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Environmental Performance Evaluation of the Total Heating System

The case of Sydkraft Värme Syd AB's Staffanstorp Heating Plant

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Abstract

This thesis deals with the environmental performance evaluation (EPE) of the Total Heating System. The main research objective was to identify all the environmental improvements made by Sydkraft after it took over the heating plant. The following research question was phrased: **How can the environmental performance evaluation be performed in a systematic way in the heating system, and what environmental improvements have been achieved at the Staffanstorp Total Heating System plant?** In order to answer this question, the environmental performance is evaluated with the help of a developed EPE model and selected environmental performance indicators.

The life span of the heating system was divided into two parts, the past state (period before 2000) and the present state (2000 till present). A set of initial and final indicators for the past and present states respectively, was developed and measured. Comparison was made between these indicators, and an analysis of their difference was conducted.

The analysis indicated that environmental improvements have been achieved by Sydkraft since its takeover. However, it also highlights the area where no improvements or a shortfall were registered. The performance of the Total Heating System plant was also compared to the overall performance of Sydkraft. Recommendations to Sydkraft address the importance of performing EPE, and the usefulness of indicators to measure those areas where performance analysis could not be accomplished due to the lack of information.

Executive Summary

This thesis addresses the problem of Sydkraft, with the Total Heating System. The definition of Total Heating System lies in the concept of total ownership of the plant by Sydkraft, which means that Sydkraft is totally responsible for the operation, production, maintenance, fuel quality, environmental issues, quality of the product and service of the heating system. Sydkraft is operating more than 2000 Total Heating System (THS) plants over all of Sweden. These plants were acquired in different years in different operational conditions. Continuous acquisition of these plants to its portfolio made it difficult for Sydkraft to track and identify the improvements made in the total heating system after the takeover. The main challenge of Sydkraft is to properly evaluate the environmental performance of individual plants, and to incorporate these evaluations into the bigger picture of the environmental performance of the overall group.

The main objective of this research was to develop a systematic model with relevant Environmental Performance Indicators (EPIs) for performing environmental performance evaluation (EPE) in Sydkraft's Total Heating System plant. Another aim of this research was to identify all the environmental improvements achieved at the Staffanstorp total heating system plant after its takeover by Sydkraft.

EPE, as detailed in the International Organisation for Standardization (ISO) standard, follows basically a "Plan-Do-Check-Act" management model. The developed model is based on the process for identification of the environmental improvements in the Total Heating System. Environmental performance evaluations based on indicators was an effective system to compare an organization's past and present environmental status. The established environmental indicators were helpful in time series analysis (comparison with the indicators of previous periods). This comparison helped to identify the environmental improvements made in the particular period, and track the environmental performance based on environmental performance criteria. In other Total Heating System plants also, the environmental performance evaluation can be accomplished based on the developed model, by comparing the initial environmental status with the final environmental status. The measurement and evaluation of environmental performance can be done with the help of suitable environmental indicators.

Earlier, at Staffanstorp plant, there was a problem of high level of flue gas from the stack. It was due to the low stack height and also the stack was not properly designed according to the flow and the velocity of the flue gas. Another problem was high level of dust in the flue gas, which due to poor condition of the boiler. Water chemistry of the plant was not good. The water wasn't softened enough to get rid of its hardness, which formed scales on the heating surfaces. Improper filtration led to accumulation of sediments in the boiler that reduced the heat transfer by reducing the heat surface area and by thickening the heat transfer surface. In the past, leakages were the main cause of high water consumption. Another problem was energy loss, mostly from the secondary system of the heat distribution network.

For developing environmental indicators, importance was placed on the operational performance indicators, quantity based indicators, and a few management performance indicators. The cost of the material or its value in economic terms, was not considered in the selection of indicators. The investment indicator, which is an MPI is the only cost based indicator in the set of EPIs. Relative indicators allow comparison of environmental performance among companies irrespective of sizes, places and technology used, provided the product remains the same.

The development of indicators was based on evaluated significant environmental aspects. The evaluation was based on the criteria developed by Sydkraft. Development of indicators also depends upon the past environmental status of the total heating system plant. The mapping of the heat production process also supported the process of indicator development. Inputs for the indicator

development are also taken from the material and energy balance as well as applicable regulatory compliances.

Sydkraft made a number of changes in the plant. Technological changes were made, such as the replacement of inefficient equipment, the alteration of some existing equipment, etc. Changes were also made to increase the energy and resource efficiency. Installation of pollution control equipment was done at different parts of the heating production process. Stack height was increased to avoid the dusting problem in the nearby areas.

Many leakages in the distribution pipes were addressed. A state-of-the-art water treatment plant based on the reverse osmosis principle was installed. Better insulation of the heat distribution pipes helped in a big way to reduce the heat losses. The exhaust boiler for the bio fuel unit was replaced with a better boiler. A degassing unit was installed in the heating plant in the year 2000. In this unit, steam flows in from the boiler and released through the nozzles placed at the bottom of the tank. Steam in the degassing unit helps to remove the gases like O_2, CO_2 and other dissolved gases, which are corrosive in nature and can damage the boiler equipment and effects its performance.

The environmental improvements were identified on the basis of the comparison of the initial and final indicators, which measured the environmental status of the past and the present state respectively. Initial indicators measured the average values for the past state, which covers the period from 1996 to 1999. The period after Sydkraft took over the plant, i.e. from 2000 till present, is the present state and the final indicator does its average measurement. In the comparison, the difference between the past and present state values is analysed.

