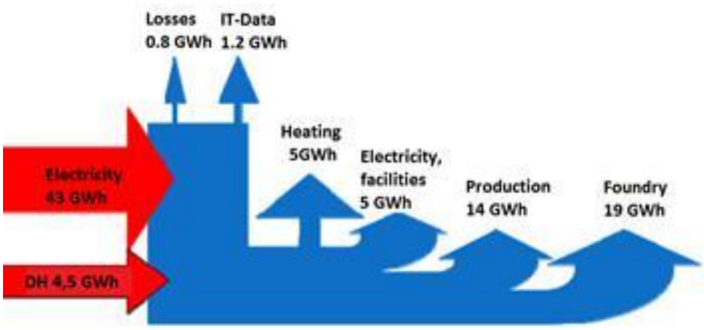

Figure1. Energy flows at Xylem, Emmaboda, 2013

The foundry and other production equipment use the majority of electrical energy and district heating is used for covering the heating needs. The company used also small amount of Liquefied Petroleum Gas (LPG) in 2013 for pre-heating ladles and trucks. The trends in EU as well as production are presented on the Figure 2. One can see that the electricity consumption follows in general the production pattern; however, there is an obvious reduction in district heating use.

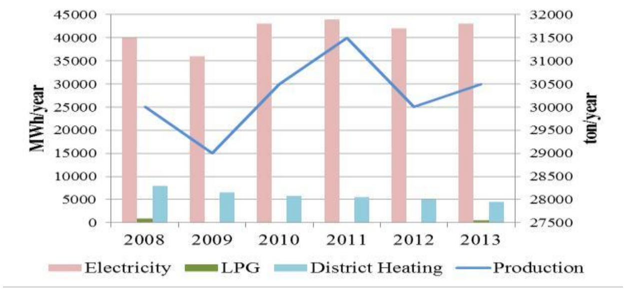

Figure2. Trends in annual EU and production at Xylem, Emmaboda, 2008 – 2013

The decreasing of the district heating use can be explained by increasing utilization of excess heat from foundry and other processes with the help of heat pumps (see figure 3).

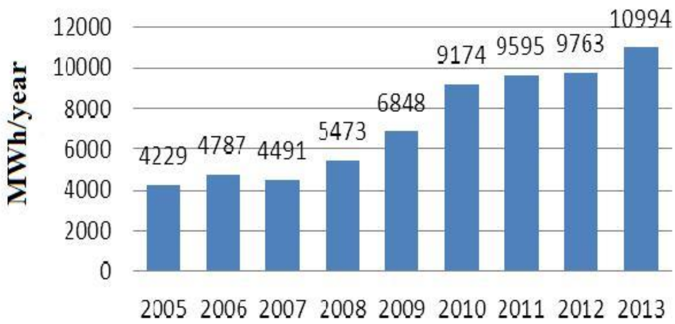

Figure3. Trends in annual recovery of excess heat at Xylem, Emmaboda, 2008 – 2013

Two important projects helped to increase the level of excess heat recovery: the bore-hole storage system as well as the heat recovery unit in the painting area. The installation of the heat pumps as well as a new furnace (LPG heated furnace was replaced by electric fur-nace) in turn resulted in slight increasing of the specific electricity consumption (Environmen-tal report, 2013) which nevertheless stays on the same level for the last four years.

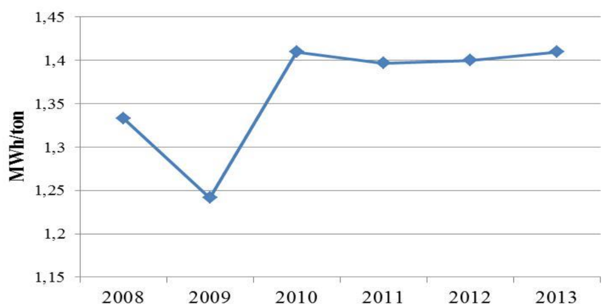

Figure4. Trends in annual recovery of excess heat at Xylem, Emmaboda, 2008 – 2013

3.1.3 Xylem's strategy in relation to energy

Xylem tries to step forward in their EE work. Reductions the use of district heating by 50% and decreasing of electricity consumption by 8% are two main goals through 2012-2015. Following two main goals which are prioritized by Xylem's managers they established the energy strategy which includes the following parameters: minimize idling losses of the equipment, sub-metering (allocation of energy use per department), estimation of opportunities to produce own electricity and use full capacity of the borehole storage.

Xylem's important principles related to energy are that the electricity they purchase should come from renewable sources and the demand for heating should be covered by bio energy or waste heat. Losses of waste heat should be minimized and every new project should be investigated for opportunities of waste heat utilization. Hot water should not be heated with direct electricity, but only with waste heat, district heating or solar energy. All the ventilation units at Xylem are demand-controlled. To complete their EnM program they set following visions for future:

Using LCC when buying new equipment;

Eliminate equipment and transport driven by fossil fuels;

Energy to be included in the 5S[1];

Cooling of processes with cooling heat pump should be prioritized due to availability of excess heat during the whole year.

The most important aspects to optimize energy use mentioned by the environmental manager are:

- involvement of the top management;
- energy control system (energy statistics);
- overview of energy use in relation to the production;
- measurements of energy use;
- information to employees;
- energy plan.

[1] 5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.

3.2 Energy efficiency projects

This part present a more detailed description of the energy saving projects and practices performed at Xylem.

3.2.1 Control system

Energy measurements and monitoring are carried out continuously with the control and monitoring systems INU, Web Factory, Siemens and Axxos. This helps to identify malfunctions of the energy system and follow the implemented measures. The heat recovery system is also connected to the control system which enables to optimize it. Operation parameters can be set by the operators that have access to the system. Buildings' performances are also monitored in the system when the performance of each building is continuously measured and compared and this energy statistics is used to assess whether an individual building's energy status deteriorates or improves. At the same time such important aspects are paid attention to as an average year correction, solar radiation and wind parameters which can affect the supply temperature for district heating. In order to visualize the energy trends several displays have begun to be installed in the facilities to increase awareness and interest in energy optimization. More displays are planned to be installed.

3.2.2 Idling driving

Idling reports are registered in the company's control system for individual processes and are presented on the energy group meetings in order to raise attention of the operators and other employees. The deviation from the pattern can help to identify the reasons for idling driving (for example, if some equipment is run during non-production time) (Energy plan, 2013). Idling reports are created monthly, based on the lowest hour value per week. The total idling losses are measured at about 50% of departments with the goal to measure it at all departments by the end of 2015. There is also an investigation work going on to look at the possibility to use Axxos stop time system to analyze the connection between the stop time and the idle consumption of equipment.

3.2.3 Heat recovery system

The heating system at Xylem consists of two parts: internal heat and external heat provided by Emmaboda's district heating company Emmaboda Energi. 4 GWh of heating demand was covered by the external network in 2012 and was further decreased to 2.8 GWh in 2013. About 11 GWh of the excess heat is used in the internal network. The waste heat of higher temperatures (from melting and casting furnaces in the foundry) is used to heat the buildings and/or domestic hot water. About half of the energy in the internal heating network is recovered from the foundry (Rydell, 2014). Waste heat at lower temperatures (below 40°C) is recovered to preheat outdoor air in ventilation systems or raised up by the heat pumps and sent out to the internal heat distribution.

A seasonal storage of the heat in the borehole storage (BHS) is a complement to the recovery system. A high temperature BHS were built in order to utilize the waste heat previously cooled off via cooling towers (about 3 GWh/year). The project was initiated in 2000 and finished in 2013. A heat pump which is an essential component of the system was bought in 2008. The BHS consists of 140 boreholes placed 150 meters down into the bedrock. Circulated water delivers the waste heat to the rock through the heat exchangers during the whole summer. During the winter the flow is turned for the heat to be used for heating purposes. All waste heat from processes and equipment is supplied to the BHS. The project includes several innovations (Energy plan, 2013):

- extremely thermally efficient heat exchangers due to direct contact of water with the rock;
- pipes made of plastic material that can withstand temperatures up to 80°C;
- there is a capacity for short storage during the winter if warmer periods occur;
- the BHS is controlled by an advanced system that allows switching between a large number of operating modes and entirely automatic (Energy plan, 2013).

The calculated efficiency of the BHS is 70%, which implies 30% losses. The system has two-direction flow with the aim to use the boreholes both when there is demand for heating or for cooling. When there is a need for cooling heat carrier is used for free cooling. At full operation it is expected to recover about 2.6 GWh. This aims to reduce the demand for the district heating from 5 GWh to 2.5 GWh out of the 8 GWh total heating demand (Abrahamsson, E. & Milesson, J., 2013)

3.2.4 Buildings/space heating process

Xylem consists of 25 buildings on a total area of 110 000 m2 in a range from 70 years old to the present. The conditions of building envelopes are different but improvements are made continuously in connection with renovations. Ports in the premises have a lock function to prevent cold drafts. Thermographing of the buildings is performed continuously during the winter to eliminate weaknesses in the building envelope. The performed projects are wall insulation of a building C11, changing of windows in buildings M12, M20, C16 (Energy plan, 2013).

3.2.5 Cooling

Free cooling is used in form of the cold water that is delivered to the ventilation units from two boreholes. Thus, a demand for cooling in the offices can be covered providing comfortable climate and work environment. Also, the cold side of the heat pump is used to cool down parts of the foundry premises. There is a further potential to expand this solution to the main part of the foundry's premises (Energy plan, 2013).

3.2.6 Ventilation

Ventilation in all buildings is controlled by VSD with the help of air quality sensors which implies that the air flow is adjusted to the ventilation demand. Installation of about 75 VSDs reduced drastically the electricity consumption for ventilation (50% savings compare to driving without the control) (Energy plan, 2013).

3.2.7 Lighting

Settings for lighting in the premises during the production time are made in the control system thus enabling avoiding using lighting when there is no production. Also, occupancy sensors are installed in the facilities. In all application where it is possible, LED-lighting has replaced inefficient lamps. There are still some quicksilver fixtures that are planned to be replaced (Energy plan, 2013).

3.2.8 Compressed air

The compressed air system using VSD compressors are equipped with pressure and flow sensors consists of four compressors. The sensors help to keep track of energy use and leakages in the system. Heat generated by the compressors is recovered to a nearby production facility. Also, the heat is recovered from the oil circuit by means of heat exchangers delivering the heat to the internal heating system of the industrial area. Furthermore, a new compressor center is under construction which will include a new variable speed compressor and cooling heat pump enabling to recover waste energy year round (Energy plan, 2013).

3.2.9 Education of staff

In order to achieve positive results in the EE improvement work, it is given an importance to involve Xylem’s staff. That is why a special attention is paid to training of staff in order to eliminate insignificant and unnecessary energy usages and minimize idling losses.

According to Xylem's energy plan, if the energy costs are to be minimized, the staff should be actively participating as well as be encouraged for proposing EE measures. In order to fulfill that, some criteria to be achieved are mentioned:

1) clear division of responsibilities related to energy issues and revision of EnM system;
2) energy issues to be a part of everyday activities from economical and environmental perspectives;
3) when purchasing energy using equipment LCC should be considered;
4) the staff should be educated about energy intensive equipment as well as support processes (lighting, idling driving);
5) energy goals should be specific for every department.

Thus, the staff aware about why some changes are made in the production or support processes can follow the instructions more thoroughly and will be able to develop the possibilities to save energy themselves.

4. Results

4.1. Definition of energy management practices

There is no single, unique and cohesive definition for EnMPs as it can be seen from different disciplines and perspectives. Apart from EnM definitions although there are some authors (see Table 1) defining EnMPs, there is a gap in literature regarding the issue.

Table1. EnMPs definitions

Reference	EnMPs definition
Caffall, 1995	Energy management practice leads to relevant savings without capital or with limited investment (short payback time compared to that of a technical measure), and such savings could be immediately re-applied to finance subsequent investment in energy-efficient technologies.
Christoffersen et al., 2006; Gordi et al., 2010; Gorp, 2004	Energy management practices have so far mainly consisted in replacing inefficient equipment and then using different methods to estimate the obtained savings.
Backlund, Thollander, et al., 2012	Energy management practices aim at improving energy efficiency of existing activities and the deployment level of energy policy programs.
Backlund, Ottosson, et al., 2012	Energy management practices have large effects on energy utilization. They affect investment decisions and the outcome of investments in energy efficiency technologies.

As shown above, some authors consider an EnMP as a technical procedure while other believes it is more managerial. However, we define *EnMPs as total continuous or frequent managerial and technical actions in a company which aim primarily to reduce energy cost or secure energy supply and secondary to reduce pollution.* Some authors believe that there is overlapping between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure (Triani, 2013). It is useful to list all EnMPs and group them based on where and how they improve the EE. Characterization of EnMP through the EnM definition can be a light to better understand what EnM is. Turner (2007) clustered EnM strategies into five dimensions: Reliability, Efficiency, Low cost/No cost, Funding, and Awareness. In this study we try to group EnMPs in these five dimensions, inspired by Turner (2007).

4.2. Xylem's energy management practices characterization

Companies' characteristics like energy intensity and size have a direct impact on energy activities (Togeby et al., 1998; Hansen et al., 1993). Xylem being an energy intensive company has been working continuously to improve EE since 1998. Information was accomplished by studying Xylem's energy plan for 2013. In table 2 an in-house EnM program and in detail EnMPs used in the company are analyzed and characterized with respect to Turner (2007) classifications. Turner clustered energy related works in industries into five different targets: reliability, efficiency, low cost/no cost, funding, and awareness.

Table2. EnMPs characterization in Xylem

Strategy	Programs	Applied practices in reference case
Reliability	Maintenance program	• Develop preventive maintenance plan by installing different class A, B, C alarm system for leaking or any other imperfection • Develop connected system to prevent energy losses • Develop maintenance program for each 3years
	Modernization	• Sensor installment for weather adjustment • Establish weather station in order to control humidity, wind direction and sun influence
	Operations	• Establish borehole storage • Heat exchangers • Establish heat recovery system • Establish sorption cooling technology • Integrate LCC to procurement strategy
	Training	

	Contingency planning	• Frequency convertor system for ventilation • Frequency reduction for ovens and switch off the washers for about 15-20 min when electric load is about 11MW which brings 2MW energy use reduction • Establish solar collector system and collecting about 35MWh per year • Establish solar shelters • Establish energy production system • Collect volatiles and burn them to produce heat • Take care of solvents burning heat in the foundry
Efficiency	Plant property evaluation	• Develop a plan for updating inefficient equipment
	Measurement	• 24hours measurement for electricity in total and specifically for the furnaces, machinery area, water consumption and heat consumption • Develop daily, monthly and annually reporting system for electricity, water and heat consumption • Develop energy report for each working area, sub metering, like: electric motors department • Develop EE index (energy use/ tonnage produced) then set EnM goal • Develop annual evaluation program in terms of production rate and energy consumption • Develop idling report (for monitoring idling drifts) • Establish permanent instrumentation for energy measurement • Procure necessary portable/ mobile instrument for measuring • Frequency converter installed in order to monitor, energy use, operating time, investment analysis • Identify and measure areas with significant energy use
	Control	• Control by portable equipment in order to investigate possible energy reduction opportunities • CO, CO_2 and VOC controlling sensor in working area • VSD control for fan's speed depending on air quality in working area • CO control sensor in foundry connected to VSD for process ventilation • CO_2 control sensor in public area connected to VSD for ventilation • Internet based controlling and monitoring system • Waste water treatment control • Heat recovery system connected to control system
	Energy organizational efficiency	
Low cost/ No cost	Alternatives for energy sources	
	Negotiation	• Receive 40% government support for 1.5 years to install PVs to produce electricity • Purchase green energy, biomass
	Time of use	• Load management, use delays for some equipment • Establish an electrical demand control system (in one sunny day it saves 5MWh)
	Elimination	• Investigate areas which have significant energy losses • Eliminate excessive heating demand

Funding	Stabilize funding	• Identify and prioritize future projects based on improved energy efficiency and pay off (less than 3years)
	Return saving to customer	
	Short term funding	• Receive 30% government support for a test program for verification of energy saving by borehole storage
	Economic analysis training	
Awareness	Training	• Set a goal of 20 kWh/m2 electric demand for heating and ventilation through borehole storage • Have high green policy • Set goals for electricity, water and heating • Avoid public water procurement for cooling in 2016 • Improve electric efficiency by 5% till 2015 • Decrease heating demand from 5GWh in 2012 to 2.5 GWh by 2015 • Inform staff since eight years back about the importance of climate change • Train staff to eliminate insignificant and unnecessary energy usages and minimize idling losses • Displays to visualize energy trends
	Communication	• Form a network of energy committee between maintenance (the energy manager is in the maintenance group) and environment departments, machinery area and production line • Involving in research program by Elforsk organization for electric demand reduction • Networking with foundry organization and Scania once a year • Established close network contact with Volvo's energy management • Publicize energy activities, e.g. seminars
	Behavior modification	
	Program evaluation	

According to Turner, for improved results in energy management programs, energy managers should be active in each target area to add the advantages of these targets to the company. It should be clear for the company what kind of advantages they can expect from the EnMPs they perform. For instance, maintenance program, modernization, developing operation procedure and contingency planning make company more reliable, but do not make company more energy efficient. As it is visible in table 2, Xylem spread their action plan in almost every cluster. Nevertheless, there are some vacant blocks such as: training for reliability target, energy organizational efficiency, alternatives for energy sources, return saving to customer, and economic analysis training.

