IIIEE Theses 2007:04

Monitoring of electrical energy – Why and how do Swedish industries do it?

In search of energy conservation, efficiency and better performance in manufacturing industries

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Thesis for the fulfilment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, September 2007

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ISSN 1401-9191

Acknowledgements

Finalising this thesis I do acknowledge that the year and two months in Lund and IIIEE were not 'spent' but lived to the full extent of every day, filling my life with more meaning and my mind with clearer understanding of myself. Not the least, I'd like to state that studying in this Masters programme was the move that made me happy for all my time in Lund.

For understanding and love of my parents, I would like to thank them for never questioning my plans and deeds and their full trust. My teacher of Swedish, Ann-Kerstin Dehlin, who extended her professional experience to teach me and my new friends from all over the world how to speak the language of the only socialistic country in the world. I am grateful as well to my Lundian Russian-speaking community, who helped me through the hard times of studies by organising parties and letting my brain rest in a Swedish sauna.

My deep gratitude extends to:

All my interviewees for their time and willingness to share their knowledge and experience;

My thesis supervisors, Torbjörn and Håkan, for 'warming-up' at the beginning, 'cooling down' with their comments, and letting me learn through the process, not losing the right path;

Doctor Lars Hansson for being always helpful and inspiring;

All teachers and researchers of the IIIEE for keeping a unique atmosphere and making the historical building, unlike any other part of the Lund University, even more special;

My tiny, diverse and happy batch 12 – you will stay in my heart forever!

The IIIEE library, that I found to be an extremely useful resource, and so friendly and helpful in the persons of all librarians: Åsa, Dagmara, Kristina, and, certainly, Fredrik;

The Visby Programme of the Swedish Institute that played an interactive part in my studies by providing my living, and, by all means, being an inspiration, - as the scholarship is a often a good incentive;

And generally, the Swedish society and the previous government that made this education possible at the very right point of my life.

Tack så mycket!

Thank you very much!

Большое спасибо!

Abstract

Improvement of energy efficiency is seen to have an unexplored potential in relation to industrial energy users. Swedish manufacturing industries and their perception of electrical energy usage at production facilities are at the centre of this thesis. Reasons and approaches towards the monitoring of electrical energy at the operational level are discussed from a number of angles. The research effort to identify the appropriate placement of energy monitoring within an industrial organisation is assisted by an overview of legal, political, market, and management factors and multiple case studies.

Based on the research conducted, cost reduction, detalisation and environmental concern are shown to have the strongest influence on the initiation of sub-metering in an industrial context. However, these drivers alone are not sufficient for the continuous exploration of energy saving potential by industries. Additional supportive forces capable of improving industrial energy efficiency are recognised. It is concluded that full integration of energy monitoring within an organisation and its business and production management is indispensable in the energy efficiency quest.

Key words: electrical energy, energy management, energy management system, monitoring system, energy metering, energy conservation, cost reduction.

Executive Summary

Scandinavian countries have a long-standing reputation of being highly aware of environmental issues and concerned about energy. Energy has always been in focus in Sweden due to economic development ambitions and colder climate conditions. Natural resources in Sweden allow for the generation of almost half of the electrical energy using hydrological resources. The other major part is generated at nuclear power plants. Hence, it is only a minor share of electrical energy that is causing CO_2 emissions. Electrical energy generated from renewable sources is on the rise both in terms of support and generated volumes.

Developments over the last decade have contributed to pushing energy issues onto national political agendas. Climate change and energy security topics have opened society's eyes to essential energy issues. The Swedish Parliament has adopted 16 environmental objectives related to the improvement of environmental quality for future generations. Among them, the 'Reduced Climate Impact' objective is related to power generation and end-use. The programme for improving energy efficiency in energy intensive industries (PFE) forms one of the activities directed towards the accomplishment of this goal.

The scope of this paper is delimited to electrical energy and its usage at Swedish manufacturing industrial plants. These are typically not energy intensive industries. The study was undertaken to identify the best experience of energy monitoring among Swedish manufacturers. This required observing the components of both the supply and demand sides of the energy market and the way that manufacturers' expenditures are formed. Various energy market actors along with manufacturing industries represent the sources of empirical data used for this thesis work.

This thesis revolves around the demand side of the energy market and factors that facilitate efficient end-use of energy at industrial facilities. The category of manufacturing industries instead of energy intensive process industries represents a very interesting focus group thanks to the changing energy market conditions and their exposure to intense competition. These changes lead to a re-evaluation of existing industrial production management practices towards a more thorough consideration of exogenous and endogenous factors. An overview of these factors is provided in Chapters 3 and 4 by looking into corporate performance aspects and energy management at production facilities.

Although energy management issues have gained increasing attention in Europe in recent years, a literature review shows that these issues continue to play a more legitimate role in North America. Some European countries have approached this issue by developing the Energy Management System Standard. Nevertheless, there seems to be a strong deficiency of understanding of the elementary grounds for such a system's implementation. Looking into energy monitoring from the perspective taken in this thesis serves as an attempt to cover the existing gap. Chapter 5 is devoted to examining the role and the components of the energy monitoring system and sub-metering activities.

Four large international companies with headquarters in Sweden are the focus of the discussion held on energy consumption monitoring practices in Chapter 6. All four companies have a number of plants in Sweden. One production site of each company represented the basis for the multiple case studies. Two of the four cases of energy management presented in the paper can be considered as 'best experience' in Sweden. Objectivity of the inductive study is supported by numerous interviews held with relevant actors professionally dealing with energy efficiency.

Industrial companies arrive at looking into energy issue due both to economic and environmental reasons. Many energy components in industrial processes eventually lead to electrical energy consumption (such as air compressing, cooling, heating, ventilation, etc.). With the introduction of market-based instruments, economic and environmental concerns became more closely interlinked. Chapter 7 provides an analysis and discussion of the findings. It is seen that together with market deregulation, introduction of market-based instruments resulted in an increase in, and a greater volatility of, electricity prices. Slowly but steadily, industrial companies reacted with price-focused strategies by pooling contracts of their subsidiaries and procuring electric power in a centralised manner. Within organisations, this leads to assigning special responsibility with knowledge of financial markets in order to deal with electricity purchases.

Energy management is called upon to search for energy saving potential, implement necessary improvements, monitor their outcome and review further actions. Its origin stems from the engineering domain. This engineering approach seems to remain strong in North America and suggests looking into various parameters of electrical current supplied to an industrial facility for the purposes of better operational and cost management. Electrical energy is only one of the energy sources in the focus of energy management. The potential for energy conservation related to electricity-powered equipment has been roughly estimated but is considered to be unexplored. Energy consumption reduction targets are set at a national level as far as Sweden is concerned. Needless to say, fulfilment of the targets is within the control of end-users.

There are benefits of engineering, environmental, and integrated approaches to energy management. The rational-decision model of an environmental management system (Deming's cycle) was a good starting point for manufacturing industries to look into energy usage. However it did not provide justified targets for energy efficiency improvements. This leads to a discussion on energy management systems being complementary to environmental management systems, where one of the functions of monitoring is to assist with adequate target setting.

Manufacturing industries not being energy or electricity-intensive are left to find their own path to energy efficiency improvements. For some plants, energy consumption concerns were mainly driven by a need for cost detalisation and reduction, even prior to market deregulation. For others, one billing meter was sufficient until now. The reasons for establishing more detailed monitoring of electrical energy consumption or sub-metering are discussed throughout the paper.

A monitoring system forms an indispensable part of energy management. Its technical set-up should be defined by the parties who are responsible for the performance aspects involved in energy usage or information related to it. There are found to be almost no obstacles to sub-metering on-site and an extensive list of benefits that are brought about with it. Certain crucial requirements though, make it important to thoroughly develop the system. A general approach to shaping an 'organic' monitoring system that will be integrated within overall production management and organise energy efficiency work is formulated in Chapter 7.

Co-operation with the energy supply chain is found to be fruitful from both a load management and an energy usage perspective. The energy provider is closer to the market than the distribution system operator and must balance the power purchased for its customers as well as fulfil its own obligations. The distribution system operator is more regulated but has 'metering' contact with the industrial end-user and can contribute to start-up electrical energy metering at manufacturing facilities.

Environmental and energy management systems integrated with a production management system represents the most viable solution for Swedish industrial companies. Integration of energy management into business management practices will steer improvement of energy efficiency and ensure adequate target setting.

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1 Introduction

As promptly observed by one of the largest Swedish and international companies, "*Two of the most important objectives confronting industry (and indeed society as a whole) are financial success and environmental responsibility…. When it comes to energy, … saved resources do translate into saved money*" (Leffler et al., 2007).

This statement is valid for all economic actors: from households to large companies. There are a number of activities, both legislative and practical, going on around energy production and end-use. Technical thought has developed various solutions to solve inefficient energy use problems; economic instruments are employed to reflect associated social costs; state agencies work on increased public awareness. How good are these measures to reach the set goal? Strong attention to energy security and climate change considerations impel society to look for tools to achieve the goals effectively and economically efficiently.

Sweden has historically been a country with plentiful energy resources and electricity has been a cheap resource. This has shaped consumers' attitude. The past decade has brought about a number of issues that required political and economic changes. Not the least was the liberalisation of electricity market first in the Nordic countries and consequently in Europe. The energy agenda has drifted from a single country perspective to the European Community.

Industries are substantial energy consumers. This explains why this economic actor is the focus of the paper. Among different energy sources in industry, electrical energy has the largest portion. A major shift towards electricity as a main energy carrier since the 1970s has been reported by SEA (2007). Please see Figure 1-1.

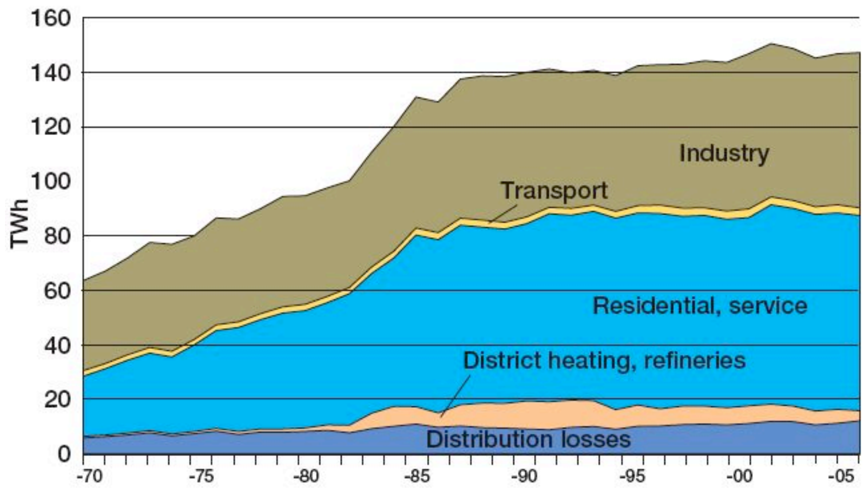

Figure 1-1 Sweden's electricity use, by sectors, 1970 – 2005.

Source: Swedish Energy Agency. (2007). Energy in Sweden 2006. p. 36.

Although the primary focus of this research lies purely with industries, it is important to look at electrical energy as a resource and an economic commodity. Electrical energy has a unique nature. It represents the purest source of energy to perform work. Electric power is valued most among other secondary energy carriers, like heat, gaseous and liquid energy carriers. It is the cleanest energy source in terms of use.

Electrical energy is converted by machinery at industrial plants into useful work. Production and service parts of industries need electrical energy for running. As any other energy source it can be used efficiently or can be called "wasted" without useful work. However, from a physics perspective energy cannot be lost – it gets converted into heat, vibration, unnecessary rounds per minute, lit and heated empty space, and stand-by consumption of connected equipment. Very few industrial plants have looked into improving their energy consumption. The rest either do not consider this a high priority or have only start considering these issues. The issue is at least two-fold here: physical consumption and conservation, and energy costs.

Before an industrial production site gets electrical energy supplied, there are a number of actors who make the delivery take place. Recent reformation of the European electricity and natural gas market has influenced energy contracting practices. European policy in the energy field has played by far the most dramatic role in the recent years. During the year 2006 Europe had witnessed sharp increases in electricity prices. The 2nd quarter of 2007 brought the situation to a more explainable price scale. This event had an inevitable impact on industries in terms of making them more vigilant towards the issue of electric power and its consumption.

With a continuous focus on renewable energy development the end-use of energy is proving to be more and more important. Demand response management including load management is considered by energy suppliers and often they initiate a closer look into energy consumption at production facilities. An industrial facility as a significant consumer of electrical energy has enormous potential to improve its energy usage and efficiency. There are certain technical and maintenance practices to reduce energy consumption at the production site. However it is becoming more and more a corporate level issue. The times are over when only technicians and electricians at industrial plants were concerned with electricity distribution and usage. Environmental concerns around energy issues move energy related indicators towards open reporting. Companies who strongly maintain their environmental performance include energy performance indicators into corporate reports. An important role is played by stakeholders and their awareness of contemporary business values.

Looking into industrial production and energy use does not mean forgetting about the contribution an individual can make. A projection of household energy consumption behaviour and awareness at the individual level is a part of solution. Having access to information is a resource that has large potential both at individual and organisational levels. Information as such does not reduce energy consumption. It forms the basis for making a weighted decision. This particular interdependence has been put into the basis of this thesis. The issues that span the paper have been selected to identify factors contributing to a closer look into electrical energy usage at manufacturing facilities.

1.1 Research Design

The subject in focus requires an interdisciplinary approach. Electrical energy is involved in and gets reflected in a number of economic activities. Therefore it is important to identify relevant actors and fields that need to be reviewed in order to structure the research, collect necessary data and find valid answers by its analysis.

1.1.1 Purpose

It can be stated that the purpose of the research is to highlight an emerging importance of monitoring electrical energy end use and to provide coverage for an existing gap in its description as an essential tool. This thesis aims to achieve an understanding of the preconditions for the development of an electric energy monitoring system as well as prerequisites of making this tool efficient in the long run.

1.1.2 Context

The context of the current research is defined by industries employing production processes with significant electric power consumption. It should be noted that in Sweden there might be different approaches attributed to energy intensive[1] and non-energy intensive industries. This is especially valid in connection with governmental protectionistic activities such as PFE[2].

Electric power has historically been considered a cheap natural resource in Sweden. Only during last few years along with liberalisation of the electric power market and introduction of the Emission Trading Scheme[3], electricity prices have experienced considerable fluctuations and rises. This engaged massive attention of different economic actors, including industries. It is unclear what the future electric energy prices development will be. A specific aspect with the research context is related to Sweden being a part of the European Community. Therefore, it is reasonable to assume a tendency for the Nordic market to become more influenced by the European market.

The monitoring activity, as a concept, has been known for a number of years as a part of management cycle and continuous improvement spiral. Nevertheless, along with changes occurring in the measurement techniques and management demands, there is a lack of attention to the monitoring systems as such within energy management.

1.1.3 Research Question

The research question is stipulated by the purpose and main title of the thesis. It encompasses a practice of monitoring at the operational level within manufacturing industries. Reasons for and practice of electrical energy monitoring at a production site under current performance requirements are the core subject of the research. Three sub-questions have been formulated to structure the main research question. The following are necessary to embrace the relevant disciplines and operational reality of an industrial company.

- What is important for manufacturing industries to know about electrical energy at their plant?;
- How do industrial companies approach management and monitoring of electrical energy consumption and what is the best experience in Sweden?;
- How is monitoring of electrical energy consumption integrated within business management practices?

The purpose is to find an answer to the main headline of the thesis, namely to the question "Why do those companies who already monitor electrical energy consumption do it and what drove them to their current stage?" The purpose of the thesis will be fulfilled if actors and

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[1] An energy intensive company must use electricity in its manufacturing process and fulfill the conditions as defined in the Energy Taxation Directive. Please refer to the Glossary for further explanation.

[2] PFE is a five-year programme for improving energy efficiency in energy intensive industries. An exemption from energy tax is provided to those who prove efficient electricity consumption and efficiency improvements.

[3] ETS – scheme implemented at the dedicated market for trading CO_2 emissions property rights certificates.

factors, organisational, management, economic, and technical consequences are identified and analysed. All these issues shall be looked upon within an environmental context.

1.1.4 Methods

Research is based on primary data collection. The main explanation for this is the lack of secondary data present in the literature reviewed. This however does not eliminate attempts to review possible accessible literature in order to correctly place electrical energy monitoring within environmental, technical, management and economic aspects of industrial operations and derive objective conclusions. The research bears more qualitative character. This is due to rare practical presence of the subject in focus. No statistical data have been available through the research in the cases with "operational" monitoring system.

The literature review intends to find an answer to the first research question and further support or oppose it using empirical findings. Identification of what industrial manufacturers need to know about electrical energy, its consumption and cost led to the next phase of research, which consisted of approaching companies in order to select several organisations for the empirical study. The empirical study is performed as multiple case studies using the identified industrial companies. Only companies running operations in Sweden were considered. Criterion for companies' selection was based on a condition that energy consumption issues are on their agenda. In order to find answers to second research question, consultation with one of the Swedish power suppliers was undertaken as a basis to locate best available experience with the subject of investigation.

Interviews covered various specialists due to involvement of economic, environmental and operational divisions. Interviews were based on a questionnaire designed to be open-ended. Mainly they were held as individual in-depth meetings. A semi-structured pattern was followed due to anticipated differences in experience with the subject of the research. Some of the interviews were done by telephone. Information was gathered to the maximum possible extent from literature, handed materials, companies' home-pages and interviews.

Once collected from all "available at the given time" sources, information went through analysis. The basis of the analysis is brought with the research questions. The method of analysis is of an inductive character. The real quantitative and qualitative data describing the investigated plants and observations from the external actors provide the basis for drawing conclusions and finding answers to all three research questions and ultimately to the head-line of research.

1.1.5 Approach

It is recognised that the issue of electrical energy consumption has not been thoroughly considered by companies representing the non-energy intensive sector. This resource gained certain attention very recently. Primarily, it can be explained with electricity market liberalisation and the introduction of number of economic instruments.

The research question lies on a border of disciplines and requires a holistic approach towards impartial investigation. In order to collect data and reflect the variety of expert knowledge and opinions it is planned to cover different actors. The manufacturing industry represents the focus group. In this group various areas are reviewed: operations, financial, energy and environmental management. In order to provide broader coverage, it was found essential to interview other actors relevant to electrical energy market and energy conservation. The following actors dealing with electrical energy have been identified as major external actors in connection with the electric power monitoring on an industrial site: the power supplier and local network operator, the metering solutions developer and energy consultants. The picture wouldn't be full without inclusion of these interrelated actors.

The approach used within the present research includes these groups in order to allow for many dimensions to be reflected in manufacturing companies' practices.

1.1.6 Validity

The research is limited to one energy carrier, namely electrical energy. It is assumed that non-energy intensive industries have electrical energy as the major or exclusive source of energy in their production processes. The industries in focus are the ones sensitive to increases in electricity prices. It is assumed that they would be interested in tracking their electricity consumption throughout the production process.

Practically very few limitations are foreseen in connection with the research question. It is expected that conclusions shall be valid throughout non-energy intensive industrial processes. There still may be found a certain subjective element due to differences in processes and the pioneering character of the companies studied.

Even though large (Sweden-wide and international) companies form the focus group and serve as data providers, it needs to be stressed that research is limited to only one production site at each company. There is a limitation related to the collection of quantitative information. Two reasons for that are as follows: the investigated system is at a planning stage or the information is considered confidential and not available to outsiders.

Generally, a high level of environmental awareness in Sweden can play a distinctive role of limitation when compared to other countries.

It is not foreseen that conclusions of the research shall have limited validity when applied to a European industrial company.

2 Electrical Energy in Sweden

This chapter is meant to give an overview of the issues that have influenced the current situation with regards to the electricity supply in Sweden. Some legislative and regulatory measures undertaken at both European and Swedish national level on the way to strengthening energy security are brought up. A description of the way that the electricity market is functioning and its main actors is provided for a better understanding of roles and responsibilities among them. This chapter is intended to provide a general understanding of the playing field when it comes to the generation, supply and consumption of electrical energy.

Sweden, namely the Swedish Parliament, has incorporated concern about sustainable energy issues into the National Environmental Goals. These were established with a Government bill 2004/05:150. Energy use indicators are reflected in seven out of sixteen goals. This implies that energy production and usage affects progress in reaching these goals. The industrial energy consumption in Sweden makes up nearly 40% of the total national figure.[4] The overall objective of the Swedish Energy Agency is to transform energy systems to the sustainable mode. This can only be done with reference to the three dimensions of sustainability: ecological, economic, and social.

Sweden is aiming at a substantial development of renewable sources of energy and at securing a supply of electricity at a reasonable price level. More effective energy use is one of the main focuses for collaboration with industries at the municipal and regional level. In accordance with the Swedish electricity regulations, the Swedish Energy Agency (SEA) supervises electrical grid companies.

All levels of Swedish authorities are in charge of securing energy supplies as well as promoting energy conservation. On the institutional side, Regional Energy Agencies have been established. Their primary task is the increase of energy production from renewable sources and facilitation of more efficient use of energy within their respective regions. As stated by the SEA, until now, the part related to the efficient energy use has been governed by a 5-year programme (2003 – 2007). The governmental white paper 2001/02:143 preceding the programme implementation had declared: *"Efficient use of resources including energy constitutes the basis of economic growth and is necessary for sustainable development".*[5]

To help companies with substantial energy costs go through the PFE (Programme for improving energy efficiency in energy-intensive industries), the SEA developed a set of guidelines. The Specification for Energy Management System was developed and made into a standard in 2003[6]. An effort to increase the share of renewable energy in Sweden has been accomplished with the help of instruments, such as electricity certificates. The system was launched on May 1st, 2003. A more detailed overview of this system is provided further in the section 3.2.1.

Pressure for more detailed knowledge of electric power consumption is coming from both ends: EU Directives, and Swedish environmental and energy goals. Governmental actions are

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[4] Sweden's environmental goals. Energy use indicator. Retrieved from: http://miljomal.nu/Pub/Indikator.php?MmID=1&InkID=Ene-1-NV&LocType=CC&LocID=SE [27 June 2007]

[5] Swedish Energy Agency. Role of Regional Energy Agencies. Retrieved from: http://www.energimyndigheten.se/WEB/STEMEx01Eng.nsf/F_PreGen01?ReadForm&MenuSelect=B736276C4A1FAD34C1256F02002E8923 [27 June 2007]

[6] Swedish Standard SS 62 77 50. Energy Management Systems – Specification.

aiming at decoupling economic growth and the use of energy by economic actors. Its intention in relation to industrial energy consumption so far is described as the encouragement of energy conservation measures.

With electricity market deregulation in 1996, it became possible to choose suppliers depending on the performance and prices they can offer. Change of supplier is possible with a one-month notice. The principle of market reform was to separate production and sales of electricity from its transmission and distribution. Network operations remained a natural monopoly status and are subject to strong regulation and monitoring. Production and sales are a part of the competitive Nordic market.

2.1 Legislative Context: The European Union and Sweden

Energy forms the basic precondition for any economy's existence, development and growth. The energy issue is closely linked to environmental, security and economic fields. It is vital for all national economies to provide energy resources without deterioration of the environment, in a reliable manner and at a competitive price.

One of the recent assessments by the European Commission indicates that during the decade preceding 2004, industrial energy intensity in Europe was decreasing, and is likely to continue the trend. However, projections[7] support a tendency for steadily increasing overall consumption, in particular of electricity. ((IEEA, 2006). p.4)

The European Union has placed energy issues amongst the highest priority and is striving towards trading energy across the borders of member countries within a single deregulated market. (ET 2006:45 (SEA, 2007)). The European Directive on energy end use efficiency and energy services (2006/32/EC) adopted in April 2006 has put a requirement for each member state to achieve a 9% improvement in efficiency of energy use over 9 years. The requirement is of an indicative character, though demanding the development of national action plans[8]. Improvement in energy use efficiency is one of the working areas within the implementation of the Swedish energy policy and on the way to an ecologically sustainable society. A shift of the energy issues jurisdiction to the Ministry of Sustainable Development (since October 2006) has been one of the important changes at the political governance level[9].

The EU Directive on energy taxation[10] has aimed at the harmonisation of tax levels for fuel and electricity. It required Swedish manufacturing companies to get to a level playing field. The Swedish government introduced electricity tax for industrial processes at the rate of 0.5 öre per kWh in force since July 1st, 2004. (ET 2006:07 (SEA, 2007)). This has put Swedish industries in conditions similar to other European companies.

The Swedish Environmental Code adopted in 1998 and in force since January 1st, 1999 requires that enterprises should conserve raw materials and energy (DS 2000:61, Chapter 2

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7 Based on the referred to Report for the European Commission, May 2006.

8 Meaning Energy Efficiency Action Plan (EEAP). Three national EEAPs shall be submitted to the Commission by Member States. First – not later that 30 June 2007; second – not later than 30 June 2011; third – not later than 30 June 2014. (Directive 2006/32/EC of 05 April 2006).

9 The reference has been obtained in English, however it is most likely that under the "Ministry of Sustsinable Development" the Division for Sustainable Development within the Swedish Ministry of the Environment is meant.

10 Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for taxation of energy products and electricity.

section 6, (2000)). Taking into account the national energy policy and the above conditions in order to encourage industries to undertake immediate measures, the SEA introduced a five-year programme for energy efficiency improvements in energy intensive industries (PFE). The PFE was launched on January 1st, 2005, specifically targeted electricity use and required that certain conditions be fulfilled before tax exemptions can apply.

There is a trend to bring all electricity consumers to metered consumption. Regulating measures towards more accurate metering of the end use of electricity have been taken gradually. The year 1996 brought a requirement to hourly metering of all consumers of above 200 Ampere (A). On July 1st, 2006 a requirement of hourly measurement of all consumers above 63A was enforced. The next milestone is scheduled for July 1st, 2009. This is the date when all electricity meters should be read on a monthly basis. The electricity market has reacted to that and distribution network operators together with developers of metering solutions are the ones shaping the interface with consumers.

A very interesting trend is being formed in Europe on the household side. On July 1st, 2007 the electricity market in all of the European Community became open to all household consumers, giving them right to choose among electricity suppliers. The end-use efficiency Directive 2006/32/EC requires member states to ensure informative billing for the end-customers. Smart meters, which are more advanced than those used until presently, allow for the obtainment of information and the making of responsible choices based on that. As noted by Morch et al. (2007) smart-metering is needed in deregulated markets. This is due to pricing and payment settlements that get affected with change of suppliers. By having a two-way communication possibility, these meters are said to bring benefits both to the supplier and consumer sides.

Large-scale trials are about to start in the United Kingdom (UK). Real-time energy displays will be closely followed to assess household consumption and the role of the devices and other energy saving measures. Planned coverage is 40 000 households over two years. The business sector is not forgotten either. UK government consultations to extend advanced metering to businesses over the next five years are on the way. (Hutton, J., 12 July 2007)

The international consulting company Datamonitor is referred to in a number of on-line editions for the prediction for smart meters to reach 41% of the metering market share by 2012. They see faster development more likely in North America (more than twice as fast, compared to Europe). According to one of the company's analysts, Anton Krawchenko, implementation of smart-metering "is a central theme in many governments' energy conservation policies." (Krawchenko, A., 12 July 2007). Despite expected reductions in household energy consumption, utilities expect savings on manpower reading and more accurate data for processing and billing. Another Datamonitor analyst, Alex Kwiatkowski, is also confident about rapid expansion of smart-metering and stresses the need for utilities to adapt to the new approach and upgrade the existing systems. (Lomas, N., 12 July 2007)

It is very likely that the smart-metering wave will influence to a certain extent other energy end-users who are not the least responsible for contribution to total electricity demand. These are the businesses and industrial companies. Due to larger consumption volumes and higher loads, there seems to be more interest for energy utilities to co-operate with industrial consumers on load management, energy metering and conservation issues. Moreover, as mentioned by Robert H. Williams (1989) institutional placement of energy utilities makes them the best actor to promote efficiency of end-use.

2.2 Electricity Production in Sweden

Production of electricity with hydropower has historically been strong in Sweden. Geographically, a major part of the country is located in Northern Europe, and cold winters are the norm. Swedish economic and industrial development had been demanding more and more energy generated locally. The world oil crisis of the 1970s facilitated the beginning of nuclear power generation. As Figure 2-1 indicates, shares of hydro- and nuclear power in generation are very close to each other nowadays. The SEA (2007) reports 47% of electricity production with hydropower and 45% with nuclear, as of 2005. The remaining production (8%) is covered with such energy sources as wind, biofuel, and fossil fuels.

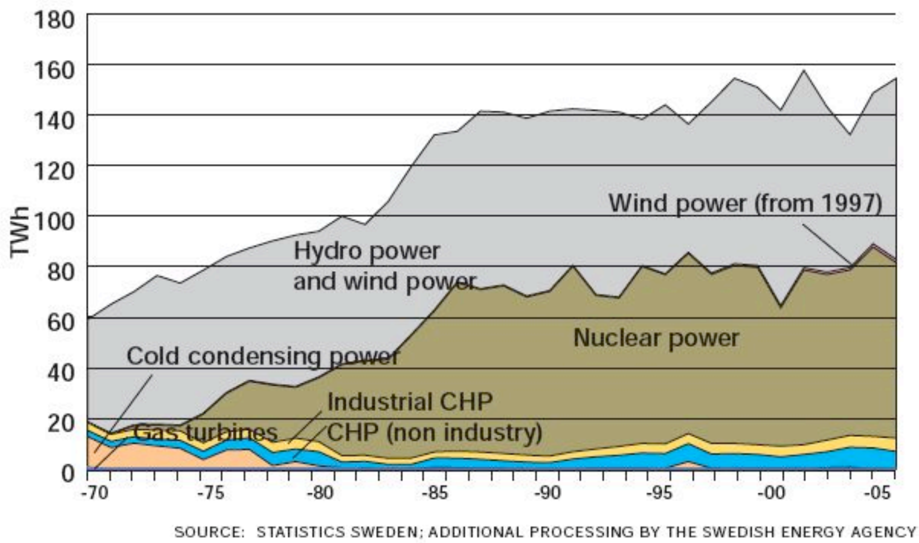

Figure 2-1 Power production in Sweden, by power source, 1970 – 2005.

Source: Swedish Energy Agency. (2007). Energy in Sweden 2006. p. 37.

Since the power market liberalisation within Scandinavia (1996 and onwards) and opening of borders to European countries, like Germany and Poland, it is not only Swedish generated electricity that is available to consumers. Higher prices at the European market make it more interesting for Swedish power producers to export, than to sell internally. When peak demand cases occur (during colder winter days) Swedish energy consumers receive imported electricity generated elsewhere in Europe. The marginal production of electricity would usually be by coal condensing power plants. Both in the continental part of Europe and in Sweden these plants have the highest portion of variable costs. (Trygg, L., 2006). The European merit order of power plants has been developed to reflect short-run marginal production costs for various energy sources in electricity generation. Coal power production costs become higher compared to gas fired CCGT with the inclusion of CO_2 allowance cost. (Vattenfall, 2007). With growth of electricity demand, more and more expensive ways of generation are employed in order to satisfy it. Hence, the marginal price of power production drives the spot-market price.

2.3 Main Constituents of the Swedish Electric Power Market

Reformation of the Swedish electricity market took place towards the end of 1995, on the turn to 1996. Electric power market liberalisation and elimination of national monopolies took place. This meant that production and sales of electricity were separated from the transmission part. The latter remained a natural monopoly, while the two former became subject to competition.

The current electricity market in Sweden is operating with the presence of a whole range of players. The following actors are listed in the publication "The Swedish Electricity Market and the Role of Svenska Kraftnät", 2007:

- Electricity producers;
- Network owners;
- The system operator (Svenska Kraftnät);
- Electricity consumers;
- Electricity traders in the role of electricity suppliers and/or balance providers;
- Marketplaces, primarily the power exchange Nord Pool.

The following Figure 2-2 depicts how these players are connected to each other and how electricity is transmitted.