The result of the analysis shows that the consumption of non-renewable (natural gas) fuel has gone down in the past few years. There is a significant reduction of natural gas consumption since the takeover in 1999. There is a reduction in electricity consumption in the plant operation, which can be termed a significant improvement. The average water consumption per production from the year 2000 to June 2002, is 5.48 Litres/MWh. Average water consumption before 2000 was 2.06 litres/MWh, which was quite low compared to the present average consumption. The water consumption has gone up significantly in spite of changes made by Sydkraft in terms of installing a new water treatment plant and preventing leakages by changing some of the distribution-piping network.

Reduction in NOx emission, measured from past to present state is about 0.03 kg/MWh. It is not a significant improvement but the emission is well within the regulatory limit. There is a significant improvement in dust emissions from the Staffanstorp plant, which was one of the problems in the early days. Carbon dioxide emission from bio fuel seems to be fluctuating. At the time of takeover (1999), the yearly CO2 emission was 11,076 tons and in the year 2001 it was 136,581 tons. Carbon monoxide was calculated in the form of kg/MWh, does not show any improvement in the local environment, but it is more related to the running performance of the furnace and boiler. Also, there is no reduction in bottom ash generation. Energy recovery from the gas condenser units has gone down.

No improvement was shown in the return water temperature due to unavailability of data. At present, the return water temperature is 58^0C. The temperature is too high for the return water, which should be around 40^0C. High temperature reduces the heat transfer. High temperature also affects the efficiency of the gas condenser. Even the boiler efficiency depends on the temperature of water entering the boiler, and return water is reused as a boiler feed, which affects its performance.

The environmental performance of Staffantorp's THS was also compared to Sydkraft's overall performance. It was compared to Sydkraft's overall group performance to see Staffanstorp's compliance with the corporate strategy and approach. Some comparisons were also made with Syd Värme AB, the subsidiary of Sydkraft involved in heat production and distribution.

The percentage of heat production from natural gas in respect to total production at Staffanstorp has gone down significantly over the past few years. At the same time, shifting the production towards bio fuel is gradually taking place to cover the same amount of production. This substitution from non-renewable to renewable fuel is in compliance with the Sydkraft's overall strategy. There is a significant drop in natural gas consumption in Sydkraft group and at Staffanstorp heating plant. At Staffanstorp, there was a continuous decrease in dust level from 1998 to 2000. The trend of NOx emission shows reduction in the emissions at Staffanstorp and in overall Sydkraft. The emissions went down in Staffanstorp due to better combustion efficiency, which also keeps balance between the CO and NOx emissions, as both are interdependent on each other. The emission of NOx at Staffanstorp is well within the regulatory limits applicable to the plant.

In some areas, the environmental performance of Staffanstorp was also compared to Syd Värme AB. The ratio of bio fuel to natural gas consumption at Staffanstorp is higher than at Syd Värme AB. In the year 2000, the ratio of bio fuel to the natural gas use was 6.79, whereas it was 0.37 in overall Syd Värme AB. So, it can be said that Staffanstorp heating system is ahead of the overall Syd Värme AB group in shift towards using renewable fuel.

The thesis concludes that the environmental performance evaluation is an effective tool to monitor and measure the environmental status of an organization. The Total Heating System should monitor and measure its environmental status based on EPE criteria, and evaluate its performance based on proposed EPE model. Indicators developed in the study are given below:

Box 1 Developed indicator for the heating system

- Total non-renewable fuel consumption per unit of energy produced
- Total renewable fuel consumption per unit of energy produced
- Electricity consumption per unit of heat produced
- Amount of CO2 emitted from the non-renewable fuel per unit of energy produced
- Amount of NOx emitted per unit of energy produced
- Amount of fly ash emitted per unit of energy produced
- Amount of bottom ash emitted per unit of energy produced
- Water consumed per unit of energy production
- Intensity of noise generated
- Frequency of breakdown of the bio fuel boiler
- Temperature of the return water
- Amount of energy recovered from the gas cooler or condenser
- Number of instances of non-compliance
- Environmental investment made per year
- Environmental training for employees or contractor conducted

Based on the study, the thesis further concludes that the environmental performance of the Total Heating System was not good when Sydkraft took over these plants. But after changes made by Sydkraft, certain environmental improvements in the process and the operation were achieved in the total heating system. Comparison of the environmental performance of the heating plant with the overall Sydkraft performance has given an indication of the plant's position at present, compared to Sydkraft's overall vision and strategy.

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1 Introduction

This thesis was carried out as part of the International Masters Programme in Environmental Management and Policy at the International Institute for Industrial Environmental Economics, IIIEE at Lund University, Sweden. The research was carried out between May and September 2002. It analyses the environmental performance of the Sydkraft total heating system plant.

This chapter builds the foundation for the research. It introduces the research problem and research methodology, and sets the scope and its limitation. Then an outline of the thesis is presented.

1.1 Background

Energy is one of the essential commodities for carrying out different human activities. All the processes on this earth are driven by energy in one form or another. Man developed his own way of generating and supplying heat and light since the direct energy available by nature is not always economically and technologically feasible for different purposes. The objective of the energy system developed is to fulfil the needs of mankind and deliver the benefits that energy offers. The term "energy services" is used to describe these benefits, which in households include illumination, cooked food, comfortable indoor temperatures, refrigeration, and transportation, etc. Energy is also required for almost every commercial and industrial activity. For instance, heating and cooling are the most important part of the industrial process and used in almost all types of industries[1].