Figure 5. shows all promoting factors for EE in the reference case studied. Incentives are classified into market related, policy related, organizational and behavioral related factors. As it is visible in figure5, market related and organizational & behavioral related factors have highly motivated EE in case studied. Likert scale is applied to rank the importance level of each motivation factor and it is answered by Xylem's energy manager.

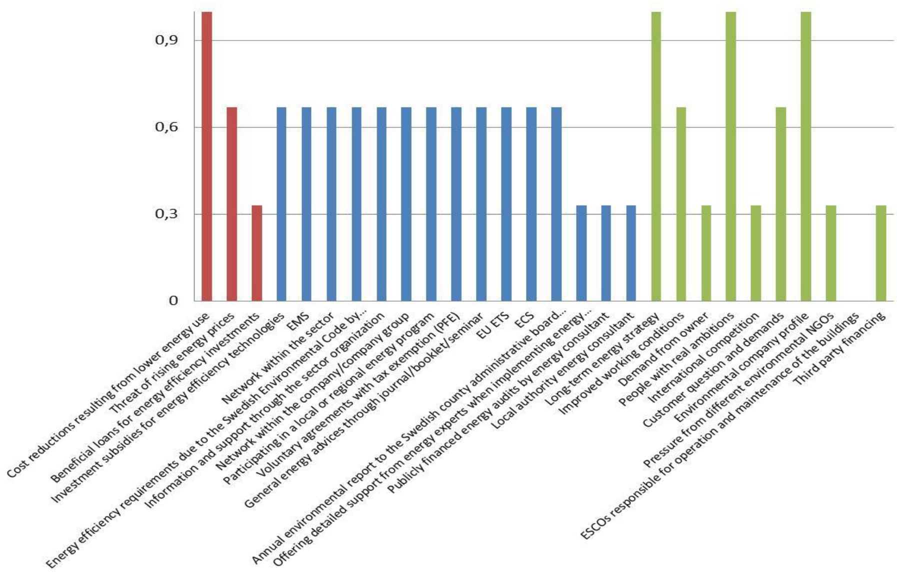

Figure5. EE Promoting factors in Xylem

Xylem's EnMPs is very comprehensive and by analyzing how EnMPs performed in the company, a unique indication is provided, the main strategy is to become self-sufficient in terms of energy supply. Practices such as heat recovery, improved electrical efficiency of the industrial appliances, installing solar panels and PV (Photo Voltaics), insulation of the facilities, using renewable energy sources at Xylem, has taken the company a long way in improving energy efficiency at the company. However, even more work is needed in order for them to fulfill their strategy of becoming self-sufficient.

5. Concluding discussion

Industrial companies strive for profit, and promoting EE can at times be difficult and not so prioritized (Thollander and Ottosson, 2010). Because many different policy instruments and pre-steps can and must be used if major improvements in EE are to take place moving industry towards improved sustainability, the results of this paper aimed to propose a comprehensive definition for EnMPs. Moreover, by characterizing EnMPs, the paper attempt to improve understanding of in-house EnM programs. Based on a literature review, there are indications that EnMPs are positively related to a top management support and ambitious, productivity, and firm's climate friendly R&D. However, large organizations often have some difficulties over SMEs in ensuring effective EnM (Baudelaire, 2014). In larger organizations, lines of communication are generally wider, organizational structures are complex enough, and access to a top management is rather difficult. All of these characteristics can be real disadvantages for effective EnM for large companies, especially for foundry industries which have more complex production process than, for example, non-energy intensive companies where the major energy use is found in the support processes. However, the same as what is running in the current studied reference case, proper meeting schedule between the energy group's members can be one means of overcoming the mentioned problems. Other tools for EnM success in large industries could be a centralized focus and energy manager's high desire to save energy and environment, as also found in Brunke et al. (2014). The energy manager's background is another important aspect which has had a direct impact on the EnM success at the studied company. Besides all these mentioned factors, there are drivers which motivate energy managers to improve EE in industries. In figure 5, driving factors for reference case are shown.

In table 2, the EnMPs for the studied case were categorized based on each practice target. Results from this paper shows that in Xylem the energy goals are set and there is a clear vision towards a green industry. Xylem developed an almost proper EnM program to enhance its EE level; however, there is some vacant room to improve it even further. Xylem's strategy is to become self-sufficient in terms of energy supply, a strategy that seems very closely related to the Passive House (PH) concept in the residential sector. This provides the idea that a modified PH concept may be possible to apply also for the industrial sectors. One major means for industrial companies in this regard, could be to modify the industrial buildings from an EE point of view similar to what has been developed in the PH concept (Feist & Schniedersa, 2009). From an energy point of view, improved efficiency is always better. If one would like to include a modified PH concept to EnM programs in the industrial sector the idea is to minimize heating, electricity, and cooling inputs. Therefore, based on the characteristics of the company insulation and other PH's criteria would then vary. So, from this perspective more is not always better, and values should be set for industrial building envelopes. The criteria and requirements which are identified for PH are applicable in industrial facilities as well. However, when designing these criteria one should pay attention to the production rate of particular industrial facility. To increase in-house EnM programs' effectiveness, the very first step is to control the cost of the energy function or service provided, but not the Btu of energy (Turner, 2007).

Since Xylem has improved the areas in regard to ventilation, heat recovery and installed various control system, the company would have an even larger energy efficiency potential if PH requirements would be included in its EnM programs. However, naturally all proposed standards such as building insulation, ventilation, heat recovery, and air tightness need to redefined and recalculated to fit for industrial facilities. As we know huge amount of heat is recoverable in the production processes, e.g. through process integration. Moreover, relating to the buildings as such, proper window installation in proper size and well insulated windows consequently lowers energy demand, heat recovery and lightning. Since defining proper means for all mentioned criteria requires simulation model for several cases this is not in the scope of current paper and are therefore suggested as an area for future work. So in conclusion the contribution of this paper for the scientific researchers is a characterization of EnMPs based on their target, and a clarification for energy managers to show them how they can successfully operationalize EnMPs, based on a state-of-the art Swedish iron foundry. Finally, a contribution is made in the introduction of the PH concept to industries to become more independent of the supply of energy.

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Paper 2
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Classification of Industrial Energy Management Practices

A case study of a Swedish foundry

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Abstract

Environmental concerns, stricter legislation and inflated energy costs together yield improved energy efficiency as an important pillar in every industrial sector. Mindful of this challenge, energy management and its related practices are deemed to be one of the major instruments to improve energy efficiency within manufacturing companies. Despite the importance of this issue, there is no precise and unanimous definition for energy management practices. Moreover, very few papers investigate energy efficiency opportunities and/or energy management practices in foundry industry. This paper aims to identify, classify and characterize energy management practices through their definition, with respect to energy efficiency, that could take place in a foundry industry.

Selection and/or peer-review under responsibility of ICAE

Keywords:energy management; practices;foundry; classification

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1. Introduction

Improved energy efficiency (EE) is recognized as an essential strategy in energy and climate change mitigation policies. However, the benefits of using energy more efficiently include not only greenhouse gas (GHG) emissions reductions, but also reducing investments in energy infrastructures, lower fossil fuel dependency, increased competitiveness and improved consumer welfare. The manufacturing sector is responsible for about one third of the primary energy use and for 38% of the CO2 emissions globally [1, 2]. The foundry sector is considered to be one of the most energy-intensive sectors in Sweden together with pulp and paper, steel and chemical industries and thus requires attention [3]. 5-15% of the added value is allocated to energy costs in foundries in Europe [3]. For sustainable and smart foundries and manufacturing industry in general, improved EE is therefore of a great importance [4].

Even though improved EE becomes of an increased importance for manufacturing industries, a number of barriers exist which inhibits deployment of the potential for improved EE. Examples in the literature and in the world of practice show that although the manufacturing sector has made continuous improvements in EE, the techno-economical potential is not yet fully exploited [5, 6, 7, 1, 8, 9]. This paradox or energy efficiency gap was first defined by Hirst and Brown (1990) [10] meaning that profitable investments into improved EE is not realized in companies because of the barriers to EE [11, 12, 6, 13, 14, 15]. A number of papers examined barriers to EE in industry, some of the high-ranked for whole sizes being technical risks, lack of options to improve energy management practices (EnMPs) [15] limited access to capital, lack of time or low priority given to EE by the management [6, 16, 18], poor information quality and/or lack of information [15] or high transaction costs [16].

Several studies have identified a low status of Energy Management (EnM) in industrial companies to be a barrier to EE [17, 3]. Implementing EnM can be a way to improve EE and to reduce the related CO_2 emissions [18, 19] and overcome barriers to EE. O'Callaghan and Probert (1977) [20] define 'Energy Management' as addressing "resources, as well as the supply, conversion and utilization of energy". EnMPs thus help to improve EE in industries by a systematized and continuous way of dealing with energy related aspects. However, despite of quite big attempts to classify EnMPs for improving EE in manufacturing industries there is still a room for improvements. To bridge this gap, the current study by emphasizing the role of EnM in improving EE aims to answer the following questions: 1) How are EnMPs defined in the academic literature? and 2) How are EnMPs classified and characterized?

2. Method

Literature review and a single case study, a foundry, which is conducted between 2009 and 2014, are applied in answering the research questions. The chosen case is defined as one of the most energy-efficient foundry in relation to improved EE [3]. Comparing the chosen case study's KPI (key Performance Indicator) in terms of energy use per tons of good castings with data from the six foundries presented in [21] reveals that the chosen case can be classified as one of the most energy-efficient examples in the field of foundries. The choice of methodology was also supported by our access to rich and comprehensive empirical sources. Also, the choice of context is grounded in the industry's international orientation and exposure to the issues of EnM. In addition, a certain level of industry representativeness in a chosen sector was considered for this study, for example, market share, sales volume, and international expertise. The primary form of data collection was a series of interviews with senior management and an EnM staff. Based on the perspective of the research questioned posed in this study, we look at the company's in-house EnM program from the perspective of Turner (2007) [22] and its main components. In addition to the interview, frequent site visits and documents research (industry statistics, annual reports, media, industry association data, and government environmental regulation reports) to examine and cross-checking qualitative data are conducted to increase research validity [23]. In the following section, the case of a Swedish foundry is analyzed from EnM point of view.

3. Results

3.1. Definition of energy management practices

There is no single, unique and cohesive definition for EnMPs as it can be seen from different disciplines and perspectives. Different researchers have different point of view about what EnMPs are. For instance Caffall (1995) [24] defines it as “relevant savings without capital or with limited investment (short payback time compared to that of a technical measure), and such savings could be immediately re-applied to finance subsequent investment in energy-efficient technologies”. However, from Christoffersen et al. (2006) [18] point of view EnMPs have so far mainly consisted in replacing inefficient equipment and then using different methods to estimate the obtained savings.

As mentioned above, some authors consider an EnMP as a technical procedure while other believes it is more managerial. However, we define *EnMPs as total continuous or frequent managerial and technical actions in a company which aim primarily to reduce energy cost or secure energy supply and secondary to reduce pollution.* Some authors believe that there is overlapping between EnMPs and EE measures. But apart from the existence of some overlaps it is possible to differentiate EnMPs from EE measure [14]. It is useful to list all EnMPs and group them based on where and how they improve the EE. Characterization of EnMP through the EnM definition can be a light to better understand what EnM is. Turner (2007) [24] clustered EnM strategies into five dimensions: Reliability, Efficiency, Low cost/No cost, Funding, and Awareness. In this study we try to group EnMPs in these five dimensions, inspired by Turner (2007) [24].

3.2. Xylem’s energy management practices characterization

Companies’ characteristics like energy intensity and size have a direct impact on energy activities. Xylem in Emmaboda, Sweden, with 1,200 employees and a manufacturing capacity of 140,000 pumps and 2,500 mixers is a large energy intensive company which it has been working continuously to improve EE since 1998. Information was accomplished by studying Xylem’s energy plan for 2013. The reason for choosing this company was the recognition of this company being highly involved in energy related questions which is also approved by the fact that they won the Swedish Foundry Association’s energy prize in 2006 [25] as well as were nominated to Sustainable Energy Europe & ManagEnergy Awards 2014 for the project “High Temperature Borehole Thermal Energy Storage at Xylem” [26].Figure 1, shows energy flow and annual trends in terms of energy and production.

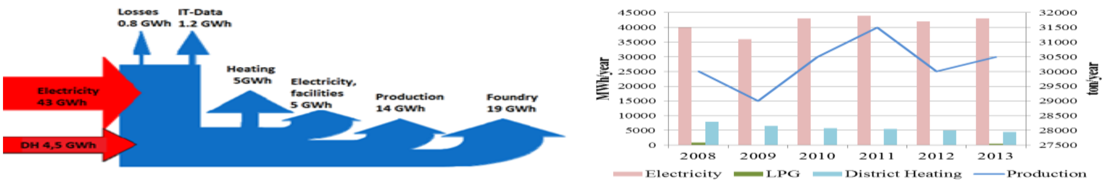

Figure 1. Left (a) Energy flows at Xylem. Right (b) Trends in annual EU and production at Xylem

In table 1 an in-house EnM program and in detail EnMPs used in the company are analyzed and characterized with respect to Turner (2007) [22]. Turner clustered energy related works in industries into five different targets: reliability, efficiency, low cost/no cost, funding, and awareness.

Table1. EnMPs characterization in Xylem

Strategy	Programs	Applied practices in reference case
Reliability	Maintenance program	Develop preventive maintenance plan by installing different class A, B, C alarm system for leaking or any other imperfection Develop connected system to prevent energy losses Develop maintenance program for each 3years
	Modernization	Sensor installment for weather adjustment Establish weather station in order to control humidity, wind direction and sun influence
	Operations	Establish borehole storage Heat exchangers Establish heat recovery system Establish sorption cooling technology Integrate LCC to procurement strategy
	Training	
	Contingency planning	Frequency convertor system for ventilation Frequency reduction for ovens and switch off the washers for about 15-20 min when electric load is about 11MW which brings 2MW energy use reduction Establish solar collector system and collecting about 35MWh per year Establish solar shelters Establish energy production system Collect volatiles and burn them to produce heat Take care of solvents burning heat in the foundry
Efficiency	Plant property evaluation	Develop a plan for updating inefficient equipment
	Measurement	24hours measurement for electricity in total and specifically for the furnaces, machinery area, water consumption and heat consumption Develop daily, monthly and annually reporting system for electricity, water and heat consumption Develop energy report for each working area, sub metering, like: electric motors department Develop EE index (energy use/ tonnage produced) then set EnM goal Develop annual evaluation program in terms of production rate and energy consumption Develop idling report (for monitoring idling drifts) Establish permanent instrumentation for energy measurement Procure necessary portable/ mobile instrument for measuring Frequency converter installed in order to monitor, energy use, operating time, investment analysis Identify and measure areas with significant energy use

	Control	Control by portable equipment in order to investigate possible energy reduction opportunities CO, CO2 and VOC controlling sensor in working area VSD control for fan's speed depending on air quality in working area CO control sensor in foundry connected to VSD for process ventilation CO2 control sensor in public area connected to VSD for ventilation Internet based controlling and monitoring system Waste water treatment control Heat recovery system connected to control system
	Energy organizational efficiency	
Low cost/ No cost	Alternatives for energy sources	
	Negotiation	Receive 40% government support for 1.5 years to install PVs to produce electricity Purchase green energy, biomass
	Time of use	Load management, use delays for some equipment Establish an electrical demand control system (in one sunny day it saves 5MWh)
	Elimination	Investigate areas which have significant energy losses Eliminate excessive heating demand
Funding	Stabilize funding	Identify and prioritize future projects based on improved energy efficiency and pay off (less than 3years)
	Return saving to customer	
	Short term funding	Receive 30% government support for a test program for verification of energy saving by borehole storage
	Economic analysis training	
Awareness	Training	Set a goal of 20 kWh/m2 electric demand for heating and ventilation through borehole storage Have high green policy Set goals for electricity, water and heating Avoid public water procurement for cooling in 2016 Improve electric efficiency by 5% till 2015 Decrease heating demand from 5GWh in 2012 to 2.5 GWh by 2015 Inform staff since eight years back about the importance of climate change Train staff to eliminate insignificant and unnecessary energy usages and minimize idling losses Displays to visualize energy trends

Communication	Form a network of energy committee between maintenance (the energy manager is in the maintenance group) and environment departments, machinery area and production line Involving in research program by Elforsk organization for electric demand reduction Networking with foundry organization and Scania once a year Established close network contact with Volvo's energy management Publicize energy activities, e.g. seminars
Behavior modification	
Program evaluation	

According to Turner, for better results in energy management programs, energy managers should be active in each target area to add the advantages of these targets to the company. It should be clear for the company what kind of advantages they can expect from the EnMPs they performed. For instance, maintenance program, modernization, developing operation procedure and contingency planning make company more reliable, but do not make company energy efficient. As it is visible in table 1, Xylem spread their action plan in almost every cluster. There are some vacant blocks such as: training for reliability target, energy organizational efficiency, alternatives for energy sources, return saving to customer, and economic analysis training.