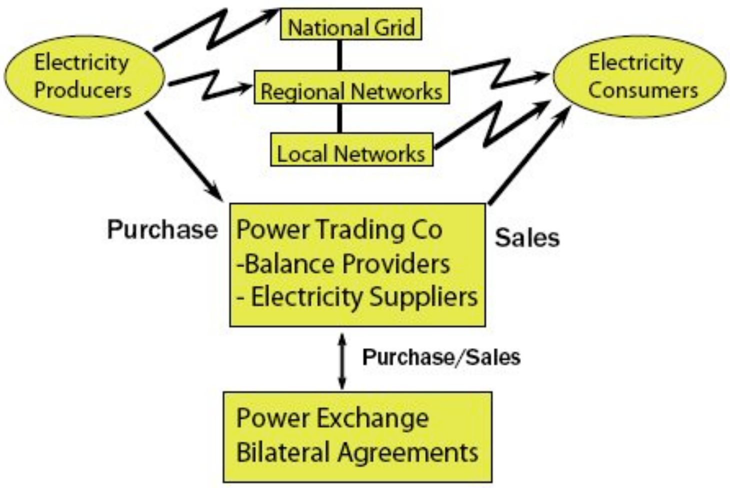

Figure 2-2 The physical flow of electricity and the relationship between the players.

Source: (SVK, 2007). The Swedish Electricity Market and the Role of Svenska Kraftnät, Svenska Kraftnät. p.2.

2.3.1 Nordic Liberal Electric Power Market, Nord Pool

Sweden has liberalised its electricity market since January 1st, 1996. Since then Sweden, Norway, Denmark and Finland gradually joined a common electricity market – Nord Pool. The Nordic Power Exchange represents the first international power exchange market. It was established in 1993. Nord Pool is equally owned by two national grid companies – Norwegian Statnett SF and Swedish Affärskverket Svenska Kraftnät (2007).

Since autumn 1996 Nord Pool operates through two product groups, namely physical markets and financial markets. The 'Clearing product group' gives access to the market to those who do not participate directly. All this makes the electricity market totally different from other commodities' markets. The financial market has 19 direct Swedish participants. 21 Swedish power trading companies directly participate at the physical market, and 78 do it through a clearing group.

2.3.2 Svenska Kraftnät

Svenska Kraftnät administers the Swedish National electricity grid. It is the state utility that "*runs national grid and has the role of Transmission System Operator (TSO)*" (SVK, 2007). Since the day of establishment (January 1st, 1992), Svenska Kraftnät has been responsible for the reliable operation of 15 000 km of high-voltage power lines (400kV and 220kV), installations, interconnections and IT system as well as for maintaining a short term balance of electricity system. The latter task is performed by the Operating Balance Service that maintains the balance between production and consumption of electricity in Sweden (production and import versus consumption and export).

To maintain the balance there is a co-operation with around thirty balance providers. Balance provider regulates electricity supply and consumption by adjusting power production and by purchasing and trading power with other balance providers and on the Nord Pool power exchange[11]. As reported by Svenska Kraftnät (SVK), when balance providers fail to match production and consumption, SVK's Balance Service would correct it. It is a paid service and its price is set for each hour of delivery.

2.3.3 Electricity Supply Network

Sweden's electricity supply network is represented by 4 sectional areas as shown on Figure 2-3. These are further divided into 360 network areas. The reports by balance providers as per consumption forecast and production plans are scheduled to SVK per sectional area[12]. Both network owner and balance providers report to SVK. This is done for the payment settlement purpose. Reported data are required of a certain quality and at a certain time. For the part of consumption which is not measured on an hourly basis there is a model used to simulate a profile curve. This model for profile settlement has been in use since November 1999. Svenska Kraftnät serves as an overall administrator for the electricity supply in Sweden. As a part of its operation it carries balance settlement with balance providers. This is done on the day following the power delivery based on hourly figures. Measurements from network owners are taken into account.

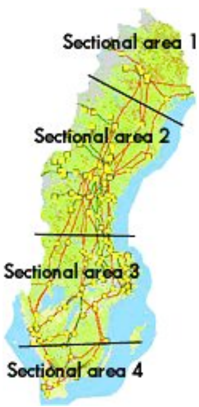

Figure 2-3 Division of the Swedish electricity supply network into sectional areas

Source: Svenska Kraftnät. The network structure of Sweden's electricity system. (SVK)

[11] Svenska Kraftnät keeps the electricity system in balance. Retrieved from: http://www.svk.se/web/Page.aspx?id=5216. [30 June 2007].

[12] The network structure of Sweden's electricity system. Retrieved from: http://www.svk.se/web/Page.aspx?id=5236 [30 June 2007].

It is important to maintain supervision of network operations. This function is performed by the Swedish Energy Market Inspectorate (within the Swedish Energy Agency). This Inspectorate is a legal regulator of power networks and the electricity market ensuring that tariffs are justified and that no other activities are subsidised from network operations. (SVK, 2007).

2.4 Electrical Energy Supply Contract

After the Nordic market liberalisation, the market was forced into a division of responsibilities within electricity supply. National, regional and local grids are owned by different network companies. Regional network owners transmit electricity to local networks or in some places directly from the grid to large-scale consumers. Industries are the most explicit example of such a consumer.

At present there are normally two organisations involved in the electric power delivery to an industrial site: one is represented at Nord Pool and balance provider, and the other is operating the local power grid. As mentioned above, this defines the necessity for having two contracts. In order to be fed with electricity, industrial consumers need to have a contract both with electricity trader – to be able to purchase physical electricity, and with the relevant network owner – to get it transmitted. Examples of vertical integration, however, are not rare. In particular, the largest electricity producers tend to have daughter companies at each level of operation.

Sweden is enjoying a period of sufficient capacity. The participants in the chain are interdependent on one another. Demand by end-users is expected to grow[13]. Sooner or later this will lead power suppliers requiring expansion of their capacity. At the same time there is a strong ongoing shift towards renewable sources. In order to continue securing energy supply in the future, all European countries are looking for energy sources that are alternative to fossil-based sources. In addition, Sweden has decided to phase out nuclear power by 2050. Therefore, pressure on the energy supply is coming from both ends: growing energy demand, and a need for developing alternative energy sources sufficient to replace nuclear power.

As noted by Peter Terwiesch, Chief Technology Officer for ABB Ltd in the Energy Review: *"The "other alternative fuel" is energy efficiency"*. ((Leffler, N., Terwiesch, P. et al., 2007) p.3.) This aspect is looked at in the section 4.1.

2.4.1 Electricity Producers, Traders, and Suppliers

Electricity producers are the companies who own power generation facilities. In 2002 the three largest electricity producers (Vattenfall, E-on Sweden, and Fortum) delivered nearly 86% of the power generated in Sweden. The share of Swedish electricity producers on the Nordic market was 31%. (Bergström, M., 2003). In 2005, the corresponding shares made up 88% and 41% respectively[14]. (n.a., 2007). The number of electricity producers has reduced over the years of liberalised market. The smaller ones were taken over by the larger ones.

A power trading company is the one having a supply contract with end-customers. Besides supplying electricity they have an obligation to provide balance between production and

[13] In the international context. There is no evidence found that Swedish electricity demand is expected to grow.

[14] This figure is based on the Draft of Internal Market Fact Sheet within the European Energy Policy. The disclaimer should be noted.

consumption. A trader can perform the balance function itself, or this service can be purchased from another company. Power traders can purchase electricity either from Nord Pool, or from an electricity producer, or from another trader. (Klee, I., 2007).

2.4.2 Distribution System Operator

The Swedish set-up makes the local distribution system operator the most regulated part of the market. It is the distribution system operator (DSO) who completes the power delivery chain. This actor is responsible for meter reading. DSO delivers power to the production site and performs reading from a so-called billing meter located at the power connection point. As well, the DSO provides actual consumption data to the Electricity Supplier and to the End Customer. Before 2006, the Swedish legislation required hourly metering of all consumers above 200A. The metering reform has progressed towards lowering this value to 63A since July 1st, 2006 (Bergström, M., 2003). However consumer organisations demanding a better billing from DSOs have forced a legal requirement of monthly reading and actual consumption billing for all metering points from July 1st, 2009. Monthly meter reading should improve customers' understanding of bills. The European Commission's Implementation Report on internal market review also points at an expected shorter time to switch the supplier. (2007) As noted by Morch, Parsons et al. (2007) some DSOs indicate their preference with hourly metering and reading. This is to be performed through automated meter reading (AMR).

A DSO charges for transmission based on network tariffs. Tariffs are reviewed by the regulatory authority ex-post. The EC's Implementation Report found this out of the Electricity Directive's[15] line.

When a peak demand occurs, a DSO falls into a situation where additional power shall be consumed from the upper level grid. This results in penalties to both parties: the industrial company and the local network owner. The mechanism for employing penalties is set by the Swedish electricity market regulator and is known to all chain participants.

DSOs are responsible for monitoring power quality and parameters of the electric current that influence invoicing and the contract created, such as the demand, real power, and reactive power. Having various roles represented by daughter companies of the largest producers is taking place at the market due to the vertical integration. Thus, one company may operate with all three functions: production, trade and balancing, and distribution.

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[15] Electricity Directive 2003/54/EC.

3 Energy-Related Corporate Performance Aspects

This chapter provides an overview of various aspects of industrial company performance that to some extent influence its energy usage. These aspects have possibly undergone changes over time, and an attempt is made to go through the major performance aspects that define the conditions of industrial operation nowadays.

Business philosophy is an important part of how a company views its performance. This shall be reflected in corporate reporting as a response to stakeholders' expectations. Having energy and climate issues at the top of the political agenda today has drawn stakeholders' interest towards this operational element. There are a number of aspects that are inevitably involved as far as energy is concerned. An empirical analysis of energy management practices was carried out among Danish industries. Its analytical framework based the 'knowledge about energy management' on such variables like: regulation, external relations, company characteristics, and internal organisational condition. (Christoffersen, L.B., Larsen, A. et al., 2006). It is likely that industries wish to improve their energy performance not purely for economic reasons. Ecological considerations and anticipated positive effect on marketing and image contribute to the reasoning.

3.1 Environmental Aspect

The whole idea of this thesis is inspired by the role of energy in an environmental context. There are at least two sides to look at in connection with electrical energy. The first is electricity production. Here we speak about environmental impact associated with generation of electricity. Sweden is one of a few European countries having the highest level of renewable energy sources employed. Norway's electricity generation is nearly entirely generated by hydropower. Being a part of Nord Pool, under favourable weather conditions Norwegian power supply helps the electricity market spot prices to go down[16]. Forty-five percent of Swedish electricity is generated in nuclear reactors. The current political situation does not make this energy source unfavourable, however it is likely that the end-costs of dealing with used nuclear fuel are not fully taken into consideration. The share of renewable energy including wind turbines, bioenergy, and small-scale hydropower plants is gradually increasing. Discussion about the 'colour' of energy is becoming a popular issue at various levels, including industries.

Green-house gas emissions have drawn attention at the international and European levels in connection with United Nations Framework Convention on Climate Change (UNFCCC) and obligations undertaken by signatory countries under the Kyoto Protocol. CO_2 emissions have taken centre stage on the global environmental agenda. Sweden's 'Reduced Climate Impact' objective contributes to a global effort in stabilising greenhouse gas concentrations in atmosphere. Direct and indirect [17] greenhouse gas emissions have entered into industries' scope of attention.

The other side is related to consumption of electrical energy. The inevitable "marriage" of production and consumption in the case of electricity causes pressure on generation. Despite

[16] The price of electricity in Scandinavia (when CO_2 allowances are not concerned) depends very much on precipitation. In the wet years Norwegian hydropower is pressing the Nord Pool electricity spot prices down. This happens because water can not bypass, it has to go through hydropower plants.

[17] Direct emissions are the ones caused by the use of sources within an organisation, while indirect emissions are those caused from the sources outside organisation.

the fact that the electricity market is liberalised, part of it is strictly regulated (DSO). In Sweden, the government and Swedish Energy Agency are setting the playing field. In the set of regulations, responsibilities are clearly defined and there is no confusion among actors about roles and responsibility. This, however, does not prevent the occurrence of peaking consumption on the demand side.

Within this paper we shall only refer to industries as consumers of electrical energy. Industrial companies (especially the large ones) represent a more manageable part of consumers. This is a result of their number and their business interests. Every plant is interested in reliable delivery of power on site. Since they have numerous machinery units and knowledge of their process requirements they cannot receive power without contracting nominal capacity requirements. Should a substantial increase in demand occur, the power generator would have to employ reserve capacity. Due to 'bottlenecks' in the power system, the generator may address an industrial company with a request to suspend production for peaking periods on a paid basis. The type of energy production with reserve capacity is the last resort, however it would usually be generated from oil, gas, or coal (in the case of import by Sweden from Europe). This situation will cause an additional environmental impact connected to generation.

At the industrial company level, energy is one of the first items that is considered during the implementation of an Environmental Management System. Prior to EMS development and ISO: 14001 certification, step number one will be an initial environmental review. A company's consumption of energy (and other resources) gets examined. (Brorson, T. and Larsson, G., 2006).

The Global Reporting Initiative (GRI) in the third version of Sustainability Reporting Guidelines included efficiency of energy resources use as part of the Environmental Performance Indicators (EPI). Five performance indicators are suggested for reporting energy[18]. Of them, two are recommended as 'core' and three as 'additional' EPIs (GRI, 2006):

- EN3: Direct energy consumption by primary energy sources (core);
- EN4: Indirect energy consumption by primary source (core);
- EN5: Energy saved due to conservation and efficiency improvements (additional);
- EN6: Initiatives to provide energy efficient or renewable energy based products and services, and reductions of energy requirements as a result of these initiatives (additional);
- EN7: Initiatives to reduce indirect energy consumption and reductions achieved (additional).

One core and two additional indicators can relate to electrical energy reporting. These indicators are most likely to be taken into account by larger industrial companies with international representation.

Introduction of ISO: 14001 and getting industries certified has greatly contributed to looking into energy as an environmental aspect. It became a part of the Plan-Do-Check-Act management cycle within environmental work. As mentioned by Brorson and Larsson (2006),

[18] http://www.globalreporting.org/ReportingFramework/G3Online/PerformanceIndicators/

"*Many companies include a commitment to save energy in their environmental policy*". As well they underline the importance of companies being aware of national and regional targets.

3.2 Economic Aspect

Energy consumption at a company level has a direct correlation with energy costs. With historically inexpensive electricity in Sweden, its costs have not really been looked at as a major cost item for reduction. This especially relates to production sites with electricity costs at a range of 3 per cent of total production costs[19]. Once the electricity bill was received it got paid, unless some financial deviation was observed. This, by inertia, remains a practice in today's industrial life. Only during the past two years (please see Figure 3-4) have industries begun viewing electricity as a resource that is worth looking into.

Russell (2003) suggests that energy management contributes to "*enhanced productivity, improved bottom-line performance or relief from business risks*". The main direct benefit of energy management is reduction in the bills. Opportunities for capacity expansion and additional revenues are other economic benefits brought along with energy management in industries. Hooke et al. (2004) underline a necessity to convey a message of controllability of utility costs (of which electrical energy is the main component) to operational staff.

Use of energy resources in an industry is noted through the whole thesis to be closely correlated to the costs associated with it. With regards to energy costs discussed in this section, only the expenditures incurred by an industrial company in connection with energy supply are meant. The total sum of expenditures would be a function of both physical energy consumption and its price for a company. These components can vary. Therefore, it is important to consider what the electricity bill consists of and how is it built up before the total monthly amount is invoiced. Over the last ten years there has been a change of the electricity bill components. Section 3.2.1 looks into this more closely.

3.2.1 The Cost of Electrical Energy for an Industrial Company: What is in the Bill?

There have been a number of items added onto the electricity bill during recent years (along with the energy market reform). Some were brought about with the introduction of new taxes (e.g. electricity taxes). Others appeared with the removal of state subsidies for renewable sources of energy. Some are calculated as a percentage of a total, whereas others are purely decided by market.

As Svenska Kraftnät indicated (SVK, 2007) the main parts distinguished in the costs are split into electrical energy, network fees, taxes and other fees. The electricity bill is the primary document within company/industry accounts that reflects electricity costs, therefore it is important to scrutinise its components.

3.2.1.1 Two Bills to be Paid

Generally, since the early days of the power market liberalisation, there have been three major parts of the electricity bill: the cost of electric energy; network fee; and taxes. As reported by Svenska Kraftnät, today in Sweden the average split shall look like about 35% of the bill for

[19] This cost percentage is given as an approximate indication. The figure can vary ±1 % compared to that mentioned.

the electric power, about 20% as a network fee, and nearly 45% will be taxes and such fees as energy certificates. (SVK, 2007, p.11).

Based on the contracts, there may be two bills invoiced to an industrial company: for physical electric power supplied and for transmitted electric power. The former is invoiced by one of the major energy generators or brokers trading at the Nord Pool. The latter is and will always be invoiced by the local utility that owns the local networks.

The energy supply company will charge industries for consumed electricity, which shall be a variable figure on a monthly basis. The distribution company will charge for the delivered power based on the loads, effective and reactive power, and consumption under highest and lowest rates.

The following parameters will influence the billed amount:

- nominal demand / connected load (kW);
- actual demand / load (kW);
- consumed electric power (kWh);
- time of consumption (e.g. day/night when rates vary);
- agreed price per kWh (SEK/kWh – as per contract terms);
- green certificates (SEK/kWh of consumed electricity – according to the suppliers' obligations and distribution of costs to all customers);
- electricity tax (SEK/kWh of consumed electricity);
- Value Added Tax (25% in Sweden)

The demand charge will reflect the investment costs that are required by energy actors to generate, distribute, and deliver electric power to customers. Compared to the total amount to be paid (including the consumed electrical energy), the demand part may account from 10% to 50% of the bill. The range would usually depend on the installed capacity of equipment units at an industrial site (connected load).

Eventually, it is the connected load, peak load and total electricity consumption that will influence the billed amount and result in the energy costs for a company.

3.2.1.2 Green Certificates

The green certificates[20] item is included into every customer's electrical energy bill. Electricity certificates represent a market-based instrument. There is a dedicated market to obtain a supplementary value of electricity produced with renewable energy sources. Therefore it performs a supportive function in a technology-neutral way and promotes cost-effective generation of renewable electricity. (Ministry of Sustainable Development, 2006). Renewable energy certificates are traded only within Sweden. As reported by the Swedish Energy Agency (2007), the system intended to replace earlier governmental funding and subsidies. The

[20] Green certificates are also known as electricity certificates or renewable energy certificates.

objective is to achieve generation of an additional 17 TWh of electricity from renewable sources by 2016 by injecting this income. It has been revised during the few years of the system operation.

Producers of renewable electricity receive electricity certificates from the Swedish Government. Electricity suppliers without a renewable portfolio are required to purchase and submit electricity certificates proportionate to their energy sales. By selling electricity certificates, the energy producer generates additional income. This allows for investment in new facilities for the production of more electricity from renewable energy sources. Please see Appendix II for the list of renewable sources of energy.

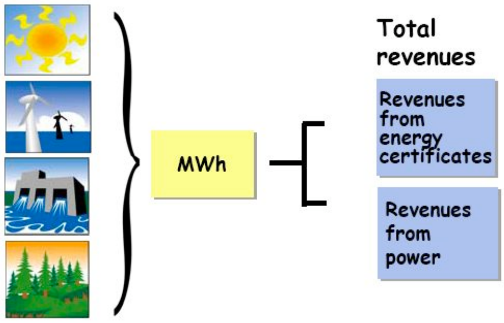

Figure 3-1 The principle behind energy certificates in Sweden.

Source: (2003). Svenska Kraftnät. Energy certificates – what are they?

Swedish Energy Agency and Svenska Kraftnät share responsibility by performing assigned functions. SEA has a regulatory role while SVK runs accounting. Trading within the electricity certificate system was launched on May 1st, 2003 and will run until the end of 2030[21]. The quantity of certificates to be purchased kept rising annually in correlation with quotas.

The electricity certificates are traded in two ways. One is through bilateral agreements directly between the producing party and parties obliged with quota. The other is through a purchasing contract and involving a broker. As remarked by SEA (2007), the year 2007 has brought about a trend of trading more via brokers. This is due to electricity certificates being a part of the electricity price exposed to competition. Contracts at this market are similar to the one at Nord Pool involving both spot price and forward trading.

[21] The period has been extended in accordance with Government Bill 2005/06:154 in force from January 1st, 2007.

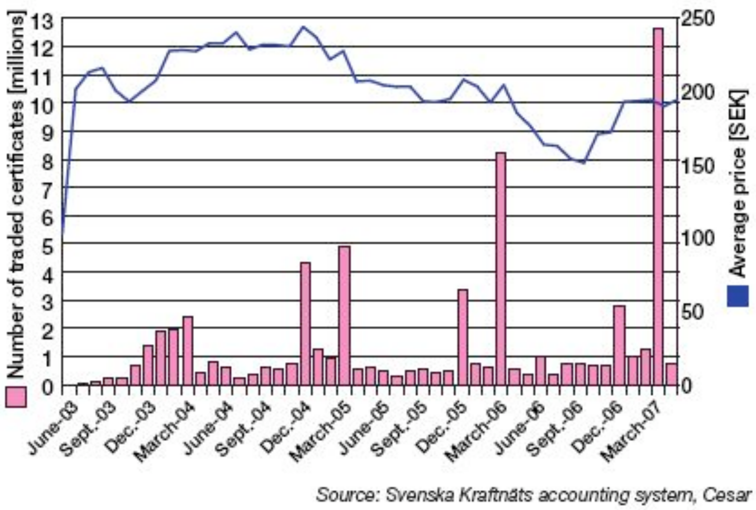

Figure 3-2 Average price for transactions of electricity certificates between CESAR accounts and monthly turnover in certificates, May 2003 – April 2007, Sweden.

Source: Swedish Energy Agency. (2007). The electricity certificate system, 2007. p.15.

The price of the electricity certificate is basically formed by demand/supply interaction at this dedicated market. The supply curve (production costs and amount) is difficult to predict. As well, some risks and future expectations influence price formation. Currently there is a surplus of certificates on the market. The future price will be dependent on costs to expand production capacity.

3.2.1.3 Tax on Electricity

In Sweden, all energy forms[22] were levied with a general tax in the form of VAT[23] since March 1st, 1990. As applied to the industrial sector, the outgoing tax was recovered through received payments. Special tax on electricity has a long history. The International Energy Agency keeps track of electricity tax applied to industry back to 1977. Two rates existed in relation to consumption: < 40 MWh/year, and Additional consumption. Starting in 1977 the rate was 0.03 SEK/kWh and 0.02 SEK/kWh. Certain variations took place before 1987, when it was established as 0.05 SEK/kWh for both types of rates. From 1993 through 2003 the electricity tax was at a zero level. From the January 1st, 2004 the electricity tax was brought back at a single rate of 0.005 SEK/kWh. (IEA, 2007).

Following the European Energy Tax Directive[24], the Swedish government had to cancel the exemption of industries from electricity tax. Manufacturing industries started paying tax on electricity since July 1st, 2004 in the amount of 0.005 SEK/kWh.

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22 Except aviation fuels.

23 Value Added Tax.

24 Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for taxation of energy products and electricity.

3.2.1.4 Emissions Allowances

A policy-related component has been introduced in the electricity price with the start-up of the Emissions Trading Scheme (ETS) for European countries. It started with 25 member states on January 1st, 2005. The trading period covers 2005-2007 and is preparatory to the first phase of the international trading scheme under the Kyoto Protocol. This European ETS turned out as the main component causing volatility of electricity prices. The CO_2 allowances price dynamics can be seen in Figure 3-3 below.

The graph illustrates the dynamics of the emission allowances market price. The ETS functions similarly to financial markets. Initial growth of the price was explained by an unclear picture of the total availability of allowances for the given period. Mostly the market participants were observing and following on market price development. Supply was thought to be substantially limited due to market non-transparency. After reaching its maximum price at over Euro 30 per tonne of CO_2, a drop in price occurred in the second quarter of 2006. This took place when statistics of verified emissions in various countries reached the market. The statistics disclosed a surplus of allowances. (EC, 2006).

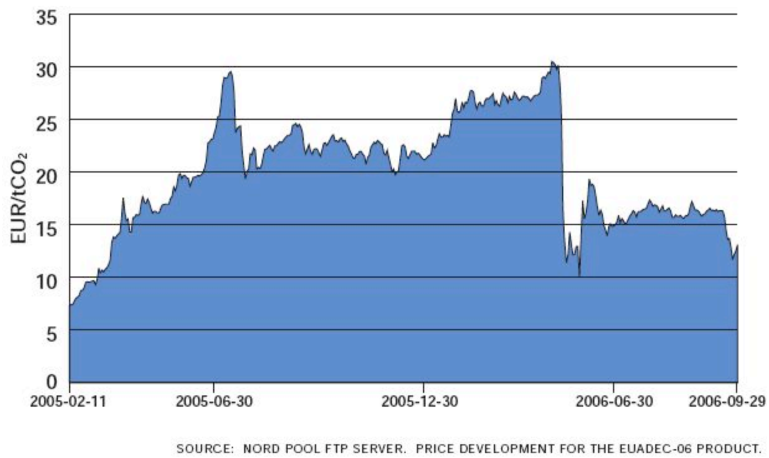

Figure 3-3 Prices of emission allowance, 2005-2006

Source: Swedish Energy Agency. (2007). Energy in Sweden 2006. p.12.

A further sharp reduction down to Euro 13.6 per tonne of CO_2 was observed. Overall, this proved the effect of the trade scheme. Most of the countries underestimated domestic emission reduction possibilities. Also, implementation of energy efficient measures became economically feasible for industries due to the achieved high prices. This was immediately reflected on electricity prices. It can be seen on Figure 3-4 in the period around June 2006 on the time axis.

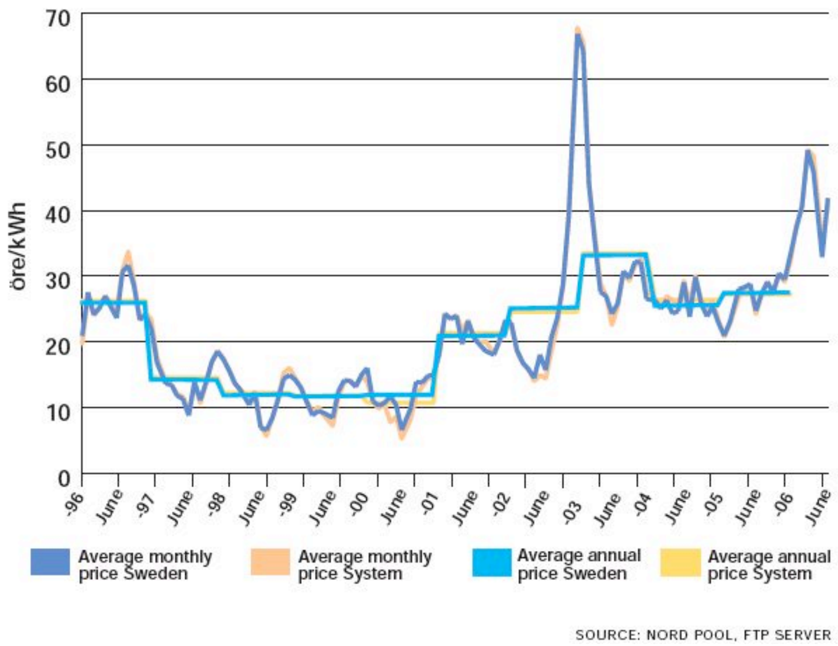

Figure 3-4 Nord Pool's spot prices, Monthly and mean annual values of system prices for the Swedish price area, 1996 – mid-2006.

Source: Swedish Energy Agency. (2007). Energy in Sweden 2006. p. 40.

The precipitation level was the strongest factor causing broad variation of the Nord Pool spot price since its start-up. Over the past 2 years, the increase in price is linked to the introduction of emission allowances trading in Europe. (SEA, 2007).

Svenska Kraftnät explains (SVK, 2007) increases in electricity prices with both oil prices increase at the international market and the emission rights trading. They additionally refer to the shutdown of the Barsebäck nuclear power plant in 2005 that affected the electricity supply and the market price of electricity. Closure of the nuclear plant, the need for developing alternative energy sources, as well as national ambition for the share of renewable energy production (green certificates) have played their role in the increase of the electrical energy price for end-users. Nevertheless, at the break of 2007, the average industrial user price of electrical power was approximately 22% lower than the European average[25]. (n.a., 2007)

3.2.2 Contracting for Electricity Purchase

With the electricity market liberalisation, it has become more and more complex to follow determinants of the market. Gradually the placement of electricity contracts in industrial companies has shifted within an organisation. This seems especially relevant for companies having branches/plants all around Sweden.

Initially it was sufficient to rely on knowledge of the operations part of industrial sites. Further it shifted to administrative staff with electricity as one of the procurement components. Nowadays, there is a sign of heavier reliance on a broker in regards to energy market surveillance and projecting components' "behaviour". It takes substantial resources these days

[25] This figure is based on the Draft of Internal Market Fact Sheet within the European Energy Policy. The disclaimer should be noted.

to follow the market and price development situation due to a considerable number of components making it less predictable.

Industrial companies tend to negotiate larger contracts for the purchase of electricity. A contract would normally last one year with a prolongation if the parties are satisfied. Both parties are interested in longer-term fixed prices as it eases production management and financial planning.

3.2.3 How to Influence the Costs?

Industrial companies are large-scale electricity consumers. To manage energy costs they may apply two major strategies: price-focused strategy and consumption reduction strategies. They may achieve some results by negotiating contracts (focusing on price) and looking for a better energy supplier and fixing an acceptable price for coming periods. Not much can be presently done to the price at the European market. However, since market deregulation, companies are free to choose their electricity supplier. Hence, the price-focused strategy is still valid for consideration.

The Report on Strategic Industrial Energy Efficiency (Russell, C., 2003) brings the following pros and cons of energy cost reduction strategies focused on energy price faced by an industrial company (see Table 3-1).

Table 3-1 PROs and CONs of price-focused energy cost reduction strategies

PROs	CONs
Easy to initiate: benefits accrue without the energy consumer having to adjust practices or procedures.	Lost consumption improvements: price improvements reduce the incentive to manage energy consumption.
Easy to sustain: the price impact is more easily sustainable: once the price is set, it requires no more thought or action.	Lost non-energy benefits: the price only focus reduces the opportunity to address related issues such as raw material waste, idle-resource costs, safety, plant reliability, and productivity
No coordination needed: price improvements accrue to all facility stakeholders without need to coordinate operational concerns.	Increased vulnerability: low energy prices may encourage unnecessary energy consumption, or at least fail to improve current consumption patterns. This puts the manufacturer in a vulnerable position should fuel prices spike upward.

Source: 2003. Alliance to Save Energy. Report on Strategic Industrial Energy Efficiency: reduce expenses, build revenue & control risk. p.4.

It is not sufficient to observe energy prices to achieve full control of energy costs. In the last couple of years energy prices have grown in the number of components that define them. As far as electricity is concerned, there is substantial number of factors that will influence the market price of 1 kWh. Some of them will reflect energy generation costs (e.g. precipitation level, investments, emissions allowances), whereas some have a purely regulative character, such as energy tax, carbon dioxide emission tax, and market based electricity certificates. What can be achieved through price regulation shall have a comparatively short-term effect. It is important to look into another variable in the energy cost function – the quantity purchased. Physical conservation of energy is going to bring a long-term result and with a further price increase, more activities become economically feasible at the industrial level.

3.2.4 Electricity Cost Allocation

Electricity costs relate to resources used for production and other industrial processes. This puts them into a category of variable costs that change with production and sales volumes. As well, there is a part of electricity costs that goes for overall facilities. It relates to such functions as lighting, conditioning. This makes part of electricity costs less variable and not related to production volumes. The way an industrial plant is dealing with electricity costs is most likely to be defined by its accounting policy.

On one hand, electricity costs are different from environmental costs associated with emissions abatement or waste treatment/disposal. On the other hand they still remain a part of support functions and are generally seen as overheads. Thus looking into debate around environmental costs that have a similar fate is reasonable to some extent.

Roger Burritt (2005) has a long history of considering the cost allocation problem. Direct costs (material, direct labour) find their way to a cost object. Indirect costs, where energy and electrical consumption fall into, usually go through an allocation procedure. Apparently the views on this issue are dichotomous. Some criticise lack of justification when allocation is performed. Others suggest that allocation through relevant keys serves as a good approximation for indirect costs distribution into total costs. It is also seen that cost allocation from overhead costs still makes managers aware of the existence of such costs. This contributes to their better management.

The result of cost allocation can be under-costing of some products and having other products subsidies them. Burritt develops further "*Allocation, or preferably direct tracing through improved measurement, of environmental costs to processes, rather than hiding them in general overhead charges is one way of encouraging cleaner production*". ((Burritt, R.L., 2005) p. 38). To avoid discretionary allocation of costs, activity-based costing (ABC) is suggested as a solution.