Industrial process heating is vital to nearly all-manufacturing processes, heat supply being needed to produce basic materials and commodities. In US the heating processes consume about 5.2 quads (quadrillion Btu), which is nearly 17% of all energy used by industry. Heat derived from combustion of fossil fuels accounts for 92% of this energy; electricity use accounts for the remaining 8%. Industry's heavy reliance on these processes creates a critical need to optimise their performance for improved productivity, energy efficiency, and competitiveness[2].

The environmental impacts of the energy generation and its use are the crucial thing in the present. For centuries, wood burning has contributed to the deforestation of many areas. Even in the early stages of industrialization, local air, water, and land pollution reached high levels. The energy sector is one of the major polluters of the environment by its emission of toxic pollutants in the air and water. Fossil fuel combustion produces more carbon dioxide (CO2) than any other human activity. This is the biggest source of the anthropogenic greenhouse gas emissions that are changing the composition of the atmosphere and altering the global climate system, including the amount and pattern of rainfall[3].

The heating system uses a huge amount of fuels, the main resources used for the production of heat. Air and water emissions with other environmental impacts are the main cause of concern. At present almost everywhere energy production is being thoroughly reviewed and innovated to make it eco friendly and sustainable. The heating system also went through some changes towards betterment by

[1] United Nations Development Programme (UNDP). (2000). *World energy assessment: Energy and the challenge of sustainability.* United States of America: UNDP, p.4.

[2] Oit. Directorate of Environment. (1999). http://www.oit.doe.gov/bestpractices/process_heat/pdfs [2002, June 24]

[3] United Nations Development Programme (UNDP). (2000). *World energy assessment: Energy and the challenge of sustainability.* p.6.

the use of the best available technology and fuel substitution. But more must be done in the future because most energy production centres are putting huge stress on the environment. To keep track on operation of the heating system and increase its efficiency and effectiveness to reduce the burden on the environment, regular measurement and performance evaluation of the system is important. This can give a clear picture of what is going on and what should be done for further improving the environmental performance. It can also lead towards continual improvement of the environmental performance.

This particular research is intended to provide a framework or model for Environmental Performance Evaluation (EPE), to evaluate the environmental performance of the Total Heating System at Sydkraft. Suitable Environmental Performance Indicators (EPIs) are developed within the EPE framework to measure and evaluate the performance of these systems.

1.2 Research Problem

Sydkraft is operating more than 2000 Total Heating System (THS) plants all over Sweden. These plants were earlier under different companies built to supply heat to industries. After the takeover of these plants, different types of environmental improvements have been made in the plant. These plants were acquired in different years with different operational conditions. Since Sydkraft kept adding these plants continuously in its portfolio and making changes, it has become difficult for Sydkraft to track and identify the improvements made in the total heating system after the takeover. The company wants to know all the changes made at the plant level and evaluate the environmental performance of the THS in the form of environmental improvements and shortfalls. There is a lack of systematic process to identify and track the environmental improvements in the heating plant. Sydkraft also want to assess the environmental status of the total heating system based on its environmental policies and corporate management strategies. The main challenge of Sydkraft is to include these environmental performance and improvements into the overall group performance.

Instead of getting the positive results from the changes made in the total heating system, regular acquisition of these plants is increasing the number of plants owned by Sydkraft, which in turn is increasing the overall total emissions of Sydkraft. One good example supporting the above problem is, due to acquiring these heating plants, the total overall CO_2 emissions of Sydkraft is increasing despite several improvements made. Changes in the plants vary from the technological changes to the fuel substitution. Improper assessment of environmental improvements is providing different pictures and messages to their stakeholders. Increase of group overall emission through THS is undermining the other environmental improvements made by Sydkraft. The company feels that it is necessary to check to determine that the changes and environmental improvements are in compliance with Sydkraft's corporate environmental policy and the environmental objectives.

1.3 Purpose and Objective

The purpose of this study is to identify and track environmental improvements made by Sydkraft in the Total Heating System from its takeover until now. The improvements could be of a general nature and/or fulfil certain performance criteria within the corporate environmental policy, objectives and targets.

The objective of this research is to develop a systematic model or criteria for performing environmental performance evaluation (EPE) in Sydkraft's Total Heating System plants. Further, the aim of this research is to define the relevant Environmental Performance Indicators (EPIs) within the total heating system in order to help the company initiate a process of Environmental Performance Evaluation (EPE).

1.4 Research Questions

1. What is Environmental Performance Evaluation and what are its potential benefits?

2. How can the Environmental Performance Evaluation be performed in a systematic way in the Total Heating System plants?

3. What is the environmental performance at the Staffanstorp Total Heating System plant?

    a) What was the environmental status of the plant before its takeover by Sydkraft?

    b) What are the changes made by Sydkraft in the plant?

    c) What is the present environmental status of the plant?

    d) What environmental improvement has been achieved in the Total Heating System plant since Sydkraft took it over?

1.5 Scope and Limitations

The study focussed on the environmental performance at the plant level. It didn't consider the analysis of environmental condition and the impact at the local, regional, national and global level. No link has been shown between the improvements done at plant level and the environmental status in the surrounding area.

The study was done on a sample basis, which looked upon some of the plants in and around Malmö. From the Total Heating System plants listed for the study, the plant located in Staffanstorp was finally selected for testing the EPE model. There may be other plants, which would have been better to study, but due to the time limitation and information limitation the area of selection was narrowed down to a few plants only.