4. Concluding discussion

Industrial companies strive for profit, and promoting EE can at times be difficult and not so prioritized [3]. Because many different policy instruments and pre-steps can and must be used if major improvements in EE are to take place moving industry towards improved sustainability, the results of this paper aimed to propose a comprehensive definition for EnMPs. Moreover, by characterizing EnMPs, the paper attempt to improve understanding of in-house EnM programs. Based on a literature review, there are indications that EnMPs are positively related to a top management support and ambitious, productivity, and firm's climate friendly R&D. However, large organizations often have some difficulties over SMEs in ensuring effective EnM [24]. In larger organizations, lines of communication are generally wider, organizational structures are complex enough, and access to a top management is rather difficult. All of these characteristics can be real disadvantages for effective EnM for large companies, especially for foundry industries which have more complex production process than, for example, non-energy intensive companies where the major energy use is found in the support processes. However, the same as what is running in the current studied reference case, proper meeting schedule between the energy group's members can be one means of overcoming the mentioned problems. Other tools for EnM success in large industries could be a centralized focus and energy manager's high desire to save energy and environment, as also found in Brunke et al. (2014) [15]. The energy manager's background is another important aspect which has had a direct impact on the EnM success at the studied company. Besides all these mentioned factors, there are drivers which motivate energy managers to improve EE in industries.

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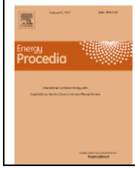

Biography

Aida Sa is an industrial engineering PhD candidate in Politecnico di Milano. She is interested in how to improve energy management programs for industries.

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Paper 3

Assessing Industrial Energy Management Program – A Multiple Case Study of Swedish Foundries

AIDA SA, PATRIK THOLLANDER, ENRICO CAGNO

Assessing Industrial Energy Management Program – A Multiple Case Study of Swedish Foundries

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Abstract: With regard to increased sustainability, it is evident that industries need to improve energy efficiency. Managers not only need to know WHAT is needed for their company to improve, but also HOW to do that in detail is equally important. Energy management (EnM) is a pillar to the transformation of industrial energy systems towards improved energy efficiency and increased sustainability. Nevertheless, managers need a framework to assess their EnM program maturity and excellence level. This paper therefore aims to classify EnM practices and develop an EnM assessment model. Moreover, it aims to assess the most important factors to promote improved energy efficiency. The investigation has been conducted as a multiple case study involving 10 foundries, a major energy-consuming industry and a strategic sector for the European economy, located in Sweden. According to the results, almost 80% of the studied foundries have no EnM control system, no measurement system and no practices for energy organizational efficiency. Lack of long-term energy strategy is another area which is left blank within the companies' total strategy. Among the studied cases, only two out of ten have conducted an energy audit. Comparison with previous literature and the result of the current study showed that drivers with high energy efficiency promoting level sometimes act as barriers. In conclusion, EnM in the Swedish foundry industry, despite the unpredictable energy market, potential climate change legislation and controls on greenhouse gas emissions, still seems to have great improvement potential for energy efficiency.

Keywords: *energy management program; energy management assessment; foundry; industrial energy efficiency*

1. Introduction

International agreements to control emissions and mitigate climate change together with energy price fluctuation and crisis have elevated the importance of energy efficiency (EE) in the industrial sector, being one of the main energy consumers in society. For that reason, it is important to study energy-intensive industries such as the foundry sector (Thollander and Ottosson 2010; Thollander et al., 2013). To improve EE in industry, long-term energy strategies and committed energy managers are both important factors in spurring improved EE in industrial firms. While several factors promote the efficient use of energy, there are also barriers. Energy management (EnM) has been addressed in several scientific papers as a robust and efficient means to overcome such barriers. The term EnM has been used in different ways in the academic literature, and there is still no cohesive definition (Schulze et al., 2015). What many definitions of EnM have in common is that they primarily concentrate on implementation of energy efficient technologies and replacing inefficient equipment. However, EnM also includes practices such as care, operation and maintenance of technology to maintain effective functioning. Continuous work and improvement practices are the first requirements for that (Gordic et al., 2010). The most recent theoretical and empirical research studies about drivers and barriers respectively can be found in Cagno et al. (2013), Brunke et al. (2014) and Trianni and Cagno (2015). As regards the foundry sector the most recent comprehensive research about barriers can be found in Trianni et al. (2013) and for drivers see Thollander et al. (2013). Meanwhile, previous policy researchers identified and classified a number of barriers to and drivers for EE in industries (de Groot, 2001; Sandberg and Söderström, 2003; Thollander and Ottosson, 2008). Two of these barriers, namely organizational and behavioral barriers, relate to the energy management practices (EnMPs) within the company. In general, however, the details of how an EnM program is practiced in the company have remained largely unexplored (Christoffersen et al., 2006; Kannan and Boie, 2003; Thollander et al., 2010). Organizational barriers relate to the unclear division of tasks and lack of financial resources, time and skilled personnel (Sardianou, 2008). Personnel values and mindset are included in behavioral barriers (Soroye and Nilsson, 2010; Stern, 1992).

The improvement of EnMPs in companies is addressed as an important but also challenging issue by policy researchers. A compounding of different policy measures has been introduced to influence industry, both directly and indirectly, including a mix of voluntary and mandatory standards. This challenge is also due to a lack of clear understanding about EnMPs and how these should be placed by organizations in order to improve EE. Sa et al. (2015) define EnMPs as “total continuous or frequent managerial and technical actions in a company the aim of which is primarily to reduce energy cost or secure energy supply and secondarily to reduce pollution.” Guidelines and different standards on EnM emphasize the importance of monitoring, evaluating and enhancing energy performance at process and system levels. However, for better results managers need to assess their program to track the strength and weakness of the current energy plan. The reasons for this relate to the need to verify and evaluate the company’s energy strategy and the current situation of the adopted practices together with assessing the company’s policy, organizing, training, performance measurement, communication and investment maturity level. Therefore, the aim of this paper is to:

1) Present the structure of the energy strategy and related practices. The strategic plan deals not only with technical aspects but also with the funding, communication, education, and behavior modification aspects of an EnM program (see Table 1). According to Turner (2007), developing a strategic plan with related practice items is the last but most important step in an organization’s EnM program development, and unfortunately this is where many stop.

Table1

EnM strategies, programs and related practices (inspired from Turner, 2007)

Strategy	Program and Related Practices	Codes
Reliability	• Maintenance program	R1
	• Modernization	R2
	• Operations	R3
	• Training	R4
	• Contingency planning	R5
Efficiency	• Plant property evaluation	E1
	• Measurement	E2
	• Control	E3
	• Energy organizational efficiency	E4
Low cost	• Negotiation	L1
	• Load management	L2
	• Elimination	L3
Funding	• Stabilize funding	F1
	• Return savings to the customer	F2
	• Short-term funding	F3
	• Economic analysis training	F4

Awareness	• Training • Communication • Behavior modification • Program evaluation	A1 A2 A3 A4

2) Assess industry's EnM program and maturity level, according to EnM matrix (Carbon Trust 2011) which is presented in Table 2. The EnM matrix gives a clear picture about strengths and weaknesses of industry's EnM program across six areas (policy, organization, training, performance measurement, communication and investment) of EE measures at site level.

Table 2
EnM matrix (inspired from Carbon Trust, 2011)

Level	Policy	Organizing	Training	Performance measurement	Communication	Investment
4	Energy policy action plan and regular review have an active commitment from top management	Fully integrated into the management structure with clear accountability for energy consumption	Appropriate and comprehensive staff training tailored to identified needs, with evaluation	Comprehensive performance measurement against targets with effective management reporting	Extensive communication of energy issues within and outside organizations	Resources routinely committed to energy efficiency in support business objectives
3	Formal policy, but not active commitment from top	Clear line management accountability for consumption and responsibility for improvements	Energy training targeted at major users following training need analysis	Weekly performance measurement for each process, unit or building	Regular staff briefings, performance reporting and energy promotion	Some appraisal criteria used as for other cost reduction projects
2	No adopted policy	Some delegation of responsibility, but line management and authority unclear	Ad-hoc internal training for selected people as required	Monthly monitoring by fuel type	Some use of company communication mechanisms to promote energy efficiency	Low or medium cost measures considered if short payback period
1	Unwritten set of guidelines	Informal, mainly focused on energy supply	Technical staff occasionally attends specialist courses	Invoice checking only	Ad-hoc, informal contacts used to promote energy efficiency	Only low or no-cost measures taken
0	No explicit energy policy	No delegation or responsibility for managing energy	No energy-related staff training provided	No measurement of energy costs of consumption	No communication or promotion of energy issues	No investment in improving energy efficiency

3) Identify and understand the nature of all those factors that promote foundries to continue EE improvement more than other promoting factors (Table 7).

2. Industrial energy management program

EnM is a pillar for the transformation of industrial energy systems towards improved EE and increased sustainability. Moreover, it is important to becoming less carbon-intensive (Worrell et al., 2009). A strategic approach, including a long-term energy strategy with support from top management, is an important element of a proper industrial in-house EnM program (Caffal, 1995). Indubitably, the program should be initiated by an initial energy audit of the company, along with adoption of a monitoring system and a well-structured energy plan (Caffal, 1995; Thollander and Ottosson, 2010). An industrial energy program nowadays goes beyond the traditional energy audit approach, thus making inclusion of EnMPs seem desirable (Thollander et al., 2010). Although EnMPs are important, it is challenging due to the complexity that arises from the variety of energy uses across thousands of processes, each one having unique energy use characteristics. In addition, it should be considered that there are different production requirements based on product, quality, and other business factors (Berglund et al., 2011). Therefore, transparency regarding an industrial energy program and more detail in assessment of EnMPs enables pros and cons to be spotted which in turn enables managers to move towards a more efficient design (Thollander et al., 2013).

3. Method

Considering the research aim described above and the nature of the study, this study was carried out as a multiple case study of 10 Swedish foundries. Case study research is especially advantageous when "how" or "why" questions are being posed (Yin, 1994). Moreover, multiple case study is preferable to a single-case study because it offers more robust analytical conclusions. Since mostly in-house conditions were to be studied, a smaller number of replications were needed (Yin, 2003).

3.1 Swedish Foundry Industry

A comparison with the foundry industry in some European countries indicates that the Swedish industry has the largest relative use of electricity (Thollander et al., 2005). The Swedish foundry industry is focused on the production of advanced iron and steel grades which are mainly produced for domestic markets (Rohdin et al., 2007). According to the Swedish Foundry Association (2004), annual production in Sweden amounts to 325,000 tons of castings of which 76% are iron, 18% non-ferrous and 6% steel resulting in an aggregated annual energy use of about 1 TWh (Swedish Foundry Association, 2004).

In the manufacturing chain for more durable goods, metal castings are one of the first steps in the value-adding process. Castings of iron, steel, light metals, and other metals are made in units that may be independent or part of a production line. Preparation of raw materials, metal melting, preparation of molds, casting and finishing are the main steps of production. Presently electric induction furnaces are used to melt the metals. In the next step, molten metal will be poured into the mold by using ladles or other pouring devices. Nevertheless, the automatically controlled pouring process is often used by large foundries. Finishing processes include fettling removals from the casting of the gating system, fins, and feeders. All the mentioned steps are accomplished by cutting, blasting, grinding, and chiseling. Melting and treatment of molten metal, as well as mold manufacture, shakeout, cleaning and after-treatment, is generally of greatest emission concern. To reduce, control, and keep the emissions as low as necessary, it is essential to implement technical measures. Integrated index of energy use per standard unit is one of the main measures. The rapid increase of natural gas prices and the deregulation of the electricity market have highlighted the necessity of addressing EE issues.

As the foundry industry is an energy-intensive industry, there is considerable focus on its energy end-use and ways to reduce and save energy. The majority of energy use in foundries goes into melting furnaces A new twin power furnace with lid and capacity of 11 tons has optimal levels of about 525 kWh in a one-hour melting time. However, this amount changes to 900 kWh for melting divisions using induction furnace without lid (Thollander et al., 2009).

3.2 Research Methods

The case studies were chosen in small, medium-sized and large companies. The study was carried out using semi-structured interviews conducted between August and November of 2014. In each case normally two persons, one from top management and the other from the energy group of the company, were interviewed (for approximately two hours) about the EnMPs, EnM program, the company's energy-related targets and motivating factors. The content of the interviews enabled the researchers to identify the practices adopted in each case. Thollander and Ottosson (2008) classified EE drivers for pulp and paper industry into market related (M1 to M3), policy instruments (P1 to P15), and behavioral and organizational (O1 to O10) driving forces. In this study the same classification has been chosen to identify which drivers among all the others promote continuous improvement of EE within Swedish foundries. During the interviews the energy manager and/or companies' energy manager representative were asked to mark and rate factors found in Table 7, which represented EE promoting factors for improved EE on a scale of 0: not important at all to four: strongly important (see Table 7). The maturity matrix (Table 2) is also developed to assess the current state of the EnM program of each foundry. The matrix consists of six themes from policy through investment, where users could rate their EnM program on a scale of 0: not important at all to four: strongly important. The matrix enables a conversation around EnM that reflects a wider set of subjects than just technology (the default solution for many). It tells the aspect of organizing, training, investment, communication and performance measurement. This tool is also a powerful way of understanding where barriers might exist in an organization.

In addition to the interview, extensive document research (industry statistics, annual reports, and government environmental regulation reports) to examine and cross-check qualitative data is done to increase research validity (Yin, 2002).

Finally the ordinary least squares (OLS) model (always with p-value of (* $p<0.10$, ** $p<0.05$, *** $p<0.01$)) is used to find the correlation between EnM program and EnMPs adoption. Also, it is used to present the correlation of EnM program and the level of each aspect of EnM matrix.

4. Results and Discussion

There are opportunities for EE improvement in all areas of a single foundry like melting, molding, ventilation, compressed air, lighting and HVAC. However, according to a current investigation, melting is the biggest area for improvements (Jarza 2011). Melting alone accounts for almost 50% of a company's total energy end-use (Thollander et al., 2015). In all cases, electricity was the main energy carrier and in some cases district heating was used to cover the heating needs. LPG devotes a small part of energy carrier of the 10 studied foundries which is used to preheat the ladles. Table 3 shows in detail the practices identified within selected foundries and their strategic role through EE improvement, according to Turner's (2007) energy strategy classification. Also, the number of companies which chose the referenced practices in their energy program is presented (see Table 3).