The ABC concept has been developed to achieve more accurate product costing. Schaltegger and Burritt (2000) indicate that implementing this concept helps spotting where and through which activities the company is benefiting or losing. Activities get chosen following cost-drives. Kaplan and Cooper (1998) highlight that the selection of the activity cost driver will still have a touch of subjective choice. It is subject to finding a compromise between the desired accuracy and measurement effort. Activity-based costing converts all costs related to production into a variable category by measuring everything through activities. Burritt claims that in practice it will mean tracing costs directly to activities. Activities are viewed as processes linked to units of products. Nonetheless, this would not eliminate allocation, as it will still be a part of the costing process. ((Burritt, R.L., 2005) p.39).

There are certain rules named by Kaplan and Cooper (1998, pp. 100, 329) for the application of ABC. Where resource expenses for a company are less than 1% of total spending, ABC is not likely to bring a significant reward on implementation. Both Kaplan and Cooper (1998) and Schaltegger and Wagner (2005) have observed that activity (process) based costing can be expensive in implementation.

Management accounting and cost accounting may, as well, bring about different perceptions of energy (electricity) costs. These two approaches are distinguished in theory and practice. Horngren et al. (2003) points that cost accounting serves as a source of information for internal as well as external reporting. Management accounting is a way to measure monetary and non-monetary values to assist managers in achieving corporate or departmental goals.

Opportunity costs of unimplemented energy saving projects should also be considered from the economic point of view.

3.3 Quality Aspect

Quality is the superior parameter for any production facility. In modern production facilities, quality management is closely linked to the production management system. It may be the case that quality drives resource and energy efficient installations.

The quality aspect is directly linked to the environmental performance of a production facility. The quality criteria are the factors defining the material and energy flow. Appropriate quality management and minimised level of faults and defects in production is the key to an optimised amount of resource consumption. Waste prevention deriving from quality management eliminates extra resources entering the production facility. Energy is one of these resources.

Various facility components are subject to energy improvement potential. The first energy improvement is likely to be sought in auxiliary processes. This part is most likely to require a low- or no cost solution. The other larger part of improvement potential is 'hidden' in production process. It is presumed to be more intricate and costly to implement. It needs to be mentioned that changing energy parameters inside the process can affect the process as such and consequently affect production quality. Aiming at process energy savings at any cost should be avoided. A delicate consideration of quality of production should not be sacrificed for fulfilment of energy reduction targets.

3.4 Technical Aspect

The technical aspect of performance is mainly looked at here from the operational point of view. In this section, a brief overview of the interconnection between electricity usage at the production site and productivity is provided.

American literature on electricity supply at industrial sites tends to focus on the machinery and equipment part. Electricity distribution within facilities to the point of use is linked by Capehart et al. (2003) to safety on-site. The Guide to Energy Management advises, "… *solving the energy problems helps to solve the safety-related problems*". (Capehart, B.L., Turner, W.C. et al., 2003) (Ch. 2, p. 15).

Maintenance of equipment draws towards another point in the Guide. This activity as well links to safety at the production site. The production level is similarly dependent on this. Capehart et al. conclude that effective maintenance helps to reduce energy costs. It is considered realistic to inspect and check equipment, specifically motors, to see if any maintenance actions can reduce the use of energy. Motors are given special attention due to their large portion in the energy using system and a variety of problems that require maintenance intervention. Motors represent a kind of equipment that is found both in production and auxiliary processes (for instance ventilation). Technical problems in motors are likely to entail higher energy costs.

Lighting is also contributing to both energy consumption and productivity levels. (Capehart, B.L., Turner, W.C. et al., 2003). Monitoring of lighting level and servicing the system would prevent excessive electricity consumption, overheating, and overconditioning.

David Bovankovich (2007) points at benefits of predictive maintenance and energy efficiency that can be identified by manufacturers with the help of energy monitoring. Real-time feedback and an accurate overview of electrical usage is required for plant operators to evaluate performance of electrically powered equipment. An increase of a unit's load above normal would indicate performance deterioration and premature problems likely to occur.

3.5 Data Management Aspect

The end of 20th century brought computer technologies into business life, making things easier and more complex at the same time. The tendency in businesses was to collect more and more information about operations. Many sophisticated software solutions were developed to handle various data by managing databases and generating reports for various purposes within a company.

At present, in larger companies it is common to find automated data collection through an integrated computer system. This kind of management information system may embrace and store large quantities of data related to different departments' areas. Hooke et al. point out that unless "*the captured data is shared and analysed in an orderly and precise way that identifies problem areas and provides solutions, this mass of data is merely information overload*". Data will become knowledge only when it is followed on a systematic basis. (Hooke, J., Landry, B. et al., 2004).

Energy related data would form a basis for reasoning when making decisions only when certain patterns and correlations are spotted. Patterns of energy consumption may be very difficult to figure out. It may be a result of complex processes or variations in production rates. Most of the cases where managers are not aware of the energy saving opportunities stem from the absence of a scrutinising look into credible and shared data or the absence of such data altogether.

Data turns into knowledge through analysis and reporting. Herewith the presentation of data is essential. To help corrective actions, the contents of reports required either by line-staff or management staff should be identified. Hooke et al. (2004) point at defining a presentation format: paper-based, control display, web-based, other. Along with defining a reporting format, they also warn about information overload.

As pointed by Schaltegger and Burritt (2000) there is a tight connection between data, knowledge and good decisions. Not all data will be helpful with building knowledge. However it is the knowledge base that is essential to decision-makers. The quality of decisions is likely linked to the data-knowledge interaction. Before deciding on what data should be collected it is necessary to observe who in the company is going to use this data. Schaltegger and Burritt highlight that "only data that are related to a desired goal and are highly likely to improve decision quality (i.e. purpose-oriented knowledge) are valuable". (2000). Data require costs incurred prior to becoming available. As such, the bulk of information does not represent value unless there are conclusions to be drawn from it and corrective actions to be taken.

Capehart et al. (2003) point out the importance of co-ordination among departments within a company. Furthermore, they suggest having an Energy Action Committee. Such a committee is supposed to develop and set goals, implement energy actions, and monitor the results. It should include but not be limited to: financial representatives, operational representatives, and line personnel.

It is important that feedback be provided by those who are able to implement changes based on monitoring data. (Capehart, B.L., Turner, W.C. et al., 2003). Providing line personnel on-site with easy access to the understandable reporting is a precondition to having due regard for energy consumption at the facility.

4 Energy Management

The chapter devoted to energy management issues is vital for this thesis since it is important to find the correct placement for electrical energy as one of major energy sources in industrial processes, and consequently for the electrical energy monitoring system (EEMS). An attempt to identify integration of the element in question within an industrial organisation is made. Different topics are covered here. All of them have a direct relation to the subject in focus. Looking at the EEMS from these different angles will serve the purpose of obtaining a comprehensive understanding of the requirements that are connected to it.

La cité des sciences et de l'industrie refers to the term 'energy management' as the management of energy consumption. Managing or 'saving' energy means improving the efficiency of powered devices. (La Cite des sciences et de'l industrie, n.d.)

Canada and United States had, at a rather early stage in 1980s, started developing energy conservation programmes with focus on various sectors including the industrial sector. The Canadian Industry Program for Energy Conservation (CIPEC) has come up with two revisions of a manual concerned with energy efficiency planning. In the 1990s, the UK Office of Energy Efficiency worked on 'Monitoring&Targeting' that became the first recognised energy management system. These two major contributions to energy management were correspondingly called first- and second-generation energy management tools.

As observed by Hooke et al. (2004), both approaches were specifically focused on energy. Most of the recommendations related to low- or no-cost initiatives. These recommendations were limited with the technical side of an industrial organisation. Opportunities for efficient and profitable improvements cannot be discovered with a lack of available, reliable data and a lack of analysis.

In this connection, it is valuable to refer to the principles of energy management suggested by Wayne C. Turner (2005), below. What is noteworthy is that the adoption of these principles, as he mentioned, will improve the effectiveness of existing energy management programmes, as well serving a good starting point for new systems.

1. Control the costs of energy functions or services provided[26]
2. Control energy functions as a product cost, not as a part of manufacturing or general overhead[27];
3. Control and meter only the main energy functions[28];
4. Put the major effort of the energy management programme into installing controls and achieving results[29].

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[26] This principle suggests that one should be specific about the functions provided by energy sources. Additionally, Turner mentioned the usefulness of measuring such costs as depreciation, maintenance, labour and operating costs associated with the function (besides the energy costs).

[27] This principle is particlularly relevant to electrical energy. There is a historical tendency to have electricity costs as a lumpsum in an overhead account without identifying what products entail higher energy consumption.

[28] Control and measurement are to be focused on considerably consuming parts. Submetering can provide useful information both to measurement and to control the costs.

These principles provide fine brush strokes to the teams who want to work on energy management and monitoring.

In 1993, the Building Research Energy Conservation Support Unit (BRECSU), active in UK, developed an Energy Management Matrix. This matrix covers six dimensions of energy management related aspects. Depending on the level, these aspects are developed in a company to a suggested 5 levels (starting with level 0). The BRECSU matrix is suggested to be very useful to evaluate the status of energy management at an industrial company. It is rather popular among authors who write about energy efficiency, even 14 years after the matrix was drafted. Location of the original matrix was not possible, however a number of matrix versions seem to be very similar to each other.

This matrix links together various sides of industrial operations with due attention devoted to advancement in energy policy, organising, staff motivation, monitoring and reporting (or information systems), staff awareness and training, and investment. These aspects represent rather good coverage of interdependent fields within an industrial organisation. Please refer to the matrix provided in Appendix I.

4.1 Energy Efficiency

Energy efficiency is the major resource to achieve energy use reduction. The Electric Power Research Institute provides four reasons to explain the current need to look into energy efficiency: increase of electricity prices; shortage of new capacity; vulnerability to import of energy; and awareness of climate and environment issues. The ultimate goal for achieving energy efficiency is to develop a dynamic energy management system meaning interaction between end-user and power supplier. (EPRI, 2006).

Technically, there are a comprehensive number of recommendations that may seem obvious for specialised technicians. Nonetheless the recommendations are of a general character and their application in every concrete case needs to be investigated by specialists.

Amory Lovins (2005) highlights that the potential of energy efficiency can be improved through policy measures. He states that energy efficiency is "*generally the largest, least expensive, most benign, most quickly deployable, least visible…*" way to provide "*more desired service per unit of delivered energy consumed*". (Lovins, A.B., 2005). As mentioned earlier, recent developments in energy policy both at the European and national levels target energy efficiency. Improvement of this aspect is seen as one of the most effective means of fulfilling the task of strengthening energy security. Many measures are assigned to the state level. They comprise such instruments like grants and tax incentives.

The Energy End-Use Efficiency Directive[30] (2006) applies the following definition of energy efficiency:

'***energy efficiency***': a ratio between an output of performance, service, goods or energy, and input of energy. Similarly definitions of '***energy efficiency improvement***' and '***energy savings***' are provided in clauses (c) and (d) of Article 3.

[29] Each initiated activity within the energy management programme needs to be closely and frequently monitored.

[30] Directive 2006/32/EC on energy end-use efficiency and energy services.

Volume of energy consumed per produced unit or per monetary value of products is what would be meant with energy efficiency at an industrial site. Calculating and following energy efficiency is not the goal for industries. Looking into this indicator serves as a means of allowing better management and attaining overall goals. (Russell, C., 2003). Russell (2003), manager of the Alliance to Save Energy, suggested that there are two ways for manufacturing companies to improve their energy efficiency: by investing in more efficient equipment and/or through "*better monitoring, maintenance, and verification of energy flows in the existing equipment*" (Russell, C., 2003). The former is named the capital improvement approach and it does provide benefits and visible results. The latter relates to a continuous activity that provides an equally important overview of the facility's production and energy consumption. However, the additional consideration of the behavioural aspect is the benefit of monitoring energy flows.

Hook et al. (2004) list a number of actions that need to be taken by a company to address energy issues. Development of an energy policy and approval of an energy strategy are the primary ones. Training and raising awareness is another step, followed by an energy audit.

Energy policy should contain objectives that are agreed upon and the commitment of management needs to be demonstrated. The energy strategy is a further elaboration of this, with an energy conservation plan on how the company intends to achieve the declared energy goals. The energy audit procedure is traditionally considered a foundation to develop the plan.

Stockmans (2007) developed a scheme as a road map towards energy efficiency and savings.

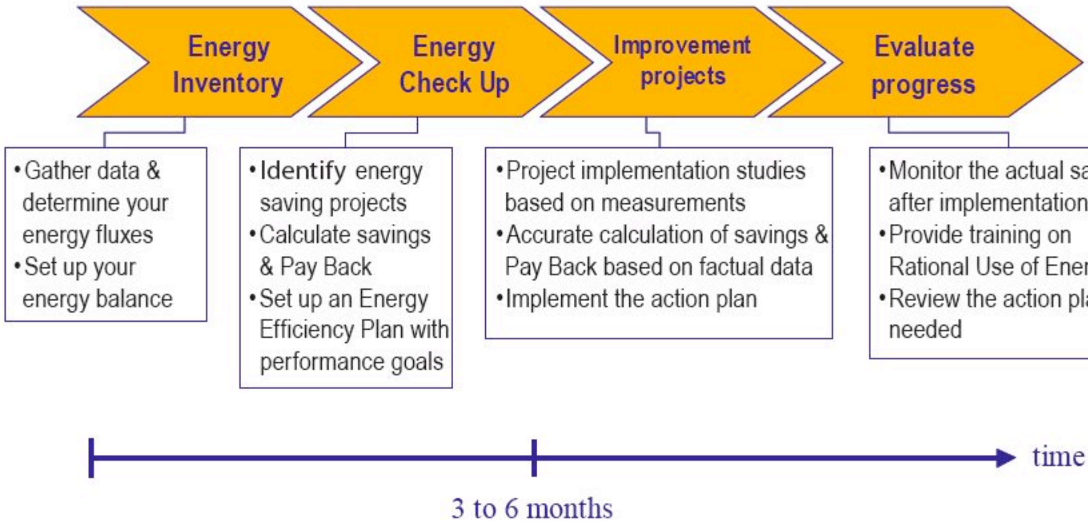

Figure 4-1 Road map towards energy savings

Source: Stockmans, P.-J. (2007). Power quality and utilisation guide. Energy management self-assessment. Leonardo Energy. p.2.

The basic activities within the energy related work path start with data collection and quantification. This will serve to help build a picture of energy consumption purposes. The inventory shall indicate how much energy is used for production and other auxiliary functions. Data gathering and measurement are the foundation of the whole energy saving activity. Without these activities, one would not know where to initiate improvement or what a particular activity has resulted in. This information is revealed by measurements carried out either on a temporary or permanent basis.

Identifying the existing potential is a precondition for efficiency improvement and energy conservation. The Swedish Energy Agency has been open towards co-operation with industries in the field of improving their energy efficiency. Since 1994, two programmes for voluntary participation have been initiated: EKO-Energi (1994) and PFE (2005). This year, participating industrial companies have submitted their reports within PFE. Considering the previous experience of SEA with the EKO-Energi voluntary agreements programme, the results achieved through energy conservation measures can be observed. Table 4-1 provides indicative percentages by items of improvements in electrical energy consumption reported by participating companies.

Table 4-1 Improvement in consumption of electrical energy

	EKO-Energi	PFE
Duration	1994 – 2002	2005 – 2014
Involvement	47 companies – 70 plants	98 companies submitted 2-year report
Process	32%	48%
Motors, drives	22%	4%
Pumps		17%
Compressed air	7%	10%
Ventilation	27%	
Space heating and ventilation systems / fan systems		3% / 6%
Lighting	2%	1%
Indirect electrical efficiency improvements		2%
Cooling systems		2%
Other electrical efficiency improvements		7%

Sources: Galitsky, C., Price, L. and Worrell, E. (2004). Energy Efficiency Programs and Policies in the Industrial Sector in Industrialized Countries. p.80. and

SEA (2007). Two years with PFE. Swedish Energy Agency, ET 2007:16 .p.9.

Savings per single energy efficiency measure within EKO-Energi varied from 4 to 28%. (Galitsky, C., Price, L. et al., 2004). Total electrical energy consumption was reduced by 11%. (Niemi, E., 1998). Process improvements scored the highest percentage in savings. The same result can be seen from the PFE. "*About half of the electricity efficiency improvement potentials are in production processes, with the remainder in what are known as auxiliary systems*" is stated based on the results of PFE after the two years of companies' participation. (2007, p.8).

Reservation needs to be taken with regards to these figures. They reflect improvement potential within energy-intensive industries. This is the only information available at the time of this research. It is likely that less energy-intensive manufacturing industries have a different distribution of the energy efficiency improvement potential.

4.2 Energy Management Systems

Energy issues can be considered in a company at different levels. Occasional implementation of energy-saving investments does not bring about continuous improvement in the long-run. A systematic approach needs to be applied to achieve that. Netherlands, Denmark, Sweden, Ireland, and Germany[31] are the European countries that have formulated energy management system requirements. Specifications for Energy Management Systems were developed for general application irrespective of the type and size of a company. Mainly it is targeting integration of energy efficiency considerations into management practices of industries.

The rationale behind developing a standard for an Energy Management System is provided by McKane et al. (2007). They refer to the difficulties encountered in real life by plant engineers and operations staff despite recognition of energy improvement potential. A central obstacle lies with management's focus on production activity. It is regarded as a core business activity and issues such as energy efficiency go beyond this. Another obstacle is the disconnection of budgets on capital projects and operating costs. This leads to investment decisions taken based on the fastest payback time rather than on the most favourable life cycle costs. The third reason relates to knowledge usually connected to individuals and not integrated into production management. This has proved to lessen efficiency gains over time with changes in production and personnel.

It appears that Denmark first approached a concept of an industrial energy management system in the 1990s. This was done in close contact with industrial organisations. DS 2403, the Danish Standard for Energy Management, was adopted in 2001. It was developed as an extension of ISO: 14001. (Energiledelse, 2005). The Danish standard set-up was inspired by an already operational family of management systems standards[32]. (Christoffersen, L.B., Larsen, A. et al., 2006). Monitoring and control of energy consumption as well as energy conscious maintenance are amongst the system's elements. A step-by-step approach of the Danish standard is rather broadly sited. Figure 4-2 shows the representation of the continuous improvement philosophy as an ascending spiral ladder.

The Dutch Energy Management Systems Specification and Energy Management Check-list were developed in late 90-s[33]. It was officially adopted in 1998 as a part of a Long-Term Agreements (LTA) Programme. While not being a standard, the system was linked to long-term voluntary agreements in energy efficiency. (McKane, A., Williams, A.R. et al., 2007). Its implementation helped to maintain attention regarding energy consumption, and proved to bring an additional 3% in energy savings. (2007).

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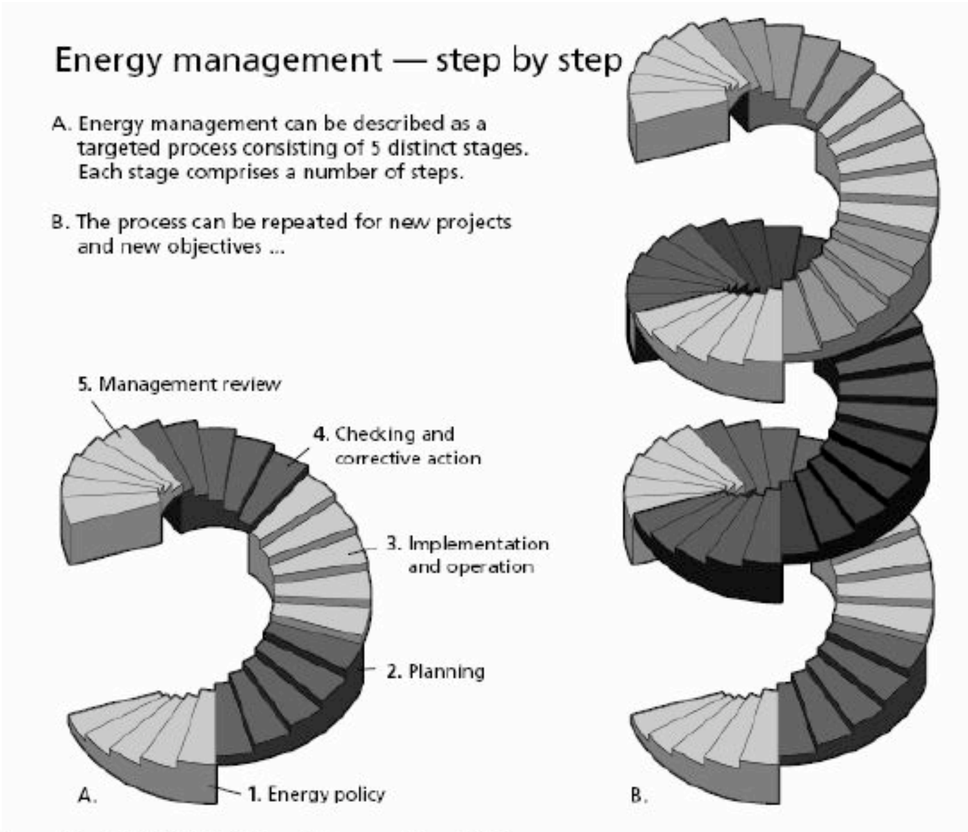
[31] Denmark, Sweden, and Ireland have Energy Management Standards. Netherlands and Germany have specifications.

[32] The family of Rational Models for Decision-Making includes such standards as Environmental Management, Health and Safety Management, and Quality and Production Management.

[33] Together with Bureau Veritas, an ISO 14001 certification institute.



Source: Danish DS 2403:2001, Energy Management-Specification.

Figure 4-2 Model for an energy management system

Source: (McKane, A., 2007). Using Energy Management Standards to stimulate persistent application of Energy Efficiency in Industry.

The Swedish Standard "Energy Management Systems – Specification" (SIS, 2004) was adopted in October 2003. This was one of the steps that allowed for the implementation of the Energy Efficiency Programme (PFE) for energy-intensive industries. A requirement that participating companies should have fulfilled was to introduce a standardised Energy Management System. This is subject to certification by an accredited certification body. Fulfilling the PFE requirements would lead to an electricity tax exemption.

The standard SS 62 77 50 was meant to be supplementary to the Environmental Management System Standard. The whole design of the standard is based on the very same approach. The methodology is founded on the "Plan – Do – Check – Act" cycle.

The Irish I.S. 393:2005 Energy Management Systems Standard appeared in 2005. The developed standard links straight to the existing two international standards: ISO: 9001, for quality management, and ISO: 14001, for environmental management. Later on a Technical Guideline for an effective and documented Energy Management System was developed. The substantial technical component of the system is recognised and focus is placed with management systems aspects.(2005).

The work seems to have found continuation in the European Committee for Standardisation (CEN). A document entitled, "Energy Management Systems: Requirements with Guidance for Use" is under development. CEN and SIS (Swedish Standards Institute) collaborate on the standard. The Irish, Danish, Swedish standards, Dutch specifications and German draft standard are taken as a reference point. Publication of the European Standard on Energy Management Systems is expected in November 2009[34]. The main idea can be observed in Figure 4-3. The Energy Management System is seen as complementary to an existing and operating management system in company.

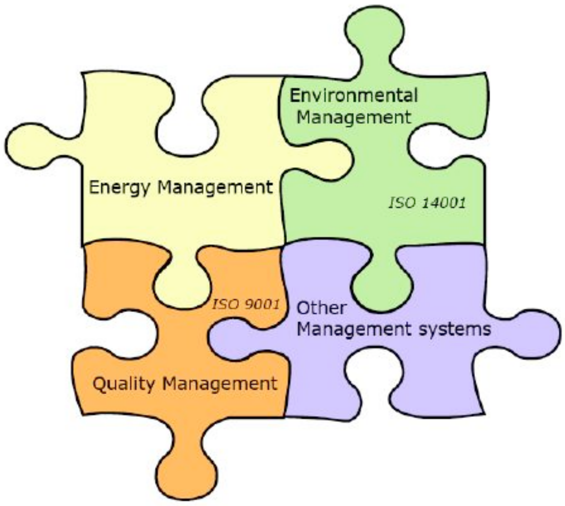


Figure 4-3 Compatibility of energy management with other management systems

Source: (2007) CEN/CLC BT/TF 189/PT. Energy Management Systems. Status Report.

P. -J. Stockmans (2007) indicates that a first step on the way to an energy management system is an overall analysis of energy flows at an industrial site. The effective starting point is to obtain information on energy consumption. In the Energy Management Self-Assessment Guide, he distinguished three major usages of energy in manufacturing:

- Direct production of goods;
- Space conditioning; and
- General facility support.

As noted by Capehart et al. (2003), energy management shall not be complete if no monitoring is established. The feedback on the monitored parameters is another crucial component in both energy management system and in the course of the energy audit.

4.3 Energy Audits

Prior to obtaining improvement in energy efficiency a company needs to perform a number of activities. An energy audit is one of these.

Thumann and Younger (2003) define an energy audit as "*a process to evaluate where a building or plant uses energy, and identify opportunities to reduce consumption*". Its primary goal is looking into efficiency evaluation and proposing energy conservation opportunities, provided that a comfortable working environment is sustained. An audit of an industrial plant will focus on

[34] http://www.cen.eu/esearch/extendedsearch.aspx

the process requirements. There may be different types of audits required depending on the intended outcomes. It is well recognised that industrial energy audits are very complex. It is a challenge for the auditor and energy management specialist to find out how the unique processes are operating and to develop improvement recommendations for different equipment units. (Capehart, B.L., Spiller, M.B. et al., 2005)

It is important to establish the level to which the audit will be performed before it's launched. Common understanding is that an energy audit implies consideration of all energy sources involved e.g. electricity, fuels (gas, oil), heat, steam. Here only the electrical energy related part is considered.

Table 4-2 gives an outline of three different types of energy audits depending on the level of investigation. Usually there would be an interdependence of the amount of data collected and analysed, the extent (or cost) of the audit, and the number of identified potential opportunities.

Table 4-2 Types and levels of energy audits

Type of audit / characteristics	Walk-Through Audit Level 1	Standard Audit Level 2	Computer simulation Level 3
Data collected	Energy consumption (quantities and patterns)	Quantities of energy uses and losses Equipment and systems inventory and their operational characteristics	Detailed data on energy use by function; Detailed equipment information; Operational data
Activities within the audit	Evaluation of energy consumption; Benchmarking against industry's average or similar activities; Preparation for a further, more extensive audit	Review and analysis of equipment, systems Some on-site measurements; Testing to quantify energy use and efficiency of processes and systems	More comprehensive evaluation of energy use patterns; Computer simulation to account for weather and other variables; Base for consistent comparison with actual energy consumption
Result of the audit	Preliminary estimate of savings potential; List of low cost saving opportunities	Analyzed efficiencies; Calculated energy and costs savings for identified improvement opportunities; Economic analysis of recommended conservation measures	Computer simulation for all-year round energy use; Interaction between systems is accounted for to prevent overestimation of savings
Cost of the audit	Low	Medium	High (applicable for complex facilities)

Source: Thumann, A., Younger, W. (2003). Handbook of Energy Audits. 6th edition. p.p.1-2.

Power utilities may perform an audit at an industrial customer's site within the existing contract or with a low-cost. Usually it is a walk-through audit.

At the outcome of energy audit comes an audit report. Its purpose is to explain the existing conditions related to the subject of the audit (envelope of the building, equipment, lighting, etc.) and to present improvement recommendations through operational improvements or energy conservation measures. (Thumann, Younger, 2003. p.9).

It is important to ensure effective communication of the energy audit findings. Thumann points at several company actors as a typical audience of the energy audit report:

- CEO (Chief Executive Officer)
- Facilities and Plant managers;
- CFO (Chief Financial Officer), Financial controllers
- Plant engineer
- Operations and maintenance staff

One of the first tasks within the audit is analysis of operational characteristics, defining energy benchmarks, and setting-up a monitoring basis to follow-up on results of implemented improvement measures. This clearly indicates that before a monitoring system can be set-up, an energy audit steps in with a preceding role. Thus, it will enable participants to spot the most important locations for monitoring and data collection.

Energy Accounting should form the basis for data collection within the audit activity. However, there may be a need to retrieve the data from the financial system, such as utility (electricity) bills. Energy accounting issues are covered in Section 4.5.

Capehart et al. (2003) suggests that industrial energy audit covers specifically the following elements of the site: lighting, electric motors, boilers, specialized equipment, and air compressors. Further description of audit activities for each of the categories is based on a number Energy Management related literature sources.

4.3.1 Lighting

Paolo Bertoldi (2007) from Directorate General JRC, European Commission assumes that lighting accounts for a substantial share of electricity consumption in industrial sector. He also sees large cost-effective potential in savings for this part – around 30% at a European scale.

A full inventory of lighting devices throughout the plant should be performed. It is important to describe tasks associated with existing lighting. There may be certain industrial operations that are colour sensitive. The number of hours related to lighting operation is also an important parameter. These are criteria to develop improvements proposals.

Lighting is one of the primary electricity consumption items that provide energy saving opportunities. In most industries, lighting does not represent a big portion of the energy costs. The more energy intensive the production is, the smaller the portion of lighting in energy consumption is. Nevertheless for most manufacturing facilities, rationalising the lighting system brings considerable reduction in electrical power consumed.

4.3.2 Electric Motors

Motors in industrial processes account for 69% of electricity consumed by European industries. The Joint Research Centre assumes that similarly to the lighting there is a potential savings of approximately 30% available at a low cost. (Bertoldi, P., 2007). Electric motors are essential to virtually any industrial process.

As with the other electricity consuming elements, a complete inventory is required in the case of motors. Capehart et al. (2003) suggests that all electric motors of over 1 horse power should be inventoried with the following data: motor size; use / function; age; model number; estimated operating hours; other electrical characteristics of which power factor at full load is possible.

The Guide to Energy Management (2003) recommends as appropriate measurement of voltage, current, power factor, and load factor for larger motors.

4.3.3 Ventilation (Heating – Ventilation – Air Conditioning)

Ventilation (Heating – Ventiliation – Air Conditioning) is presumed to be a mandatory attribute of contemporary industrial facilities and offices. It does add a lot to the comfort of the interior and contributes to health and safety matters. Nevertheless there is no need for the system to run 24 hours a day at the same speed. Often employees would not realise that overheating is taking place.

As with other functions, inventory forms an integral part of the audit performed. The usage pattern is also important to put on the paper for further comparison with the working hours. The first item to bring about energy savings is the ventilating fans. There is a conservation opportunity by replacing motors.

4.3.4 Special Equipment

All production equipment tailored for specific production site is related to this section. The audit allows for equipment examination. Noting periods and hours of equipment use is required.

Many authors note that this element is the most complex and non-trivial as far as energy conservation is concerned.

Such equipment, like presses, shall require substantial demand and will be causing the peaks in the production due to the nature of torque needed for the work to be performed.

4.3.5 Ovens

Many production sites incorporate oven rooms. These are electric ovens with high capacity and high electrical energy consumption. Most encountered efficiency problems with ovens include poor insulation and malfunctioning thermostats. Timely correction of such problems will improve unit efficiency.

4.3.6 Air Compressors

This element of industrial equipment shows the lowest efficiency and nearly 90% of used energy results in waste heat. Most often they are used as a control media, for cleaning operations, or to power machines or tools. Performance of the compressor can be diminished by air leaks. This will further reduce the already existing low efficiency. All will consequently result in excessive electricity consumption. Certainly the examination of the air compressing system along with size, operating pressure, and type recording needs to be performed.

4.3.7 Emission Abatement Equipment

This type of equipment, thanks to its environmental purpose, is often dropped out of the energy consumption scope. It is important to be aware of this component of industrial equipment. Reasonable thinking would lead one to understand that energy consumption of this equipment will obviously be linked to the production process itself and resource management. Cleaner production approaches with optimisation of input and elimination of wastage both on the material and energy side shall be reflected on the abatement side.

As a general remark relevant to all functional elements listed above, it is worth noting that inefficiency in operating machinery will also result in the production of excessive heat that will further need to be removed by the air-conditioning system. (Kennedy, W.J., 2005).