The total environmental impact of the heating plant are significant when viewed over its entire life cycle, from cradle to grave – from land requirements and construction to the extraction and transport of fuel to heat production, and finally to the demolition of the power plant and disposal of the resulting waste. Typically, the Life Cycle of the heat production starts from the extraction of raw material, which is used as fuel at the heat production unit. Then come the boiler and other accessories, which produce heat and then supply of heat through the distribution system. The final stage is the heating service at the customer's end of the life cycle where there are other environmental impacts. It provides numerous services like process heating, space heating, providing comfort, etc. Sydkraft's job in the selected heating system is to produce and distribute heat. Since the prime objective of this research is to identify changes and improvements at the production unit, Life Cycle Assessment approach was not taken for this study. The scope of the research restricts itself to the operational boundary of Sydkraft, i.e. heat production system (Total Heating System) and the distribution system shown in Figure 1. Distribution operation is usually covered in the production system.

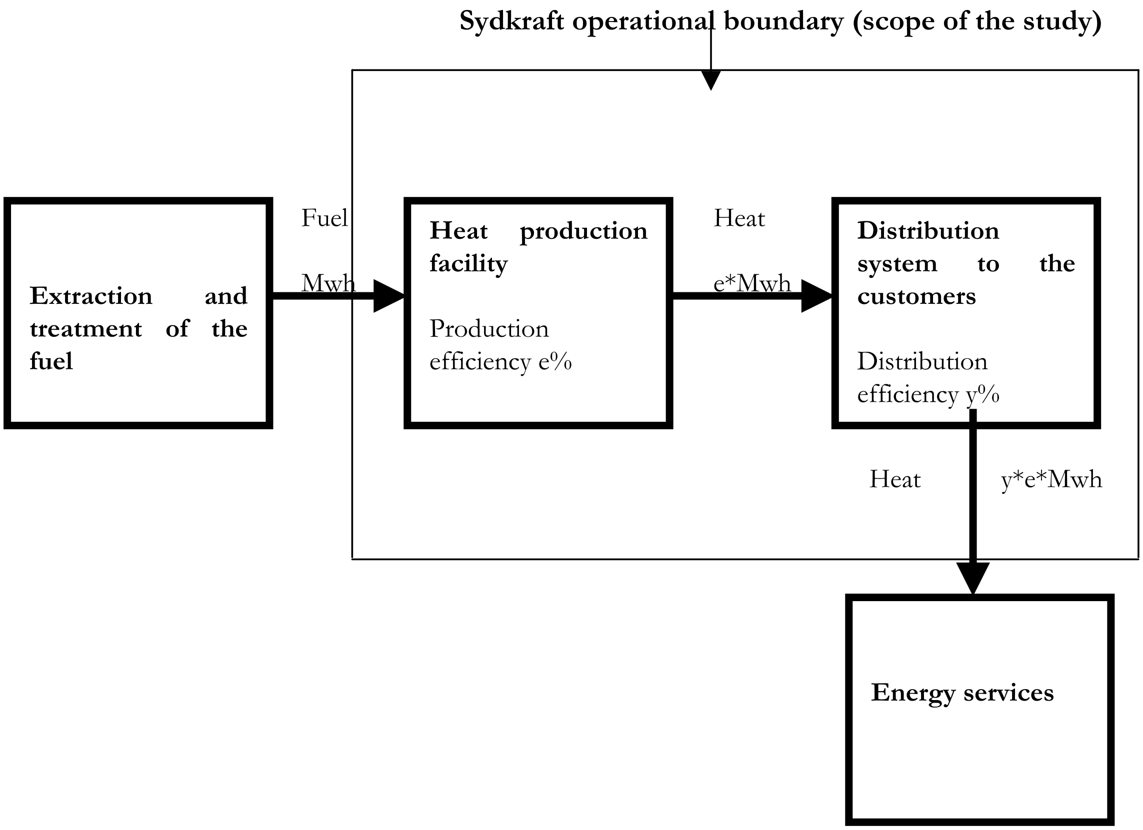

Figure 1Operational boundary of Sydkraft Total Heating System

The major limitation of this research is the availability of required and relevant data. The outcome of the research totally depends on the availability and quality of the information required. Since the environmental improvements are analysed on the basis of the past state (period before the takeover) and the present state (after the takeover until present), it is difficult to get all the information of the past state. The reason for unavailability could be lack of an effective system to record and use data earlier. Due to lack of information about the heat distribution efficiency (y%, shown in Figure 1), environmental performance indicators were developed on the basis of heat produced from the boiler.

Limitation in the study due to the language barrier can't be neglected, since most of the company's documents were in Swedish language. Translation of that information has been tried but certain things were still overlooked due to the complication of converting into English. Selecting a plant and doing the research study based on that was also a part of limitations for the applicability of the study to other plants. Even though there are no major differences between the heating system plants, environmental improvements evaluated are specific to the selected plant. The reason is that in the study a certain type of process and data quality and information were covered.

The limitation of the evaluation process used in this study could be in the implementation in other Total Heating System plants. The EPE study is done on a specific type of operation and technology. It is possible that certain performance criteria are relevant only to certain resources or fuels or processes, but slight changes in these criteria could make the study applicable to other types of plants as well.

Finally, the time available for conducting the research and writing the thesis was limited to fourteen weeks only. There were limitations to the number of visits to different total heating system plants for practical information gathering. Due to the limitation of the time, the process and other functions of the heating system were observed briefly, which led to certain assumptions.