Table 3
Adopted EnMPs by 10 foundries (A to J represents 1 to 10 foundries)

Practices	A	B	C	D	E	F	G	H	I	J	Sum
R1	X	X	-	X	-	-	X	-	X	X	10
R2	X	X	X	X	X	X	X	X	X	X	
R3	X	-	-	-	-	-	X	X	X	X	
R4	-	-	-	-	-	-	-	-	-	-	
R5	X	X	X	X	X	X	X	X	X	X	
E1	X	-	-	-	X	-	X	-	-	-	3
E2	X	-	-	-	-	-	X	-	-	-	
E3	X	-	-	-	-	-	-	-	-	-	
E4	-	-	-	-	-	-	-	-	-	-	
L1	-	-	-	-	-	-	-	-	-	-	2
L2	X	-	-	-	-	-	X	-	-	-	
L3	X	-	-	-	-	-	X	-	-	-	
F1	-	-	-	-	-	-	X	-	-	-	1
F2	-	-	-	-	-	-	-	-	-	-	
F3	-	-	-	-	-	-	-	-	-	-	
F4	-	-	-	-	-	-	-	-	-	-	
A1	X	-	-	-	-	-	-	-	-	-	2
A2	X	-	-	-	-	-	-	-	-	-	
A3	-	-	-	-	-	-	-	-	-	-	
A4	X	-	-	-	-	-	X	-	X	-	
Sum	**12**	**3**	**2**	**3**	**3**	**2**	**10**	**3**	**5**	**4**	

Turner states that a successful EnM program spreads its practices in all classified strategies. However, as seen in Table 3, almost all companies have a poor action plan on EE, low cost, funding, and awareness. Only company A and company G have distributed their practices across all classified energy strategies. Almost 80% of the studied foundries do not have a proper EnM control system, any sub-metering system and there are very few practices for organizational EE, which is recognized as one of two practice-related barriers in the literature. Although literature indicates the important role of long-term strategy, such long-term energy strategies are lacking within the companies' total energy strategy. About one in ten stated that they have used Energy Performance Contracting (EPC) and Third Party Financing (TPF). Among the studied cases, only two out of ten have conducted an energy audit.

If improvement is the primary question, assessing the current status would be the foremost step to see the intensity and weak aspects of the plan. The EnM assessment model (Table 2) enables managers to deliver a clear picture about the current state of the company's EnM program. Table 4 clearly presents the maturity level of an EnM program for each foundry.

Table 4
EnM assessment model results

Size	L	SM	SM	L	SM	SM	L	L	L	SM
companies	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**
Policy	4	1	1	3	1	1	4	1	2	1
Organization	4	2	2	3	2	2	3	2	2	2
Training	2	0	0	0	0	0	0	0	0	0
Performance measurement	4	0	2	2	0	0	4	2	2	2
Communication	4	2	2	2	2	2	3	2	1	2
Investment	3	2	2	2	2	2	3	2	2	2
Average	Tends to 4	Tends to 2	Tends to 2	2	Tends to 2	Tends to 2	Tends to 3	Tends to 2	Tends to 2	Tends to 2

According to the results of the assessment model (Table 4), only two large foundries positioned their EnM maturity level relatively in 4 and 3 while all the others are positioned in a mode of 2 and average maturity level for all 10 foundries fell in a mode of 2.3. A comparison between Tables 3 and 4 illustrates the results of Table 4. Wherever there are no EnMPs the maturity level decreases. The main weaknesses for all foundries, except company A, relate to training, performance measurement, energy policy action plan, and investment. Given the huge emphasis in literature on the influential role of energy efficiency service provider companies on improved EE, between all studied cases only two foundries of large size addressed ESCOs, and then only in small part, in their entire EnM program (the reasons in most of the cases are: lack of trust, lack of information, and the complexity of the industry itself). In almost all cases it was observed that lack of metrics when projects are implemented hampers the next implementation. Moreover, without top management support and interest, energy-saving investment decisions would not be made.

Through the results from Tables 3 and 4, OLS model is set in Tables 5 and 6 to reflect the correlation between an EnM programs with each item of Table 3 respectively and the rate of each practice in Table 4.

Table 5
Regression results (A) [a]

	(1) Policy	(2) Organizing	(3) Training	(4) Performance measurement	(5) Communication	(6) Investment	(7) Matrix level
	b/se	b/se	b/se	b/se	b/se	b/se	b/se
Energy management program	2.63***	1.36***	1.00**	3.50***	1.63***	1.00	1.50***
	(0.55)	(0.33)	(0.40)	(0.69)	(0.33)	(.)	(0.19)
Constant	1.38***	2.13***	0.00	0.50	1.88***	2.00	2.00***
	(0.25)	(0.15)	(0.18)	(0.31)	(0.15)	(.)	(0.09)
N	10	10	10	10	10	10	10
r2	.74	.69	.44	.77	.75	1	.88
F	22.76	17.60	6.40	26.13	24.58	.	57.60
r2_a	0.71	0.65	0.38	0.74	0.72	1.00	0.86
Ll	-9.45	-4.27	-6.14	-11.64	-4.27		0.79

* p<0.10, ** p<0.05, *** p<0.01. [a] standard errors appear in parentheses.

Table 6
Regression Model (B) [a]

	(1)	(2)	(3)	(4)	(5)
	Reliability	Energy efficiency	Low-cost	Funding	Awareness
	b/se	b/se	b/se	b/se	b/se
Energy management program	1.13	2.38***	2.00	0.50**	1.38*
	(0.62)	(0.33)	(.)	(0.19)	(0.65)
Constant	2.88***	0.13	0.00	0.00	0.13
	(0.28)	(0.15)	(.)	(0.09)	(0.29)
N	10	10	10	10	10
r2	.29	.87	1	.44	.36
F	3.32	52.51	.	6.40	4.50
r2_a	0.21	0.85	1.00	0.38	0.28
Ll	-10.59	-4.26		0.78	-11.09

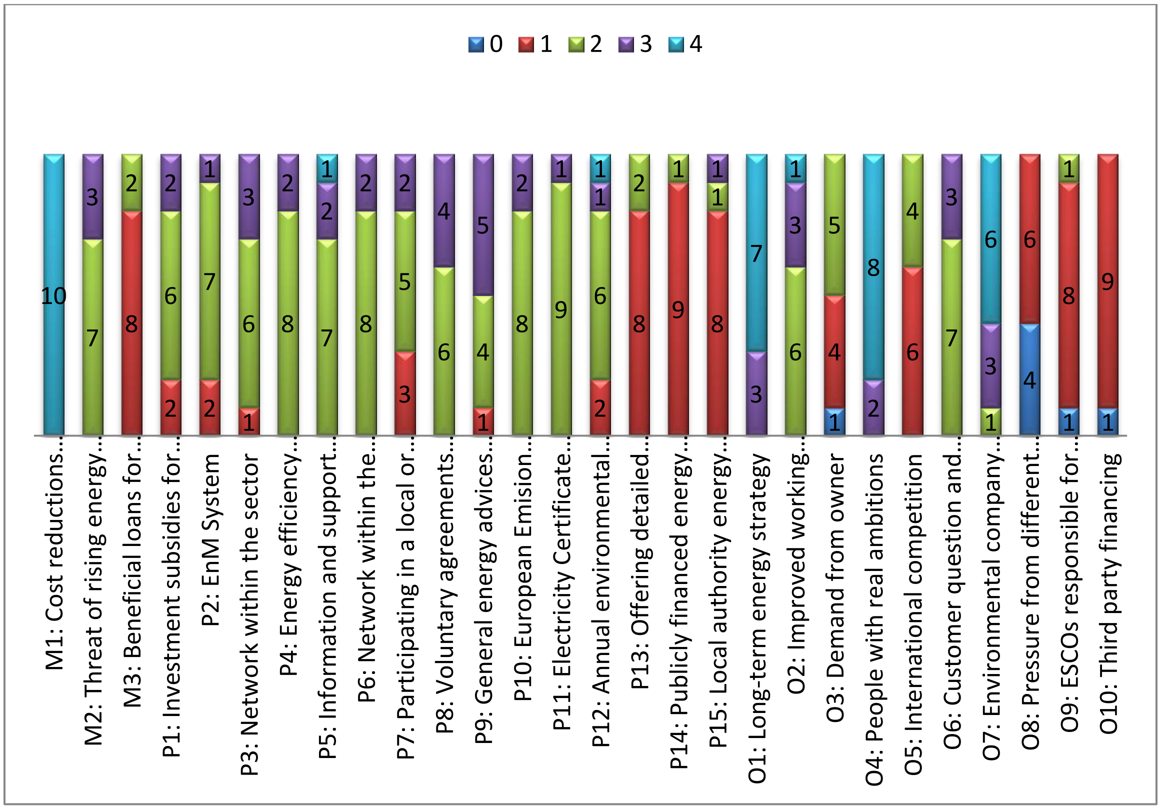
* p<0.10, ** p<0.05, *** p<0.01. [a] standard errors appear in parentheses.

It is clear that the relation between EnM program and each item of EnM matrix is strongly positive. Also, results from Table 6 show strong relationship between EnM program and EE practices, low cost, funding and awareness, the areas from which almost all of the barriers arise. Results once again demonstrate the strategic role of EnM in improved EE within industry.

Results (see Table 7) show that the most important driver for the adoption of EnMPs is cost reduction resulting from lower energy use, because it has a mode of 4 (strongly important) from all 10 foundries. People with real ambition with a mode of 4 from eight foundries is the second important promoting factor, which also has almost the same importance level in studies by Venmas (2014) and Thollander and Ottosson (2008). On the contrary, third-party financing together with a publicly financed energy audit by a technical consultant with a mode of 1 (not important) from nine companies has the lowest level of importance to promote EE between study cases.

Table 7 shows that there are promoting factors from different perspectives, such as market related (M1 to M3), policy related (P1 to P15), and organizational and behavioral related (O1 to O10), which push and motivate industries more and more to adopt EnMPs to continue the EE improvements. Table 7 shows in detail the EE-promoting factors.

Table 7
EE promoting factors (inspired from Thollander and Ottosson (2008) and Brunke et al. (2014))



From all that is discussed here, one question stands out from the content: since EE projects are profitable for the companies, *why do EnM programs not receive enough support, in all their energy strategy programs, from top management and why are they not adopted?* The most likely reasons for this would be that not only economic factors matter, because in our studied cases there were programs which in theory were profitable, but in practice were not adopted. According to the result shown in Table 3, practices with reliable strategic characteristics are mainly adopted, rather than the other energy strategy programs where they received a quite low level of adoption for their related practices. This result obviously is contrary to capital investment theory. Although this claim might seem challenging, the need for further investigation about determinant factors in energy investment decision-making is highlighted.

5. Conclusion

To successfully implement an EnM program, standards provide proper guidelines to specify WHAT to do. But HOW to do them in detail is something which is left for the individual industrial company to decide. In this paper, we tried to deliver a clearer picture about the current situation, from an energy perspective, of Swedish foundries and identify aspects missing in the companies' energy strategy plans and why. Lack of proper EnM programs by definition within an in-house energy program caused the poor level of EnMPs to be widespread as well as at a generally low maturity level. The investigation has shown that more than half of the studied cases lack a long-term energy strategy, sub-metering system, or proper EnM control system. Also, lack of information about and trust in ESCOs through the company's EE improvement program is highlighted among selected Swedish foundries. Comparisons with previous literature and the result of the current study showed that drivers with a high EE promoting level sometimes act as barriers.

In conclusion, the assessment made in this study showed that the real level of EnM program in a Swedish foundry is far from what it should be, based on the adopted highest success levels, and the choice of evaluation method applied in the conducted research. Therefore, this paper concludes that the sustainability target would be hard to achieve if managers will not be committed enough to develop a proper and comprehensive EnM program in their agenda. Moreover, it would be difficult to achieve if managers do not tie energy targets to the company's overall target and/or strategy.

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Paper 4:

Assessing the Driving Factors for Energy Management Program Adoption

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Assessing the Driving Factors for Energy Management Program Adoption

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Abstract: Energy management became topical in industry as a result of the energy crises in the 1970s. However, energy management was not implemented within industry with all its potential to improve energy security, raise the maturity level of energy management and increase sustainability. According to the results of previous empirical investigations, the expected interest in energy programs is not found and there is no clear understanding about program adoption criteria within an industry. Keeping in mind the adoption of energy investment through conformation with financial analysis and choosing the investments through contextual factors in the organization (e.g. organizational energy culture, power relationships, energy management system, expertise availability, managers' mindset) together with characteristics of energy management program as two macro perspectives in energy efficiency literature, this paper aims to understand the main driving factors which lead organizations to either adopt or not adopt a particular program (always with respect to energy management). Moreover, it aims to express the impact of those driving forces of implementing a successful energy management program which could contribute to better understanding of suitable EnM configuration. The investigation has been conducted as a multiple case study involving 15 manufacturing companies of varying size and in different sectors located in Sweden. After analyzing the minimum required steps to establish energy management, assessing the adoption of practices according to their energy strategy, and through assessing energy management maturity level, we found a low level of risk (which arises from lack of certainty and awareness) and the program's alignment with the core business as prominent driving factors for all sizes which foster positive investment decision-making through top management. On the contrary, complexity of industry (for large manufacturing companies) and access to capital (for small and medium-sized companies) are the main barriers to adopting those programs.

Keywords: energy management, assessment, driving factors, manufacturing industry, energy efficiency

1. Introduction

Believing energy to be finite and nature as a place to live not only for the present generation, but for future generations increasingly leads us to use energy smarter and more efficiently. Meanwhile, industry, especially energy-intensive industries, as a major energy user receives relatively more attention. While according to an International Energy Agency report in 2007 [1], industry in all sectors had made successful improvements, Hirst and Brown's claim in 1990 [2] about the existence of the gap between theactual level of energy efficiency (EE) potential still remains strong [3]. According to IEA, if current trends continue, two-thirds of the economic potential to improve EE will remain untapped until 2035 [4]. Several researchers addressed barriers to implement EE measures, namely the complexity of energy efficient technology [5], and implementing EE measures is a challenge because of industry's complexity (an industry's characteristics) [6]. Therefore, this challenge makes it difficult to generalize any success stories or programs. Researchers addressed energy management (EnM) as a tool for overcoming EE barriers. Energy management means to optimize one of the most complex and important managerial and technical creations that we know: the energy system.

The necessity of EnM for those industries willing to be and stay competitive is mature enough, according to the different type of drivers which lead a particular industry to adopt EnM. Within the last twenty years, with increasing energy prices and a global energy crisis, previous studies addressed its strategic and efficient role in improved energy systems. Figure 1 shows the most discussed drivers for EnM adoption within industry. Drivers can be classified through EnM's capability to overcome barriers related to implementing EE measures, energy fluctuation trends, through its capability to increase a company's focus on improving energy system and other external pressures like environmental legislation (Figure 1). To establish a proper EnM program in the body of EnM literature, certain minimum steps must be implemented. Those elements, illustrated in Table 2, are addressed in previous studies [7,8,9,10,11] and cited in [6]. However, improving energy system through EnM is also difficult because of many misconceptions between practitioners (e.g. only big companies can do it, only plants with new equipment can do it, large capital budgets are required, we don't have enough time and staff, we already do everything we can, and everybody manages energy) and the barriers which depend on the geographic location and nature of the industry itself (such as energy intensity and size) [12, 13]**.** Therefore, the maturity level of EnM programs (which can be assessed through EnM programs for policy, organizing, training, performance measurement, communication and investment [Appendix B] with its huge potential for improved energy systems is still far from what it should be in practice based on the adopted highest success levels.That remaining potential has been untapped not only because of the mentioned barriers, but also because of lack of understanding about *how* an EnM program should be planned. Consequently, it causes a weak alignment between energy programs and the company's total strategy or the company's macroeconomic policy and also because of lack of transparency which accordingly increases the nature of risk at different levels.