4.3.8 Industrial Assessment and Process Improvement Opportunities

Development in the application of energy audits in the United States led to the integration of industrial energy audits with industrial assessments. This was an important transition related to a multi-dimensional look that includes energy savings, waste optimization, and process improvements. It would be reasonable to assume that process improvement opportunities shall be sought when both quality and productivity have the potential to be improved.

This kind of assessment has been launched in 1993. The core of the assessment is in a combination of three angles: energy, waste, and process. ((Thumann, A. and Younger, W.J., 2003) p.310).

4.4 Energy Management Information Systems

The Energy Management Information System is an integral part of the overall corporate (Management) Information System. The title stresses the orientation of data within the energy field. An approach to developing and operating the Energy Management Information System (EMIS) was suggested by Canadian Industry Program for Energy Conservation under the auspices of Office of Energy Efficiency of Natural Resources Canada. Due to lack of other sources focusing on this issue, only one principle source shall be referred to in this section.

Hooke, Landry and Hart refer to EMIS as "*an important element of a comprehensive energy management program*". (2004). It is necessary to enable performance improvements through the provision of relevant information to key people. The EMIS is covering various energy sources at production facilities. In principle, there are many similarities with what needs to be said about the monitoring system itself. Coverage of the EMIS is not fully coinciding with monitoring system though. Characteristics of the EMIS include:

1. Deliverables (early detection of subpar performance, support for decision making, energy data and reports, historical operations, statistics, provision of evidence, support budgeting and management accounting);

2. Features (format of data storage, calculation of effective energy targets, comparison of actual data with targets);

3. Elements (sensors, meters, hardware, software);

4. Support (management commitment, delegation and allocation of responsibility, routines, training, regular audits).

The Canadian approach places EMIS within an Energy Management Programme that should run on a regular basis. Continuous progress is also anticipated through verifying targets and achievements. It is recognised that EMIS serves performance management throughout all levels of organisation. Meanwhile, the traditional role of the basis for energy improvements remains with energy audits. Figure 4-4 shows the location of EMIS in relation to Energy Management Programme.

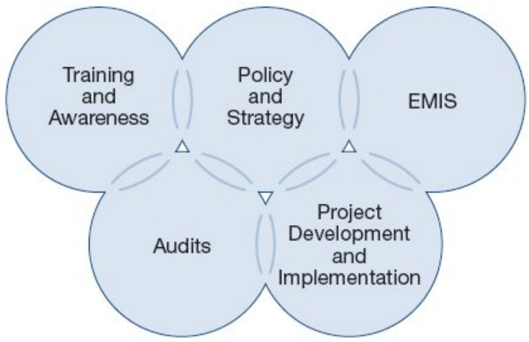


Figure 4-4 Elements of an energy management programme

Source: Hooke et al. (2004). Energy Management Information System. Achieving improved energy efficiency. A handbook for managers, engineers and operational staff. p. 8.

Particularly because of many issues in common, it is worthwhile to study EMIS requirements. British experience with EMIS is referred to have had a substantial development over past 15 years. EMIS implementation brought approximately up to 15 percent of savings in annual energy costs.

4.4.1 EMIS Deliverables

Hooke et al. (2004) speak about knowledge used when making decisions. Knowledge comes either from experts, or from operating data. The primary issue to look into within energy is what information is available, required and what data can be delivered. The way the data is delivered to the key personnel responsible for performance and consumption volumes will influence promptness of their actions. Capturing the knowledge and making it available is becomes increasingly important with higher complexity of processes at facilities.

When setting up the EMIS and monitoring frequency within it, a process and application shall be the defining factor. Various interested parties require reporting of the EMIS. Different levels may need a different layer of information and reporting. Operational staff would for example receive actual, target, and best practice performance in a short run. Executive staff may be more interested in reviewing longer-term indicators.

Having data stored in the system serves many purposes. Historical events can be investigated with bringing in additional factors that influenced some variations. Some new energy saving opportunities may be revealed through such an analysis. Likely the energy data shall serve a quantification purpose to justify implemented activities and help replicate positive experiences.

Also important is the contribution of the energy consumption statistics to energy budgeting and management accounting. It is a common practice that correlated production and energy consumption values are used along with production estimates to forecast energy consumption. The more precise the forecasts are the better the plant's economy is. Accounting benefits from EMIS by defining true energy costs connected to specific products.

Furthermore, EMIS data is relevant for and can be made available to other parts of the corporate information system. Environmental reporting, energy and resource planning will be the most likely information recipients.

4.4.2 EMIS Elements

Hooke et al. (2004) refer to elements of EMIS that are integrated to build up a complete information management solution. Sensors, instruments, data infrastructure, software tools – these, to the maximum possible extent, should be the same as the components used for plant and performance management. The handbook warns about taking a risk when developing an independent energy system. This is said to have the potential to lead to difficulties. The authors stress that energy is only resource and one aspect of operational performance. It is essential that other objectives of corporate performance be considered. Not least are output, quality, reliability, environment, and profit.

Sensors and instruments form a part of the monitoring system. Hooke et al. point out that in this case, the monitoring system as well as control system should be the ones for process control. Data collection is foreseen to be automatic. A data archive should be a part of the system. Software tools would build up on the control/monitoring system and the archive storage. Software element of EMIS includes data analysis tools, reporting tools, monitoring software, optimisation and decision support software. The latter is most likely to be optional and is linked to the complexity of decisions to be taken.

4.4.3 Critical Elements for a Successful EMIS

It is crucial that efficiency of energy use is a matter of corporate concern. It needs to be upgraded from a side issue to the integral part of business management plan. Clear energy policy and respective organisational arrangements have to be developed with the involvement of senior management. Lack of active support from management active has proven to be an obstacle to energy improvements. It will obviously undermine the EMIS development. Energy management is referred to by Hooke et al. as mainly organisational and management effort.

The people orientation of energy management activities is underlined. It is therefore important to structure and plan personnel's contribution. Motivation plays an important role here. An adequate responsibility with both authority and accountability is necessary to achieve objectives, goals and targets. The structure of the EMIS is vital to review and inspect the energy system within continuous improvement. Reporting of achievement as well as getting approval for proposed activities may help to modify investment criteria for energy investments. Modification could imply consideration of life-cycle costs and a more realistic payback period.

Along with personnel involvement, training, as well as the possibility to share data amongst departments, is of essence. The latter can be secured through integration into the business information system. The data and knowledge associated with the system belongs to the whole company.

Real-time data is pertinent to the operation of the EMIS. The frequency of data collection is often of similar cost whether daily, hourly, per second reading is undertaken. A low frequency of data collection may result in inadequate target setting. This may cause diminished credibility of the system.

Reports form a part of the EMIS. Their circulation within the organisation is important, though with an adequate level of detalisation. As such, performance overviews should reach senior managers, whereas operational staff should be provided with detailed energy profiles and main influencing factors.

4.4.4 EMIS Implications for the Monitoring System

The essence of EMIS and generated reports is to have comparison of real-time data, historical records, and targets. This will define what measurements need to be undertaken. Metrics should correspond with the levels where process is managed. This has a link to accountability for energy use. In order to have due accountability, energy metering should be as detailed as process management.

As noted by Hooke et al. (2004), technology itself cannot help unwillingness or incapacity to deliver gathered information and reports throughout the organisation. The barriers are more associated with cultural and organisational issues than with technical issues. What needs to be considered is the interaction between people and technology to be utilised for monitoring.

4.5 Energy Accounting

Energy accounting is an important source of information for a quality energy audit. Information from energy accounting contributes to an analysis of operational characteristics and performance. It also allows benchmarking against an industry average. Moreover its existence forms the basis for savings potential measures, and setting conservation or reduction targets. It creates a baseline for further monitoring of implemented activities.

"*Energy accounting is the art and science of tracing Btu and energy dollar flow through an organisation*" as stated by Capehart et al. (2003, Ch.1, p.39). Capehart mentions three main parts in energy accounting: energy use monitoring, energy use record, and performance measure. (2003, Ch.1, p.24). The Guide also mentions the lack of necessary meters as the decisive obstacle to wider application of energy accounting systems. The preliminary goal is said to be twofold:

- Observe electricity consumption by major units / departments;
- Discern contribution to peak load from each of major units / departments

The fundamental objective for energy accounting would be possibility of allocation of energy to product(s) as it is done with other direct manufacturing costs.

4.5.1 Energy Accounting Form

As far as electric power consumption is concerned the following data is necessary according to Thumann to fill in the Energy Accounting Form on a monthly basis:

1. Number of days in the corresponding month;
2. Electric usage (kWh);

3. Electric demand (kW);

4. Electricity cost (monetary unit, e.g. SEK)

5. Electric unit cost (SEK/kWh)

6. Load Factor ([2]/[3]*[1]*24)

The quantitative data should relate to the specific facility name and type, electric utility supplier, identification number of electric power meter, and details on applied electric rate schedule.

In the United States, the electricity market set-up it is noted useful (by Thumann) to evaluate the impact of demand and power factor penalties on the monthly bill[35]. Regulating the demand and power factor will provide little energy savings, but the cost savings are reported to be significant. As stated in the Handbook on Energy Audits (Thumann, A. and Younger, W.J., 2003), it is recommended to include these parameters in the analysis during the audit. It may occur that billing demand figures deviate from actual demand, however this is explained by special conditions that may apply within the electricity supply contract.

4.5.2 Load Factor

Load factor and share of the load-induced payment would depend very much on the type of facility. Demand charges comprise from 20 to 40 per cent of the electricity bill. The Handbook of Energy Audit specifies: "*The user will get the most electrical energy per dollar if the load is kept constant, thereby minimizing the demand charge*"(Thumann, A. and Younger, W.J., 2003) p.17. The theoretical maximum value of the load factor is 1.00. This would imply that there is no variation in consumption or no peaks in demand. In principle this indicator helps to fulfil the demand control objective and to level out highest and lowest consumption values by regulating and rescheduling the peak consumption. Ideally the load factor should be as close to a unit as possible, however this is not possible in reality.

As with any indicator, it is necessary to establish what is normal for a facility and meter, and to further monitor the development.

4.5.3 Base Loads

Even in cases when there is no production running, a facility engineer would be able to see electricity continuously consumed. Usually such functions like lighting, office equipment, plugged in appliances, and ventilation will be responsible for the base load. It is worth knowing the base load figures in order to find out if energy conservation and cost saving efforts are required at this end of electricity consumption.

4.5.4 Power Factor

The power factor is another important value for energy accounting. As already mentioned, the electrical energy is consumed to perform work. This part of energy is measured in kW and kWh. There also is another part of energy that is used by certain kinds of equipment such as transformers and inductive motors, DC (direct current) motors, and lighting ballasts.

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[35] See the Glossary for explanation of terms.

There are three types of electric power employed at the production facilities:

- Power producing current or ***real power*** (measured in kW)
- Magnetizing current or ***reactive power*** (measured in kVAR)
- Total current or ***apparent power*** (measured in kVA)

Total current (total power) represents a vector sum of the other two. In the electric circuit this current can be read with an ammeter.

Loads of equipment run on alternating current are powered with both kinds of current: real and reactive. (Capehart, B.L., Turner, W.C. et al., 2003).

Reactive power is the result of electric current flowing to a certain degree out of phase. Such an event requires additional current delivery to equipment. The consumption and demand in such cases cannot be measured. The power factor is very important for the power supplier. Increases of reactive power above controlled level weaken the grid capacity. (Thumann, A. and Younger, W.J., 2003). The harm of excessive reactive power exists for an industry itself as well. One of the consequences is reduced capacity inside the facilities. At the same time poor power factor at a facility is a waste of delivered energy through heat and magnetising power. It can be corrected but as pointed by Bovankovich (2007), first it needs to be quantified.

The unit for measuring reactive power is kVAR (kilovar or kilo Volt Ampere Reactive). This parameter gets its place on the bill if the power supplier registers deviations from the agreed value (normally 50% of resistant power). To improve the on-site capacity and even level of reactive power, special devices are used. Capacitors help filtering the electrical network. They can be installed at any location between the point of application and source of power. Material and installation costs are relatively inexpensive. (Lobodovsky, K.K., 2005). There are options of having capacitors on each piece of equipment, on the group, or on the main service electric line.

Another way to help level out this parameter is to check the power factor of equipment before purchasing it. High power factor (closer to 1.00) should be given preferences. Capehart et al. also see a solution in performing control and adjusting schedule for running loads. The aim is to reduce peak value.

4.6 Energy Management in Danish Manufacturing Industries: Relevant Empirical Findings

This section will reveal some findings from empirical research carried out among Danish industries. While recognising that there are some differences in energy sources and energy policies between Denmark and Sweden, the drivers behind energy management are likely to be similar. First of all, both countries are parts of Nordic area and in terms of electricity supply are operating at the same electricity markets. Secondly, they are members of the European Union, therefore, the same policies at the European Council level apply. Thirdly, taking a broader international perspective, both Sweden and Denmark are considered advanced in terms of energy efficiency. Fourthly, the survey looked into the manufacturing sector specifically. The fact that Christoffersen, Larsen, and Togeby (2006) mention is that energy consumption represents a larger share of electricity compared to other fuels. This also makes it rather similar to the part of the Swedish manufacturing industry focused on in this paper.

On average, the fraction of energy costs in total financial expenses in Danish industries is low – at the level of 1.6%. It is noted that development of energy management has been steered by the Danish Energy Agency during last 10 years. The goal was to drive it away from technical measurement orientation and turn it into a management system. This was supported by the adoption of Danish Energy Management System Standard DS 2403:2001 (please see section 4.2 above). The intention of the introduction of energy management system was to draw industrial companies to such aspects as information, communication, energy audits, and involvement of employees.

The analytical framework of the survey has been mentioned in the beginning of Chapter 3. It is based on the knowledge that industries obtain rather than on energy saving they achieve. Knowledge about energy management is formed by regulation, energy prices, external relations, and will depend on company characteristics and internal organisation.

Only part of the findings is brought up here. One of them refers to motivation of energy savings. The following results have been obtained: reduction in costs (76%), environment (26%), image as a 'green' firm (16%), energy management as a natural part of EMS (11%).

The other part refers to the origin of inspiration to work with energy efficiency on site. The following has been observed: electricity utilities (26%), consultants (22%), Energy Agency (20%), own initiative (20%), suppliers (18%)[36].

Among the companies with energy management as a natural part of general management, the most frequent element appeared to be monitoring. Nevertheless companies with a relatively high degree of energy management and related organisational aspects were found rather weak at implementation of energy specific projects.

[36] Only the main incentives are brought up here. The rest of incentives can be found in the Empirical Analysis.

5 Monitoring System

Managing the activity of resource consumption presumes having relevant information on the management object. Collecting and interpreting data are the main functions within a monitoring activity.

Performance of an energy audit helps to establish a basis for future energy conservation opportunities. Normally these opportunities shall be incorporated in a plan and get scheduled in a prioritised manner. Natural question will arise on how to define the effect of implemented projects and measures. This role is supported by the monitoring activity, which is the core subject of the paper. Hereinafter, monitoring refers to measuring electrical energy consumption.

For the purposes of the Energy Management Standard, the definition of monitoring given by I.S. 393:2005 (the Irish Energy Management System Standard) is relevant:

Box 5-1

Monitoring
A process intended to assess or determine the actual values and variations in energy usage, based on procedures of systematic, periodic or spot surveillance, inspection, sampling, measurement or other assessment methods, intended to provide information about energy usage.

Source: (2005). I.S. 393:2005 Energy Management Systems Technical Guide, Sustainable Energy Ireland.

W.J. Kennedy (2005) names three functions of monitoring:

- Evaluate progress;
- Show which measures work;
- Show which measures don't work.

Hooke et al. (2004) stress the imperative connection of measurements to EMIS. Metering and measurement represents the key component in it. Ambient conditions, process variables, and consumption of resources are supposed to be measured timely in order to to:

- Provide cost-centre accounting;
- Identify problem areas before they become out of control;
- Verify utility billing;
- Assist in energy purchasing;
- Assist in maintenance and troubleshooting;
- Aid in identifying and monitoring energy projects;

- Offer meaningful data towards sizing and design for capital installations and improvements.

The data itself, though measured, do not reveal deviations. Patterns and changes are to be looked for in available records. Having a profile and accumulated statistical records allow benchmarking[37]. Benchmarking process can be both internal (within a company) and external (with other companies).

5.1 The Role of Monitoring in Energy Management

Intelligent energy management is reliant on learning about energy distribution and consumption in a company. Neither energy audits nor energy management would be complete without having it monitored. Analysis and feedback are essential. It is crucial to follow what has contributed toward goals and energy conservation targets. Finally, target adjustment takes place once it becomes clear that they were set too high or too low.

Craig Smith (1997) has suggested that monitoring is viewed as an element of the Energy Management Programme. He would place it in the Implementation Phase after Management Commitment as first phase and Audit and Analysis as second. The part of measurements and monitoring procedures is found vital for the evaluation of the progress of implemented activities within the energy management programme. This will further be used to establish or adjust goals, rectify procedures, and review the programme. Certainly, monitoring and measurement contributes to continuity of the process as a part of management cycle.

Capehart et al. (2003) reinforce the idea that energy reporting is done with the objective of comparing consumption readings with goals within the company, or as a benchmarking to some standard. In the best case, measurement should take place for each operation or production cost centre (Ch. 1, p. 18). The reporting scheme requires regular / periodic review. This should secure that only the necessary data is being read and gathered. Checking that the required data is available is as important as preventing the system from becoming inefficient and useless.

Setting the target at the adequate level is necessary for management by the objective process. Goals should be set at the level that is "*tough but achievable, measurable and specific*" (Capehart, B.L., Turner, W.C. et al., 2003) (Ch.1, p.22). In addition, monitoring will assist with learning about what has contributed to, or on the contrary, served as a negative factor in the implemented measures. (2003, Ch.2, p.24). Moreover, monitoring activity will indicate if the goals set are lower or higher than feasible/realistic.

The Swedish standard for Energy Management Systems has due regard for monitoring and measurement. Within the PDCA cycle, the monitoring activity is placed in the Check-phase. The standard (SIS, 2004) requires "*registration of information demonstrating / tracing the use of energy of the organisation*".

5.2 Electrical Energy Monitoring System

Monitoring of electricity consumption technically consists of metering, data collection and analysis. During last decades equipment prices followed a reduction trend. Metering

[37] Benchmarking is a concept of discovering what is the best performance being achieved. Definition by iSixSigma. Retrieved from http://www.isixsigma.com/dictionary/Benchmarking-1.htm [08 September 2007]

equipment and automated solutions became less costly. Electrical energy as a media should be given a special tribute. Absence of material friction and special characteristics of this media make it easy to measure nearly at any point. This may be especially valuable when electricity consumption needs to be measured along the process line.

Both electricity usage (kWh) and electric demand (kW) need to be measured. There should be monitoring in place before plan implementation is commenced. By the term “plan”, the Energy Plan aiming at energy conservation is meant. Base figures from the preceding year shall form the basis for comparison. Such comparison will give an indication if there is an improvement or what is the development. (Kennedy, W.J., 2005).

Electrical energy meters remain very accurate over a long period of time due to the non-substance nature of the media. According to the interviewee representing an energy generation company, no calibration is necessary for up to over ten years. Only regulatory requirements induce network companies to carry out inspections of billing meters every six years. All measurement equipment inside the company will follow internal rules and requirements.

The solution and detalisation for electric energy monitoring will vary with the individual circumstances of production sites. The optimum solution, as referred to by James Hooke et al. (2004), will depend on the importance and level of cost savings achievable, the rate at which faults can develop and the time required to act on them, the existing infrastructure that can be utilised for monitoring purposes, and capital available for investments.

Irish Energy Management Systems Technical Guideline suggests following one important principle when deciding upon the energy monitoring system. Metering and its outputs need to be integrated into the business management cycle. (2005, p. 14). Most attention in monitoring needs to be placed with significant energy usage. This will allow identification of unnecessary consumption.

Capehart et al. (2003) mention looking into electricity bills as the weakest of monitoring activities. Monthly graphs should reflect total consumption, peaks, and other factors associated with costs. Output-related energy values need to be recorded and/or calculated, and graphed. It is important that direct feedback on the data collected is secured to the personnel in position to take action upon that. This entails the necessity of having recording instruments at the departmental level. A departmental metering set-up will help department managers to understand and control power consumption. Not the least will it ease identification of causes in variations and raise awareness of employees at the plant level.

A Canadian team (Hooke et al. (2004)) have developed a structured approach to deciding upon the location of monitoring equipment (please see Figure 5-1).

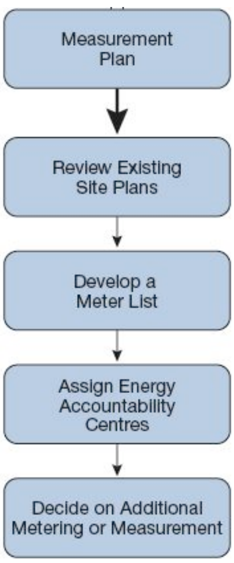

Figure 5-1 Measurement Plan – A Structured Approach

Source: Adopted from Hooke, J., Landry, B., et al. (2004). Energy Management Information Systems: achieving improved energy efficiency. A handbook for managers, engineers and operational staff, Office of Energy Efficiency of Natural Resources Canada.

The Measurement Plan represents a road map for up-coming installations of monitoring equipment. The table below describes the steps that need to be undertaken in order to draft the plan.

Table 5-1 Steps and deliveries for Measurement Plan

Step	Findings and deliverables
Measurement Plan	• All monitoring points; • Types of sensors and their location; • Signal cable route and wireless communication; • Necessary documentation
1. Review existing site plans	• Illustration of electrical distribution to major loads; • Schematics for metering (if ready by layout) or changes required
2. Develop a Meter List	• Meter List with indication of Metering Point and Metered Load (in concord with overall cost allocation strategy)
3. Assign Energy Accountability Centres	• Centres assigned corresponding to plant's business units; • Configured with Meter List, including performance variable e.g. production unit, outdoor air temperature
4. Decide on Additional Metering	• Sub-metering of major process loads to gain more knowledge on usage (pumps, motor drives, compressed air)

Source: Adopted from Hooke, J., Landry, B., et al. (2004) Energy Management Information Systems: achieving improved energy efficiency. A handbook for managers, engineers and operational staff, Office of Energy Efficiency of Natural Resources Canada.

5.2.1 How is Electrical Energy Metered?

There is a legislative requirement to a local network owner to report hourly on electricity consumption of facilities above 63A. This covers all industrial sites in Sweden. A normal and standard case is that each industrial plant has a billing meter. The DSO owns the meter as such. Consumption values, as well as values stipulated by the electricity supply contract are reflected in the monthly bill issued by the DSO and energy provider. For further detalisation, it is possible to make a request to the DSO.

Hooke et al. (2004) find it inadequate to rely only on the main utility meter. Further metering at production facilities can be organised on a temporary or permanent basis. It should be clear for operational staff what meters are dedicated to verify savings, and what installations are permanent or temporary. The end-user of energy is the actor deciding what data is to be acquired and analysed, how frequently and for how long it needs to be collected. Should a survey be an option, the Handbook of Energy Audits (Thumann, A. and Younger, W.J., 2003) lists the following measuring equipment: ammeter, voltmeter, wattmeter, power factor, and power quality meter. These are used with a purpose of measuring electric system performance. Thumann (2003) referred to the power factor as a basic parameter to calculate usage of electrical energy.

The Guide to Energy Management, (Capehart, B.L., Turner, W.C. et al., 2003) suggests having an industrial light meter to measure incident light at workplaces and general lighting conditions. Though in more recent industrial buildings this can be done through design and layout of the lighting system and dedicated measuring. As for the core electrical system measurements, a volt-ohm-ammeter is suggested. It is used for checking voltages of equipment (on various phases) to analyse efficiency loss and overheating. A recording ammeter gets mentioning in the Guide to determine peak kW usage times and amounts.

In locations with limited access there is an option to utilise data loggers (for amperage and voltage). They represent an alternative to a more permanent data acquisition scheme.

A permanent monitoring solution links to more advanced sub-metering. This would usually be in hand with a collection unit, data transfer and analytical software solution with a computer system. Advanced meters, as referred to by Bovankovich (2007), are helpful in determining what drives excess energy use. He does not foresee interruption of service for the meters' installation as such. Sensors, he writes, can be placed on nearly any load in the building, providing constant data on energy consumption.

Most meters can be used as stand-alone devices. Having them in a system means integration through an open architecture into the plant-wide system. This can be done through a common communication link.

5.2.2 Components of the EEMS

The technical set-up of the monitoring system is strictly dependent on the data collection ambitions of a manufacturer. It will also be defined by the roles or functions associated with the monitoring system.

Bovankovich (2007) counts three main parts as technical components of the EEMS: meters, interval data recorders, and energy intelligence software. Reliable transport of data is provided through having meters connected to a collection unit – data recorder or concentrator (see Figure 5-2). This element practically receives data registered on various meters and records them before data are transferred further to the database (DB) and computer system. There is virtually no limitation to the distance of meter from the computer system. This can all be solved with the appropriate selection of communication technology that is in easy access nowadays (GPRS, internet, intranet).

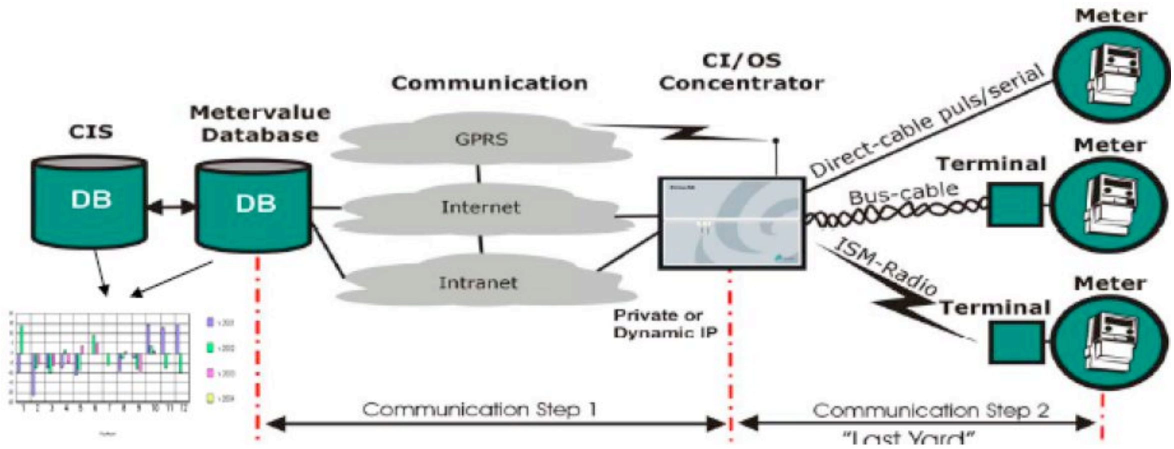

Figure 5-2 Internet based monitoring and diagnosis, Based on Comsel and Ennovatis solutions.

Source: Pietiläinen, J. (2005). VTT. Energy Assessment and analysis methodology. "Energy Assessment Guide for Energy Managers and ESCOs". Overview of the Subtask A scope. p. 83.

This outline of advanced metering represents an emerging scheme rather than a commonly used set-up. Eventually the type of system installed is likely to depend on the cost-effectiveness and anticipated savings.

5.2.3 Costs Associated with the Monitoring and Measurement

The cost of monitoring system cannot be defined with one figure. It will vary depending on the number and specifications of meters in question. Turner (2005) stated "*the cost of metering and submetering is usually incidental to the potential for realizing significant cost improvements in the main energy functions of a production system*". (p. 6).

The costs associated with the monitoring system shall include a number of items. The Irish Technical Guideline suggests considering the following items: ***design, purchase, initial installation, operation, data storage, analysis of data output, and maintenance***. (2005)

Installation of a monitoring system is an investment decision itself. It comprises hardware and software, should automatic data collection be required. The price of an individual meter is not high when compared to the system solution as a package. High precision is not really a question for an electrical meter at a production plant. Therefore the meters as such comprise the minor part of the costs. There are meters of not more than Euro 100 in price. Within the complex solution, with 100 meters to be installed and connected, the price per meter would become from Euro 700 to Euro 1000. The heavier part of the costs is related to installation and not to the hardware itself. Especially tangible installation costs turn out to be high in older facilities. Naturally, design of the earlier built plants didn't foresee the automation and metering needs of the future.

Maintenance and running costs are quite small compared with initial investment into the monitoring system. Operating costs may be more sensible if data collection is performed manually. This will require personnel man-hours to perform data collection and registration for further reporting. With an automatic system, running costs would not appear an issue to consider. The function of operating a monitoring system would usually fit into the organisational set-up of units and departments. Daily operation, though, would not demand additional time devoted by line-personnel.

An automated system allows overviewing the elements including meters themselves from a computer. The system requires one person being responsible for running it and doing analysis of data gathered on daily/weekly/monthly basis. This function is not difficult to be delegated as an extension to one of the existing positions. In this case additional personnel costs are not going to be high either.

Further on, during operation of the system, on-going support costs are inevitable. It is more likely that slight modifications will be required in the course of business activity and changing practices. Getting the knowledge and experience accumulated, updated, and shared within a plant should be anticipated and taken care of when budgeting.

Meanwhile as underlined by Hooke et al. (2004), non-monetary benefits should enter cost-benefit evaluation. One of the non-monetary benefits will be knowledge generated within a company based on the data gathered and lessons learnt. This will remain within a company regardless of personnel rotation. Cost-effectiveness of the monitoring is noted to be highly linked to the economy of scale (load-wise).

5.3 Actors Relevant to Energy Management and Monitoring of Electrical Energy Consumption

Due to the special nature of the electrical energy, which makes it different from any other resource or energy carrier, it is important to analyse the supply chain. The speciality of electrical energy is that basically it has to be produced at the same moment when it is consumed with the required quality. This is why the market of electrical energy differs from consumer markets and rather resembles financial markets with their forward contracting and hedging of prices.

When generating electrical energy, there is a requirement to have engaged in production as many facilities as would be sufficient to satisfy the consumption. Such condition leads to a situation where participants in the supply chain are interested in having an overview and control over the consumption and some parameters. The thesis places an industrial company as a central actor. Eventually an industrial facility is the end-user for electrical energy to be delivered. All the decisions on the volumes, loads, time of delivery and the way of consumption are within the boundaries of an industrial plant. Therefore it is assumed that when lacking internal knowledge on some issues, a company would call in a consultant engineer, specialising in a particular subject. Here we are talking about a consultant working with energy efficiency issues including electrical energy.

This section is an attempt to embrace the views over industrial electrical energy consumption by the following actors:

- Energy provider (who sells the demanded volume of electrical energy to an industrial company);
- Energy consultant (who would carry out an energy audit, advise on metering and energy saving opportunities);
- Developers of energy metering solutions (who would have front-end knowledge of the market demand and technical capacity of metering equipment and data processing).

There is no standard monitoring solution that would suit all industrial plants. Nevertheless, some features that are useful shall be identified based on these actors' experience.

5.3.1 Energy Provider and Distribution System Operator

The industrial company has a direct relationship with both electrical grid actors: the energy provider and the distribution system operator. Before the electricity market was deregulated, this could have been one company. Their interests in relation to an industrial company are quite similar. The information they operate with is based on the billing meter.

Two companies, each playing both roles, have been contacted. The following experts have been interviewed:

1. Marcus Hansson, Energy advisor, E-on, Lund (since July 2007 – Malmö)[38]

2. Magnus Gunnarsson, District Heating and Cooling Department – in charge of major customers, Halmstads Energi och Miljö AB (HEM), Halmstad[39]

Mr. Hansson noted the political pressure within the energy field. This goes for the European Community and Swedish energy goals. Customer pressure is also realised by industrial companies and energy producers. In Sweden, renewable energy is highly demanded. The response of both industries and energy providers to energy targets is slow.

E-on offers those industrial customers who are interested a load management system (hard- and software). This is not a part of E-on's grid operation. The system would be installed at the production facilities when there is an agreement about importance of the load management. The load management system[40] acts upon main meter's readings and consumption trend. It is designed and set in a way that part of the equipment is disconnected should the load approach the nominal value. The electrical system continues supply to operation of the main sections. Some customers became more interested in further metering of electrical energy consumption. Mr. Hansson indicated that monitoring would often start with load management and continue with sub-metering at production facilities. Energy audits represent an additional service that the company offers to its clients. This would go beyond the electricity supply contract and solely depend on client's position.

Load management results in customer's cost savings. The high load is shifted in time. Often there is a substantial amount of money to be saved. This however does not result in energy savings as such.