1.6 Research Methodology

The conduct of this study basically involved reviewing literature, developing an EPE system and pilot-testing the system on a selected company. The entire research task involved can be divided into six stages, as described below in Figure 2. The first stage was to do intensive review of some general literature on EPE and available Sydkraft documents. In the initial stage a brief survey of some Total Heating System plants was also made. Based on the knowledge gained from the first stage and research objective, a comprehensive EPE model was developed in the second stage, keeping in mind its suitability to different heating plants irrespective of some differences in their processes and operations. The third stage was the process of selecting the Total Heating Plant (THP) for the case study from the group of Total Heat Systems. The selection criteria are defined according to a matrix, and the THP most suited to the criteria, was selected. The fourth stage was the indicator development. It was based on evaluated environmental aspects, mapping of the complete process, and material and energy balance. The fifth stage was the analysis phase. The framework or model, which was self-developed based on ISO Standard, is used for the analysis. Collection of data was done through interviews, company's document reviews, and site surveys. Data collection followed measurements of indicators according to their indices and comparison of initial and final indicators. The sixth stage was the final stage, where the results of the analysis are drawn in the form of environmental improvements and comparisons of environmental performance with Sydkraft overall performance.

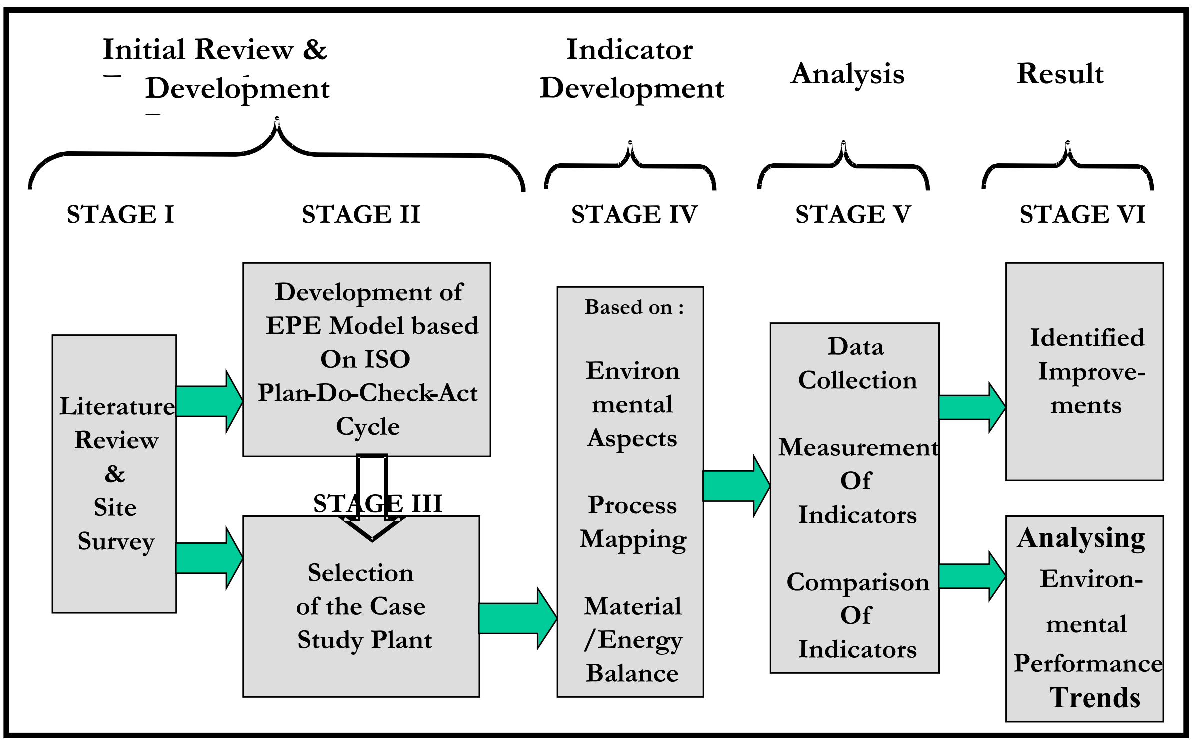

Figure 2 Stages of Research Process

Stage I: Literature Review

The first stage of the study involved literature review of ISO[4] standards, environmental performance indicators and measurement books, journals, and relevant articles in order to gain better understanding in the following areas:

- Performance measurement system in general

[4] The International Organization for Standardization

• ISO 14000 Series, especially ISO 14031, ISO 14032[5]
• Environmental performance evaluation (EPE)
• Benchmarking in environmental performance

The company's environmental reports, documents, previous gap audit reports for different sites and other related documents were also reviewed in order to facilitate the development of model and selection of the case study plant for pilot-testing of the proposed EPE model. Few surveys of the Total Heating System plants in and around Malmö [6] were made before developing the EPE model.

Stage II: Development of the EPE Model

The developed evaluation model is based on the ISO Standard formula of 'Plan-Do-Check-Act,' which is shown in Figure 3. The attempt was also made to fit it into the continuous improvement model in the ISO 14001[7] standard (1996).