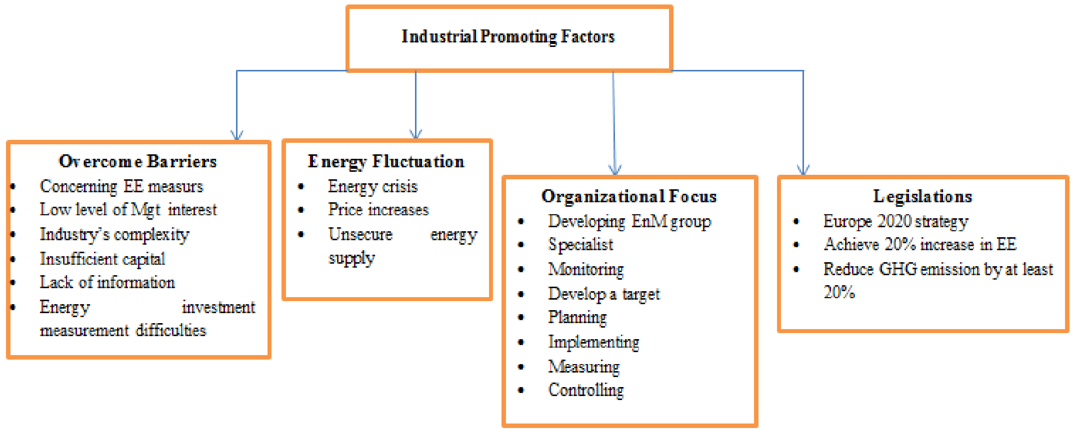

Figure 1. Industrial drivers to adopt EnM

In EE literature, EnM through its systematic programs and more precisely through its practices is characterized as an industrial energy system support function. However, EnMPs is not properly implemented and/or not fully adopted in practice, with all its potential, to help companies improve their EnM maturity level and, as a consequence, to enhance the energy system. In a macro perspective, there are two different perspectives in the body of EE literature about investment decision-making. A number of earlier researchers [14, 15,16,17] believe EE investments would be decided upon if the financial analysis conforms to the investment for a particular program (which is in line with finance theory). However, others [18, 19, 20, 21] emphasize other contextual factors, such as organizational energy culture, power relationships, EnM system, existence of expertise, managers' mindset as well as external factors such as energy price. Moreover, earlier researchers [13, 22, 23, 19] addressed strategic links between any EE investment with the company's core business as an important driving factor. Fleiter et al. (2012) [5] in a study about the low adoption rate argues that the characteristics of EE measures can enhance the adoption rate. Therefore, among other driving factors, the strategic characteristic of an investment is essential to foster its adoption through top management [24]. However, strategic decision-making literature did not provide a clear and applicable answer about what makes an investment strategic. Some researchers in this field have described strategic decisions as follows:

Table 1
Strategic investment descriptions

References	**Description of strategic investment**
[25, 26, 27]	Decisions as vital importance.
[28]	Decisions which have a significant effect on the organization as a whole.
[25, 28, 29]	Decisions which have a significant potential for improving corporate performance.
[30]	Strategic means important and not secondary issue.
[31]	Decisions regarding the goals, domains, technologies and structure of a firm.
[32]	Decisions regarding a firm's development through products-market-technologies triplets
[33]	An investment is "strategic if it contributes to create, maintain or develop a sustainable competitive advantage"

The definitions provided by strategic process research are not comprehensive enough to understand the strategic character of investment decisions because the aspect of the scope and content of investments is not properly taken into account. Adopting a practice based on how it is aligned with an organization's strategy would not lead us to clear and proper selection and would leave us in a vague situation. The reason is that either the firm's strategy is not often identifiable or it is nonexistent [33]. Cooremans (2011) [33] and Sa et al. (2015b) [34] argued in their paper about enhancing the understanding of the scope and/or target of each practice or investment to make it more strategic and aligned with organization's total strategy. Sa et al. (2015a) [35] argues that without understanding the scope and target of a particular EnMP it is not possible to avoid an overlap between EE measures and EnMPs, and it also causes failure in adopting a proper EnM configuration through a single industry's characteristics. Therefore, Sa et al. (2015b) [34] in another study, with inspiration from Turner (2007) [36], classified energy strategies as follows for each subcategory: Reliability, efficiency, low/no cost, funding and awareness and allocate program. It is important to analyze how a particular program enables a firm to strengthen its strategic position [33]. Therefore, in this way energy-related issues would not be seen as a secondary issue but as a strategic issue. Therefore, this paper, in an investigation of 15 Swedish energy-intensive companies of different size and in different sectors, aims to understand the main positive and/or negative driving factors which lead organizations to adopt or not adopt a particular EnM program.

For this, and also to have a better and clearer understanding about establishing a proper EnM, all minimum required steps which should be taken by the company to establish and operate energy management are assessed. Also, the adoption level of energy management practices (EnMPs) has been analyzed according to their strategic energy role which was proposed in [36] and presented in [34]and shown here in Appendix A. Moreover, a company's EnM maturity level is tested according to the EnM matrix proposed in the Carbon Trust (2011) [37] and shown in Appendix B. Measuring the maturity level of an EnM program is essential because it enables managers to understand and identify the hidden barriers within their ongoing energy program and related practices. At the end, we discuss the impact of positive decision-making drivers of successful implementation of an EnM, which could contribute to better understanding of suitable EnM configuration.

2. Methodology

Considering the research aims described above and the nature of the study, this study was carried out as a multiple case study of 15 Swedish energy intensive industrial sectors, where the term "industrial sector" means any sub-sector of the manufacturing sector, in small, medium and large size. Distribution of interviewed cases is shown in Table 3. Case study research is especially advantageous when "how" or "why" questions are being posed [38]. Moreover, multiple case study is preferred over a single case study because it offers more robust analytical conclusions. Since mostly in-house conditions were to be studied, a smaller number of replications was needed [39].

Table 2
Case study distribution

	Iron & Steel	Chemical	Plastic	Food	Foundry	Cement	Sum
Small and Medium	1	1	1	1	2	1	7
Large	1	2	1	1	2	1	8
Sum	2	3	2	2	4	2	15

2.1 Adoption driver factors

Literature determines top management support as a key and very important driver to adopt any proposed EnM program [40]. Payback time is another driver which gives priority to or leads to rejection of any proposed program [40, 41, 11]. Thollander and Ottosson (2010) [11] in an empirical investigation within the Swedish pulp and paper and foundry sector showed that companies apply a criterion of three years or less for an EE's pay off. This result, in an investigation which was conducted in the developing countries across nine manufacturing subsectors, fell to 0.9 to 2.9 years [42]. Pay-off criterion differs through countries and time horizon when we look at what Gruber and Brand showed in 1991 [43]. In an empirical study in Germany with a sample size of 500 SME companies, the average required payback criterion was about four years [43].

Having top management support be seen in a variety of studies as a fundamental and necessary driving factor to implement a program, highlights the need for investigation into managerial perspective. Many believe that as long as a program is profitable the possibility of adopting the program would increase [19]. However, this is not the case in every situation. Many EE practices which theoretically are profitable are not adopted in practice [44]. Often it is due to lack of execution, not valuing the project properly and improper definition, as maintained respectively by [6 and 34, 35]. Sometimes, though, it is due to uncertainty and its associated risk, lack of transparency and weaker understandable calculation [23]. Top management is positioned at a strategic level of a company and makes decisions about what is in line with the company's total strategy. In other words, they are dealing with the core business. Energy is considered a non-core business, i.e., non-strategic, but a secondary and peripheral issue [19]. Moreover, since energy-related costs may be small in comparison with a company's total costs, energy-related practices thus receive relatively little attention [24].

According to capital investment theory, investments with profitable return would be decided upon, and where there are several proposed projects, the one with highest return would be prioritized [33]. Moreover, according to the organizational finance and decision-making literature, financial factors are a pillar in investment decision-making. However, organizational behavior literature determines other contextual factors whose role is important in this regard: organizational energy culture, power relationships, managers' interest and mindset, and last but not least the characteristics of the investment itself, in other words, how they link with the core business and/or how strategic they are [47, 46, 45, 23, 19, 13]. In an investigation of about 100 Australian companies, 35% of respondents mentioned that EE projects often are not adopted because of their weak link to the core business [22]. Therefore, it seems that being profitable, while important, is not a sufficient criterion for an investment to be decided on [23]. Many previous studies tried to list barriers to EE, however, just a few of them focused on the practices' characteristic role as an important barrier and/or driver to EE investment [34]. In a study conducted by Velthuijsen (1993) [46] within 70 companies, “non-core business character” was addressed as one of the most important barriers to EE investment.

Another important point which results in low levels of EnMPs adoption and/or decision-making is due to high levels of EE investment risks. Neoclassical energy economists [e.g. 17, 16] believe the EE gap is not real because their energy-saving programs technically are energy efficient but not economically so (due to hidden costs and return overestimations). Although the nature of making any decisions involves risk (due to uncertainty), the level of the risk increases if it becomes more strategic. EE investment literature has very little to say in this regard. Apart from financial risk which arises from these investments, Sorrel et al. (2000) [19] listed core business risk or technical risk linked to adoption of new technologies as a third important barrier to adoption and/or positive decision-making with regard to EE investments. Several strategic risks threaten a company when a decision is made [see 33]. However, the uncertainty of EE investment outcome leads to negative investment decision-making.

2.2 Research Methods

The case studies were chosen from small, medium-sized and large companies from different industrial sectors. The study was carried out using semi-structured interviews conducted between August and November of 2014. In each case normally two persons, one from top management and the other from the energy group of the company, were interviewed (for approximately two hours) about the EnMPs, EnM program, the company’s energy-related targets and motivating factors. The content of the interviews enabled the researchers to identify the adopted practices in each case.

According to the EnM literature, there are eleven minimum steps (presented in Table 2) required for implementing EnM. During the interview the energy manager in each case was asked about how they considered these eleven steps (fully considered=2, partially considered=1, and not considered=0). The content of the interview about EnM program and related practices which has been adopted so far within the company enabled researchers to understand the status of adopted practices. In Appendix A, an energy strategy classification inspired from Turner (2007) [36] is shown. Moreover, the level of adoption for each practice (fully considered=2, partially considered=1, and not considered=0) has been marked.

Table 3
Minimum required steps to establish the EnM

References	Required steps	Code
[36, 11, 7]	Long-term strategic planning	S1
[36]	Energy practices by allocating responsibilities and tasks	S2
[36, 10, 7]	Establish energy management team by energy manager	S3
[10]	Developing procurement policies	S4
[36, 10, 7]	Conducting initial energy audit	S5
[36, 9, 10, 11,7, 8]	Implement energy-saving projects	S6

[36, 10]	Monitoring the project's progress	S7
[36, 11]	Monitor energy use by main energy user equipments	S8
[36, 10, 7]	Develop report documentation	S9
[36, 11]	Top management support	S10
[36]	Awareness and training	S11

The maturity matrix (Appendix B) is also developed to assess the current state of EnM program of each company. The matrix consists of six themes from policy through investment, where the user could rate their EnM program on a scale of 0: not important at all to four: strongly important. The matrix enables a conversation about EnM that reflects a wider set of subjects than just technology (the default solution for many). It indicates the aspects of organizing, training, investment, communication and performance measurement. This tool is also a powerful way of understanding where barriers might exist in an organization. Understanding the Industrial EnM Model enables us to design an effective energy cost reduction program and offer services that best match a company's specific needs according to where they are in the overall EE maturity process. The following equations (1) to (5), are used to quantify the consideration level for each energy strategy category and for each sub-category:

$$SMi\ (average) = \frac{\sum_{i=1}^{7} Sism}{7}, \qquad Li\ (average) = \frac{\sum_{i=1}^{8} Sil}{8} \qquad (1)$$

$$Rsm\ (average) = \frac{\sum_{i=1}^{7} Rism}{7}, \qquad Rl(average) = \frac{(\sum_{i=1}^{i=8} Ril)}{8}, \qquad (2)$$
$$Rsm = \frac{Rsm(average)}{5}, \qquad RL = \frac{Rl(average)}{5}$$

$$Esm(average) = \frac{\sum_{i=1}^{7} Eism}{7}, \qquad Eil(average) = \frac{\sum_{i=1}^{8} Eil}{8}, \qquad (3)$$
$$Esm = \frac{Esm(average)}{4}, \qquad El = \frac{Eil(average)}{4}$$

$$Lsm\ (average) = \frac{\sum_{i=1}^{7} Lism}{7}, \qquad Lil(average) = \frac{\sum_{i=1}^{8} Lil}{8}, \qquad (4)$$
$$Lsm = \frac{Lsm(average)}{3}, \qquad Ll = \frac{Lil(average)}{3}$$

$$Fsm(average) = \frac{\sum_{i=1}^{7} Fism}{7}, \qquad Fl(average) = \frac{\sum_{i=1}^{8} Fil}{8} \qquad (5)$$
$$Fsm = \frac{Fsm(average)}{4}, \qquad Fl = \frac{Fl(average)}{4}$$

$$Asm(average) = \frac{\sum_{i=1}^{7} Aism}{7}, \qquad Al(average) = \frac{\sum_{i=1}^{8} Ail}{8} \qquad (6)$$
$$Asm = \frac{Asm(average)}{4}, \qquad Al = \frac{Al(average)}{4}$$

3. Results

3.1 Factors affecting adoption of EE investments

3.1.1 Minimum required steps

Having classified the minimum required steps to implement EnM, within each study, according to Table 2, we assessed whether all these steps has been taken within a sample of studies and how they were considered within energy-related programs. By allowing the results to provide a quantitative picture

(Table 4), it delivers the clearest picture about how industrial sectors move toward implementing EnM. The results are summarized in Figure 2 as well.

Table 4
Results for minimum required steps to implement EnM
(Key: fully considered=2, partially considered=1, not considered=0)

Code	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**	**O**	**SM** *(average)*	**L** *(average)*
S1	1	1	1	1	1	0	1	1	0	1	1	2	1	0	1	0.71	1
S2	1	1	1	1	0	1	1	2	2	1	1	2	1	1	1	1.14	1.13
S3	1	1	0	1	1	0	0	1	1	0	0	2	1	0	1	0.29	1
S4	2	2	2	2	2	2	2	2	2	1	1	2	1	2	2	1.71	1.88
S5	0	1	0	1	1	1	0	1	1	0	0	2	1	0	1	0.29	1
S6	1	1	1	2	1	1	1	1	2	1	1	2	1	1	2	1	1.38
S7	0	0	1	1	1	0	1	0	1	0	0	2	1	0	1	0.14	1
S8	1	2	1	0	1	1	1	1	1	0	0	2	1	1	1	0.71	1.13
S9	1	1	0	1	1	1	1	1	1	1	1	2	1	1	1	0.88	1.13
S10	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
S11	0	0	0	0	1	1	0	1	0	0	0	1	0	0	0	0.29	0.25
Total average																0.83	1.17

*Columns in green present SM companies.

The analysis by firm size has allowed observing that companies with large size are far ahead in comparison with small and medium-sized plants. However, even large companies are in a far from ideal situation. In particular, such differences regarding establishing EnM team by energy manager, conducting the initial audit, and monitoring project progress emerge much more between SM companies and large companies. Consequently, for SM companies each step mentioned with low level of consideration emerges as a barrier to implementing EnM properly. On the contrary, SM companies' behavior for top management support, developing procurement policies, awareness and long-term strategic planning, implementing energy-saving projects, monitoring the main energy-using equipment, and documentation respectively are the same or quite close (Figure 2). Interestingly, all companies are ranked as fully considered for top management support, however, as is clear except for developing procurement policies, a major gap exists in implementing EnM regarding low average level of consideration for the rest of the steps. This can be explained mainly, but not only, through low level of consideration regarding awareness and training in Figure 2. This consequently causes a lack of clear information, expertise and certainty within an organization. About "establish EnM team by energy manager," small and medium-sized companies receive relatively low consideration compared with large companies. Since they do not establish a team, as a result initial auditing, monitoring the projects, and documentation of energy use trends are not planned, organized, implemented and checked properly, as is evident in Figure 2. It might be first of all because of the industry's characteristic (similar size) and then time and lack of expertise which in consequence causes the imperfect establishment of EnM mainly between small and medium-sized firms.

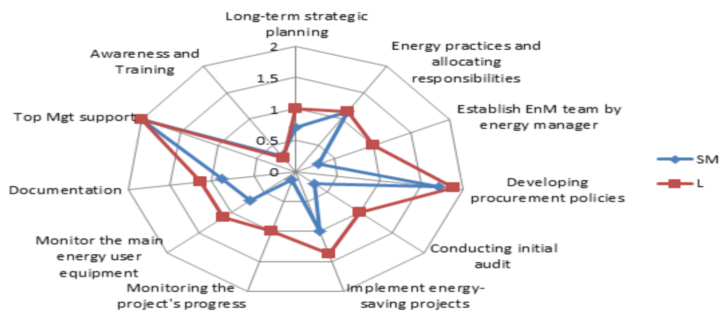

Figure 2. Results for minimum required steps to establish EnM

3.1.2 Energy Strategy

Having classified the relevant practices within each energy strategy according to Turner's (2007) classification, we identified not only the adopted programs, but also the level of consideration for each practice. The results provide some indication of the relative importance of each barrier in preventing cost-effective improvements in industrial energy efficiency. The results are summarized in Table 5 and Figure 3. In addition, the individual studies implied a ranking order that some barriers were discussed more prominently than others. The implied importance of barriers for each individual study is captured in Table 5.