Mr. Gunnarsson from HEM finds it natural for an energy supplier to co-operate with their clients in the field of energy management. This would be especially true if the energy provider supplies not only electrical energy but also heating and cooling. HEM (as a DSO) owns one meter at the industrial site used for billing purposes. Besides reading the consumption values, active and reactive power passing through the meter are logged and used in the billing. An industrial client will be informed if reactive power exceeds the one set in the contract (normally 50% of active power). In this case, HEM would help the industrial client to figure out the reason and remedy the situation.

Mr. Gunnarsson stressed that the DSO is not willing to have unexpected load increases by clients. This may result in peak demand and higher delivery volumes. He highlighted that

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[38] Personal communication. Interview held on 14 June 2007.

[39] Personal communication. Telephone interview held on 19 July 2007.

[40] The described load management system is similar to what is generally referred to as load shedding.

"*unexpected peaks are causing bad economy for a distribution company*". When experiencing peaks, the DSO has to pay penalties to a higher level grid and to the power generator.

Mr. Hansson can see a number of benefits of having internal electrical energy monitoring at the plant. Among them are a better overview and understanding of the equipment on-site, verification of adequate sizing of such equipment like pumps, and running support systems (e.g. compressed air) more efficiently.

It is important, according to the Energy advisor, to link monitoring to the monetary side of production life. Cost centres must be responsible and accountable for the electricity they consume. More accurate cost allocation is essential. The most common allocation such as overheads proportionate to square meters or other allocation keys should be revised if plant has started with monitoring.

The electrical energy monitoring system should presume automatic data collection. Reports generated for users should be easy and clear. It is crucial to have a person in charge of the system. It will not run itself and will require good co-ordination with other departments of the company to be valuable. There is an eternal risk that the system will be turned into a bureaucracy instead of a management instrument.

Mr. Gunnarsson would distinguish between permanent and temporary monitoring of electrical energy consumption by equipment. He believes that permanent metering is the best but that it is also possible to arrange for temporary measurements. This would be especially important before equipment gets replaced. As well, when changing equipment it wouldn't be expensive to install permanent metering. This should always be worthwhile doing. Especially when a turnkey solution is purchased – there is virtually no cost for a metering component.

It sounds reasonable to Mr. Gunnarsson to have a gradual start-up of monitoring. He believes monthly manual reading could be a start-up. The follow-up would be hourly reading for the largest consuming sections. He admits though that hourly metering of major units should be an ambition. Major units could be: each production line, compressed air systems, fans, cooling systems, pumps, and ovens. The big saving opportunities can be found through comparison of running hours of core production and auxiliary systems. The divergence occurring when production is off while auxiliary system continues running at full scale should be the first one to taken care of.

Among characteristics of a good electrical energy monitoring system Mr. Hansson named the following:

- Accessible (access by various personnel);
- Correct/reliable information (data base);
- Possible to follow-up (through reports);
- Transparent (for integration with information system);
- Understandable (by the users);
- Continuous (in time);

- Enabling knowledge transfer (knowledge of historical events accumulated and available);
- Multidimensional (integratable).

Mr. Hansson is very positive about actions and tools to work with energy conservation. Electrical energy monitoring system is clearly one of these tools. He admits that there is a lot of potential with this energy source. Sweden could be a showcase and example about electrical energy saving activity in regular industrial operation. The benefit of that will be a possibility to export Swedish 'cleaner' energy to European market. Both interviewees expect further increases in electricity prices in the mid-term perspective.

5.3.2 Energy Consultant

The only energy consultant working with industries that was available for an interview happened to be SWECOEnerguide. Project manager, Gunnar Nordberg, and business consultant, Rose-Marie Ågren, have kindly provided their views on industrial energy management and electrical energy monitoring[41]. The description of relevant items given in this section is based on the consultants' experience and aspirations that arrive from their numerous projects implemented with industrial customers.

5.3.2.1 Industries and Energy Management

Industries do approach the electrical energy issue from both ends: cost oriented and conservation oriented. The cost oriented approach in a large company would result in a centralised purchasing contract. Interaction of an industrial facility with the energy supplier will cover loads and consumption profile in order to keep the balance[42].

Gunnar Nordberg stressed that there is a lack of energy management in Sweden. A lot of employees are dealing with energy issues as such but rather on the maintenance side than management. There is a lot of space for improvement, he stated. Mr. Nordberg believes that "*the potential for energy conservation is much larger than we understand*", not least with electrical energy. Electric power is historically perceived as a cheap and always available resource in Sweden. Moreover, industries looked at electricity as a media servicing and maintaining the main business. This has resulted in having managers responsible for all infrastructure, utilities or real estate to deal with electrical energy. Such managers focus on full demand delivery and reliability of the supply and electrical system. Looking into energy efficiency is not a part of their job description.

Mr. Nordberg noted that it is possible to make a rough estimate of energy distribution within a plant even with the data available before metering solutions are in place. There are cases when the part perceived to be minor energy consuming turns out to 'eat up' not less than 60%. As well, auxiliary processes may consume as much as a core production process.

The project manager believes it is important to have one person overall in charge of the energy situation at the industrial plant. This will ensure that energy accounting fits into the information system (both the energy management information system and the business information system).

[41] Personal communication. Interview held on 16 August 2007.

[42] Balance providing responsibility is meant.

5.3.2.2 Target-setting

An interesting observation was made by the project manager. Environmental awareness developed rapidly in Sweden and environmental management spread widely with support received from companies' senior management. For some industries this resulted in viewing energy consumption as a significant environmental aspect. This didn't mean though that targeting became efficient. On the contrary, targets set within environmental management system tend to look low compared to available potential. These targets rarely have substantiation. Rather willing to be on the safe side, environmental managers would be satisfied with 1-3% of energy consumption reduction per year. This will likely remain even if an energy auditor identifies energy saving opportunities that can bring about a 25% reduction.

Instead of looking into maximising energy savings, industrial companies shift their attention towards purchasing green electricity. Most often it is done purely for image and trademark purposes and creates no incentive at all to work with conservation. The costs don't get smaller as they continue paying twice: for purchasing the "green" electricity and for electricity certificates. This still looks as a fair deal to them, for shareholders, consumers, and society in general will approve such a move.

5.3.2.3 Levels of Monitoring

Answering management related questions precedes the monitoring solution. Mr. Nordberg referred to such questions as, 'What data do we need, and why?'; 'How can we use it, and when?'. There is more of a management aspect in these questions than a metering one. Once the answers are found, it is not hard to motivate the required level of metering solution. Technically, there are no real limitations to metering, as it is seen to SWECOEnergiude.

The energy consultant's approach to a monitoring solution starts with a machinery inventory and the overall plant meter. This is the most common situation for industrial plants that invite energy consultants. Identification of the largest consumers and building up an energy distribution tree is the basis for further investigations. The ideal case for metering solution according to Mr. Nordberg is to have electrical energy meters for each production unit, further on for each production line, and further on down to individual metering of a large pump or a motor. This implies four sub-metering levels, namely:

plant – production unit – production line – machine

Data from monitoring helps find out problems, improve controls, and is vital for identifying new energy optimisation solutions.

The development may take gradual pace. Every time the next level is approached it is the largest consuming parts that are in focus.

Automatic reading seems the only viable solution for Swedish industries in the future. This is particularly valid for the new metering systems installed. Frequent data is very valuable. Readings at a frequency of every 5 seconds are desirable. Manual readings can suit weekly, maximum daily, records. This implies personnel involvement. A lot more is gained with frequent reading and automatic generation of user-friendly reports. Frequent reading is a prerequisite of work with energy conservation. An additional benefit of automatic reading relates to possibility to enhance the control feedback loop.

The requirement for frequency of readings would differ depending on the actors concerned. The overall plant meter read by the DSO provides hourly readings. This is what is required and is sufficient for the grid actors and reporting.

It is preferred to have separate metering for different energy sources, though it is possible to have integrated or combined meters with electricity being one of measured components. Electrical energy meters for on-site monitoring do not require the highest precision. Only the billing meter owned by DSO and used for reporting requires rather high precision.

The more valuable information at the production site is seeing the trends. There are technical solutions available for that. Moreover, the electrical consumption figure on its own would not suffice. Other values, such as production, and perhaps some external factors can make a better use of energy data. Generally, power quality in the Swedish grid has never been a problem. Therefore energy consumption will be the most common figure to extract from the on-site monitoring system. Other parameters like the power factor will need to be considered only when a DSO faces excessive reactive power in the grid.

5.3.2.4 Obstacles to Detailed Electrical Energy Monitoring

There are essentially no organisational, technical or financial obstacles to establish more detailed metering with automatic reading and metering becoming cheaper.

Difficulties that may arise about establishing an electrical energy monitoring system are within the physical and organisational limits and their intersection. In order to fit well into the management system, the physical layout of the electrical network at the plant should follow the organisational set-up.

Functional metering of auxiliary (lighting, ventilation, compressed air) and core production systems electrical energy consumption may be complicated at old plants. Though when rebuilding or relaying electrical network this opportunity should be investigated.

5.3.2.5 Energy Supplier and Industrial Monitoring

Load management lies more within energy supplier's interests. Having a minor (insignificant) part cut off the electricity supply is a common solution applied. This however does not result in energy conservation. All it does is to help avoid peaks and extra payments as penalties for exceeding the plant's nominal connected load.

Apart from avoiding peak consumption, there may be other reasons why energy suppliers extend their interaction beyond just selling electricity. There is a need to keep balance in the grid and the energy supplier is one of contributors to that. On the other hand it may be a heritage from before 1996[43]. Before electricity market deregulation, the energy provider and distribution system operator used to be one organisation. This resulted in rather strong ties present until now with industrial customers.

Mrs. Ågren noted that it is a general situation when there is only one meter for the whole plant. Those who have more than one meter at the production facilities are rather an exception.

[43] The electricity market was regulated and ran only within Sweden.

5.3.2.6 Data Management and Use

It is of utmost importance to define before the metering solution is developed what data is required and what it is to be used for. The 'must' is to know how a plant is going to manage the recorded information.

There are a number of departments that become involved when monitoring is in place. Currently industries face a situation when the person who signs the electricity bill has no influence over the consumption level. The consultants underlined that the data should be made available to those who can change something and see the result of it.

5.3.3 Developer of Metering Solution

There are no ready made metering solutions available off-the-shelf for industrial companies. Honeywell and Siemens are the largest actors in automation and metering systems development. Unfortunately the information about Honeywell present in Sweden was discovered at a very late stage of the paper's progress. Therefore their experience is not reflected. It was not possible to get in contact with Siemens within the given period. Instead two leading developers of metering solutions for energy companies have been reached. Their market is currently primarily represented by distribution system operators. The solutions and equipment they develop is mainly for use by this actor of the electrical energy chain. The attempt to interview the two companies represented at the Swedish market has been made to learn from their experience and cast it to an industrial company situation. The following experts have expressed their views, though admitting that currently there are no industrial companies among their clients.

1. Ola Lindén, Key Account Manager. Enermet AB

2. Bo Forselen, Sales Manager; Electricity. Kamstrup-Senea AB

Ola Lindén has noted that some Swedish industries are getting closer to electricity trading. It is not much they can do about electricity price as such. The three largest producers dominate at the market and lead the price setting, according to his opinion. It is more important for industrial companies to have a secured price level. Hence they prefer to enter long-term contracts with power suppliers.

Bo Forselen indicated that it has always been important for Sweden to have sufficient power production. Nowadays it is more difficult to get permission for a new generation facility unless it produces energy from renewable sources. Environmental considerations rule in this case and it has been important for many years. Mr. Forselen is confident that the electricity demand in Sweden is growing. He observed that mostly it is the energy-intensive industries who are looking into their electrical energy consumption and try to optimise usage.

According to the Kamstrup manager, capacity shortage is an event familiar to Sweden during colder winter days when electricity consumption in the country is peaking. For these periods due to bottlenecks in the national electricity supply grids, energy suppliers (or SVK) are trying to convince larger industrial companies to suspend operation for agreed period and pay certain compensation for that. The Enermet manager believes that the main reason for an energy supplying company to be interested in helping industrial companies to monitor their consumption is to achieve a more even consumption curve and press down the peak consumption. Peak levels will put pressure on investing into new capacity or in the net. Therefore, the longer the existing capacities can run, the better 'economy' the energy supplier will experience.

Although it is an impression of the Enermet manager that industrial manufacturers don't practice monitoring of the usage of electricity by their equipment, he finds it a useful function to see a trend in electrical consumption at the plant. This should help to prevent exceeding the load by employed equipment. Load measurement is critical for the DSO as well. They have a responsibility for a certain area and in the cases when the load exceeds contracted levels, penalties are inevitable. Otherwise, a demand response needs to be employed in order to maintain an area supply. It is the DSO who is responsible for power quality in the grid and measuring reactive power. The meters owned by the DSO are of high precision and measure various electrical power parameters including active and reactive power. The ones interfacing with industrial plants have a four-quadrant design allowing for both input and output metering. The power factor is more important for the DSO as the actor responsible for demanded quality of power. However the energy supplier is responsible for this at the corresponding grid level. Some larger industrial sites are fed with electricity directly from the energy supplier's net.

Usage of electric appliances may also cause disturbances affecting the net. Disturbances are caused by poor design of devices and should be questioned before they get connected. The Kamstrup manager notes that disturbance is rather an electric noise and is not related to a poor power factor. As for the power factor shaped by the phase or angle of different currents, he reflected that the closer to the source of reactive power it is corrected, the better. Mr. Forselen considers that it is more interesting for a power supplier to have a closer dialogue with an industrial company. The DSO is very much regulated for that and is concerned with fulfilment of its responsibilities. The energy provider instead is closer to the market and is willing to balance the power purchased for its customers.

The Kamstrup manager sees that the meter reading in the electricity supply field is strongly heading towards complete automation[44]. The reading system becomes more sophisticated and driven towards real-time data processing. There is likeliness to have an interesting development about data availability and managing electricity data collected on an hourly (or even more frequent) basis. There are chances that price-scheduling will appear more time-differentiated compared to the earlier night/day set-up through access to more accurate information. It will certainly require fast feedback between DSO and customer.

Regarding the cost of metering solution the following was noted by Enermet manager: the price of hardware and communication was decreasing whereas installation costs associated with it have been rising. Meters are getting more and more functions in one unit. If, in earlier days, communication with a meter required a terminal for data collection, nowadays it is possible to have a meter with a communication module inside. Another useful function being introduced nowadays is the breaker. This allows having a power supply to the meter and regulating the ON/OFF status of supply after the meter. The function as such has been requested by DSOs to be integrated within billing meters[45].

Mr. Forselen has pointed out the following items and the respective share of what they comprise in a price of metering solution: meter with communication (50%), installation (25%), monitoring system (user interface) (10%), infrastructure (5%), fine-tuning and project management (the rest). Among obstacles to electrical energy monitoring system he noted only the costs, mentioning that there are no technical impediments. For a plant as such it is

[44] This is especially stipulated by regulation in effect from July 1st, 2009.

[45] It is presumed to help in fighting bad payers. Instead of facial contact and certain complications associated with manual cut-off of power supply the tendency is to have it remotely controlled by the DSO.

important to ensure that the system is taken care of and that there is a person keen on running it and who is responsible.

6 Empirical Study

The empirical study has a qualitative character and is performed as a multiple case study. Due to confidentiality reasons the key to companies' titles and disclosure to certain sensitive information is not provided. Companies and persons referred to shall be marked with A, B, C, and D, and corresponding numbers attributed in the chronological sequence of held interviews.

All companies presented in empirical study run business on an international basis. They have production facilities in other countries worldwide. As well, they have a number of factories around Sweden. This is a common feature that makes the study itself more representative and interesting.

Some brief background information regarding the production sites in question shall be provided in each relevant section. The information given in this chapter has become available through the following sources: personal communication (interviews); printed material (brochures); and companies' home-pages. The interviews were carried out in a semi-structured way. The main reason for this is the unexplored level of the research question and the need to understand each company's key characteristics that influenced their electrical energy monitoring situation. The outline for the interview is provided in Appendix IV. The number of interviewees varied among the companies. This depended solely on the level of monitoring in place and local specialisation among functions.

6.1 First Company (A)

Company A is a company with long history, established in 1889. Nowadays it is owned by an international group with various production activities worldwide. The investigated production site in Sweden is manufacturing high-speed steel thread-cutting tools of the range 0.4 – 25.0 mm. The product range includes drills, threading taps, milling cutters, countersinks and reamers.

Worldwide turnover in 2006 was 72.3 BSEK generated by 42 000 employees. The Swedish tools production division contributed with 22.5 BSEK with the efforts of 15 000 employees. The company is listed on the Stockholm Stock Exchange.

The company has competitors worldwide, however not in Sweden. The organisational structure of operations is matrix.

Four interviews have been held at this production site. They are further mentioned in the text with the relevant numbers that should be considered substitutes to the names (in the chronological sequence of interviews):

A1: Production Manager (the investigated production unit);

A2: Industrial Maintenance Engineer (the investigated production unit);

A3: Quality and Environmental Manager (the investigated production unit);

A4: Financial Manager (the investigated production unit);

A5: Category Manager (corporate level). *Inter alia* responsible for electricity purchasing.

Two out of four interviewees have commented on the good profit margin in both worldwide and local operations. For all interviewees electricity is an important resource that gained more attention within the company during recent years. The financial manager regards it as a complex area (especially nowadays). This has been reflected by corporate response and assigning specialists to work with centralised electricity contracting.

6.1.1 Production Site

The investigated production site manufactures steel thread-cutting tools for several brands within the group. Human resources consist of 140 employees of which 125 are blue collar. The site consists of three production sections. Each section has a number of flow groups. Each group is responsible for planning production and setting targets.

Manufacturing is structured by the three main areas. The process is performed by various equipment, i.e.: cross-cut grinding machines; vacuum ovens (hardening); grinding of shanks; intermediate (blank) stock; sorting and transportation; final manufacturing (flute-, thread-, and chamfer grinding); neutral stock; final finishing: washing, laser marking, surface coating, rust proofing; packaging. Besides production equipment there are auxiliary components like compressors, and oil pumps (oil is constantly used for cooling during tools manufacturing).

The only source of energy at the plant is electrical energy. Energy issues have gained particular attention since one year ago. The two main reasons for that are: environmental concerns and the cost aspect. Nevertheless, energy has been looked into for a number of years by now. This is mainly attributed to the EMS and management review within the plan-do-check-act cycle.

Joint discussion and consultation with local network operators has taken place along with measuring electrical energy consumption. Considerable idle (beyond operation hours) electrical energy consumption has been discovered[46]. Currently the dialogue continues and energy saving opportunities are being looked into.

6.1.2 Reporting and Management

The plant is certified both under ISO: 9001 and 14001 since 1992 and 2003 correspondingly[47]. The quality management system has lead to the "Lean Production" philosophy spread over the plants. By considering energy as one of major environmental aspects, the Environmental Management System has lead to recognition of energy consumption. Energy consumption, direct and indirect emissions of CO_2, costs and indicators are reported internally within the Group in order to be further incorporated in the Group Annual Report. 'More efficient use of energy' was included in environmental objectives only in May 2006.

Plant A had been considering electrical energy as a part of the Environmental Management System before. Targeting for reduction in energy consumption had been in place since start up of the EMS (2003). This resulted in developing overall goals. The production site goals are within the corporate goal. Consequently targets had been set. The energy saving targets are set at the corporate level down to the plant level. The Tooling Division Manager of the matrix organisation would fix it after consultations with each specific site. In 2006, there was 2% reduction in volume of electricity consumed compared to 2005. The current target is a 1% reduction compared to 2006.

[46] Personal communication with Production Manager (A1). Interview held on 25 June 2007.

[47] Personal communication with Quality and Environmental manager (A3). Interview held on 26 June 2007.

Energy related performance is currently followed for a three-year period on a quarterly basis: quarterly for 2006, annual 2006, annual (Q1-4)2005, annual (Q1-4)2004. The following performance indicators are looked into within the company reporting, however only internally at this stage:

- Total electricity consumed (MWh per annum or quarter);
- Electricity per unit added value (MWh per SEK);
- Electricity per unit invoicing (MWh per SEK).

There are two persons on-site responsible for energy (electricity) reporting. Namely: Production manager (A1) and Quality and Environmental Manager (A3). Internal reporting requires CO_2 emissions calculated in the case that electricity is generated on-site. The questioned site does not generate any electricity nor does it use other energy carriers; therefore CO_2 emissions are not reported. Actual annual electricity consumption decreased by 2.5% in 2005 and by 3.7% in 2006. This is believed to have been achieved by rising awareness and energy-saving lighting installations.

A recent environmental investment took place in the oil department of the plant A, where substantial volumes of oily wastewater are generated. When making the investment decision, the energy consumption issue was one of the most important. The distillation installation for oil and water separation is an environmental improvement that will contribute to resource savings.

Energy issues represent a part of environmental reporting to the Board meeting. Environmental and energy saving investment shall be included into the special report on quality and environmental issues and reported by the Quality and Environmental Manager. Review within the EMS takes place three times per year.

Electricity consumption related data is not used for benchmarking, however there are plans to have such comparison with another similar plant in Sweden (within the corporation). The group annual report for 2006 contained the group electricity consumption in relation to production volume. GRI indicators for energy EN3 and EN4 are also calculated. Of them the latter is for electricity consumption as indirect energy. Direct and indirect CO_2 emissions are reported globally with EN16.

6.1.3 Technical Set-up of Existing EEMS

The only device actually used at the site for electrical energy monitoring purposes is the so-called "billing" meter. This is the one owned by the Distribution System Operator (DSO), read by them and reported to the company A and the corporate Electricity Provider for further invoicing. Electricity consumption is followed on a monthly basis, in total for the plant. The invoice is thoroughly looked through as well a monthly cut through year based on the first invoice of a year.[48]

The production facility has six transformers on-site. Each transformer is equipped with a meter owned and read by the DSO. Company A does not log readings. The data is available but not used. The level of electric current (A) can be seen on every machine. This value is not

[48] Personal communication with production manager A1. Interview held on 25 June 2007.

really used. The power factor (or reactive power to be more precise) is measured by the DSO. In the cases when the plant exceeds the agreed level of reactive power the DSO will invoice an additional charge. In cases of concern, the DSO shall enquire for the reasons in order to remove excessive reactive power return into grid. This will be known rather quickly. Telephone enquiry and discussion with the Maintenance Engineer shall be a normal practice.

As mentioned in 6.1.1, the plant co-operates with a local network operator regarding measuring electricity consumption. One monitoring session was held in February – March 2006. Discussion on energy issues is taking place, but slowly. Company A fully relies on the expertise of the local network operator. There is a clear wish to have a better knowledge and better control.

Power quality is not a concern for the plant A. The Production Manager is confident about stability of power quality and reliability of power supply. Therefore only demand (peak demand) and total consumption are figures of significance for managers.

Load management is not taking place at the site. The maximum demand (paid within the certificate) is never (currently) reached. A2 believes that monitoring of electricity consumption on a continuous basis is needed to see the trend and regulate the load based on that. The connected load can be cut by 100 – 200 kW (of 2000 kW total active power).

6.1.4 Electrical Energy Cost and its Allocation

Company A's production site is not energy intensive. Electricity costs comprise approximately 3% of production costs. Energy consumption figures participate in the plant's budgeting. This is done at the production unit (site) level annually with monthly cut depending on the anticipated production volumes. Electricity costs are known as a lump-sum from one bill. It is not considered as a direct production cost. All electricity costs are allocated as overhead items based on the allocation key. Machine hours (operating hours) serve as the allocation key for energy.

The costs are reviewed and managed along with real estate costs. Eventually the electricity cost component is allocated to production site along with other Costs of Goods Sold (CoGS). The Production Unit is considered as one cost centre. Inside it consists of Direct Cost Centres (DCC). The overheads (including electricity costs) are allocated among these DCCs with the allocation key.

The Financial Manager is satisfied with the existing system. A4 does not see a need to better division of electricity costs within the production site based on more detailed monitoring. Participation of electricity costs at a DCCs level in addition to the existing internal costs distribution is considered superfluous. It may provide better information however A4 is not sure if an effect will be good.

Production at the site is rather homogeneous. Therefore there is no need to see a better allocation of energy costs per product. The average electricity costs part is sufficient as it makes up 3% of a unit's production costs. Total annual electricity consumption for 2006 is slightly above 8000 MWh. Currently annual electricity costs make up around 5 MSEK.

The electricity bill used to be two in one before central electricity purchase was introduced at the corporate level. The electricity bill is received simultaneously by both Production Manager and Financial Manager. Each will be concerned with the part that is relevant for them: Production – with physical values; Financial – with cost values. Clarifications may be required by both. The Production Manager (or Maintenance Engineer) serves as a contact person between the energy supplier and Financial Manager. Should there be no questions, no clarification would follow and bill will be paid as a regular activity.

A4 and A5 admit that costs for electricity have been changing substantially during the last year. This is mainly attributed to the price components. Electricity price depends on various factors. Of them, the most volatile is emissions trading part, namely market price of allowance for emission of 1 tonne of CO_2. At the corporate level energy supply is thought of as politically unstable. The Lean Production approach is called "to minimise the use of energy throughout the supply chain"[49].

6.1.5 Actions Towards Electrical Energy Management

A number of first-things-to-do activities have been implemented. Replacing all lighting to an energy saving standard was one of them.

The decision to change the electrical power provider at the corporate level has been taken for all Swedish plants. Since April 2007 all divisions have shifted towards a centrally managed electricity purchase contract. This is one of the steps aimed at reduction of electricity costs. Due to substantial volumes of electricity consumption (1TWh annually in the whole of Sweden) the contract is negotiated centrally for all divisions.

Most of the interviewees (A1-A4) agree that before energy saving activities are implemented some monitoring of electricity consumption should be in place. A1 and A2 are not satisfied with the current level of metering. A more detailed electricity consumption lay out will be of interest. Initial consideration has been given to the departmental split up (for example; blank production, oil house, hardening ovens) and the ability to see per shift consumption figures.

A1 and A2 do not foresee any obstacles for detailed monitoring – neither technical nor financial. However, the Production Manager considers the financial side to become an issue when a certain point is reached and further investments can not be justified. This point is now far from being reached though. It is farther in the time-scale.

A2 would like to launch monitoring at the transformers level in order to start with managing electricity consumption of bigger units. They are the ones to bring about larger saving opportunities. Monitor with graphical information is of high importance. Physical values such as kW and kWh are deemed sufficient. A2 is convinced that since every employee is paying for electricity consumption at home, these values "speak" in money terms straight away.[50]

Preventive maintenance is undertaken on a regular basis. This does not seem to be influenced much by improved electricity monitoring. However A2 would consider it helpful to see motors' electricity consumption.

When looking at potential costs that will be associated with additional monitoring equipment, A2 would not see much difference with the required maintenance level. Maintenance Engineer has stressed reliability of today's systems for logging, reading, collecting and analysing data.

[49] E-mail correspondence with A5. 10 July 2007.

[50] Personal communication with Industrial Maintenance Engineer, A2. Interview held on 25 June 2007.

The behavioural aspect of energy related issues has been stressed by both A1 and A2. Awareness raising activities and reminders about everyday good housekeeping practices (switching off the lights when not needed, switching off a machine, etc.) bring immediate results but these do not continue on a long-term basis. Therefore the monitoring system should have a visual outcome – available to all employees and easily understandable. This will, as A2 believes, make it manageable.

The monitoring activity shall, as well, serve a benchmarking purpose. First of all to compare with other plants, secondly to the machines inside production. Electricity has benefits when compared with other media or energy sources.

The cost of a monitoring system is not known to A1-A4. The scale and detalisation is not yet understood and/or decided. A2 is sure of very fast pay back. A3 is confident that there will be no financial constraints provided the installation is feasible. From the technical point of view, the Quality and Environmental Manager foresees only the software incompatibility issue to be a concern. There are no organisational concerns regarding staff capability and availability even if manual monitoring is in place as a start-up.

Substantial hope is connected to the co-operation launched with the DSO. Company A would rather see this as an extension of the DSO's service. They believe that energy saving services is of interest for the DSO, since they are keen on keeping Company A satisfied with their long-term contractual relations. These services will enlarge the role of DSO from an electricity delivery company to a long-term partner. There is already trust with the DSO, since their role in electricity transmission is rather passive and they are not the ones who sell the physical electricity. Neither do they generate it.

6.2 Second Company (B)

Company B is another investigated company with a long history that dates back to 1883. This is as well a global manufacturer whose shares are traded on the Stockholm Stock Exchange. Equipment, systems and services are intended to optimise operations of producing customers. The range of products starts with heat exchangers (48%), separators (31%), valves, pumps, and other fluid handling equipment. Equipment manufactured by company B is environmentally oriented and serves filtration and separation purposes[51]. Historically, the organisation was oriented on the three key technologies, namely: separation, heat transfer and fluid handling.

The company's turnover has substantially grown during last couple of years and in 2006 it comprised 2.5 BEuro. Almost 10 thousand employees contributed to it worldwide. Across the world there are 20 production facilities. Turnover consists of products and solutions sales and aftermarket sales. The former makes 77% and the latter 23% including parts and services.

Since 1998 the company passed through substantial restructuring with centralisation of many functions. Electricity costs are becoming more and more tangible. In the earlier days, a company would pay around 15 MSEK per year, whereas currently this cost item requires 25-30 MSEK annually, nearly double. Energy costs are still somewhere in the minor end compared to other production costs items for company B.

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[51] "Optimising the use of natural resources is our business…The company makes significant contribution to reducing environmental impact of industrial processes", states Company B's homepage.

Four specialists have been interviewed at the production site. Some of them have not only local but also regional responsibilities.

B1: Electrical Manager; Operations Development

B2: Group Category Manager; Indirect Procurement

B3: Financial Controller; Finance&Support, Consolidation and controlling

B4: Environmental Manager; Member of the Corporate Environmental Council.

"Six sigma" is the overall management concept applied throughout the company. This programme has been implemented in line with quality management.

6.2.1 Production Site

The investigated plant is 30 year old. 450 blue-collar workers are working on-site manufacturing heat exchangers. Production is order-based and the complete order is performed at the site. It starts with pressing the plates for heat exchangers, further treatment and assembly. Press machines are the most energy consuming equipment units.

The heat exchangers production line consists of phases. Some parts of production are fully automated (e.g. pressing of heat exchanger plates). Some parts, like assembly, remain manual. Annual electricity consumption of the site is around 27 000 MWh. At some point in 2006 electricity consumption was measured during the night when the production line was off. Substantial electricity was still consumed. The team involved concluded that must have been lighting required for the large production site area (around 40 000 m^2). Some light oriented activities have been undertaken. Task lighting was introduced. No measurement was repeated afterwards.

6.2.2 Reporting and Management

The site under investigation has only recently (in 2006) been certified under ISO: 14001.

Electrical Manager B1 is responsible for the electrical part of the plant and the electric design of the production equipment. He has seven electricity specialists to perform maintenance of the electric parts of machinery. Additionally, three to four specialists are outsourced to perform special tasks within the electrical maintenance team.

No specific energy conservation or monitoring improvement activities are expected at this site. If that is going to be the case, each activity shall be treated as an individual project with budget and pay-back consideration. The Electrical Manager is the person responsible for project preparation and proposal to the management level. A project would compete for financing with other internal investments. Should the pay-back period exceed 2 years, it is not likely that energy saving project will have "go" verdict.

Environmental concerns are growing both inside and outside the company. This contributes to the urge of inclusion of energy related indicators into corporate reporting. Moreover it pushes towards the purchase of green electricity. B2 commented that "*having green energy certificates on the electricity bill is not enough*".[52] The company is going towards demanding that all

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[52] Personal communication with Group Category Manager. Interview held on 04 July 2007.

electricity purchased should be generated in a 'green' way. This is expected to be well received by investors who tend to more and more appreciate environmental actions by the companies whose shares are traded at the stock exchange.

On the other hand, energy consumption by the company is not a crucial factor when it comes to end customers. It is the quality of product and its price that is important, however, not the energy efficiency or amount of energy consumed during production. The fact that company B's products are used in the environmental area and as pollution abatement equipment does not put any focus on how the product itself was manufactured.

Environmental management is very young at this site. This does not completely exclude resource management. The company is practicing "Six sigma" as a quality and resource management programme. This programme is an umbrella for a number of process optimisation projects, as well as environmental projects. "Six sigma" forms a part of the current environmental management system.