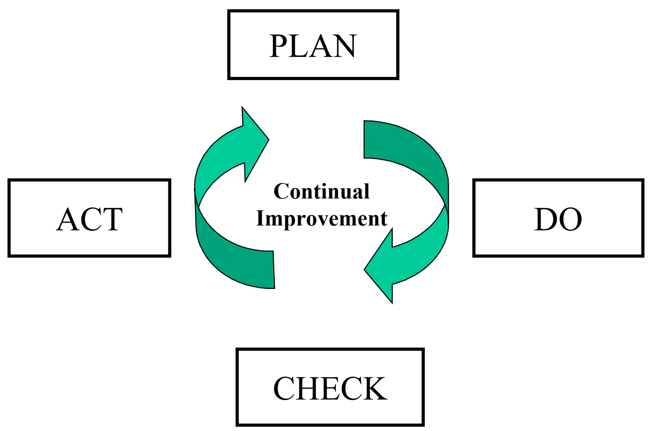

Figure 3 Deming's Plan-Do-Check-Act cycle (Source: ISO 1999)

The basic framework of this formula is the same but some changes are made in the implementation phase, especially considering the type of approach needed for this particular research and the nature of the companies taken. The required modification has been made in the implementation (Do) part of this standard framework.

The EPE model is based on the literature review and the initial diagnostic work done at some of the Total Heating System plants. Types of indicators to be selected and the process of doing the analysis with the help of the proposed model are explained in Chapter 3.

Stage III: Selection of the Case Study Plant

After development of the EPE model, it needs to be tested. This study is primarily with the Sydkraft AB and a plant selected for this research was from the 2000 Total Heating System, which is under the umbrella of the mother company Sydkraft AB. Staffanstorp total heating system plant was selected for the testing. The selection was made based on certain criteria, which are presented in matrix form. Several plants in and around Malmö are analysed on the pre-defined criteria, and a final selection is made which fulfils the criteria in a most appropriate way.

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[5] ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines & Examples

[6] A city in southern Sweden

[7] ISO 14001 Standard: Environmental management system- Specification with Guidance for Use

Stage IV: Development of Indicators

Based on the environmental evaluation process according to EPE model, two sets of environmental indicators were required, i.e. initial and final set of indicators. These indicators were developed primarily on the basis of identified and evaluated environmental aspects. Process mapping, input and output analysis, and the diagnostic of the past environmental status, supported the indicator development. Detailed description is presented in section 4.6

Stage V: Process of the Analysis

This section deals with the ways the data were collected and measured, and analysed. First the collection of primary data is described, followed by a description of how secondary data were collected, and then the process of analysis is briefed.

Collection of Primary Data

The data collection was done to measure the selected environmental indicators. Most of the information about the environmental status of the total heating system was collected through interviews and company's report. Interviews were chosen as the one of the main data collection methods, because this research was intended to identify the environmental benefits, and interview was considered the best possible way to fill the gap, left by the company's documents. The people interviewed were selected deliberately based on their position in the company and probability of getting data that could not be gathered as easily from other sources. The interviews conducted can be characterized as qualitative, non-standardised and semi structured. One of the interviews was recorded on tape and written down, which was not done with other interviews.

Most of the quantitative data were collected from the company's documents and reports. The environmental reports of the case study plant, which are sent to the regional regulatory authority, were the most important primary sources of quantitative data used in the study. Environmental reports from 1996 to 2001 were used as the source of data for all those periods, and data of the current year was taken from the unofficial documents, e.g. company's data bank. Sydkraft's corporate environmental reports, annual reports and some other documents were also referred to.

Collection of Secondary Data

The use of secondary data has fulfilled different purposes. It has provided a conceptual context for developing the environmental performance evaluation system and identifying indicators. Definitions, standards, guidelines and some framework related to the EPE process have been studied. Secondary sources also helped in collecting information about the Sydkraft and the Total Heating System in general. Most of the secondary data collection was done through scanning of literature in the IIIEE library, searching the Internet and some other databases.

Indicator Measurement and Analysis based on the EPE Model

To answer the research questions it is important to analyse data and information and extract the result in the form in which it is needed. Analysis is done on the basis of the developed EPE model (shown and described in Chapter 3) based on the framework of ISO Plan-Do-Check-Act cycle. Following each and every step in the model was part of analysis. It starts with the planning phase of the EPE work and ends with identifying the environmental improvements made by Sydkraft. In the process of analysis, a set of initial and final indicators were measured based on the data collected The final part of analysis was the comparison of the value measured by the help of initial and final environmental indicators meant for the past and present states respectively. The average values of different set of years are taken to calculate the average values for the past and present states. Table 1 shows the process of calculating the values for different states. The difference between the measured values was taken for further analysis of the environmental performance.

Table 1Process of calculation for the measurement of indicators

PAST STATE				**PRESENT STATE**		
Average value (1996 – 1999)				**Average value (2000 – June 2002)**		
1996	1997	1998	1999	2000	2001	2002 (up to June)

Stage VI: Draw Results

Based on the analysis with EPE model, the results are drawn. The results are in the form of identification of all the environmental improvements (including shortfall) at the Total Heating System plant. Wherever there are shortcomings, some proposals are made on how to fill the void and tackle the problem in the future.

Comparison of the environmental performance of the case study plant was also done with the overall performance of Sydkraft. Yearly trends of few parameters were compared between Staffanstorp and Sydkraft, and analysis was made about the position of the Total heating system in respect to Sydkraft's overall vision and strategy.

1.7 Outline of the Thesis

Chapter 1 serves as an introduction to the research topic, research problem, objective of the research and presenting the research methodology. In Chapter 2, an introduction to Sydkraft and its subsidiary company Syd Värme AB is given. It also gives the description of the Total Heating System (THS) and its environmental performance.

Chapter 3 presents the definition of environmental performance evaluation (EPE) and its benefits. The developed EPE model with the process of performing EPE is also presented in Chapter 3. The selection process of the case study plant and its introduction is presented in Chapter 4. It describes the process of selection of environmental performance indicators (EPIs), and presents the set of initials EPIs with its measurements. Chapter 5 contains description of changes made by Sydkraft at Staffanstorp THS plant, and the present environmental status of the plant. It also presents final set of indicators with its measurement.