Table 5

Energy strategy and related practice results

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	SM sum	SM average	L sum	L average
R1	1	1	1	1	1	2	1	2	2	1	1	2	1	1	1	9	1.29	10	1.25
R2	1	1	0	1	1	1	1	2	2	1	1	2	1	1	1	7	1	10	1.25
R3	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	7	1	7	0.88
R4	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	1	0.14	1	0.13
R5	0	1	1	0	0	0	0	0	1	1	0	1	0	0	1	2	0.29	4	0.5
Average																	0.74		0.80
E1	1	1	1	1	1	1	1	1	2	1	1	1	1	1	1	7	1	9	1.13
E2	0	1	1	1	0	1	0	1	1	0	0	2	1	0	1	2	0.43	7	0.88
E3	0	0	0	1	1	0	0	0	1	0	0	2	1	1	1	1	1.14	7	0.88
E4	0	0	0	1	0	2	1	1	2	1	1	2	1	1	1	6	0.88	8	1
Average																	0.58		0.97
L1	0	0	0	0	0	1	0	1	0	0	0	1	1	1	1	3	0.43	3	0.38
L2	0	1	0	0	0	0	1	1	0	0	1	1	1	1	1	3	0.43	5	0.63
L3	1	1	1	1	0	1	2	1	1	1	2	2	1	2	1	9	1.29	9	1.13
Average																	0.72		0.71
F1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.14	0	0
F2	0	1	0	0	1	0	0	1	1	1	1	1	1	0	1	3	0.43	6	0.75
F3	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	1	0.14	1	0.13
F4	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	2	0.25
Average																	0.18		0.28
A1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	2	0.29	1	0.13
A2	0	1	0	0	1	1	0	1	1	0	0	1	0	0	1	2	0.29	5	0.63
A3	0	1	1	1	0	1	1	1	1	0	0	2	1	0	0	3	0.43	7	0.88
A4	1	1	1	1	1	2	1	2	1	0	1	2	0	1	1	8	1.14	8	1
Average																	0.54		0.66

*Key: fully considered=2, partially considered=1, not considered=0

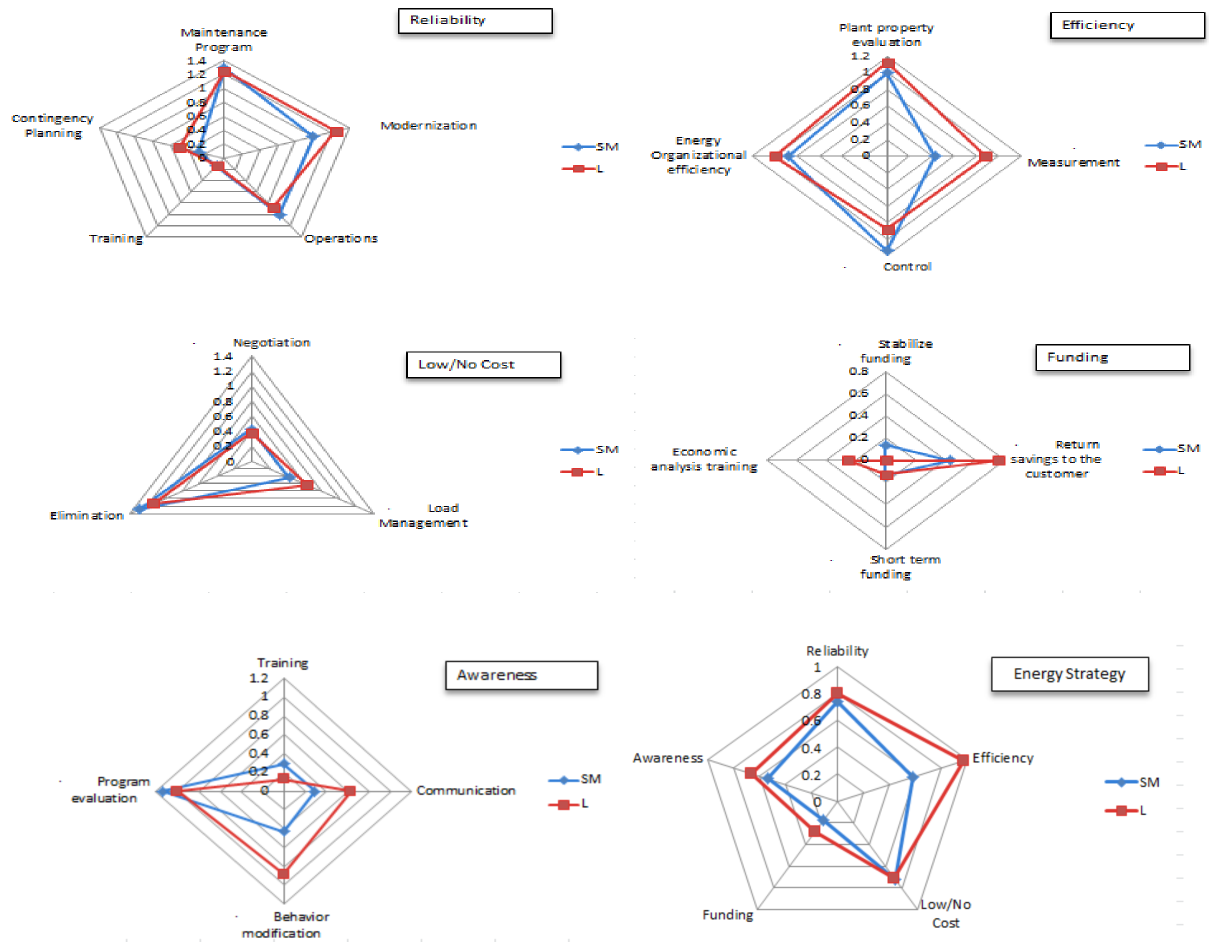

Figure 3. Energy strategies and consideration level. Each radar reports the consideration level for each sub-energy strategy category, namely: reliability, efficiency, low/no cost, funding, awareness. The chart with "Energy Strategy" title reports in general the consideration level of the energy strategy with respect to the firm size.

Results in Table 5 show in greater detail the level of adoption for each category and their related programs. In particular, we can note that the average value, both for SM and large firms, for each category is quite low and becomes much lower when it comes to funding and awareness practices. Comparing the results about how large companies behave with respect to SM companies is much easier when we look at Figure 3. Through "energy strategy" radar in Figure 3, we can note that larger plants are more focused on EE programs rather than reliability, low/no cost, funding and awareness.

3.1.3 Maturity Level

In Figure 4, we can note that energy maturity level for both SM and large companies is relatively low and surprisingly, for this aspect company size works as an independent variable. Moreover, we can note that companies are more focused on policy, organizing and performance measurement. On the contrary, regarding training maturity level is quite low and consequently results from lack of expertise and awareness. Results for investment shows almost all companies, of different size and sector, share close criteria to invest in a particular program. Receiving the maximum mode of 2.5 on the scale of 0 to 4 shows industry still needs further improvement to enhance its position regarding energy and environmental concerns. Special effort is needed for training and communication, which are observed as two prominent barriers according to Figure 4.

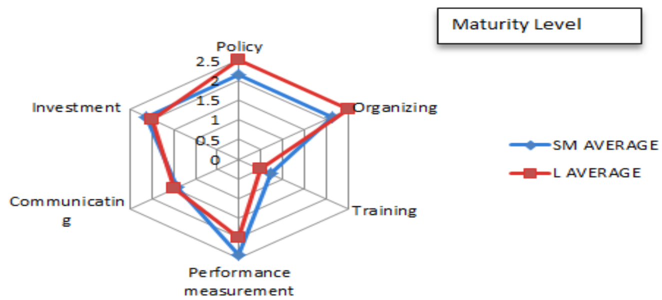

Fig 4. Maturity level

3.1.4 Barriers and drivers for EnM program investment decision-making

Having the results for minimum required steps, classification assessment of EnMPs, and EnM maturity level assessment together with the knowledge we received from the practitioners during the interviews enabled the authors to specify the most relevant and pronounced barriers and drivers to negative and/or positive investment decision-making for a particular EnM program. In Table 6, those barriers and drivers have been listed. Absence or presence of each factor in Table 6 arises accordingly as a barrier and/or driver to receive negative and/or positive investment decision-making from top management.

Table 6
Taxonomy of barriers and drivers for EnM program investment decision-making

Barriers	**Comments**
Access to capital	A commonly cited barrier to implementing EE projects is lack of access to capital. This might be more relevant for the smaller companies which have low capability in terms of capital investment.
Time and expertise	Time, resources and skilled persons are essential to identify opportunities for cost-saving targets and implement the threats
Awareness and uncertainty	Lack of information about energy use trends, lack of benchmarking with best practice in same sector and lack of proper training are the most pronounced elements which increase uncertainty and decrease awareness between practitioners.
Practice characteristics	Transparency regarding scope, target, and moreover the link to the core business build the characteristics of a particular practice.
Risk	Disruption of a production line, overestimation about turnover, higher investment demand for EE projects in comparison with other type of investment and uncertainty about payback time horizon are the topics of EE-related risk felt regarding time, cost and quality.
Industry's complexity	Characteristic of an industry through its process and operation line even between same sectors are different and makes an industry, mostly in large-sized companies, a complex place.

Having classified the relevant barriers within each study according to our taxonomy, we recorded the number of times that each of these factors was mentioned within the sample of studies, thereby allowing a quantitative picture to be provided with the results. Although this is a crude procedure, the results provide some indication of the relative importance of each barrier and/or driver in preventing cost-effective improvements and the investment decision-making process in an industrial EnM program. The results are summarized in Figure 5.

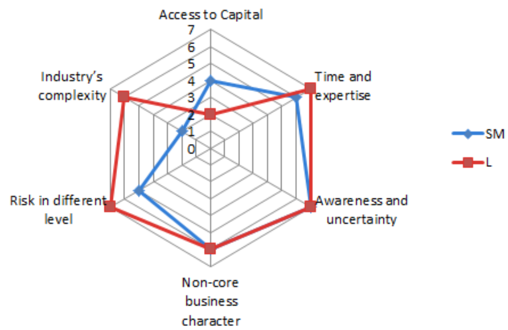

Figure 5. Simple count of the number of mentions of specific barriers to EnM investment decision-making within the sample of studies

While all six of the barriers in our taxonomy appeared in the sample, the two that appeared most prominently were the non-core business character of the programs and awareness and uncertainty which cause relatively high perception of risk. Therefore, increasing the strategic characteristic of the programs which leads to higher alignment with the core business strategy of the organization and decreasing the perception of risk which arises from uncertainty and lack of enough information can be highlighted as two main positive driving factors which foster the adoption rate for EnM programs.

3.2 Impact on successful EnM implementation

The various arguments are discussed here about how an investment would be adopted from top management as a strategic management level. Therefore, according to EE investments literature and what energy managers in 15 studied cases have reported, we determined, contrary to EE literature, that if EnMPs are not adopted it does not mean they do not receive support from top management, but it means they are not strategic enough. The influence of the strategic character of investment in the decision-making process and its result (a positive, negative or no-decision), and this same influence on the capital budgeting tools used, as well as on financial requirements for profitability (pay-off criterion), to develop Figure 6.

Another important aspect of positive decision-making is risk reduction. Energy managers need to reduce an EnM program's risk and uncertainty through risk management, which consists of: identify the risk, identify the person in charge and allocate responsibility through planning and resourcing, and then re-evaluate. Risk reduction improves transparency and certainty, and moreover, brings value to the company. According to all these arguments, this paper suggests the following framework for EnM programs which can be adapted to all types of manufacturing companies. Energy managers need to accurately interpret and identify the company's total strategy and capacity in order to implement an energy strategy which is aligned with the company's core business. Moreover, the need to "plan, organize, implement and control" in each step of an EnM program is highlighted to improve the transparency and reduce associated risks in each step as much as possible to improve the certainty level. To set the energy strategy, the energy manager always needs to align the program with core business and adopt programs which are more strategic to improve positive investment decision-making. Last but not least, besides all the determining factors, the character of the energy manager is the most important element in a successful energy strategy. S/he not only needs to be experienced enough in the field, but being a professional project manager is another strong characteristic for this position. Any energy program can be seen as a project which needs to be completed in proper quality, cost and time, always in alignment with the company's total strategy and capacity. The more alignment with core business, the greater the possibility to receive positive decision-making from top management.

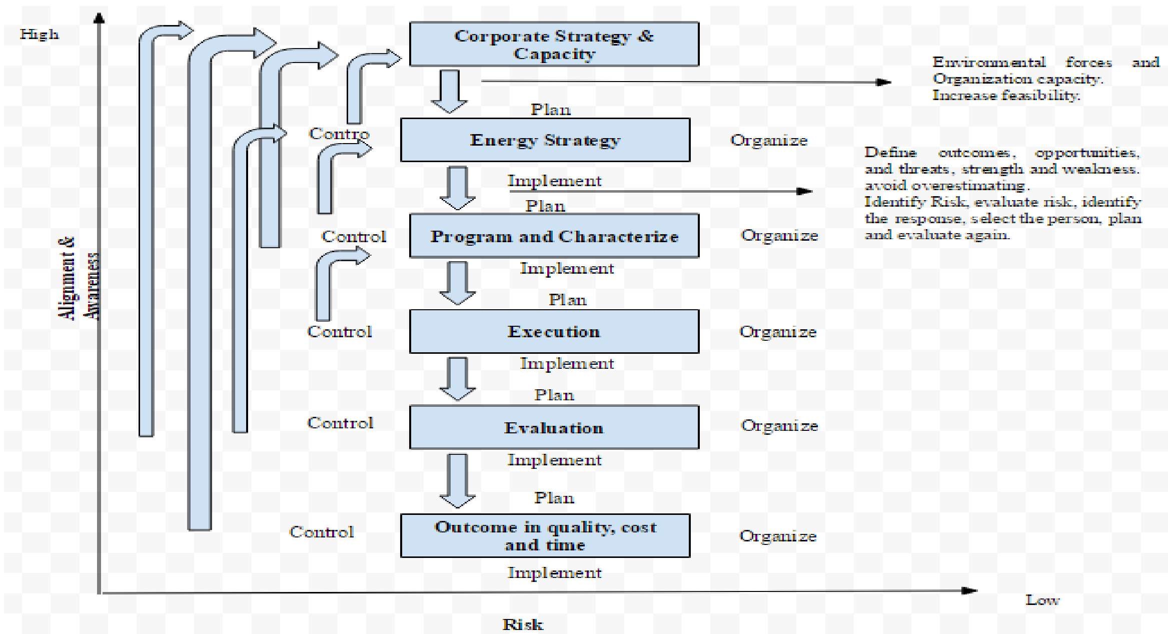

Figure 6. The contribution of the result of implementing successful EnM

4. Conclusion

EnM through its systematic programs and more precisely through its practices is characterized as an industrial energy system support function. However, EnMPs is not properly implemented and/or not fully adopted in practice, with all its potential, to help companies improve their EnM maturity level and, as a consequence, to enhance the energy system. Considering two macro level perspectives regarding energy investment adoption criteria, this paper assessed EnM programs from A to Z to better understand the existing barriers and drivers for energy-related decision-making criteria. After assessment of minimum required steps for establishing an EnM program, adopted practices according to their scope and target, and finally assessing the maturity level of EnM programs, the current study developed a taxonomy of the barriers to EnM program adoption. Moreover, two of the listed barriers that appeared most prominently were non-core business character of the programs and awareness and uncertainty which causes a relatively high perception of risk. According to the result in the first step, this study finally tried to make a contribution on the impact of the main driving forces of positive investment decision-making in implementing successful EnM programs.