6.2.3 Technical Set-up of Existing EEMS

This production site has been co-operating with their energy provider. A dedicated load and consumption monitoring system was installed over a year ago. It has been offered by the Energy Provider as additional service (beyond the electricity contract). In principle, each building at the site can be separately measured. These data are not used separately though. Currently all electricity consumption is summed up. There are numerous transformers on-site (around a dozen). They serve for voltage reduction from 10 000 V delivered by the grid to operational 400 V. Some of the transformers are connected directly to single machinery units, some to the number of equipment units. Generally, transformers supply power to either a bigger machine (e.g. press), or production line.

Monitoring of electricity consumption (kWh) and load (kW) per each transformer is taking place. The Electrical Manager has an output at his office computer. B1 is responsible for the electrical part of the plant and the electric design of the production equipment. Load management is taking place. It is considered rather important to set the level of peak consumption rather low and maintain it. This will help avoiding excessive load penalties.

All equipment operation is automatically regulated. For instance, motors in the production line switch off after 15 minutes of idle status. This has been possible with the load management system and software.

The Electrical Manager can see a graphical output of the collected electrical data. The graph shows load and consumption on hourly basis, and total consumption accumulated per month. Peak load values are spread over each hour. B1 is not fully satisfied with the data set. He would find useful a peak load per second. This will clearly show the peak created by press machines. They have the highest instant load compared with other machinery units. Knowing this detail will allow more precise and correct choice of transformers serving the press line. Currently it is not possible to see if existing transformers are the right dimension for press line or they are oversized.

The plant is expecting capacity growth and recently a new power inlet station has been installed. This was also necessary to enlarge plant's capability of handling larger electricity volumes. The inlet station as well serves higher security of electricity delivery. It has a built in logging of load (kW), electric current (A), and voltage (V).

For a better view of the electric part of the production line, the Electrical Manager would like to have electricity data logged for each piece of machinery[53].

6.2.4 Experimental Work at Another Production Site

It is useful to describe activities that are taking place at another production site of the company. This is considered relevant since company B keeps a policy of implementing and testing a project at one plant and further disseminating the best experience to other production facilities. An Italian production site of company B has been the first to obtain certification under ISO: 14001.[54] This stipulated a leading role of the plant in environmental management and leadership among other production sites of company B. This site will eventually serve as internal consultant, sharing the best practice with other production facilities worldwide.

The energy measurement project was started at the Italian production site in 2006. Installation of metering equipment took place only in June 2007. Electrical energy is a part along with other energy sources. Use of electricity is regarded as a significant but indirect impact. It is accounted for by primary sources.

15 energy meters are currently installed and in operation in two production buildings out of five. The current monitoring level makes it at least one meter per large machine unit or per production line. A number of organisational functions have their roles in the project implementation: *operational department* (technical set-up of the system); *financial and business control* (to follow the split of energy costs in each area of the organisation; *environmental manager* (overall co-ordination and environmental reporting). These divisions contribute as a part of the project team. Each represents a project stakeholder and would like to benefit and the most out of the measurement system. Logged data is supposed to be used by each of these functions on a regular basis.

This production site is looking forward to a better picture of energy usage by the facilities. Electrical energy consumption data shall be delivered to a "shared service" who is responsible for electricity contracting. It is expected that a better contract can be negotiated with clear identification of how the load and consumption is spread over the day and month and how that relates to accompanying factors. The targets for the Measurement Equipment System (the title the project received inside the company) are:

- to measure efficiency of each equipment unit;
- to see which unit causes the biggest load, when and why;
- to follow up individual investments by more detailed knowledge of energy savings.

The following parameters are in focus for the electrical energy side instantaneously: ***consumption*** (kWh) by unit and ***cosΘ*** (power factor). The Environmental Manager is not sure if having instantaneous measurement and presentation of data is significant. B4 confirms that for analysis and decision making, hourly and daily figures are more important.

[53] Personal communication with B1. Interview held on 18 June 2007.

[54] Current section is solely based on the personal communication with B4. Interviews held on 23-24 July 2007.

It is not easy according to the Environmental Manager to have some intermediate metering solution. The system is the best when it is (or designed to be) very detailed from the beginning. The best picture can be obtained for all purposes with measuring all that is consumed by (major) equipment units. It is important to see fractions of the overall consumption and individual trends. Before an optimisation solution is developed, a clear understanding of performance is vital. When extra consumption occurs, the cause and circumstances must be identified.

The site has been involved in the project implementation for 1 year up to this point. Not everything was easy on the way of project development. The Environmental Manager could describe the complex points that arose during preparation and implementation of the measurement system project.

Financial Implications

Cost is always an obstacle. The only way to overcome this is to strongly motivate the need for the monitoring system. It was critical to explain what should be measured and why. The optimisation potential would depend on having consumption figures available.

Regarding coinciding of the cost and savings “centre” - in the case of this plant it was consistent. The Operations department incurred the costs and is a savings generator at present.

Knowledge Improvement

The project initiation forced looking into existing measurement techniques. There was a lack of knowledge which created this obstacle. This is rather mentioned in connection with all kinds of energy measurements and not only electrical. By looking thoroughly into available measuring equipment and technologies knowledge on this subject was created in the company.

Another aspect related to knowledge is linked to environmental management. The previously formulated Environmental Policy and existing EMS were based on rough knowledge. More reliable energy data collection will contribute to a better understanding of the company’s aspects and more precise environmental policy and responsibilities. All this will make possible implementation of common corporate environmental management. This issue receives more and more attention due to interest from stock exchange analysts.

Project Ownership and Stakeholder Involvement

It was not clear in the beginning about measurement system ownership. It was necessary to decide inside the organisation whom shall own, lead, and continue the process. Project ownership was placed with Environmental Department. The “shared service” responsible for real estate and utilities are the stakeholders within the project. They are involved in all decisions around the system implementation and further data analysis.

The efforts undertaken at this site are stipulated by two main reasons: market pressure for better resource management and commitment of the top management. B4 believes that top-management involvement is crucial to go through and implement the improvement strategy.

6.2.5 Electrical Energy Cost and Its Allocation

Interviewees B1-B3 have commented that until now electricity has been considered a cheap resource in Sweden (and at the plant level). Company B has only during recent years turned its attention towards electricity costs reduction. On the way to have electricity costs more manageable the decision was made to centralise the electricity purchase. The company even started trading itself in order to have a better overview of the electricity market.

At the corporate level there is one dedicated person dealing centrally with electricity purchasing (along with other indirect procurement items). The most recent step was to change electricity providers (also a broker at the Nord Pool) and rely on their experience and previous successful operation on the electricity market[55]. Before the following semester of a year begins, all the lots (15 per year; 5 per semester) are fixed through the broker. 100% of the anticipated volume fixed is the basic case for the company. When the prices are on a sliding side, the Purchase Manager may decide to leave around 10% of the electricity to be purchased at the spot price directly from the market.

The Electrical Manager does not receive any cost information in connection with electrical consumption. Bills for electricity are delivered directly to Financial Department and get paid as a regular practice. Should substantial deviation from other periods' invoiced amounts occur, clarification will follow[56]. There is one dedicated Financial Controller to take care of the electricity bills (performing both control and pay function).

The decision to implement energy saving activities is considered on an (individual) project basis. The above described peak-load avoidance software resulted in 1.5 year payback. This was commented as too long by B2. He expressed management concern about shareholders and investors who press the company to be profitable. This according to him is the reason why internally decisions are taken heavily if payback exceeds 1.5 years. The Financial Controller, B3, specifies a period of 2-4 years as a satisfactory payback.

In the accounting system, electricity is a part of overheads. Office space together with production space is regarded as one cost centre. It goes without saying that major electricity consumption is with the production site. Electricity costs have a special account. Further on the costs get combined with other utility costs (such as water, heating, etc.). This turns out as a lump sum that gets allocated according to the allocation key. The number of square meters of production area will serve as a basis for allocation.

B3 shared that there was an attempt to implement Activity-Based-Costing. This did not bring success and was abandoned.

Knowing electricity costs down to each production line is deemed sufficient to be able to make use of it. The cost of the monitoring system as such does not seem an obstacle for implementation. The issue of who is responsible for such an investment that serves as a tool is of a more political nature within company B. The benefit shall be spread over the whole organisation and primarily will stay with the production site. Cost responsibility is attributed to Real estate unit. The internal question that remains unanswered - who should bear the costs of such an investment.

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[55] Personal communication with B2. Interview held on 04 July 2007.

[56] Personal communication with B3. Interview held on 12 July 2007.

6.3 Third Company (C)

Company C is in the business of developing processing and packaging solutions. There are a number of sites manufacturing food packaging. The company operates worldwide. Net sales in 2006 reached 8.5 BEuro. (Company C in the world 2006[57]).

Energy issues are considered at different levels. Energy is taken into account both when developing food processing solutions (equipment) and inside production. Current research is based on the experience of a dedicated department established by the mother company C. Since 1999 the department is responsible for energy supply and energy management of daughter companies whose production sites are located in Lund. Only one interview has been held with the Manager of the department. Its specific function is with energy and engineering infrastructure like utilities (water, sewage, gas, electricity, fuel etc.).

The company's home page provides a very good indication of different energy sources utilised in production. It is stated that electricity forms the main source of energy and accounts for 78%. Energy efficiency has improved by 6.6% in 2006 (measured per unit of produced package). Improvements in heating, cooling and ventilation system, reduction in wastes and more efficient utilisation of product machines are named among the reasons for this achievement.

29 production sites have undergone energy saving audits since 2001. This fact clearly indicates the issue being on the agenda for 7 years by now. The company has initiated energy management under internal environmental pressure. Electricity monitoring was likewise stipulated by environmental goals. It is only recently that this became a part of financial pressure. Electricity market deregulation along with the complex price structure and emission trading brought the company to view energy consumption both as the price component and as an environmental concern.

Energy use is one of the three priorities given within environmental sustainability (see the Environmental and Social Report for 2005). The energy efficiency goal to achieve a 15% reduction in 2005 compared to 2002 is said to have had been accomplished. The World Class Manufacturing programme is playing an important role as the tool driving the company's environmental performance. This framework programme has been in place for a number of years but is rather recent compared with the environmental management system. Best practices in various fields are disseminated throughout the daughter companies.

6.3.1 Production Site

As mentioned above in the case of company C no individual production site has been explored. The information obtained in the only held interview with the Technical Manager (Department for Energy and Engineering Infrastructure) is generalised and will give an average picture of how is electricity monitored at Swedish sites without specifying a facility[58].

Six daughter companies operate a number of production sites. The facilities occupy approximately 80,000 square meters for production of packaging material and assembly of filling machinery. Besides the production sites there is also a research and development site. Total number of employees in the group of plant on site is 3500 including mother company personnel. Of them, approximately 3200 work on the production sites of daughter companies.

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[57] Facts & figures based on company C's homepage. Figures as of March 2007.

[58] Personal communication with C1. Interview held on 09 July 2007.

6.3.2 Reporting and Management

The Technical Manager is working with energy issues both on the local and international scale. Company C is on the way to developing a global approach to dealing with energy including electricity purchasing. An energy network is being established among the countries/regions with the most mature energy market. This means more attention is placed with the source of energy[59]. Swedish production facilities have been ahead of other parts of the company worldwide[60]. Energy is reflected in the environmental policy.

The energy department belongs to the mother company and has a responsibility for purchasing electrical (and other) energy for the production sites. Further on accounts are settled by daughter companies with this department. It means invoices are issued by the mother company to daughter companies. Energy monitoring is performed by the department and collected data is reported to daughter companies.

Daughter companies in their turn report their energy efficiency results to the mother company. Information is available on-line (intranet). Energy related indicators are monitored on a corporate level through consolidation from different production sites. There are targets set for energy consumption at each daughter company level. Each plant would set their own target which can be different from the corporate target. Some targets may just follow the corporate lead.

The department employs 13 technicians. They are responsible for all utility installations at the facility (excluding maintenance of production machinery). Four of them are electricians, others are working with other energy equipment. Cooling, heating, and compressed air installations are closely linked to electricity consumption at the facilities. Energy issues are tackled in interconnection among different energy sources. Energy management is strongly represented as a function but it is not standardised as PFE requirements.

Not only energy itself has gained focus. One of the related energy issues globally is CO_2 (green house gas) emissions. For instance, the company reported a 4% reduction in CO_2 emissions in 2006. Currently the green house gas issue has turned out to be the most important energy related aspect. Company C has launched an emission reduction programme for carbon dioxide generated from energy use. The adopted target is considered rather tough. It presumes 10% reduction by production plants worldwide by 2010 in absolute terms. This should not be interfered with by increased production volumes. C1 mentioned that the corporate goals serve a very good incentive for production sites to manage their energy usage and look for improvements.

Each production facility is calculating the amount of carbon dioxide emitted indirectly and directly in connection with different energy sources (electricity, natural gas, district heating, fuel, etc.). Worldwide there are different coefficients applied for calculation by the mother company. Sweden has one of the lowest conversion factors since over 90% of electricity is generated with no green house gas emissions.

Electrical energy consumption is budgeted by the Energy Department in order to secure the total amount to be consumed and purchased. To achieve higher accuracy, statistics from previous years, natural conditions forecasts, and production by the sites are consulted. The energy provider (who is trading at Nord Pool) is consulted for electricity prices forecast.

[59] The tendency is to purchase gradually more and more electricity generated from renewable sources.

[60] This is thanks to considerable volumes of electricity generated from renewable sources.

Experience and data collected through the monitoring system as well as weather conditions serve well for planning and budgeting.

The current interface of the system is not very user-oriented and is rather technical. Improvement in visual presentation is planned. Basic graphs delivered to the Technical Manager's PC show actual consumption figures per month, and accumulated consumption. It is possible to check the current level against the previous month, or the same period in the previous year. Nowadays the reports are sent out to the daughter companies every month. The reports contain packages of various graphs generated through the monitoring system. The content depends on each plant. It is generated the way they specify. Further upgrade of the system will add a function of broader availability of consumption figures. The Department Manager plans for web-based system with access to the company staff secured with a log-in.

The main users of the data recorded by monitoring system are the Department staff, production managers, environmental co-ordinators and technicians on the site.

It is expected that electricity prices will continue to slowly rise. The last budgeting year however was unprecedented. Electricity prices development due to market immaturity and no experience about emissions allowances trading led to substantial increasse in electricity prices in 2006. By the end of 1^{st} quarter 2007, the price, due to a lowered CO_2 allowance price, slid strongly downward. This resulted in an overestimation of electricity costs during 2007. For the following years the forecasts are going to be more conservative.

6.3.3 Technical Set-up of Existing EEMS

The current outlay of electrical energy monitoring started up with one plant. The first 50 energy meters were installed in connection with plants attempts for ISO:14001 certification. The plant required installation of meters in order to be able to set their environmental goals. Nowadays energy metering is more driven by cost consideration.

Despite initial consideration of load management, the company's Energy Department does not see much role for it nowadays. Load management is rather a regular machinery start-up routine activity. It does not impact electricity consumption as such, but only helps reduce the overload penalties. Perhaps, there is no more interest in load management since it was among the first steps in managing electricity consumption. At present, the load is as close to the purchased certificate level as possible.

There are more than 250 meters installed at the production sites and other facilities of the six daughter companies. It is the plant manager at each plant who decides whether more detailed metering is required. Some facilities are metered at a rather detailed level. A Sankey diagram is a useful tool to see the distribution of energy within facility. In some plants it helped visualising energy consumption. The results were unexpected for managers when electricity consumption for lighting and ventilation showed 50% of the total, indicating the area to work with. The Technical Manager's recommendation would be to have possibility to see the consumption by separate functions, e.g. lighting, ventilation, production, air compression, cooling.

Meters allow measuring consumption and the power factor and following power quality on site. Input of reactive power causes additional consumption in the local net. The power factor is the problem at sites and the Department is following and rectifying it.

The monitoring system is both process and alarm-oriented. An alarm would signal if consumption is reaching the peak level. This will be followed by questioning a respective production manager for clarification.

Automatic data collection has never been questioned by the Department. Thanks to this hourly information is available. The monitoring system utilises a serial communication technique. This allows two-way communication. Technicians can contact the meter and observe individual readings: current, reactive power, power factor.

The Department Manager admits a rather good level of monitoring electrical energy consumption. However, he is looking forward to improvements.

The monitoring system implemented at Lund plants is considered the 'best practice' among production factories. It is a part of disseminated practices at a corporate level.

6.3.4 Electrical Energy Cost and Its Allocation

Electricity costs at the production sites in Lund comprise 4 to 5 per cent of production costs. Energy improvement investments were undertaken to a certain extent prior to establishing electricity monitoring. While daughter companies were investing, the mother company as a whole enjoyed savings. It didn't drive the efficiency before daughter companies had an opportunity to see where and how investments are paying back. This defined further development towards clear connection between usage and costs falling into each daughter company's books.

The Technical Manager does not consider the electricity bill very informative. Firsty, this is because it reflects only general consumption figures. Secondly, the electricity price would be fixed before each quarter of a year. Having fixed electricity prices is the department's strategy these days. Earlier (a few years ago) the company has experienced having both spot and fixed prices at the same time. The split of the electricity purchase and distribution costs is approximately 70-75% to 25-30%. The former is invoiced by the electric power provider and the latter by local distribution system operator. Excessive load and high reactive power will be charged by the DSO as penalties.

Once received by mother company (Energy Department), the electricity bill is split among the daughter companies based on the monitoring data. Each company is invoiced by the Energy Department. Their respective financial units will take further actions regarding payment.

As far as the energy consumption is concerned, it is the production site manager who is responsible. Ultimately, the electricity costs are the responsibility of the daughter company's managing director. Likewise, each director is responsible for target suggestions (setting) and for reaching the goals.

Due to having a number of sites in the picture with company C it is not possible to say how companies allocate the electricity costs. It is presumed that the costs are regarded as indirect production costs. Cost allocation is taking place depending on how detailed the monitoring is and how good the knowledge by a daughter company within its production sites is. The tendency among daughter companies is to have electricity consumption figures as accurately as possible. Therefore services and expertise of the Energy department is well received.

The Department Manager is sure that each daughter company is interested in relating corresponding costs to different product. This will imply that each product is fully reflecting costs associated with its production. Such approach is very useful to avoid one product subsidising another.

Having the costs and savings (in relation to energy) on the same cost and profit centre is rather crucial. Even in those energy improvement projects when the mother company makes initial investment, further accounting is gradually putting each daughter company in charge of their part of the system. Experience shows rather high initial investment costs for such projects. This makes it prohibitive for a single site or company implementation.

On the other hand, some of the returns from energy investments can be intangible or slow to be observed. For instance, a ventilation system and smart lighting will sooner or later result in a better working environment. These improvements may be observed after a long period, whereas investments in production equipment are much quicker to bring returns. It happened when Company C (being a private company) made decisions to support investments that were expected to take 15 years until fully paid back. Strategic investments are given special attention despite payback time but rather with respect to environment improvement. The latter goes both for indoor and outdoor.

In addition, it is important to reflect on the Department Manager's experience with costs associated with implementation of the electrical energy monitoring system. C1 estimates total cost per meter plus installation costs to round up to Euro 1000. Of this amount, up to Euro 250-300 is the cost of the meter itself, however installation turns out to be the most tangible part of the cost, costing up to Euro 700-750.

6.4 Fourth Company (D)

Company D represents a group of companies with worldwide running operations. The core business of the company is to supply commercial transport solutions. In reality this implies manufacturing of trucks, buses, and drive systems. The Group's production facilities are located in 18 countries. In 2006, the Group reached the level of net sales of 258 835 MSEK. Company D's shares are traded on the Stockholm Stock Exchange.

The production facility in focus belongs to the Powertrain Business Unit in company D's Trucks Division and is manufacturing truck engines of various dimensions. The history of the business unit dates back to the late 1920s. There are a number of production facilities in Sweden. The plant selected for investigation is located in Skövde and was chosen particularly thanks to a rather advanced level of work with energy management issues.

Three specialists have been interviewed in connection with electrical energy monitoring. Following the earlier introduced description set-up they are given respective names and listed in the chronological order of the interviews held:

D1: Development Engineer. Technical Development Department (corporate level);

D2: Purchase Manager (corporate level);

D3: Energy Manager (plant level).

Energy issues have been in focus in the company for around twenty years by now. Environmental issues are considered not only for the product sake but for the production site as well. On company D's webpage it is stated that it strives to improve energy efficiency of its operations. The interviews held with the employees indicate substantial work in progress for a number of years. Both the Development Engineer[61] and Energy Manager[62] highlighted that energy improvement has for a long time been a corporate value for company D. Likely it was treated as environment related. This environmental commitment resulted in interest towards tools applied to achieve improvements. An additional driving force is said to have been governmental policy and shareholders requirements, and not the least the committed top-management.

Company D makes obligatory it for each plant to have an energy review and perform energy mapping by the end of 2007. The aim is to save 50% of energy input per produced unit. This goal looks quite ambitious when compared with other Swedish companies.

6.4.1 Production Site

The production site in focus is quite big. In terms of consumed electricity it is the biggest of the company D in Sweden. This explains having energy issues dealt with more carefully. The plant is 300 000 m^2. There are 2600 blue-collar employees working at this location. It differs slightly from other investigated production sites. Electrical energy including compressed air represents 62% of energy sources consumed at the plant.

The production consists of three main sections: foundry, machining, and assembly. Casting of metal components takes place in the foundry. Cleaning, refining and preparation of the components are done in the machining. Finally components go through assembly for the final product. The whole plant operates within 17 factories. Each section has either one or a number of factories. In turn, factories are subdivided into departments. For instance, a foundry operates in one factory and consists of 6 departments, whereas machining is taking place at 2 factories and counts for 13 departments inside. Some of the factories though can be used as warehouses or for other auxiliary purposes.

Energy issues are handled in complex. It's natural that various uses of energy at the production site are interrelated: e.g. heating, cooling, compressed air may demand electrical energy. Certain improvements in transfer to district heating, heat recovery, heat pumps installation, and patching compressed air leaks have resulted in lower electrical energy consumption.

Among the electrical energy consuming departments, hardening within foundry has the highest demand. Overall, the foundry is consuming 50% of electrical energy, machining 30%, and the rest is consumed by assembly. The auxiliary infrastructure over the plant such as energy saving lighting and ventilation with converters has been implemented. A lot of attention is paid to the housekeeping in relation to electricity: e.g. check that machines and lights are off when department is not running.

Lighting is gradually becoming time or presence controlled. This has been implemented in two departments. Further work is planned. So far it is on the waiting list in the stock of optimisation measures until quicker return on investment (less than two years) is shown.

[61] Personal communication. Meeting on 21 August 2007.

[62] Personal communication. Interview held on 21 August 2007.

6.4.2 Reporting and Management

The president of the company D set a target related to reduction of energy consumption for all energy sources. A 50 per cent reduction within a five-year period with 2002 as a base year for overall energy consumed[63] per unit of product is perceived within the plant as an ambitious but realistic target. The background for this target and its adoption by the plant relates to earlier benchmarking of energy consumption figures. Big differences between a couple of other plants was found striking. This triggered further ambitious target setting within the company.

Company D runs an Energy Network among all Swedish production facilities and an Environmental Network among the plants worldwide. Seminars are held within these frames.

The Plant's compliance with ISO: 14001 has been certified in 1998. All energy saving activities are developed under the frame of the Plan for Energy Optimisation. This is solely the responsibility of the Energy Manager. The Plan represents a living document and addresses all types of energy. The overall plant target is 'distributed' to the departmental level and goals are discussed with each department. Target adjustment is at the level of the Plant Manager.

Opportunities for energy saving are constantly under investigation. The Plan receives practical extension beyond the written part every now and then. Some energy types at the plant are worked with better than others. Particularly, the sub-target for electrical energy is lagging behind (23% versus 33% reduction compared to 2002 base year) and is not likely to be achieved by the end of 2007. Interviewees D1 and D2 noted that although the base level for energy consumption reduction was the chosen year 2002, certain complications in the beginning shifted real work to 2004-2005. The accomplishment year is most likely to be reconsidered to 2009 due to the later start-up.

Discussion of investment proposals for the Plan and results of energy performance is taking place four times a year at the Plant's internal management meeting – Internstyrelsen. It is held with participation of the Economic department, Production Managers, the Technical Development Department, and the Energy Manager.

The energy management information system is integrated to the Plant's Business Management System. This is a part of the corporate information system. Such integration allows analysing various factors that may have influenced certain consumption results. Energy Management in turn is run on the same principle as the Environmental Management System and, according to D1, is included in it.

The Energy Manager is responsible for the whole monitoring system. There is a detailed inventory of each meter with specifications. The inventory exists both in hardcopy with the layout and, naturally, is available on the web-interface. A special web place called "Performance Manager" can be accessed at each department. It provides table and graphical information. The format is kept rather simple, since "*it has to be easy to understand energy performance compared to production*"[64]. The graphs are built for different time periods and dimensions. They can be:

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[63] The target was set for all energy types with subtargets for each.

[64] Personal communication with D3. Interview held on 21 August 2007.

- current weekly (daily) / monthly (weekly) / annual (monthly) consumption level and production level versus targeted;
- electrical energy consumption per detail / engine produced / tonne melted;
- historical values for previous years.

Different departments would have various options to generate a report based on the gathered data. The Energy Manager is following the consumption values on a weekly basis and would call for clarification with a department if something were beyond the budgeted values. D3 is assured that the existing reporting format satisfies the need of production managers and personnel concerned. At the same time, the Energy Manager has his personal (professional) workstation. This allows getting a more specific overview of the data available. More in-depth browsing and outreaching various levels within the automated monitoring system is authorised just to D3.

There is quarterly budgeting procedure for the coming three years by D3. Energy price forecasts are used with the same periodicity. Regular corrections are required on a monthly basis. The budget is sent directly to the energy provider. This allows the energy provider to fix necessary future volumes of electrical energy to be purchased through Nord Pool.

While practically the Energy Manager has no specific staff, energy management as such is carried out throughout the existing organisation. Figure 6.1 depicts how the energy optimisation is organised down to the departmental level. It should be stressed that so-called energy hunters form the basis in the delegation chain.

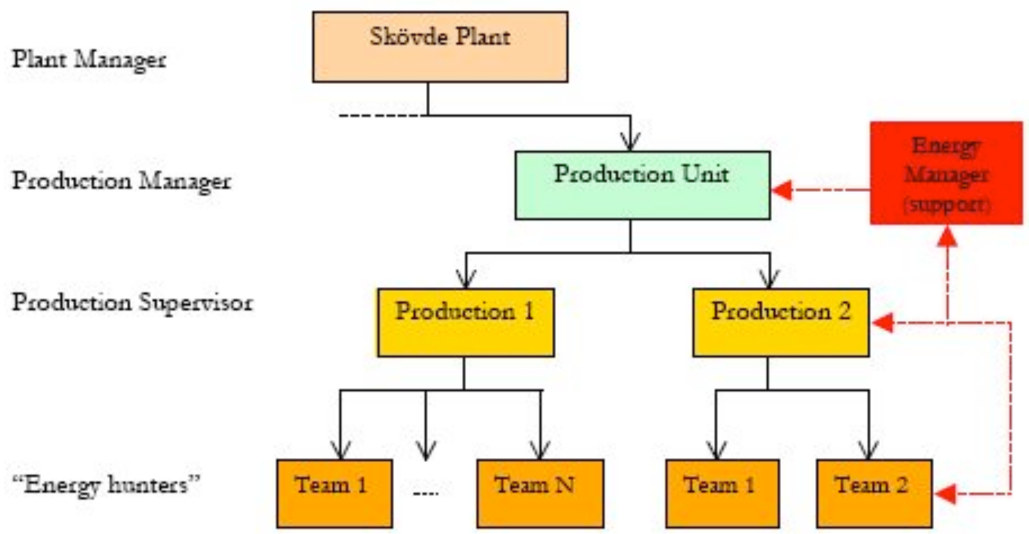

Figure 6-1 Delegation of responsibility in energy optimisation, Company D, Skövde Plant.

Source: Powertrain. Adopted from "Reduced energy consumption in engine production" slides from the meeting. Personal communication with D3. Interview held on 21 August 2007

The Energy Manager has no staff as such working directly with him. This does not prevent close collaboration with various levels of operational organisation. The production manager, supervisors, and especially the 'energy hunters' are the right hand of the Energy Manager in the attempts to achieve the targets. The Energy Manager provides energy-hunters with training. This enables the operational staff to learn what can be done down at the production floor. They are in day-to-day contact with their co-workers. Such a local presence is extremely important at the larger facilities. As the Figure above indicates, communication with the energy manager is mutual. Some specific knowledge arrived from the production ground is used to develop energy optimisation proposals.

Energy consumption data is used for calculation of the Skövde plant's Key Performance Indicators (KPIs). Further, the energy related KPIs find their place in the environmental report issued annually. Company D's energy related KPIs include the following:

- Energy consumption, GWh;
- Direct emission of CO_2, tonnes;
- Energy related to Net Sales, MWh/MSEK

As noted by Energy Manager, energy has always been seen as a part of environmental concerns. Among the driving forces, government and top management was mentioned. The energy monitoring system is seen as a tool to observe and be aware of the 'impact' of consumption at various levels at the production plant. The data set from this tool is required to set the target.

6.4.3 Technical Set-up of Existing EEMS

D1 reported that the earlier monitoring system was delivering rather a snapshot. Work has been carried out towards having more continuous monitoring. Nowadays, the energy monitoring system consists of 350 energy meters for various sources of energy. Of these, 250 are dedicated to electrical energy metering. The monitoring system has developed in two phases, on a rather lengthy time scale. Originally energy metering was launched in 1985. The system was purchased long ago, however basically its shape and reporting framework remains. This was done as a complex solution with collection and communication stations and customised software. Coverage was as detailed as the plant and factories level within it.

The current system has been upgraded during 2005 and extended with an additional 130 energy meters. At present it covers the whole plant, including every section and factory down to departmental level. The system has been in operation since January 2006. Each department is aware of their electrical energy consumption and is responsible for the figures. Their task is to keep the budget while keeping the set quality and financial targets.

The system is targeted purely at recording and reporting consumption values at the level of each department. 250 meters are connected via 8 data collection centres (DUC). The meters themselves do not have a manual interface and communicate directly with DUCs. Information regarding energy consumption is available to everybody with a computer at the plant. However before the reports appear on the internal web, they will be checked by D3. The meters are spread among the plants unevenly. Machining, that is operating in two plants and has 13 departments, naturally has the largest number of meters.

The system also registers the "up" and "down" hours when equipment is correspondingly ON or OFF. No load management is taking place currently. D1 reported that this issue has been considered at the early stage of energy management. The power factor is not measured. No reactive power values are monitored by the system. The existing level of the system development is considered sufficient and controllable. It is considered sufficient by D3 for the plant monitoring, planning, budgeting, and energy management purposes. The Energy Manager believes that the making system more detailed will turn it far too complex.

The structure of data is linked to the organisational set-up. However, as noted by D1, a permanent continuous monitoring system is never going to be enough for a specific development project. Such projects will most likely require measuring a certain component with temporary meters.

At the same time company-wise continuous energy mapping by means of monitoring is regarded an important endeavour. When it comes to the functional use ofelectrical energy, D1 reported on taking this into account when equipping the new construction (buildings). It is not reasonable with the old parts of plants, which is the case with the Skövde plant. One of the obstacles to development of the monitoring system D1 links to organisational structure relation with electrical distribution system set-up at production facilities. Company D encountered this discrepancy and it took a number of years to relay and change the system. This was done at a natural pace when some machinery got replaced due to production requirements.

Infrastructural processes like lighting, ventilation, compressed air are deemed rather easy to measure and implement optimisation. Due to having older plants the functional division for metering is impossible. The major potential though, still is with the production share of energy use. It is estimated that the production process consumes around 60% of electrical energy. This is a longer and more serious phase and gradual exploration shall continue. According to D1 it is hard to expect external consultant to bring the knowledge about process improvements. This knowledge is usually available within the plant / factory / department specialists. For some technical investigations, specific temporary metering can take place in addition to the permanent system.

6.4.4 Electrical Energy Cost and Its Allocation

It was not possible to obtain the share of electricity costs in the overall production costs. This however was said to be rather negligent. Neither does this plant fall into the category of energy intensive. According to the Energy Manager D3 this criterion has been checked and not satisfied.