Chapter 6 contains the analysis based on the comparison between initial and final indicators. It presents the results in the form of environmental improvements, and the compliance of Staffanstorp's environmental performance with Sydkraft overall environmental performance. Finally, conclusions and recommendations are given in Chapter 7.

2 Sydkraft and its Total Heating System

This chapter gives the description of Sydkraft including its history, organisational structure, and business. It also contains the introduction to Syd Värme AB, which is the subsidiary company of Sydkraft. The description of Syd Värme AB was given because the case study plant for the research is part of this company. Then, the conceptual description of the Total Heating System is presented in this chapter, and finally, the general environmental performance of the Total Heating System is described.

2.1 Company Description of Sydkraft

Sydkraft AB is the holding company of Sydkraft Energy Group. It was established in 1906 under the name, Sydsvenska Krafttiebolaget. The company was listed on the Stockholm Stock Exchange in 1996 and delisted in September 2001. The name was changed to Sydkraft AB in 1977. There are approximately 5100 employees in the group, among which are 109 in Sydkraft AB. Sydkraft became a subsidiary of the German energy company E.ON Energie AG[8] in May 2001. The largest shareholders are E.ON Energie and Statkraft[9].

Sydkraft AB represents the entire Group and is responsible for corporate management, policies and strategic planning within the Group as well as decisions on acquisitions and selling of other companies.

Sydkraft group[10] includes companies, which supply electricity, natural gas, heating, liquefied petroleum gas (LPG), solid fuel, information technology (IT), electrical installation, measuring, telecom and consulting services. Its operation is based mainly in Sweden in about 125 locations and in some other locations in Scandinavia. The Group's energy services range from the supply of electricity, heating and gas to maintenance tasks and consulting services. It comprises four business areas consisting of 60 operating subsidiaries, of which 35 have their own personnel. Each business area has a managing director.[11]

The top management of Sydkraft AB is headed by the Chief Executive Officer (CEO) and Vice Executive Directors. Four managing directors are in control of the four business areas: distribution, consulting, marketing and production. Management groups include: the Business Development Controller, Business Development for Heat, Finances, Research & Development/Environment, Future Centre, Company audit, Information and Society, IT, Group controller, Corporate Law, HR (Human Resource) and Business Development, Production, and Strategic Business Development[12].

In 1997, The Group top management set a target for all its companies to implement an Environmental Management System (EMS) and seek certification according to the ISO standards 14001. In March 2000 the decision to implement an ISO 14001 based EMS was also made for Sydkraft AB.

The goal of Sydkraft is to have strongest brand name in the energy sector. Two new pieces of the puzzle in this respect are the Group's focus on materials and energy recovery operations, and water supply. Materials and energy recovery operations are important since the amounts of waste being

[8] A German energy major involved in different business

[9] Sydkraft AB. (2002). http://www.Sydkraft.se (14th July, 2002)

[10] "The Group" stands for the entire Sydkraft Energy (electricity & heating units), production, consulting, sales, IT Group.

[11] Sydkraft. AB. (2000). Annual Report 1999. Malmö: Sydkraft AB, Group Management, p.70.

[12] Sydkraft. AB. (2001). Annual Report 2000. Malmö: Sydkraft AB, Group Management.p.45.

generated are increasing, and at the same time this trend must be reversed and a reduction achieved over the long term[13].

Sydkraft's environmental work shall be characterized by a holistic approach, openness and objectivity and shall contribute to globally sustainable development. Environmental work is an integral part of Sydkraft's commercial operations and the care and cultivation of Sydkraft brand. With a couple of exceptions, all Group subsidiaries and the Parent Company, Sydkraft AB, were environmentally certified in accordance with ISO 14001 at year-end 2001[14]. The corporate environmental policy shown in Box 2 is followed in all the concerned units of Sydkraft. For Sydkraft, sustainable development means being able to contribute to the quality of life and people's welfare today without jeopardizing the prospects for future generations. Efforts in this area will be based on the three cornerstones of sustainable development: economic, environmental and social sustainability[15]. Sydkraft's current vision of the environment and sustainability is encapsulated in the Group's environmental policy. The vision provides the basis for Sydkraft's long-term work on environmental and sustainability issues.

Box 2 Sydkraft's Environmental Policy (Source: Sydkraft, 2002).

Sydkraft's Environmental Policy

Vision

The environmental work of the energy group Sydkraft will be characterized by a comprehensive approach, openness and expertise, and will contribute to global sustainable development. Environmental work is an integral part of business operations and management of the Sydkraft brand.

Through continuous improvement, Sydkraft will reduce the environmental impact of its operations, and its products and services will contribute to a better environment, harmonizing people, the community and nature. Concern for the internal and external environment will be integrated into day-to-day operations at all levels.

Sydkraft's commitment in the environmental field will be distinguished by strong initiatives and foresight with respect to current and future demands from the community, customers, employees and other stakeholders.

Objectives

The task of continuous improvement will be characterized by a desire to:
- increase our customers' comfort and competitiveness
- reduce and limit environmental impact
- work well within the standards laid down by the community and other
stakeholders, as well as foresee future requirements and identify new challenges at an early stage

Strategy

Our work to improve the environment is based on a clear division of responsibility and established routines supported by environmental management systems and quality control procedures.