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APPENDIX A

EnM strategies, programs and related practices (inspired from Turner, 2007)
Key for each practice (2=fully considered, 1=partially considered, 0=not considered)

Strategy	Program and related Practices	Codes	Weight (0 to 2)
Reliability	• Maintenance Program	R1	
	• Modernization	R2	
	• Operations	R3	
	• Training	R4	
	• Contingency Planning	R5	
Efficiency	• Plant property evaluation	E1	
	• Measurement	E2	
	• Control	E3	
	• Energy Organizational efficiency	E4	
Low cost	• Negotiation	L1	
	• Load Management	L2	
	• Elimination	L3	
Funding	• Stabilize funding	F1	
	• Return savings to the customer	F2	
	• Short term funding	F3	
	• Economic analysis training	F4	

Awareness	• Training • Communication • Behavior modification • Program evaluation	A1 A2 A3 A4

APPENDIX B

EnM matrix (inspired from Carbon Trust, 2011)

Level	Policy	Organizing	Training	Performance measurement	Communicating	Investment
4	Energy policy action plan and regular review have an active commitment of top management	Fully integrated into the management structure with clear accountability for energy consumption	Appropriate and comprehensive staff training tailored to identified needs, with evaluation	Comprehensive performance measurement against targets with effective management reporting	Extensive communication of energy issues within and outside organizations	Resources routinely committed to energy efficiency in support business objectives
3	Formal policy, but not active commitment from top	Clear line management accountability for consumption and responsibility for improvements	Energy training targeted at major users following training need analysis	Weekly performance measurement for each process, unit or building	Regular staff briefings, performance reporting and energy promotion	Some appraisal criteria used as for other cost reduction projects
2	No adopted policy	Some delegation of responsibility, but line management and authority unclear	Ad-hoc internal training for selected people as required	Monthly monitoring by fuel type	Some use of company communication mechanisms to promote energy efficiency	Low or medium cost measures considered if short payback period
1	Unwritten set of guidelines	Informal mainly focused on energy supply	Technical staff occasionally attends specialist courses	Invoice checking only	Ad-hoc, informal contacts used to promote energy efficiency	Only low or no-cost measures taken
0	No explicit energy policy	No delegation or responsibility for managing energy	No energy related staff training provided	No measurement of energy costs of consumption	No communication or promotion of energy issues	No investment in improving energy efficiency

Paper 5:

Reduced and full version

Introducing Passive House Concept to Industries

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Introducing Passive House Concept to Industries

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Abstract: Number of countries over the past years attempt to develop standards for energy management. Although challenges in national energy management standards are different, the basic structure for almost all of them is Deming cycle and main objective is reducing energy costs and greenhouse gas emissions. Lower level of agreement in some parameters (such as: management commitment, strategic planning, energy profile, purchasing, design, energy project implementation, contingency planning) in different national energy management standards highlights the need of injection of new defined standards to improve existing energy management standards. Therefore, this study by introducing self-sufficient industries through passive house concept attempts to focus on industrial facility design.

Key-Words: energy management practices; passive house; self-sufficient industry; energy management standards

1 Introduction

Energy management practices (EnMPs) with its systematized and continuous way of dealing with energy related aspects help to improve energy efficiency (EE) in industries. Different energy management (EnM) standards have been defined to structure the work [1, 2]. Often the standards underlying EnMPs are taken for granted. However, some aspects are addressed in the EnM standards not to the full extent. Jelic´ et al. (2010) [1] made a comparison of national EnM standards and listed some elements that have lower level of agreement. Management commitment, strategic planning, purchasing and design are all those listed with low agreement level.

Considering energy crisis and high energy costs for industries, current paper attempts to introduce self-sufficient industries through Passive House (PH) concept which is applying for residential buildings. In coming future it would be rather important for industries to support and maintain some part of their energy demand by their own. It is rather important to consider the design of an industrial building to increase EE level of the company. However, after analyzing EnM standard like ISO 50001, it was observed that the aspect of a facility design is not paid enough attention. Although, the design aspect is placed in "Do"-block of PDCA-cycle, it is not sufficiently described. It is mentioned in the block that design of facilities should be considered (alongside with design of equipment and processes) as well as it concerns "new, modified and renovated" objects, also the design options should be identified, analyzed and evaluated (ISO50001). However, further guidelines and recommendations are missing which is also approved by [1] which states that it is not mentioned in the standard what parameters the design of the facilities aspect should consist of. There is however, one more parameter which is included into ISO 50001 and this is compliance with legal requirements where building code is one of them.

2 Passive House

Energy efficient design of the residential facilities is quite a thoroughly researched topic. Passive residential buildings resulted from the attempt to reduce heating needs of buildings [3]. Later it developed into a wholly new concept with such necessary components as good insulation, air tightness; big low-energy windows oriented southwards, ventilation and water system with heat recovery, solar energy, efficient household equipment [3].

In our definition of passive industrial facility and/or self-sufficient industries we include such aspects as: building envelope, heat recovery, passive solar gains, electrical efficiency and renewable energy sources for meeting remaining energy demands [4].

2.1 Drivers

As it was already mentioned above the aspect of energy efficient facility design is only mentioned limitedly in EnM standards. That is why it is rather important to mention in the standards the necessary factors intrinsic to energy-efficient design. This study suggests enhancing the notion of passive industrial facilities in EnM standards.

This notion should also be taken into consideration continuously not only at the time of introduction of EnM systems in a company alternative during a building's design stage. Design of industrial facilities should be reconsidered all the time when changes in production processes are introduced. There are many interconnections between industrial facilities and production processes and thus changing of production line, installation of new equipment have a direct effect of energy use within a facility, it changes thermal conditions as well as energy demand.

Muler et al. (2013) [2] raises a question of integration of factory planning and operation into energy management systems. He mentions that the structure of energy management (PDCA-cycle) overlaps with how an energy efficient factory is planned and operated in form of objectives, measures, methods, information, etc. Energy management in this way contributes to planning and operational activities by providing additional energy-related information. Thus, energy management should be addressed when new projects are planned in order to define present energy use and prognosis for future. Muller mentions as well that in spite of energy management can be seen as an intrinsic part of energy efficient firms it can be quite challenging to develop a holistic view on energy management within organization. This is also supported by [1] that highlights lack of integration of energy management into firms' strategies. However, in this paper we would like to highlight only the necessity of considering facilities' design and operation when planning new projects.

3 Passive industrial facilities

The walls of industrial facilities should be built from materials that assure necessary insulation. Especially the industrial facilities built long ago are characterised with poor insulation. By improving wall construction, eliminating thermal bridges and leakages it is possible to save significant amount of energy. An example can be a Chinese automobile factory where after reconstruction of the walls by internal thermal insulation it was possible to achieve reduction of U-value from 2.6 to 0.62 W/ (m^2K) resulting in decreasing of around 3.5% energy use [5]. XuLei & LiuLi (2013) [5] mention as well the availability of modern design solutions comprising heat storage walls as well as double glass curtain walls combined with new materials which are thin and environmentally safe.

Construction of doors and windows is also crucial for industrial facilities since buildings can lose up to 50% of heat consumption through doors and windows. There are a lot of possibilities to reduce heat losses through doors and windows, for example, to install automation systems to close the doors, to seal them properly, to use energy efficient windows (triple glazing, low emissivity windows) and shading devices [5].

A controversial aspect here can be the mismatch between industrial facilities' insulation and their heat demands. For example, foundries producing a lot of excess heat in their ovens can have high cooling demands instead. This can be a problem when complying EnMs legal requirements such as the building code's requirements on insulation.

The excess heat of the industrial facilities should be recovered [6]. Lots of heat is always wasted within industrial companies so, recovering excess heat in industries is a key factor to build passive industries.

Proper design of windows (efficient framing, orientation southwards) as well as low-energy glazing help to reduce the losses as well as cover

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heat demand and demand for lighting [4]. This aspect is paid not that much attention in industrial facilities. To increase natural lighting it is not necessary to reconstruct the windows in order to increase glazing area, XuLei & LiuLi (2013) [5] mention such solutions as installation of a light pipe and a reflector.

Adjusting of lighting can be appropriate when doing renovation of the industrial buildings. For example, it is possible to install atrium layers. In this way it is possible to improve natural lighting as well as working conditions (better side window lighting) and thermal environment [5].

Electrical efficiency of industrial appliances is a necessary criterion as well [7].

Indoor air quality can be a crucial factor for industrial facilities. One important aspect can be not to cool and warm a facility at the same time which happens quite often in industries. Atriums mentioned in the lighting section can be useful for ventilation purposes as well: ventilation through the stack effect of atriums due to the hot-pressing difference. This happens when cold air from outside comes in through the bottom of atrium while warm air goes out through the bottom of atrium.

Also, properly designed ventilation system can help to optimize the excess heat use (heat from processes can be used for preheating of incoming air) as well as improve the heat exchange between inlet and outlet air. Also, it is important to assure that ventilation does not run when there is no need for it as well as that the fan motors are controlled by demand (VSD are installed between motors and fans).

The opportunities for covering different energy requirements by means of renewable energy sources should be investigated for the conditions of a particular industrial facility. The examples can be solar or wind energy. Installing solar cells on the roof is one solution which requires different investigation regarding integration of the system according to the building parameters [5]. XuLei & LiuLi (2013) [5] mention also the opportunity of using geothermal energy throughout the whole year by switching between cold water from cold temperature zones for air-conditioning needs during the summer and hot water for heating needs during the winter time.

A control system collecting the information about the energy uses by all the processes of an industrial facility is an important criterion to create the conditions for a self-sufficient industrial system. First of all, it gives an overview of energy uses, secondly it helps to monitor the trends in energy use and third it can help to understand what reasons lay behind certain changes in the trends. The system can also give the possibilities to change the operating parameters for a particular process or program the settings so they can change automatically (flows, temperatures, pressure, operating time, etc.). Thus, all the processes can be smartly and collaboratively coordinated and controlled. Also, a system gives an opportunity to visualize the processes and assign specific indicators to each of them which increases understanding and helps to develop ideas how to work further with improving energy efficiency. By visualizing the costs and assigning them for specific energy users it gives also further motivation to reduce energy use.

The possibilities how industries can use control systems can be very huge. There is an example of automatic adjusting of lighting if one connects detectors capturing natural light from the windows [5].

The requirements can be suggested and energy efficient design should be put into the loop of continuous adaptation to the industrial activities. That is why it is important to further work on the idea of self-sufficient and low-energy industrial facilities which gives ample scope to imagination. A special and more thorough analysis can be made during the renovation of industrial facilities.

4 Case Analysis

Based on the perspective of introducing self-sufficient industry, we look at Xylem's EnM program. The site in Emmaboda has around 1200 employees and a manufacturing capacity of 140000 pumps and 2500 mixers and is considered a large energy intensive manufacturing industry in Sweden. Companies' characteristics like energy intensity and size have a direct impact on energy activities [8, 9]. Since 1998, Xylem is working continuously to improve energy efficiency with EnM department. Xylem won the Swedish Foundry Association's energy prize in 2006 [10] as well as were nominated to Sustainable Energy Europe & ManagEnergy Awards 2014 for the project "High Temperature

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Borehole Thermal Energy Storage at Xylem" [11]. Programs and EnMPs which are running in Xylem day by day make them more and more self-sufficient industry from energy supply point of view.

3.1 Heat recovery system

The district heating system at Xylem consists of two parts: internal and external provided by Emmaboda's district heating company Emmaboda Energi. 4 GWh of heating demand was covered by the district heating (external network) in 2013 and was further decreased to 2, 8 GWh in 2013. About 11 GWh of the excess heat is used in the internal network. The waste heat of higher temperatures (from melting and casting furnaces in the foundry) is used to heat the buildings and/or domestic hot water. About half of the energy in the internal heating network is recovered from the foundry. Waste heat at lower temperatures (below about 40°C) is recovered to preheat outdoor air in ventilation systems or raised up by heat pumps and sent out to the internal heat distribution.

A seasonal storage of the heat in the borehole storage (BHS) is a complement to the recovery system. A high temperature BHS was built in order to utilize the waste heat previously cooled off via cooling towers (about 3 GWh/year). The project was initiated in 2000 and was finished in 2013. A heat pump which is an essential component of the system was bought in 2008. The BHS consists of 140 boreholes placed 150 meters down into the bedrock. Circulated water delivers the waste heat to the rock through the heat exchangers during the whole summer. During the winter the flow is turned for the heat to be used for heating purposes. All waste heat from processes and equipment is supplied to the BHS.

3.2 Building/ space heating

Xylem at Emmaboda consists of 25 buildings on a total area of 110 000 m^2 in a range from 70 years old to the present. The conditions of building envelopes are different but improvements are made continuously in connection with renovations. Ports in the premises have lock function to prevent cold drafts. Thermal photographing of the buildings performed continuously during the winter to eliminate weaknesses in building envelope. The performed projects are wall insulation of a building C11, changing of windows in buildings M12, M20, C16.

3.3 Cooling

Free cooling is used in form of the cold water that is delivered to the ventilation units from two boreholes. Thus, a demand for cooling in the offices can be covered providing comfortable climate and work environment. Also, cold side of the heat pump is used to cool down parts of the foundry premises. There is a further potential to expand this solution to the main part of the foundry's premises.

3.4 Ventilation

Ventilation in all buildings is controlled by frequency converters and air quality sensors which mean that the air flow is adjusted to the ventilation demand. Installation of about seventy five frequency converters reduced drastically the electricity consumption for ventilation (50% savings compare to driving without the control).

3.5 Lightening

Settings for lighting in the premises during the production time are made in the control system thus enabling avoiding using lighting when there is no production. Also, occupancy sensors are installed in the facilities. In all application where it is possible LED-lighting has replaced inefficient lamps. There are still some quicksilver fixtures that are planned to be replaced in 2014.

4 Conclusion

EnM is a robust tool to improve EE in industries. However, it needs some defined standards to inject into the EnM programs for better results. Criteria and requirements which are identified for PH are applicable in industrial facilities also. However, all proposed standards need to redefine and recalculate to be fit for industrial facilities. As we know huge amount of heat recoverable in production line. Proper window installation in proper size and well insulated windows consequents lower energy demand, heat recovery and lightning.

For better EE results it is pillar point to work continuously and properly. Even small modifications in EnMPs might bring adorable improvements. Introducing passive industries and/or self-sufficient industries, this paper attempts to highlight more and more the importance of facilities' EE improvement not only in design, but also in construction.

The requirements for industrial facilities, in turn, can differ. In this paper we will not give an attempt to set the standards for passive industrial facilities, however, we will try to make some suggestions based on best-known example found among industries.

A suggestion can be trying to define the optimal value for heat demand for a specific industrial sector (HD) as well as energy use (EU) by electric appliances. To difine HD and EU it is necessary to measure heat demand for a particular company, kWh/m^2 (HD_i), average heat demand for a particular sector, kWh/m^2 (aveHD), energy use (by electrical appliances) for a particular company, kWh/m^2 (EU_i) and average energy use (by electrical appliances) for a particular sector, kWh/m^2 (aveEU) (Zimmerman, 2005). The PH concept has 19 or 20 kWh/ m^2, year for external heating supply. The average in Swedish industry is 250kWh/ m^2, year for heating. Xylem is down to 27 kWh/ m^2, year by injecting almost PH requirements into its EnM program and practices.

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Article

Is Passive House Concept Applicable to Self-Sufficient Industry?

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Abstract: Costs, quality and time are three main objectives for industries all over the world. Due to rising energy prices, environmental and political demands, and companies are nowadays more eager to cut energy costs. A number of countries over the past years have in joint effort developed standards for energy management, where the main objective is reduced energy costs and greenhouse gas emissions. Lower level of agreement in some parameters (such as: management commitment, strategic planning, energy profile, purchasing, design, energy project implementation, contingency planning) in energy management programs highlights the need of research on how to develop and improve existing energy management programs. Therefore, the aim of this study is, by the introduction of the concept of self-sufficient industries through passive house concept, an attempt to further develop guidelines on the success of in-house energy management programs.

Key-Words: energy management practices; passive house; self-sufficient industry; energy management standard; facility management

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1 Introduction

Energy management practices (EnMPs) with its systematized and continuous way of dealing with energy related aspects help to improve energy efficiency (EE) in industries. Different energy management (EnM) standards have been defined to structure the work [1, 2]. Often the standards underlying EnMPs are taken for granted. However, some aspects are addressed in the EnM standards not to the full extent. Jelic´ et al. (2010) [1] made a comparison of national EnM standards and listed some elements that have lower level of agreement. Management commitment, strategic planning, purchasing and design are all those listed with low agreement level.

Considering volatile energy prices and high energy costs for industries, the current paper attempts to introduce self-sufficient industries through the Passive House (PH) concept, which is applied for residential buildings. In the future it will be rather important for industries to support and maintain some part of their energy demand by their own. It is rather important to consider the design of an industrial building to increase EE levels of the company. However, after analyzing EnM standards like ISO 50001, it was observed that the aspect of a facility design is not paid enough attention. Although, the design aspect is placed in the "Do"-block of the PDCA-cycle, it is not sufficiently described. It is mentioned in the block that design of facilities should be considered (alongside with design of equipment and processes) as well as it concerns "new, modified and renovated" objects, also the design options should be identified, analyzed and evaluated (ISO 50001). Furthermore, to successfully implement an energy management system (EnMS), standards are provided proper statements in order to *WHAT* to do. But *HOW* to do this in detail is something which is left out for the single industrial company to decide [2]. Thus, further guidelines and recommendations are needed which is also approved by [1] which states that it is not mentioned in the standard what parameters the design of the facilities aspect should consist of.