The plant is reporting substantial savings in the range of over a hundred million SEK within five-year period while working on achieving the target. Though this figure included all kinds of energy sources, and the total investments in order to achieve those savings are not known, it reflects the substantial scale of savings potential. Overall, the electricity bill for the plant in 2007 will make up 111 MSEK, which is essential despite the minor share in the overall production costs

The monthly energy bill is not important to D3. It is received by the financial department. D3 can obtain all information necessary for his work from D2 and from the monitoring system.

After facing electricity costs being above budgeted in the beginning of electricity market deregulation, company D was convinced that some actions needed to take place. Eventually the decision to manage electricity purchasing in a centralised fashion was adopted. The whole procurement scheme was changed in 1999-2000. The contract with the electricity supplier was started as a 2-year contract and now is on a 3-year term base. The Purchase Manager D2 is constantly watching the market and competitors' behaviour.

Contracts are made for the purchase of electricity with Vattenfall and for hedging price levels with Vattenfall Power Management. Company D is large enough to negotiate margins of its electricity supplier and broker. D2 has expressed his opinion about buying energy: "*We always buy energy but we can also save it. Saving is the best buying we can make*"[65]. In total, Company D operates three contracts: physical power; broker; and local transmission.

Stable prices in the physical purchase contract are very important for Company D. Hedging is performed to have more fixed prices level. However with higher risk and uncertainty involved, hedging horizon runs from 2 to 4 years. It depends on current market observations. For drier years a longer hedging horizon is preferred. For wet years a shorter horizon and larger portion of electricity purchased at the spot price level is preferred. Company D has developed an electricity purchasing strategy and hedging policy in order to shift responsibility to the broker. The broker has a mandate for actions within a 'corridor' for a percentage of forward electricity purchases with decreasing time-horizon.

There is a good communication going on between the broker and Purchasing Manager. Regular market surveys and reports are delivered and if necessary are distributed further to whom he finds relevant at present. D1, Facility Manager, D3, and those who are related to energy issues receive regular circulation.

Corrected monthly budgets delivered directly to the energy supplier are sufficient to keep the planned level close to actual consumption.

The 'colour' of purchased electricity is also becoming an issue. Company management is developing an internal policy for electricity purchase. There is a discussion of what kind of energy should be considered 'green'. D2 commented that his task is to purchase at a good price with a good contract. D1 has indicated that in September 2007 company D has reached the point when all electrical energy purchased for the investigated plant is generated from renewable sources.

As noted by the Development Engineer "*monitoring itself does not help if there are no targets for each department, and the best thing is when you allocate costs on each department*".[66] Costs for electricity consumption are traced to the departmental level since January 2006. Each department is responsible for their electricity usage.

Thanks to the information from the monitoring system, electrical energy costs are split down to the departmental level. Each department is a cost-centre within the plant. The bill is issued internally. Electrical energy costs go into departments as indirect production costs.

The energy provider includes a charge for consumption profile. It is presumed to be linked to the electricity consumption pattern. None of the interviewees mentioned this item specifically.

The cost of the monitoring system as such did not prevent it from installation in the first place and further extension at the Skövde plant.

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[65] Personal communication. Interview held on 21 August 2007.

[66] Personal communication. Interview held on 26 July 2007.

7 Analysis and Discussion

This chapter intends to reflect upon factors that have influenced the formation of electrical energy monitoring in the discussed empirical cases. The most decisive features of electrical energy monitoring shall be compared across the companies with the contribution of relevant actors. Factors related to environment, costs, and the data management side of monitoring are brought up to analyse the achievements and possibilities.

The analysis is intended to discuss what has been observed at the investigated plants. Related expert opinions and factors identified through the study are brought up.

The table below attempts to provide a simplified summary of the situation identified through the empirical study. Opinions expressed by the Energy Provider and Distribution System Operator as well as the Energy Consultant, have been incorporated to the maximum possible extent.

Table 7-1 Comparison among the investigated plants (A-D).

(With inclusion of views expressed by Energy Consultant (En.Cons.), Energy Provider (EP), and Distribution System Operator (DSO))

Characteristic	EP, DSO	En.Cons.	Plant A	Plant B	Plant C	Plant D
Size of the plant, workers.	NA[67]	NA	125	450	3500	2600
Production Management	NA	NA	Lean Manuf.	Six Sigma	World Class Manuf.	Lean Manuf.
% of el.en.costs in prod.costs	NA	NA	3%	2.5%	4-5%	-
Environmental Management System	-	Good to start, but low targets	ISO: 14001 – since 2003	ISO: 14001 – since 2006	ISO: 14001 – since 2000	ISO: 14001 – since 1998
Energy in Environmental policy	-	Must	Yes	Yes, under development	Yes	Yes
Energy Policy	-	Must	No	No	No, Energy Goal – 2000, Climate goal - 2005	No, Energy optimisation Plan
Energy	-	Must	Industrial	Electrical	Yes, dedicated	Yes, dedicated

[67] Note: NA – not-applicable.

Characteristic	EP, DSO	En.Cons.	Plant A	Plant B	Plant C	Plant D
Manager			Maintenance	Manager		
Characteristic	EP, DSO	En.Cons.	Plant A	Plant B	Plant C	Plant D
# of specialists energy issues/ electr. System	-	At least 1 with energy management	1-2	1 – overall / 7 – 10 electr. maintenance	10 persons only energy, not mainten.	Energy manager + en. Hunters
Energy cons. reduction targets	-	Adjusted to potential in conservation	2% for 2006 1% for 2007	-	15% 2005 vs. 2002; CO_2 – 10% till 2010	50% overall 5 year with 2002 as base
# of meters	Down to production lines	Down to production lines and larger machinery units	7 (Billing and transformers)	Around 10 (Billing and transformers)	250-300 + by functions	250 down to departmental level
Automation level	Manual start-up followed with automated if frequent	Fully automated data collection	Billing and transformer meters	Billing and transformer meters	Fully automated data collection	Fully automated data collection
Meters reading period (resolution)	Weekly, daily	Every 5 seconds	Monthly (daily possible)	Monthly, hourly within load man-t	Hourly	Hourly
Monitored parameters	kW, kVAR, kWh	kWh, V, kVAR, power factor, power quality	kWh	kWh, kW, V; experimental site: kWh, power factor	kWh, kVAR, power factor, power quality	kWh
Use of data	-	Plant Man., Production Man., Environmental Man., Energy Man.	Production Man., Maintenance Man., Q&E Manager – once a month	Separately: Financial controller and Electrical Man. – once a month	Energy Man., Environmental Co-ordinator, or Manager, technicians at each company; Billing	Energy Man., Production Man-s, Economic dep., operational staff; Billing
Electricity purchase contract	-	Centralised	Centralised + hedging up to 3 years ahead	Centralised + trading themselves	Purchased through Energy Department	Centralised + hedging 2-4 years.
Cost type	NA	NA	Indirect, Costs of Goods Sold	Utilities, indirect production	Utilities, indirect production	Indirect production

Characteristic	EP, DSO	En.Cons.	Plant A	Plant B	Plant C	Plant D
Allocation of costs	NA	NA	Based on machine-hours	Based on m^2	More detailed split within plants	Down to departmental level

The following can be summarised to clarify some points of the comparison.

Three production management concepts are practiced within the respective plants. They were noted in connection with energy saving oriented activities implemented within production processes beyond energy or environmental management specifically. WCM philosophy represents a development of the Lean Manufacturing and SixSigma, and, basically, evolved from the same principles. These production philosophies contributed first hand to the optimisation of resource usage in the production process. All companies mentioned this as a strong driver for resources saving. To enable a brief look into their role in energy optimisation a brief explanation of each of the three is provided in the Appendix III.

It has to be noted that among these four companies only two have more detailed submetering in place (C and D). Plant A has performed an energy survey, and plant B has implemented a load management system. For both A and B, activities have been initiated by the energy supplier.

The investigated plants appeared to be diverse in size. C and D have more similarity in terms of employees and size managed. Production facilities of the both consist of a number of factories. At the same time among the four investigated companies the two larger plants have advanced in their energy management issues and electrical energy monitoring. All plants have been certified according to ISO: 14001. For most of them it resulted in closer attention towards energy issues through the introduction of an Environmental Management System. Currently, all companies have energy aspects reflected in their environmental policies. Plant B has it under development and certification was obtained in 2006. None of the companies have a stand-alone energy policy.

The two larger plants (C and D) running intensive energy management have a dedicated energy manager, whereas the two smaller plants, A and B, have assigned persons responsible for interaction and communication with the energy supplier. Target setting in companies A and C takes place at a global scale and further down to plant level. Plant B has no specific energy targets. All work related to setting goals and targets is at a development stage. Companies C and D show high level of targets. Company C had successfully achieved a global target of a 15% reduction in energy consumption related to turnover during 3 years. A further target introduced for 2005-2010 is related to direct and indirect global CO_2 emissions in absolute terms including those caused by electricity consumption. Plant D has the highest target among these companies.

The number of meters used on site obviously indicates the development level of the monitoring system and its coverage. In accordance with the energy consultant's experience, C and D, by all means, can be referred to as the best practice found in a manufacturing industry. It is rather obvious that such system can only be run with automated data collection. In both cases this has been the set-up from the very beginning. Therefore an hourly data collection is the common solution for C and D. As for the measurements, at present, C is concerned with consumption and the power factor. D's plant is only monitoring consumption and their system is well integrated in terms of data management.

It is quite remarkable that all four companies have applied the scheme of centralised power procurement. Both C and D use the results from the energy accounting system to help with more accurate cost allocation within their respective production units, while A and B don't have this capacity and sum up energy costs with other utility costs.

7.1 Management

The framework management practice, resources and quality management programmes such as World Class Manufacturer (WCM), Lean Manufacturing, Six Sigma, have played certain a role at initiation of resource and energy use optimisation. WCM was said to facilitate attention to energy issues at a later stage. However, to enforce focus on energy, it should be strengthened with energy management and corresponding responsibility. Danish empirical findings described in the section 4.6 add to argumentation about what is important for industrial energy management.

7.1.1 Energy and Environmental Management Systems

Experience of the investigated plants indicated that in most of them larger attention towards energy issues has been brought up with the introduction of an environmental management system. At the plants A and C, the energy aspect was considered due to the need for obtaining certification. Plant D has been among the first ones to start with energy management, and EMS certification. Energy had a special attention within production management and resource optimisation even before the EMS. Plant B is the least active in looking for energy improvements. This is also explained with an environmental image of the company as its core business contributes to environmental technology.

Strong management support and commitment has been identified in A, C, and D. Companies C and D are very good examples of the importance of this particular factor. There is a clear message from senior management regarding energy saving as a part of corporate values. Company B's experimental work although outside Sweden is initiated with Swedish environmental values disseminated throughout corporate culture. Governmental policy is one of the driving forces.

All four companies have been targeting at extensive certification of their plants on compliance with ISO: 14001. With an Environmental Management System in place, energy falls among significant environmental aspects. The year of certification has influenced sooner start-up with energy management. Despite the fact that the lion's part of electricity in Sweden is produced not entailing carbon dioxide emissions, companies tend to look into the energy issue from this angle. This is especially the case with C. Company B is following the same path, however only at an experimental phase, yet beyond Sweden. Calculation of direct and indirect GHG emissions are likely to have been influenced by GRI and environmental performance indicators, recommended for sustainability reporting. All four companies run international operations and report at the aggregate level.

None of the companies apply a standardised Energy Management System. C and D's energy management practice is likely to be characteristic of larger and more complex manufacturing facilities. It is linked to EMS and participates in EMS reporting. The technical core of the system is slightly inclined towards an individual working set-up with an energy manager as a focal point. Both energy managers have a high profile and standing within their companies. The major difference is that the Energy Department of the C is selling its services and provides energy consulting to C's plants on non-profit basis, whereas D is a part of the organisational and management structure.

Plant A has rather homogeneous production (tools) and therefore there is no pressure from the product cost allocation side. The environmental aspect here prevails in terms of dealing with energy performance improvement. The examples of A and B indicate that lack of cost-side pressure prevents active and organic development of the monitoring system.

It is relevant to discuss why being successful in achieving energy efficiency requires proactive energy management along with environmental management. The reason originates from a number of facts:

- Energy cannot be stored;
- Energy is a unique resource that produces work;
- Environmental management deals with minimisation and prevention of environmental impact.

These facts lead to a slight distinction between energy use management and influencing the impact of the energy use. The scope of environmental management helps the work with CO_2 reduction targets. Energy as a resource has been and remains within the production management scope. However, a common production site will have various sources of energy employed. Their usage will be interlinked in the process, and electrical energy will remain the major energy source affected towards increase or decrease. The physical property of energy and its characteristics make it distinguished among other resources used in production processes. This is the strongest argument for treating energy management on its own account. Not the least this is explained with the engineering expertise required to identify and undertake energy improvements.

This is strongly supported with the North-American[68] literature on the subject. As an extension to production management, energy management received development as a more technical discipline with substantial engineering inclination. In Sweden, energy efficiency seems to have been on the agenda for decades and it was rather integrated in design and production philosophy among manufacturers and recently steered by regulation. A number of Swedish technologies and machinery are positioned in respective markets worldwide as energy-efficient. A shortcoming may though be observed: production of energy-efficient equipment does not imply by default that the production itself is energy efficient. This should be helped with energy management at the production site.

7.1.2 Target Setting

Setting energy related targets within the Environmental Management System does not provide justification for improvement when the savings potential is not investigated. Due to international operations companies follow energy indicators at a corporate i.e. global level. Data aggregated at the corporate level, if not substantiated at plant level, do not bring about realistic targets. Plant A is an example of this. Even though certain activities towards reduction of electrical energy consumption have been implemented, improvement potential for the plant has not been identified. This can be seen in the extremely low targets set within EMS despite the fact that they were co-ordinated with corporate targets.

[68] USA and Canadian publications and references are meant.

Company C has proved a possibility of a 15% reduction within 3 years globally, although it was admitted that growing turnover helped achieving that target.

Company D's experience proves the major role played by monitoring in setting realistic targets. The benchmarking experience between other plants led to setting a rather ambitious target for plant D. Having an operational monitoring system initially, and expanding it in the course of energy improvements, helped a great deal to achieve the target partially. Knowing the potential substantiates extension of the target fulfilment period until 2009.

The monitoring system established in Company C is well integrated throughout the organisation. It helps the mother company to reach daughter companies and make them implement the corporate targets, thus contributing to improvement of corporate environmental performance indicators.

In fact, both companies C and D provide clear examples of having energy management in addition to an environmental management system, however without all prescribed[69] attributes, such as an Energy Policy. In companies A and B there is no dedicated person looking into energy optimisation. However both companies C and D have a person in the role of Energy Manager. This supports a benefit of the energy management system being a supplement to the environmental management system. This can be explained with strong gravitation towards the engineering component in energy management. Due to the interrelation of energy sources usage at industrial facilities, it is important to foresee consequences of changes in one energy source and its influence on another. Environmental management has numerous environmental aspects to deal with and therefore may not extend professionally adequately to cover engineering data. Or in other words, it shall take an energy manager to deal with energy optimisation and conservation issues should it be within EMS or as an extension.

The production management system strongly contributes to both energy management and the environmental management system through aiming at minimum use of resources. This has influenced all four companies.

The importance of the behavioural aspect in connection with energy saving is well recognised by Plant D. Its experience with "energy hunters" at the production floor has proven extremely valuable. These assigned floor-workers handle the behavioural improvement and housekeeping in relation to electrical energy. Moreover, process knowledge and ideas originate from them and are communicated to the Energy Manager. Plant A has noticed a short-term effect of raised awareness among employees. This serves as additional evidence in the range of required regular practice. Another important issue supporting behavioural influence is the clear message from senior management underlining corporate values and placing accents on energy use.

Among the companies it seems to be found sufficient to have one professional specialist in charge of preparation of energy-related project proposals for management review. This specialist's role is crucial for an operational monitoring system. Having a responsible specialist makes the system a well-established, recognised, and 'organic' tool.

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[69] According to the way energy management is treated in the North-American literature.

7.1.3 Information Management

Data gathered through monitoring provide a good overview of the whole production process and system performance. However, it is of utmost importance to have data readily available to all relevant staff members (beyond the primary receivers). The energy consultant stressed that collected data needs to be available to those who can actually change the consumption. Monitoring is meaningful only with this opportunity of providing feedback.

Data presentation is a sensitive element in data management. Energy mapping with Sankey diagrams is used in company C. Plant D applies tailor-made software giving the energy distribution tree. To avoid a too technical level of energy monitoring, generated reports must be easy to understand. Having graphical representation is fundamental for all recipients. The information presented should be adjusted following interests and requirements of each level. The production department will benefit viewing consumption levels in relation to production volumes, and against the targeted or budgeted amounts. This is successfully implemented at plant D.

Graphs and diagrams serve as a very good presentation form. The more explicitly it is presented the easier shall be the analysis and decision-making should there be a need for intervention or adjustment.

Both company C and plant D have energy consumption values provided in relation to either target level or production volume. This helps D to generate informative reports on a weekly, monthly, and yearly basis at each department level.

Information overload proves to be a shared concern among the plants. Therefore selection of collected data should strictly correspond to the recipients' requirements and ability to interfere for correction.

7.2 Prices, Costs, and Cost Reduction

Electricity prices were regarded by the companies as volatile and difficult to forecast. This has resulted from two market based economic instruments introduced at the European level and in Sweden. These instruments are emission allowances and green certificates.

Deregulation of ethe lectricity market turned it into a more financial arrangement. This has lea companies to first look at how the volatile electricity prices can be dealt with at a company level. In the investigated companies, responsibility to observe the market and build up the electric power portfolio was shifted towards stronger reliance on brokers and suppliers represented at the Nord Pool.

Initial reaction to increasing prices mainly due to the immature and non-transparent emissions allowances market has brought about the decision by A-D to centralise power procurement. Energy saving measures followed this decision but at different rate at different companies. Centralisation of electrical energy purchase is discussed further as a cost-oriented strategy. C and D approached the electricity cost issue by making costs more controllable and manageable with the help of monitoring.

7.2.1 Price-focused Energy Cost Reduction

The four cases indicate that industries have reacted to the growing complexity of the electricity market. B, C, D cases show that the cost-oriented or price-focused strategy was the first to come into action. Industrial companies tend to separate the purchase of physical power from delivery by the local network owner. A's case was the last in the time scale, when it happened. The stronger position of energy provider is purely explained by open market and competition. It is likely that main functions of local network operators (DSOs) do not allow them to follow closely very dynamic development and complexity of the electricity market. They are too small, compared with energy providers dominated by larger companies. The energy supplier is capable of the performing market surveillance function and consequently is more competitive when offering its prices and other services. Companies prefer to arrange for electricity contracts in a centralised fashion. Further on actions to secure prices and bring them to a rather stable level are undertaken at the financial part of electricity market.

A, B, C, and D consider centralised purchase to be better managed from the procurement point of view. This requires neither local branch nor production site managers to investigate the more and more complex market. The responsibility regarding power purchase at a 'good' price is shared with the energy supplier. Prices are generally secured through hedging operations. This helps companies to improve their position in terms of budgeting. In principle, they steer the situation to the state it was in before market deregulation.

It is found important to forecast future development of power prices. This is vital for companies' long-term planning. There is no single opinion among experts. Too many factors are said to exert influence. Especially, this refers to the CO_2 allowances and electricity certificates as the market components of the electricity price. The market players work with forward contracts and hedging at the financial part of Nord Pool. Forecasts depend on the portfolio of market players. Existence of political uncertainty along with other risks, and dependence on future weather conditions in the Nordic region add precariousness in forecasting future electricity prices. Most of the interviewees anticipate continuation of growth in electricity prices[70]. This leads to the likelihood of having longer-term contracts with energy suppliers. Part of the risks of fluctuating future prices is put on brokers' 'shoulders'.

7.2.2 Load Management

Load management is mentioned by interviewees as a cost-oriented activity whether a company or energy supplier is concerned. Load management at plant will result in avoiding excessive load and penalties and making the load curve more even. The company benefits by not paying load-induced charges over the contracted power demand. The energy supplier's benefit is that the actual consumption is close to the planned consumption and that marginal power production needn't be employed.

Although both the energy supplier and DSO are interested in an even load, the heritage of the previous system and extensive regulation of the electricity market make the energy supplier a more appropriate actor to co-operate with an industrial site. Besides direct economic benefit, this also involves environmental benefits. By managing industrial loads and preventing peak consumption to occur, the energy provider stays within core generating facilities and avoids marginal generation. Marginal production will in some cases result in additional environmental impact. With load management, the balance-providing function of energy supplier is not damaged, and generation is run with the planned resources. Co-operation with industrial end-users allows minimising reserve capacity. Having large reserve capacity turns out as a financial burden for the supplier. Inability to manage demand creates pressure on new investments.

[70] In addition, one of July issues of DI has published an article on expected electricity price increase based on opinion of one of the major traders at Nord Pool – Bergen Energi. (Lundin, K., 2007)

The case of C and the energy supplier's activity show that load management takes place at the early stage of energy management. Once an even load curve is achieved this turns into a routine practice. Nevertheless, it is a good beginning for energy management activities. Plant D, despite advanced metering level, is not questioning a 1.5% charge for its consumption profile. It is not regarded as matter for load management while, most likely, it is.

The energy provider may play a very important role in raising awareness, and sharing knowledge and expertise with industrial end-user. This will be mutually rewarding: common environmental benefit, cost-savings and improved environmental performance for an industrial company, improved co-operation and service-extension for the energy provider.

7.2.3 Cost Accounting

The level of metering is directly linked to the way that energy costs are accounted for. Having energy costs known down to those levels, where they can be improved, turns out to be an important condition in their reduction. Within a company, linking end-users to information about their actual consumption cost, and making them aware of it and responsible for it, is likely to push departments, units, or shifts to view energy differently.

Energy accounting goes hand-in-hand with cost accounting. By having a better overview over the electricity consumption at the industrial plant there is a more accurate split inside production units. Nevertheless, allocation is not likely to be avoided, as electricity will always remain an indirect production cost. With better electrical energy monitoring, less ambiguous allocation is achieved thanks to having a larger portion of the electricity costs actually measured. Furthermore having costs identified at a more detailed level serves as an incentive for continued efficiency improvement. Energy accounting should be an integral part of the management information system.

Having monitoring of electricity consumption in place and correspondence of cost accounting centres with energy accounting centres helps companies C and D to handle the costs more accurately. Company C has achieved a certain success by billing daughter companies based on their actual consumption. This gave facility managers an indication of actual consumption and resulted in their actions towards sub-metering. In turn, facilities' managers addressed C's Technical Manager to help identify potential for reduction. Plant D has succeeded the most in bringing the cost knowledge and accounting possibilities down to the departmental level. It has been confirmed to be sufficiently detailed both for energy management, accounting and cost allocation purposes.

In principle, each product be responsible for all costs it has incurred during production. No other product should subsidise it. On the other hand, allocation based on keys can be appropriate with homogeneous production (e.g. tools in the case of A).

7.3 Energy efficiency and monitoring on site

It has been shown in the chapters 4 and 5 that energy management and continuous improvement of energy efficiency is limited in the absence of reliable data collected with adequate resolution and available to relevant staff. It is vital for having a good overview of energy distribution on site and enhancing the plant's performance. This section is devoted to a discussion of implemented monitoring solutions at the investigated plants. The C and D cases are treated as the best experience at manufacturing industries in Sweden.

A, C, and D report on energy efficiency by calculating key performance indicators both for operational and corporate levels.

Plant A practices internal reporting of electricity consumption. Energy consumption per turnover and value added are reported internally, but not externally. At the corporate level, direct and indirect total energy consumption as well as amounts of direct and indirect CO_2 emissions are included in annual reporting.

Plant B is in the phase of defining its energy performance indicators. It is most likely that to enable fair comparison among its plants worldwide the KPI will be consumption per value added.

Company C has shifted energy management issues into its Climate Goal since 2005. Direct and indirect greenhouse gas emissions in equivalent of CO_2 are reported at a global level. At the operational level, energy consumption per unit of product will remain. Yet in 2000, energy audits and sub-metering were pointed out as important resources for the company's energy efficiency improvement.

Company D is reporting total energy consumption, direct emissions of CO_2 and energy consumption related to Net Sales. At the plant level, operational figures for energy consumption in relation to production are constantly reported and followed.

The existence of internal and external reporting of energy related indicators reflects the presence of the focus on these issues in companies. Inclusion of the CO_2 indicator shows growing influence of the climate change concern by stakeholders. Direct and indirect emissions serve a good aggregate indicator reflecting energy consumption, though these have an analytical character and are not clearly linked to commonly understood energy values. It is seen important to maintain reporting of relative indicators such as energy consumption per turnover or value added. At the operational level, energy consumption related to total production and specific energy consumption (per unit of product) shall be decisive to energy efficiency improvement.

7.3.1 Monitoring System

The investigated plants have different approaches to and needs for monitoring. The American and Canadian approach presented in the chapter 5 is more technical and suggests a rather detailed look into electrical energy usage and parameters starting from voltage and active power consumption to power factor and power quality. Both energy-field actors, such as the DSO and energy consultant support rather broad collection of data describing electric current and its distribution over industrial site. The energy consultant's views are the most critical and this is not without relevant grounds.

As can be seen in Table 7-1, D's monitoring system is intended only to meter consumption. At the same time, C is looking into the power factor and disturbances in the local net. Having the power factor measured with the monitoring system is recommended by North American literature as a value indicating equipment efficiency. The energy consultant and DSO suggest that this parameter be measured on some machinery units.

It is most likely that a need for monitoring was actually realised first within this kind of energy management approach. The technical approach to electrical energy monitoring suggests that the more parameters of electric power are monitored, the better shall a plant manage equipment efficiency, productivity and maintenance. Deciding on what information is useful and where will always remain within a plant's decision. Among the investigated plants, only Company C is measuring the reactive power component of electrical energy and improving the power factor with the assistance of capacitors. Plant D is satisfied with metering energy consumption only. This is related to the current goal.

The energy saving perspective, on its own, does not seem to require metering much more than consumption sub-metering at various levels. All other parameters of electric current acquire attention when disturbance of quality or excessive reactive power enters the DSO's grid. The DSO will inevitably inform the end-user about such deviations. Most probably a joint investigation will be undertaken and a solution developed. Mostly the parameters to monitor will depend on the qualification of specialist in charge of the monitoring system.

DSOs have all meters interfacing with industrial facilities automatically read on an hourly basis. As for the production site, HEM suggested a possibility for manual start-up of monitoring. This is said to be possible with infrequent (low resolution) data recording like some times during a month or weekly. Even with daily data recording, automatic data collection is recommended. Automatic data collection within permanent monitoring is desirable. Nevertheless, manual reading at major consumption units once per month for preliminary analysis is also possible. Regular and automated recording is a normal contemporary solution. In the circumstances of expensive labour (Sweden) it gives other benefits and saves personnel man-hours.

Setting up a monitoring solution can be co-ordinated with the DSO. They are likely to be interested in covering data needs to a certain extent. For instance, co-operation with Plant A gives the opportunity to collect data on energy consumption from 6 transformers. Meters are owned by a DSO and data is regularly received by them (though does not reach plant A itself due to lack of interest).

The measurement plan can be subject to discussion with the DSO before the locations for metering are finally selected. Monitoring should seek to fulfil as many functions as can be utilised and maintained at facilities. Process management needs will serve as additional criterion in developing the measurement plan.

Energy accountability centres are most likely to be those business units that can influence parameters, should intervention be required. Company C has it differently at various plants. The plant manager, depending on the structure, may require energy mapping down to the production line level. Plant D has defined their energy accountability centres at the departmental level.

Resolution or frequency of measurement turns out to be a decisive value. It helps correct sizing of equipment and makes possible further investigations in operational and energy improvement opportunities. Both companies C and D having a similar level of monitoring are collecting data on an hourly basis. While company D is satisfied with the current level and resolution of metering, company C would be willing to have monitoring at an even more detailed level. Plant B would benefit from seeing the load value every second. Moreover, Energy Manager C1 underlines the usefulness of functional split of electricity consumption and having production usage on its own. It has been argued by D that lighting and ventilation consumption are relatively easy to calculate. Estimation is still not the same as reported consumption figures. Hence, new facilities should be equipped with meters with provision of functional division – auxiliary systems (lighting, ventilation, etc.) and core production. Old factory structure can be an obstacle though.

Base-load or stand-by consumption by machinery is in focus for companies A and D. Measurements from the monitoring system at plant D indicate massive base-load consumption. The energy manager estimates that over 30% of electrical energy consumption is caused by stand-by operations. In order to help reduction of the base-load, D is planning to adjust and improve start-up and shut-down cycles for production equipment. Based on the developments within DSO's metering, a similar approach with 'breaker' function and 2-way communication could be applied for the base-load management purpose.

Permanent metering of energy consumption should become a 'must' when machinery gets replaced. The tendency with energy monitoring is to move from a snapshot picture to more continuous energy mapping.

7.3.2 Supportive and Disruptive Forces

Motives for energy saving have been discussed in the empirical analysis of energy management in Danish industries. A realistic assumption is made that conditions in Sweden and Denmark are rather close and findings from the Danish survey are valid to discuss the Swedish context.

Table 7-2 provides a summary of forces at the operational (production facility) level. It discusses empirical evidences of how they *contribute* to a company's search for energy efficiency and pathway to more detailed metering or *prevent* them from pro-active energy improvement seeking.

Table 7-2 Energy management supportive and disruptive forces

Supportive forces	
Cost detalisation, Cost reduction and environmental considerations	Cost accounting is one of the main drivers supporting sub-metering. Tracking costs will help to make them more manageable at the level where it is incurred. Cost reduction, environmental agenda and image seem to be the real triggers for development of monitoring solutions. All three factors were mentioned by a number of interviewees. When answering questions about why has monitoring started, Plant D named costs reduction and detalisation. Company C was pushed by the internal environmental agenda. Company A and B started looking into energy efficiency following stakeholders' demands. While in the Company A, it is related to corporate environmental considerations.
Production philosophy	Production management created a solid starting platform for the plants. Before integration of energy as an aspect within EMS, production and quality management was driving resource consumption considerations.
Environmental Management System	Energy Management as a natural part of the Environmental Management System is also among triggers, though scoring only 4th place in the Danish empirical study. This can be observed from both Company C and D's cases. The EMS, however, was strengthened by appointment of a dedicated person constantly looking into energy optimisation.
Management commitment and	The widely known and insurmountable requirement of having management commitment is valid in this case as well. Its presence

dedicated energy manager	serves as a trigger, while its absence is an unavoidable obstacle. The same goes on account of dedicated specialists assigned to deal with energy management issues.
Ownership of monitoring system	It is crucial to have a specialist in charge of all hard- and software of the monitoring system. Having a staff member keen on running the system to its full capacity for energy improvement is a very strong supportive factor. The presence of 'ownership' within an organisation makes the system either useful or useless.
Energy utility (power supplier)	As the Danish empirical study has shown, the strongest role in turning companies to look for energy efficiency opportunities is played by energy utilities and energy consultants. It is seen that by having long-term agreements with industrial users, energy providers become the best actor to help advancing energy efficiency at their clients' side. The case of three plants actually proves this assumption. Plant A has started looking into energy consumption more closely under initiative from their power supplier (now DSO), and is going to continue to rely on their energy expertise. Another plant – B – has, in co-operation with their energy supplier, implemented load management software providing hourly resolution of the electrical energy data. Company C has maintained a contract with its energy supplier for almost 7 years by now and developed a joint service package. The service is offered to daughter companies' plants. Implementation of the "Energy Efficiency" package on site is helped by the energy adviser/auditor from the power supplier beyond the main supply contract.
Energy consultant	The Danish empirical study shows that for some industries energy consultants serve as good motivation for closer attention towards energy issues. Among the studied companies, company C has used consultants extensively in the beginning of energy management. Company D as well has addressed various energy consultants rather on an individual project basis. The outcome has shown that the energy consultant has facility knowledge and is very helpful to advise on improvement of auxiliary systems. However, the process knowledge is mostly acquired within the company itself.
Cheaper meters and no technical limitations	Looking into electrical energy as a resource and into available solutions for monitoring (both permanent and temporary), one would discover that it is easy to do practically anywhere and the costs are reported to be incremental compared to savings that can be obtained with the help of this tool. It has been noted by large portion of interviewees that over the years, metering equipment has gotten less expensive. Having a system installed provides better information management capacity. Automatic data collection makes it easier to analyse. Access to the information of this kind provides a learning possibility, and enhances capacity and knowledge building.
Common language with financial department	Companies A and C have expressed an opinion regarding too technical an orientation of energy management. Both A4 and C1 reflected on having a positive role of financial specialist on board when energy optimisation issues are considered for implementation. While Company

	D has experienced that energy saving 'talks' money for itself and serves as a good motivation provided an acceptable pay-back time is presented.
Disruptive forces	
Initial investment and installation	Financial costs can certainly be seen as an obstacle to implementing a monitoring system. However this proves to be a relative barrier. All companies realise that a lot more can be saved once a detailed overview is obtained. Neither company C nor plant D had difficulties in motivating the need for initial installation and further extension of the system. Installation is mentioned by a number of interviewees as an essential part of monitoring system costs (mainly due to a relative reduction in the price of hardware and means of communication). In old facilities, it may turn impossible or entail substantial costs at first.
Incompatible organisational and physical electrical wiring lay-out	Incompatibility of the physical lay-out of the electrical system and the organisational set-up can be a major obstacle as well. This has been experienced by Company D and took a number of years to rectify by natural replacement.
Payback period limitations	Acceptance of pay-back period should be noted separately. Companies A, B, and D have their shares traded on the Stockholm Stock Exchange. This puts substantial pressure by shareholders on their financial performance. 2-3 years payback is considered in these companies rather long and it is not likely for an energy improvement project to get started before the payback is acceptable (1, maximum 2 years). Company C represents a different example – it is privately owned. In its case, environmental motivation both for indoor and outdoor climate is more important than payback period. There were records with accepted investments that pay back in 10-15 years. As far as the monitoring itself is concerned, all the interviewees expressed strong opinion that before energy improvements take place a monitoring system should be functioning.
Electricity generated from renewable energy sources	'Green' electricity purchase can undermine efforts in energy saving activities, unless it is done simultaneously with energy efficiency improvement.