So, this study tries to highlight the importance of facility management in the industrial sector since it is an important part of EnM and a large proportion of total operating costs, up to 75 percent of the total energy costs, can be facility related energy costs. According to the International Facility Management Association (IFMA), facility management is "a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, processes and technology". In the future, it seems that it would be of great importance for industries to maintain some part of their energy demand by themselves. Therefore, the current paper, by aims to introduce the PH concept in relation to industry, and the drivers, which shows the importance of enhancing the notion of passive industrial facilities in relation to EnM standards. It follows by passive industrial facility and case study which is selected from large energy-intensive companies in Sweden. Finally, it would be ended by conclusion.

2 Passive House

Energy efficient design of the residential facilities is quite a thoroughly researched topic. Passive residential buildings resulted from the attempt to reduce heating needs of buildings [3]. Later it developed into a wholly new concept with such necessary components as good insulation, air tightness; big low-energy windows oriented southwards, ventilation and water system with heat recovery, solar energy, and efficient household equipment [3, 4, and 5]. According to Canadian Passive House Institute [6], PH is the world's most ambitious and scientifically verified route to truly sustainable buildings, achieving 80–90% energy savings over conventional construction through radical conservation.

In adopting definition of passive industrial facility and/or self-sufficient industries we include such aspects as: building envelope, heat recovery, passive solar gains, electrical efficiency and renewable energy sources for meeting remaining energy demands [7].

The various components of the PH approach can be classified under the following basic elements. The first three (superinsulation, heat recovery and passive solar gain) are crucial to the PH concept. To fully minimize environmental impacts, however, the other two are necessary (electrical efficiency) or expedient (meeting remaining energy demand with renewables) [8].

Potentially this process of innovation can help to bring about wider innovation in the industrial buildings – transforming design, improving quality and changing the industrial building process through, for example, modern methods of construction [9].

3 Passive Industrial Facilities and Drivers

As it was already mentioned above the aspect of energy efficient facility design is only mentioned limitedly in EnM standards. However, facility management is an important part of any EnM structure due to its huge proportion of energy cost within total operating costs. That is why it is rather important to mention in the standards the necessary factors intrinsic to energy-efficient design. This study suggests enhancing the notion of passive industrial facilities in EnM standards.

This notion should also be taken into consideration continuously, not only at the time of the introduction of an energy management system (EnMS) in a company or during a building's design stage. Design of industrial facilities should be reconsidered all the time when changes in production processes are introduced. There are many interconnections between industrial facilities and production processes and thus changing of production line, installation of new equipment have a direct effect of energy use within a facility, it changes thermal conditions as well as energy demand.

Muller et al. (2013) [2] raises a question of integration of factory planning and operation into energy management systems. He mentions that the structure of energy management (PDCA-cycle) overlaps with how an energy efficient factory is planned and operated in form of objectives, measures, methods, information, etc. Energy management in this way contributes to planning and operational activities by providing additional energy-related information. Thus, EnM should be addressed when new projects are planned in order to define present energy use and prognosis for future. Muller mentions as well that in spite of EnM can be seen as an intrinsic part of energy efficient firms it can be quite challenging to develop a holistic view on EnM within organization. This is also supported by [1] that highlights lack of integration of EnM into firms' strategies. However, in this paper we would like to highlight only the necessity of considering facilities' design and operation when new projects are planning.

Developers, managers, engineers and their supply chains are in position to drive economics of scale and innovation in improved EE and distributed EE related technologies. The use of new and innovative approaches can have a demonstrator effect, not only to industrial EE improvement but to increasing operation profit in existing industries too.

The walls of industrial facilities should be built from materials that assure necessary insulation. Especially the industrial facilities built long ago are characterised with poor insulation. By improving wall construction, eliminating thermal bridges and leakages it is possible to save significant amount of energy. An example can be a Chinese automobile factory where after reconstruction of the walls by internal thermal insulation it was possible to achieve reduction of U-value from 2.6 to 0.62 W/ (m^2K) resulting in decreasing of around 3.5% energy use [7]. Xu & Li (2013) [10] mention as well the availability of modern design solutions comprising heat storage walls as well as double glass curtain walls combined with new materials which are thin and environmentally safe.

Construction of doors and windows is also crucial for industrial facilities since buildings can lose up to 50% of heat consumption through doors and windows. There are a lot of possibilities to reduce heat losses through doors and windows, for example, to install automation systems to close the doors, to seal them properly, to use energy efficient windows (triple glazing, low emissivity windows) and shading devices [10]. It should be noted however, that for industrial buildings with high industrial excess heat generation, re-allocation of heat demand is key. Otherwise, insulation of building shells only leads to increased temperatures and thus negative working conditions for the workers.

A controversial aspect here can be the mismatch between industrial facilities' insulation and their heat demands. For example, foundries producing a lot of excess heat in their ovens can have high cooling demands instead. This can be a problem when complying EnMs legal requirements such as the building code's requirements on insulation.

The excess heat of the industrial facilities should be recovered [11]. Plenty of heat is often lost within industrial companies so, recovering excess heat in industries is a key factor to build passive industries. However, it needs to be done using a systems perspective and not only on a single technology component perspective.

Proper design of windows (efficient framing, orientation southwards) as well as low-energy glazing help to reduce the losses as well as cover heat demand and demand for lighting [7]. This aspect is paid not that much attention in industrial facilities. To increase natural lighting it is not necessary to reconstruct the windows in order to increase glazing area, Xu & Li(2013) [10] mention such solutions as installation of a light pipe and a reflector.

Adjusting of lighting can be appropriate when doing renovation of the industrial buildings. For example, it is possible to install atrium layers. In this way it is possible to improve natural lighting as well as working conditions (better side window lighting) and thermal environment [10, 12].

Electrical efficiency of industrial appliances is a necessary criterion as well [13].

Indoor air quality can be a crucial factor for industrial facilities. One important aspect can be to not to heat and cool a facility at the same time which happens quite often in industries. Atriums mentioned in the lighting section can be useful for ventilation purposes as well: ventilation through the stack effect of atriums due to the hot-pressing difference. This happens when cold air from outside comes in through the bottom of atrium while warm air goes out through the bottom of atrium.

Also, properly designed ventilation system can help to optimize the excess heat use (heat from processes can be used for preheating of incoming air) as well as improve the heat exchange between inlet and outlet air. Also, it is important to assure that ventilation does not run when there is no need for it as well as that the fan motors are controlled by demand (VSD are installed between motors and fans).

The opportunities for covering different energy requirements by means of renewable energy sources should be investigated for the conditions of a particular industrial facility. The examples can be solar or wind energy. Installing solar cells on the roof is one solution which requires different investigation regarding integration of the system according to the building parameters [10]. Xu & Li (2013) [10] mention also the opportunity of using geothermal energy throughout the whole year by switching between cold water from cold temperature zones for air-conditioning needs during the summer and hot water for heating needs during the winter time.

A control system collecting the information about the energy uses by all the processes of an industrial facility is an important criterion to create the conditions for a self-sufficient industrial system. First of all, it gives an overview of energy uses, secondly it helps to monitor the trends in energy use and third it can help to understand what reasons lay behind certain changes in the trends. The system can also give the possibilities to change the operating parameters for a particular process or program the settings so they can change automatically (flows, temperatures, pressure, operating time, etc.). Thus, all the processes can be smartly and collaboratively coordinated and controlled. Also, a system gives an opportunity to visualize the processes and assign specific indicators to each of them which increases understanding and helps to develop ideas how to work further with improving energy efficiency. By visualizing the costs and assigning them for specific energy users it gives also further motivation to reduce energy use.

The possibilities how industries can use control systems can be large, e.g. automatic adjusting of lighting if one connects detectors capturing natural light from the windows, which can daytime reduce electricity for lighting to a large extent [10].

The requirements can be suggested and energy efficient design should be put into the loop of continuous adaptation to the industrial activities. That is why it is important to further work on the idea of self-sufficient and low-energy industrial facilities which gives ample scope to imagination. A special and more thorough analysis can be made during the renovation of industrial facilities.

Criteria and requirements for PH can be applicable in industries as well. However, these requirements differ from all those which are defined for the residential sector. Through one of the best-known examples of industrial energy efficiency, the current paper investigates the applicability of PH for industries and makes some useful suggestions to improve existing EnM program. Beside the reason of being the most heat efficient industry in its sector, and, the main reason for selecting the case was their main strategy to be self-sufficient.

4 Case Analysis

Based on the perspective of introducing self-sufficient industry, we look at Xylem’s EnM program. The site in Emmaboda of 110 000 m2 has around 1200 employees and a manufacturing capacity of

140000 pumps and 2500 mixers and is considered a large energy intensive manufacturing industry in Sweden. Companies' characteristics like energy intensity and size have a direct impact on energy activities [14, 15]. Since 1998, Xylem is working continuously to improve energy efficiency with EnM department. Xylem won the Swedish Foundry Association's energy prize in 2006 [16] as well as were nominated to Sustainable Energy Europe & ManagEnergy Awards 2014 for the project "High Temperature Borehole Thermal Energy Storage at Xylem" [17]. Programs and EnMPs which are running in Xylem day by day make them more and more self-sufficient industry from energy supply point of view.

4.1 Heat recovery system

The district heating supply at Xylem consists of two parts: internal and external provided by Emmaboda's district heating company Emmaboda Energi. 4 GWh of heating demand was covered by the district heating (external network) in 2012 and was further decreased to 2, 8 GWh in 2013. About 11 GWh of the excess heat is used in the internal network. The waste heat of higher temperatures (from melting and casting furnaces in the foundry) is used to heat the buildings and/or domestic hot water. About half of the energy in the internal heating network is recovered from the foundry. Waste heat at lower temperatures (below about 40°C) is recovered to preheat outdoor air in ventilation systems or raised up by heat pumps and sent out to the internal heat distribution.

A seasonal storage of the heat in *the borehole storage (BHS)* is a complement to the recovery system. A high temperature BHS was built in order to utilize the waste heat previously cooled off via cooling towers (about 3.4 GWh/year). The project was initiated in 2000 and finished in 2013. A heat pump which is an essential component of the system was bought in 2008. The BHS consists of 140 boreholes placed 150 meters down into the bedrock. Circulated water delivers the waste heat to the rock through the heat exchangers during the whole summer. During the winter the flow is turned for the heat to be used for heating purposes. All waste heat from processes and equipment is supplied to the BHS. The project includes several innovations (Energy plan, 2013):

- extremely thermally efficient heat exchangers due to direct contact of water with the rock;
- pipes made of plastic material that can withstand temperatures up to 80°C;
- there is a capacity for short storage during the winter if warmer periods occur;
- the BHS is controlled by an advanced system that allows switching between a large number of operating modes and entirely automatic (Energy plan, 2013).

The calculated efficiency of the BHS is 70% which implies 30% losses. The system has two-direction flow with the aim to use the boreholes both when there is demand for heating or for cooling. When there is a need for cooling heat carrier is used for free cooling. At full operation it is expected to recover about 2.6 GWh. This aims to reduce the demand for the district heating from 5 GWh to 2.5 GWh out of the 8 GWh total heating demand [18].

4.2 Building/ space heating

Xylem at Emmaboda consists of 25 buildings on a total area of 110 000 m^2 in a range from 70 years old to the present. The conditions of building envelopes are different but improvements are made continuously in connection with renovations. Ports in the premises have lock function to prevent cold drafts. Thermal photographing of the buildings performed continuously during the winter to eliminate weaknesses in building envelope. The performed projects are wall insulation of a building C11, changing of windows in buildings M12, M20, C16.

4.3 Cooling

Free cooling is used in form of the cold water that is delivered to the ventilation units from two boreholes. Thus, a demand for cooling in the offices can be covered providing comfortable climate and work environment. Also, the cold side of the heat pump is used to cool down parts of the foundry premises. There is a further potential to expand this solution to the main part of the foundry's premises.

4.4 Ventilation

Ventilation in all buildings is controlled by frequency converters and air quality sensors which mean that the air flow is adjusted to the ventilation demand. Installation of about seventy five frequency converters reduced drastically the electricity consumption for ventilation (50% savings compare to driving without the control).

4.5 Lightening

Settings for lighting in the premises during the production time are made in the control system thus enabling avoiding using lighting when there is no production. Also, occupancy sensors are installed in the facilities. In all application where it is possible LED-lighting has replaced inefficient lamps. There are still some quicksilver fixtures that are planned to be replaced in 2015.

Xylem’s important principles related to energy are that the electricity they purchase should come from renewable sources and the demand for heating should be covered by bio energy or waste heat. Losses of waste heat should be minimized and every new project should be investigated for opportunities of waste heat utilization. Hot water should not be heated with direct electricity, but only with waste heat, district heating or solar energy. All the ventilation units at Xylem are demand-controlled using VSD. To complete their EnM program they set following visions for future:

- Using LCC when buying new equipment;
- Eliminate equipment and transport driven by fossil fuels;
- Energy to be included in the 5S[1];
- Cooling of processes with cooling heat pump should be prioritized due to availability of excess heat during the whole year.

[1] 5S is a system to reduce waste and optimize productivity through maintaining an orderly workplace and using visual cues to achieve more consistent operational results.

5 Conclusion

EnM is a robust tool to improve EE in industries and its main task is to reduce costs for provision of energy in buildings and facilities without compromising work processes. However, it needs some defined standards to inject into the EnM programs for better results. The self-sufficient and/or passive industries concept can be designed and developed to promote leadership in this important area, .i.e. it point towards a direction on how to reach overall sustainability, not only aim for continuous improvements using the PDCA-cycle.

The requirements for industrial facilities, in turn, can differ. In this paper it has not been the attempt to set the standards or criteria for passive industrial facilities, however, it has been emphasised to make some suggestions based on best-known example found among industries.

A suggestion can be trying to define the optimal value for heat demand for a specific industrial sector (HD) as well as energy use (EU) by electric appliances. To define HD and EU it is necessary to measure heat demand for a particular company, kWh/m^2 (HD_i), average heat demand for a particular sector, kWh/m^2 (aveHD), energy use (by electrical appliances) for a particular company, kWh/m^2 (EU_i) and average energy use (by electrical appliances) for a particular sector, kWh/m^2 (aveEU) [19]. However, based on the characteristics of any industrial company requirements would be different. For instance, open foundries and close foundries are differing in insulation. Therefore, important parameters should be characterized when passive industries are defining.

For improved EE results it is pillar to work continuously and properly. Even small modifications in EnMPs might bring sound improvements. Innovation sometimes does not come from expected places. Thus low-carbon and/or EE solutions can be expected to emerge from all parts of economy – not just the established “energy” or “environment” sectors, both of which can be hidebound by traditional ways of thinking. And real progress can be made when a series of innovations link together and set off a chain reaction. We need to think of innovation as “tipping points” and create policies that support them. Therefore, introducing passive industries and/or self-sufficient industries, this paper attempts to highlight more and more the importance of facilities’ EE improvement not only in design, but also in construction.

The PH concept has 19 or 20 kWh/ m^2, year for external heating supply. The average in Swedish industry is 250kWh/ m^2, year for heating. Xylem is down to 27 kWh/ m^2, year by injecting almost PH requirements into its EnM program and practices. Moreover, the major part that has made Xylem so successful is not focusing on components but on the whole system. They have for example done very little in terms of insulation but extremely much on excess heat utilization using heat pumps etc. This may be seen as remarkable. An industrial company with 110 000 m2 of heated area have reached near the PH requirements.

Xylem developed an almost proper EnM program to enhance its EE level; however, there is some vacant room to improve it even further. As it was mentioned, Xylem’s will to become self-sufficient from the perspective of energy supply is very similar to the PH concept. One major means for industrial companies could be modifying industrial buildings from EE point of view through facility management same as what has been developed by PH concept for residential buildings [3]. From an energy point of view, higher efficiency is always better. When one tries to add PH concept to

EnM programs for industries the idea is to minimize heating, electricity, and cooling inputs. Therefore, based on the characteristics of the company insulation and other PH's criteria would vary. So, from this perspective more is not always better and values should be set for industrial building envelopes. The criteria and requirements which are identified for PH are applicable in industrial facilities as well. However, when designing these criteria one should pay attention to the production rate of particular industrial facility. Since Xylem has improved the areas in regard to ventilation, heat recovery and installed various control system, it would have a huge potential to include PH requirements in its EnM programs. However, all proposed standards such as building insulation, ventilation, heat recovery, and air tightness need to redefine and recalculate to be fit for industrial facilities. As we know huge amount of heat is recoverable in the production processes. Proper window installation in proper size and well insulated windows consequently lowers energy demand, heat recovery and lightning. Since defining proper means for all mentioned criteria requires simulation model for several cases which are not in the scope of current paper and are therefore suggested as an area for future work.

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