From this extensive list of factors that may affect introduction and development of advanced energy management, it can be seen that there are fewer factors that prevent it compared to the number that can be employed to make it start working.

7.3.3 Integration of Energy Monitoring Within an Organisation

Initial development of energy management and more detailed monitoring was a pure prerogative of engineers. Likewise, going into details of properties and characteristics of electricity belonged to electricity experts. Nowadays, a rare plant would have an expert dealing particularly with electrical energy. Recent recognition of energy issues in a broader context has shifted the energy use concern to the level of environmental issues. Thus, energy management had its rebirth linked to the environmental management system. Both approaches are found at present.

The discussion of supportive and disruptive factors shows numerous factors that can facilitate energy monitoring. Besides having monitoring as a basis for energy management, it is crucial to have it integrated with a plant's operation and information system. The need for real-time data and the possibility to extend and develop the energy monitoring system requires co-ordination among divisions' activities.

Various company actors, departments and managers are involved in using data generated through monitoring. It is likely that the primary receivers of energy reports are energy managers (or responsible), environmental managers, and financial controllers. Their demands regarding the level of detalisation would be different. The plant manager may also pay special attention to energy figures and therefore is likely to be a recipient. Probable actions of these specialists will be:

- Energy manager – take a close look, analyse, benchmark, look into energy saving opportunities;

- Environmental manager – report on environmental performance (energy consumption is involved), report on improvement or lack, suggest corrective actions in EMS;

- Financial controller – overview the costs split and related to various production sections for better cost-allocation and reporting.

Besides making energy consumption information available to these particular managers, broad access by all operational staff is essential. Operational staff and floor supervisors are at the very level that can bring the action about. Access to this information and awareness makes the behavioural aspect more influential. Thus, integration within the daily management scale is important.

Historical data serve a reliable basis for operational budgeting. A detailed overview helps finer adjustments due to implemented changes. The purchase manager also benefits from a reliable monitoring system by having a more informed position towards the energy supplier. Closer co-operation and the fact of well established energy management helps better contract conditions for electrical energy purchase. Moreover, in the case of faults, there is a need to have a comprehensive overview of all interrelated functions. Energy statistics together with other factors shall be scrutinised to better understand reasons for the occurrence of the event.

To summarise various levels that should utilise the resource of the energy monitoring system the following need to be mentioned: energy management, environmental management, production management, and the overall information management system for financial and management reporting.

The radical integration throughout the organisation will play a role in helping further energy improvement investments to take place. It is likely to bring the financial and energy manager to a closer understanding of the physical and financial savings perspectives. The strongest driver for integration is likely to be inclusion of energy into corporate values and having it well communicated as one of the management's priorities.

7.3.4 Tackling Energy Monitoring Within an Industrial Organisation

The investigated cases and interviews with the relevant energy market actors indicate a certain need for developing a general approach towards an energy monitoring system for industrial use. According to the scope of the thesis, herein only electrical energy monitoring is in focus. However, in a larger industrial company energy sources are interconnected within the process.

Through the discussion above and studying the best Swedish experience it is possible to draw a framework of the adequate monitoring solution and its development steps. Such a solution can be built upon co-operation between a manufacturing industry and energy supplier.

Table 7-3 represents a number of steps that need to be considered when approaching development of an 'organic' energy monitoring system for its successful implementation. It has to be noted that the scale of application of these steps will depend on the size and organisational complexity of industrial company.

Table 7-3 General framework for developing an adequate energy monitoring system

Step	Activity	Deliverable
1	Build a team with representatives of Financial, Environmental, Quality, Health&Safety, Technical divisions of a company with clearly defined responsibles for energy issues. Appoint the energy responsible.	Responsibles within team are appointed.
2	Perform energy audit (see section 4.3). Review and check compatibility of organisational structure, physical layout of facilities, and distribution of major energy loads. Identify corrective actions to improve the compatibility.	Schematic layout for production processes and organisational divisions is available. Energy distribution chart.
3	Within the established team identify needs for metering, data and format requirements, frequency and reporting outline, interaction with energy supplier.	Clear understanding of metering needs is obtained.
4	Identify and locate benchmarking requirements (what parameters at which levels can be compared in connection with energy, environmental and performance management).	Benchmarking criteria are identified and justified
5	Carry out vertical cost analysis, define energy cost portion, and check for necessity of less ambiguous cost allocation; develop cost allocation strategy.	Level for cost allocation is defined and justified.
6	Assign energy accounting centres in concord with the cost accounting centres.	Energy accounting centres are established.
7	Identify functional division of energy usage within a production facility (core and peripheral processes).	Energy supported functions are identified.
8	Locate operational staff and workshop personnel capable of interference and feedback in relation to energy consumption on site.	Feedback points are established.

Step	Activity	Deliverable
9	Investigate entrance points and compatibility requirements with the existing operational Corporate Information System (CIS). Identify reporting interface requirements, format and integration possibilities.	Compatibility requirements with CIS are analysed, reporting interface is formulated.
10	Develop a meter list following the structured approach to measurement (see section 5.2, Fig. 5-1, Table 5-1).	Measurement plan and specification is in place.
11	Integrate the energy monitoring system by harmonising it with accounting, reporting, maintenance, management, and planning routines in all relevant aspects.	Monitoring system is ready for implementation.

The table above represents a detailed list of activities and anticipated deliverables in a general form. The full extent of implementation may not be necessary for a smaller production scale. A brief explanation is provided further, in order to describe the achievements of each step. In the case of smaller industrial companies, a number of steps can be simplified, however, one general activity – the energy audit - cannot be omitted despite the size of the company.

The interconnectedness of the performance aspects requires, first of all, deliberate on-going co-ordination of monitoring activity. Viability of the monitoring function depends on assigned responsibility. Both aims will be achieved with establishing a team among the departments contributing to performance improvement.

An inventory or energy audit sheds light on where to look for performance improvements. This activity is not subject to omission irrespective of the plant's size. At the same time, schematic layouts for the production and organisational structure need to be extracted for the purposes of further a metering plan and installations. Consequently, metering needs shall be reflecting information demanded by various departments.

The information and reporting format will, as well, link to the need to compare parts of the production at various levels: plant, building, department, production line, machine. This can serve the benefit of various performance aspects. Cost allocation and management prove to be a natural liaison for incorporating energy usage within conventional business procedures. Thus, energy accounting centres shall be linked to the desired cost accounting units.

To optimise the instigated monitoring set-up, core and peripheral sub-metering are essential. This will indicate energy flow distribution based on its functional use. The importance of corrective action and feedback dictates connecting the information with the end-users and reinforces their awareness.

Finally, to avoid detaching the monitoring system from the overall plant management it should be harmoniously placed within a practiced corporate/plant management system. For this purpose, integration links should be built and established within organisational and operational structure. Casting energy usage data throughout company's information flow will enable various relevant parties to initiate corrective actions towards performance improvement. Automation and resolution of metering will be determinant to the time gap of controllability.

8 Conclusions and Recommendations for Further Research

Previous experience with energy monitoring was rooted in an engineering approach to energy management. The need and tendency of today is moving from having energy management and monitoring in its own domain towards more integrated energy management with environmental and overall production management.

The subquestions to the main research question have helped approaching the issue of energy monitoring at the investigated case plants. This allowed drawing some conclusions regarding an appropriate monitoring system that turns into an organic tool within production and performance management. Further some recommendations to industrial plants participating in the empirical study are provided. As only few companies have established such a system and operate it in a concise manner, some observations and implications for policy makers are provided. This thesis has found an indicative answer to the main question. There are a number of ideas that could be considered for further research.

8.1 Main Findings

The legal and political context, and not the least, the energy market situation, has created conditions where resource management, in particular energy, becomes essential for overall industrial company performance. Two cases (C and D) amongst four have proven to be the best examples. It can be stated in accordance with opinions expressed by the energy consultant and metering solutions and equipment manufacturers that there is a general lack of energy monitoring among Swedish manufacturers. Cases of having more than one energy meter installed are rare.

There are various corporate performance aspects that are relevant to the usage of energy or information about energy at a manufacturing plant. This implies a number of benefits overlooked by not treating this resource adequately, as well as by missing real energy distribution data that could be obtained with the monitoring. Neglecting these benefits results in underestimating the payback period and the importance of energy saving measures that belong to the strategic area.

The monitoring system becomes an important energy, environmental and overall performance management tool. It has been clearly shown that the monitoring system is dependent on the organisational structure and falls into a focal intersection of various departments' interests. Few currently obvious driving forces lie within cost and environmental management. Throughout interviews it has been stated that cheaper metering and communication technology allows for high resolution automatic data collection and credible and accessible information. These advantages are best utilised when the data is shared, data-knowledge interaction is in place, and corrective actions mechanisms are institutionalised. The future seems to be with high-resolution automatic data collection and processing under permanent metering, however, manual readings at a certain phase can be sufficient.

Responsibility and ownership play crucial role in a monitoring system's successful application. These will secure regular practicing and applying the tool. Only through regular use does monitoring become the basis for knowledge and capacity building within an industrial company. Integration throughout the company structure allows improvement of awareness and continuous motivation and reinforcement.

There are no commonly known obstacles in establishing detailed sub-metering at a production site. At the same time, the approach needs to be co-ordinated and justified within a company. It is essential to have sub-metering at industrial facilities in order to be able to improve performance with the help of adequate target-setting. Moreover, there are quite a number of issues that need to be considered before an appropriate monitoring system is in place. The company size will certainly matter in terms of the scope of preparatory work, however, energy audit and co-ordination with environmental and production management are indispensable.

To summarise, the role of monitoring of energy consumption at manufacturing facilities is essential for various aspects of performance management in terms of:

- energy distribution overview and energy accounting;
- detalisation of costs and cost reduction;
- realistic assessment of improvement potential;
- verification of achievements and adequate target setting.

It should as well be noted that unlike any other energy carrier, the nature of electrical power provides certain advantages. Among them are low maintenance requirements, when it comes to the metering equipment.

A general observation based on the interviews is related to a lack of energy management and exploring the full potential for energy conservation opportunities among Swedish manufacturers. An energy manager's function is essential as a focal point to receiving and analysing data collected through the monitoring system. A special focus on energy is required in addition to the Environmental Management System that is broad in itself and focusing on minimisation and prevention of environmental impact.

Costs associated with development and implementation of sub-metering for the purposes of monitoring are expected to be incremental compared to improvements, benefits, and savings that can be achieved. This does not diminish the role of the structured approach to measurement and consideration of all expenditures either at initial or later stages.

Levels of energy monitoring at manufacturing facilities are likely to be dictated by cost allocation and benchmarking drivers. Size of the plant and heterogeneity of production are, as well, the likely determinants. It is not only the consumption figures themselves which serve the management purpose. These need to be related to targets and production levels or else benchmarked against a similar production line or machine.

In order to make monitoring of electrical energy a living management tool, its integration and co-ordination with all departments of an industrial company is vital. It will only be functional to the intended and adequate level when it is integrated throughout the organisational structure and overall information system. The behavioural and functional importance of the collected information and generated reports requires it to be communicated to the end-users and operational personnel. Permanent metering with an extension possibility and automatic data collection seems to be the optimum solution, if envisaged from the beginning.

Co-operation with the Distribution System Operator and Energy Provider can be decisive in what the industrial plant can achieve in terms of steering long-term performance improvement.

8.2 Recommendations to the Companies Participating in the Empirical Study

Larger companies are the front-runners, which can also be seen from the study undertaken. It is important that the best available experience is disseminated to others and followed.

Plant D, though very advanced at present, does not utilise all available data and is given the recommendation to look into the load management issue. Participation and sharing experience within Sweden at such arrangements like Energitinget and Energiledaregruppen is highly recommended.

Company C is likewise advanced with monitoring. Nevertheless, a lot in relation to energy issue is left by the mother company to be decided at the individual plant manager level (the daughter company). It is recommended to draw more attention of plant managers and environmental co-ordinators to looking for energy saving and efficiency at the respective plants.

Plant B has the biggest unexplored potential. It is recommended to bring the energy issue to the attention of senior management, develop responsibility for energy consumption throughout organisation, and initiate an energy audit. The starting point is recommended to be placed within the existing co-operation with the energy supplier regarding load management.

Plant A has sufficient human resources and understanding of activities that need to be done. Development of a measurement plan with sub-metering in co-ordination with the energy supplier (now the DSO, since centralisation of power purchasing function) and relevant internal departments is recommended as the first activity on the way to energy management and exploring energy efficiency potential.

The base-load consumption reduction is a concern shared among three of the companies. Opportunities could be explored by expanding routine start-up and shut down procedures with the addition of a 'breaker' function within the metering solution. Provided that two-way communication is an available option, the DSO's experience can be promising at production sites. A recommendation for all four companies is to work on a model energy monitoring solution suitable at a corporate level and dissemination of the model to other plants worldwide.

There is also a need to develop energy expertise inside industrial plants. This is due to the admittedly high energy saving potential in the production process. Having the process knowledge and expertise in energy efficiency all together should serve the purpose of knowledge accumulation, management, and transfer to secure uninterrupted energy efficiency perusal.

8.3 Some Implications for Policy Developers and Governmental Bodies

It has not been a purpose of the thesis to develop policy related recommendations. The political context was rather taken as a departure point. Due to certain gaps observed during the thesis work, some implications encased in the encountered situation have been thought relevant for the attention of governmental bodies and policy-makers.

Economic instruments such as the ETS at the European level, and green certificates and electricity tax at the Swedish national level are intended to raise end-users awareness and willingness to reduce energy consumption. They have influenced substantially the final electricity price. However, it is seen that as soon as industrial companies have good profit margins, higher electricity prices (expected to grow further) do not trigger their energy saving activities immediately. Volatile prices rather lead them to a price-oriented strategy through long-term contracts and insuring the risk of price changes. Energy saving measures are lagging behind despite implemented environmental management systems.

It is the first tier in the electricity supply chain – the energy producers – that happens to initiate a dialogue. The End-Use Efficiency Directive 2006/32/EC that, first of all, harmonised the major terms used around energy end use and promoted energy efficiency improvement measures, might have strengthened this.

The Swedish Energy Management System standard has been adopted solely in connection with the PFE. The companies eligible for PFE are predominantly large and therefore are capable of implementing the required energy management set-up. Nevertheless, it is likely that by being large energy consumers, they have a precursory incentive to implement such an initiative. In the meantime, the numerous non-energy intensive manufacturers remain outside of the targeted activities. For successful policy implementation at the national level, it is recommended to draw companies' attention to energy saving practices by developing Energy monitoring guidelines supplementary to the standard. Such guidelines could cover various sources of energy including electrical energy. If undertaken by the Swedish Energy Agency, this would highlight an elementary activity that will bring about environmental performance improvement and more rapid achivement of the national targets as well as emphasise the significance of monitoring as a tool for adequate assessment and implementation of energy saving potential.

Energy audits are already a part of the Swedish Energy Management System Standard (SS627750) used within the PFE. Establishment of mandatory annual energy audits for legal entities could be a more radical action undertaken by governmental bodies. This is likely to provoke energy management at a broader scale and a search for opportunities on a consistent basis.

A recommendation related to the industrial building code can be concluded from a complication faced by industries with older production facilities. Since it has been noted that the old plants were not meant for functional sub-metering, there can be a special requirement set for such a submetering option for new industrial buildings in the Code.

In order to respond to the emerging fashion of purchasing of 'green' electricity (generated form renewable sources), it should be awarded authorisation subject to energy efficiency improvement measures at production site. Otherwise, it may act as a 'mask' by providing an easy solution to environmental performance improvement.

8.4 Suggestions for Further Research

Contribution of the present research can be summarised as identification and description of the best experience of electrical energy monitoring existing among Swedish manufacturing industries. Placement of the system as a tool within an industrial organisation's operational and management practice has been verified. Having only two examples of applied sub-metering proves the further need for looking into this aspect of operational activity in industries. Generally, empirical analysis on energy management in Swedish industries and factors that are shaping it would be valuable.

Due to lack of quantitative information during the current research, the conclusions are based on available qualitative information. Having more measurable data and outcomes of achieved energy efficiency improvements with the operational monitoring system would be of high merit.

It would be valuable to investigate the role of business management practice, production and quality management systems in energy efficiency improvement. Studying the contribution of production management systems and manufacturing philosophy towards the improvement of energy efficiency at industrial plants is another 'line' that deserves its own elaboration.

The indispensable presence of energy in various forms in every production process and connection to resources and quality management, as well as participation in implementing cleaner production, serves a good basis in scoping further research.

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Abbreviations

ABC –	Activity Based Costing
DSO –	Distribution System Operator
EC –	European Community
EEMS –	Electrical Energy Monitoring System
EMS –	Environmental Management System
EMIS –	Energy Management Information System
EPI –	Environmental Performance Indicator
ETS –	Emissions Trading Scheme
GHG –	Green House Gases
GRI -	Global Reporting Initiative
KPI –	Key Performance Indicator
PDCA –	Plan – Do – Check – Act
PFE –	Program för energieffektivisering i energiintensiv industri (Programme for improving energy efficiency in energy-intensive industries)
SEA –	Swedish Energy Agency
SVK –	Svenska Kraftnät

Glossary

Energy intensive company must fulfil the following criteria (as set by the SEA following Council Directive 2003/96/EC (2003):

a) Its costs for the purchase of energy products amount to at least 3 % of its production, value and / or;

b) The total energy, sulphur and carbon dioxide tax for the company amount to at least 0.5 % of its added value.

Examples of companies participating in the PFE are mostly represented by pulp and paper industry, wood product industry and chemical industry. As well food, iron, steel and mining industries are participating.

Green house gas is "a gas that absorbs infrared radiation and in turn emits it in the atmosphere. The net effect is a local trapping of energy and a tendency to warm the Earth's surface. Water vapour, carbon dioxide, methane, nitrous oxide, and ozone are the primary greenhouse gases in the Earth's atmosphere". (Environment Canada)

kW is related to active power, also known as Real / True Power. Watts measure that portion of electrical power which does work. 1kW=1000 W; 1MW=$1*10^6$ W

kWh is a unit of electrical energy equivalent of 1000 watts of power provided for one hour. 1kWh≈3.413 Btu (British thermal units)

Load factor "is the relationship between electric consumption (kWh) and demand (kW) for the same billing period. It is commonly calculated by dividing the monthly consumption (kWh) by the demand (kW) multiplied by the number of hours in the billing period." (Thumann, A. and Younger, W.J., 2003). The ideal load factor is as close to 1.00 as possible.

Peak load or Peak demand is "the electric load that corresponds to a maximum level of electric demand in a specified time period". (Thumann, A. and Younger, W.J., 2003)

Power factor is "the ratio of real power to apparent power. Devices that need electromagnetic field to operate, such as motors and fluorescent lighting ballast, tend to lower the power factor within a facility." (Thumann, A. and Younger, W.J., 2003)

Smart-meter – device for measuring electric power consumption with remote communication and data collection function. As described in the "Smart meters by Sustainability*first*"

"Key smart-meter capabilities:

- Measures energy consumed **-** both quantity and when (i.e. on a time-interval basis).
- Two-way communication
- Stores interval-data and transfers it remotely to a data collector / utility
- Capable of displaying consumption, tariff and other information." (Owen, G. and Ward, J., 2006)

Appendix I. Energy Management Matrix

Table 0-1 Energy Management Matrix

Energy Management Matrix						
Level	Energy Management Policy	Organising	Staff Motivation	Tracking, Monitoring and Reporting Systems	Staff Awareness/ Training and Promotion	Investment
4	Energy management policy, action plan and regular review have commitment of top management as part of a corporate strategy. Energy management fully integrated into management structure.	Clear delegation of responsibility for energy consumption.	Formal and informal channels of communication regularly exploited by energy manager and energy staff at all levels.	Comprehensive system sets targets, monitors consumption, identifies faults, quantifies savings and provides budget tracking.	Marketing the value of energy efficiency and the performance of energy management both within the organisation and outside it.	Positive discrimination in favour of energy saving schemes with detailed investment appraisal of all new building, equipment and refurbishing opportunities.
3	Formal energy management policy, but no active commitment from top management.	Energy manager accountable to energy committee representing all users, chaired by a member of the managing board.	Energy committee used as main channel together with direct contact with major users.	Monitoring and targeting reports for individual premises based on submetering, but savings not reported effectively to users.	Program of staff training, awareness and regular publicity campaigns. Some payback criteria employed as for all other investment.	Cursory appraisal of new building, equipment and refurbishment opportunities.
2	Un-adopted energy management policy set by energy manager or senior departmental manager.	Energy manager in post, reporting to ad-hoc committee, but line management and authority unclear.	Contact with major users through adhoc committee chaired by senior departmental manager.	Monitoring and targeting reports based on supply meter data.	Energy unit has ad-hoc involvement in budget setting. Some ad-hoc staff awareness and training.	Investment using short-term payback criteria only.
1	An unwritten set of guidelines. Energy management the part-time responsibility of someone with only limited authority and influence.	Informal contacts between energy manager and a few users.	Cost reporting based on invoice data.	Energy manager compiles reports for internal use within technical department.	Informal contacts used to promote energy efficiency.	Only low-cost measures taken.
0	No explicit policy. No energy manager or any formal delegation of responsibility for energy consumption.	No contact with users.	No information system.	No accounting for energy consumption.	No promotion of energy efficiency.	No investment in increasing energy efficiency in premises/sites.
Based on BRECSU 1993 Energy Management Matrix.						

Source:(Europe Intelligent Energy Programme, 2005). Energy Management Review Report p.31 .

Appendix II. Renewable Energy Sources

Energy sources entitled to electricity certificates based on Swedish Energy Agency report "The electricity certificate system, 2007":

- Wind power;
- Solar energy;
- Wave energy;
- Geothermal energy;
- Biofuels, as defined in the Ordinance (2003:120) Concerning Electricity Certificates;
- Peat, when burnt in combined heat and power production (CHP) plants;
- Hydro power:

- small scale hydro power which, at the end of April 2003, had a maximum installed capacity of 1500 kW per production unit
- new plants
- resumed operation from plants that had been closed
- increased production capacity from existing plants
- plants that can no longer operate in an economically viable manner due to decisions by the authorities or to extensive rebuilding.

Appendix III. Approaches to Production Management

Box 0-1 Lean Manufacturing

Lean Manufacturing is "A systematic approach to identifying and eliminating waste through continuous improvement by flowing the product at the demand of the customer."

Lean is about doing more with less: Less time, inventory, space, people, and money. Lean is about speed and getting it right the first time.

Source: (Lean Manufacturing Guide .Com ©). http://www.leanmanufacturingguide.com/

Box 0-2 Six Sigma

Six Sigma is "A quality management initiative that takes a very data-driven, methodological approach to eliminating defects with the aim to reach six standard deviations from the desired target of quality".

The following is implied by Six Sigma

- Continuous efforts to reduce variation in process outputs is key to business success
- Manufacturing and business processes can be measured, analyzed, improved and controlled
- Succeeding at achieving sustained quality improvement requires commitment from the entire organisation, particularly from top-level management

Source: (Authenticity Consulting LLC.) http://www.managementhelp.org/quality/sixsigma/six-sigma.htm

Box 0-3 World Class Manufacturing

World class manufacturing (WCM) is "the philosophy of being the best, the fastest, and the lowest cost producer of a product or service. It implies the constant improvement of products, processes, and services to remain an industry leader and provide the best choice for customers, regardless of where they are in the process".

Companies engaging in World Class Manufacturing strategies focus on improving operations, strive to eliminate waste and create lean organisations.

Source: (GDC Total Business Solutions). http://www.gdc-tbs.com/GDCLeanDictionaryFormatted.htm and http://rockfordconsulting.com/wcm.htm

Appendix IV. List of Interviewees

Note: The list is provided without company indication in the chronological order of interviews.

1	Marcus Hansson	Energy Advisor	14 June 2007 (08:00 – 10:00)
2	Ronald Hansson	Electrical Manager	18 June 2007 (14:00 – 16:00)
3	Göran Blom	Production Manager	25 June 2007 (09:30 – 12:00)
4	John Thulstrup	Maintenance Manager	25 June 2007 (15:00 – 16:00)
5	Per Arne Nilsson	Quality and Environmental Manager	26 June 2007 (09:30 – 10:30)
6	Jonas Roy	Financial Manager	26 June 2007 (13:00 – 15:00)
7	Mats Nordenberg	Manager, Groups Indirect Procurement	04 July 2007 (14:00 – 16:00)
8	Patrik Nilsson	Energy Manager	09 July 2007 (09:15 – 11:15)
9	Erik Johannesson	Category Manager	10 July 2007 (e-mail correspondence)
10	Tomas Bohlin	Financial Controller	12 July 2007 (14:00 – 15:00)
11	Magnus Gunnarsson	Account Manager	19 July 2007 (09:15 – 10:15)
12	Marco Coquinati	Environmental Manager	23 July 2007 (09:00 – 10:00) 24 July 2007 (09:15 – 10:15)
13	Martin Kurdve	Development Engineer	26 July 2007 (17:00 – 19:15)
14	Gunnar Nordberg, Rose-Marie Ågren	Project Manager and Business Consultant, Business Development	16 August 2007 (13:00 – 14:45)
15	Ola Lindén	Key Account Manager	17 August 2007 (10:00 – 12:00)
16	Bo Forselen	Sales Manager, Electricity	17 August 2007 (13:00 – 14:30)
17	Alfred Renne	Segment Manager	21 August (08:00 – 09:00) 21 August (13:00 – 14:00)
18	Tomas Haakon	Energy Manager	21 August (09:00 – 11:00)

Appendix V. Questionnaire Outline

A. Information about interviewee

1. What is your position in the company?
2. How long have you been working for the company (in this position)?
3. Please describe your responsibility regarding energy (electric power) issues in the company.

B. Information about the company

1. What sector of industry your company is related to?
2. How long have you had the contract with the current energy supplier and distributor?
3. Do you purchase all electric power required (or generate some)?
4. How many people from the staff are dealing with energy issues?
5. How does company report its energy performance to the stakeholders?

C. Information about production site

1. What is the type of production at this production site?
2. What is the size of the production site in terms of employees and production lines, square meters?
3. What is the major source of energy in the production process?
4. What are the major energy-consuming units of equipment in production process?
5. What drives the electric power consumption (operating hours, conditions e.g. tariff, weather, other)?

D. Information about Energy Management

1. Do you have Energy Management System?
2. Does load management take place? Who has initiated it?
3. Do you calculate energy balance for production site (s)/company?
4. Do you follow development of energy management solutions (how)?
5. What do you see as benefits of electric power savings?
6. What are the major items for energy management?

7. What parameters of electric current are of interest for you to optimise energy system (in terms of better operation of equipment)?

8. What are the incentives inside the company to the cost savings related to energy and/or energy conservation?

9. Is management (incl. corporate management) involved in energy related issues?

10. Who is looking into energy conservation opportunities? (responsible)

11. Where on the site do you see potential for energy savings?

12. Who takes decisions on development of energy management issues?

E. Information about power monitoring system (MS)

1. Do you follow electric power consumption at the site, on what basis (hourly, daily, monthly, yearly)?

2. Would you describe your MS as a process-oriented or alarm-oriented?

3. How many electricity meters are there on site?

4. What sub-units or sub-processes in production are metered?

5. What parameters of electric current do you measure (consumption, demand, power factor, other)?

6. What parameters of electric current influence equipment performance?

7. Are you satisfied with the current level of metering?

8. Who is using the data? (in terms of involved people and managers)

9. How the data is used?

10. Who takes action upon data analysis? What actions?

11. How is energy tracked through the production site / company? Is there energy accounting?

12. Is there a need for a more detailed knowledge on energy consumption on site?

13. How would you describe the way the monitoring has developed over years (if it did)?

14. Why do you think there may be a need for more detailed monitoring?

15. What according to you can be an obstacle for more detailed metering?

F. Information on environmental issues.

1. When have you been ISO 9001 and ISO 14001 certified?

2. What does company environmental policy state?

3. Do you find your environmental policy aimed at compliance?

4. Do you consider energy among your environmental aspects?

5. Do you have energy related indicators in environmental report?

6. What energy related activities/measures take place in connection with environmental management?

7. Is energy considered within the environmental management continuous improvement cycle?

8. Do you use energy consumption to measure corporate performance (relative indicators, e.g. per unit of product; per employee; per added value)?

9. What has influenced your energy efficient measures so far?

G. Future electricity prices

1. Forecast for electricity prices for 3-5 years. If possible please indicate development.

2. What is the ultimate goal of electricity purchase contract?

3. How long is the term of your electricity purchase contract and how long ahead is hedging performed? (for how many years or months is it valid since the start, what are the normal adjustments)

4. How the total electricity costs are influenced with loads at different industrial sites (focus on non-energy-intensive sites)?

5. What are the incentives inside company to implement electric power conservation measures and monitor power consumption at industrial sites?

6. It is becoming more realistic that household customers may soon be able to shift electricity suppliers based on the current prices. Do you think this at all can be considered in connection with industries?

H. Information on cost-related issues

1. How is the electricity bill constructed (cost components of the invoice)?

2. How big is the portion of electricity costs related to other production costs?

3. Does energy use influence financial performance of the production unit; corporate level?

4. Do you track energy efficiency investments within production unit; at the corporate level?

5. How electricity is accounted for in the company (by financial unit or production unit)?

6. Who is accountable for electric power consumption in the production unit; on-site?

7. Where in the cost system the energy gets recorded (direct/indirect production costs, overheads, other)?

8. Do you produce relative indicators on electricity consumed per unit produced/invoiced or per value added? (KPIs)

9. Do energy costs get split by departments/production lines/cost-centres/profit-centres?

10. Does energy represent a budget item for sites/departments?

11. Why do you think there may be a need for more detailed monitoring?

12. Would you see internal billing for energy costs as a viable option?

13. Will you find knowing energy costs per each product (and different brands) useful?

14. What do you think about allocation of energy costs as any other direct production costs?

15. If the costs of energy conservation activities fall on the cost centres, where will the generated savings get reflected?

16. Does anybody in the company follow opportunity costs of potential savings due to energy conservation when it comes to investment decisions?

17. Is the price of metering equipment (monitoring systems) an important issue to consider before decision-making?

18. Will there be a difference in the way energy is accounted for management accounting or financial accounting?

19. Why will financial department be interested in seeing reduction in energy costs?

20. Do you see any use for Life-Cycle Costing approach as one of the factors for decision-making in investments? Why?

21. If there were an Energy Action committee, would you like to be a part of such?

22. The declared peak load (kW) is paid for (to secure) but is never reached. What can be improved?

23. Do you use forecast electricity prices? how