We will follow and conduct research and development as well as develop our own expertise in order to be able to evaluate the environmental implications of alternative measures and relate them to future requirements and possibilities.

We will improve efficiency in order to use resources in a sustainable manner together with our customers and suppliers. When purchasing products or services, we will always consider whether a product or service can be replaced by one with better environmental characteristics.

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[13] Sydkraft. AB. (2002). Annual Report 2001. Malmö: Sydkraft AB, Group Management, p. 45.

[14] Sydkraft. AB. (2002). *Annual Report 2001.* Malmö: Sydkraft AB, Group Management, p.10.

[15] Sydkraft AB. (2001). *Sydkraft and The Environment: Responsible business-today and tomorrow.* Malmö: Sydkraft AB, p.5.

Heat production in Sydkraft amounted to 5,658 GWh (3,939)[16] in the year 2001. District heating production increased due to the acquisition of Norrköping's heat operations and colder weather during parts of the year, and amounted to 4,649 GWh (3,131). Deliveries of Total Heat rose to 1,009 GWh (808) in 2001, as a result of newly contracted volumes in combination with colder weather conditions.

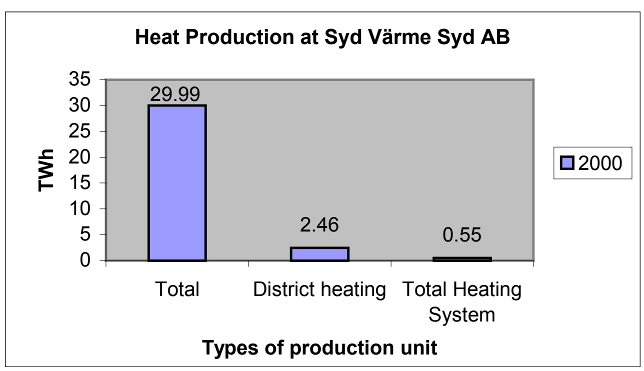
Heat operations continued to develop during the year through several acquisitions. In Denmark, six small co-generation plants were acquired. In Poland, two new acquisitions were concluded in Koszalin and Zlotów, in which Sydkraft holds 31% and 70% of the shares, respectively. Discussions and analyses are underway in both Denmark and Poland regarding new acquisitions.

2.2 Company Description of Sydkraft Värme Syd AB[17]

Sydkraft Värme Syd AB is the subsidiary company of Sydkraft, which deals with the production of electricity and heat in southern Sweden. It produces and distributes district heating and district cooling to customers as well as offer local heating and cooling solutions to their customers according to its suitability. Total heat production by Sydkraft Värme Syd AB is around 3,000 GWh (shown in Figure 4) by totalling all types of district and total heating units. The biggest district-heating network is in Malmö-Burlöv. Through it the company delivers annually around 2000 GWh of heat, of which 50% is produced from renewable energy source, to 10 000 customers. In parts of the western harbour in Malmö, the company offers district heating and district cooling that is based on 100% local renewable energy.

The company has several smaller district and total heating networks in different areas of southern Sweden and in them it delivers annually over 1000 GWh. The fuel used in those networks is mainly bio fuel. They have even undertaken all the aspects of providing heat to customers where it is responsible for its heating and cooling maintenance. The fuels mainly used are bio fuel and natural gas but even, electricity. It also owns electric pans that are placed with customers, and when electricity is cheaper, the customers' requirement is taken care of by this alternative means that uses electricity for heating.

Figure 4 Heat productions at Sydkraft Värme Syd AB



[16] Values in the brackets are referring to the previous year values.

[17] Sydkraft AB. (2002). http://www.Sydkraft.se (2002, July, 21)

Sydkraft Värme Syd AB's Environmental Policy[18]:

Sydkraft Värme Syd AB should, as a producer and distributor of energy in the form of heat, coolness and electricity, offer its customers cost-effective products and services. At the same time Sydkraft should show a clear environmental respect to internal and external stakeholders, and strive for decreased environmental impacts as shown in Box 3.

It means that:

- The focus on our environmental impact is part of our daily work, which creates confidence in our business.
- We stimulate our employees to engage, to be involved and take responsibility in the environmental work through education and information.
- We prevent and limit, during normal as well as abnormal occasions, noise and emissions to air, soil and water.
- We provide households with energy and use as far as possible best fuels and technology that decreases environmental impact, locally and globally.
- We strive for decreased waste, increased re-use of bio-ashes and coordination of transports to and from our facilities.
- Laws and demands within the environmental area are minimum demands and we set high demands on safety and quality in our work.
- We constantly strive for improving ourselves according to our environmental goals.
- We strive for setting as high environmental demands on suppliers and entrepreneurs, as well as on other cooperation partners, as we do on ourselves.
- We inform openly about our environmental work and our environmental impact through an open dialogue with customers, co-workers, suppliers, entrepreneurs, authorities and other stakeholders.

Box 3 Explanation of Sydkraft Värme Syd AB Environmental Policy (Source:Sydkraft Värme Syd AB, 2001)

Company's main products in heating business and services:

- District heating
- District cooling
- Total district heating
- Total heating system
- Total cooling system
- Combined heating system

[18] Sydkraft AB. (2002). http://www.Sydkraft.se (2002, July 21)

2.3 Total Heating System

The total heating system is similar in function and operation to the district heating system, differing only in the way it defines its management and service.

The definition of Total Heating System lies on two aspects[19]. First is the concept of total ownership of the plant by Sydkraft. It means that Sydkraft is totally responsible for the operation, production, maintenance, fuel quality, environmental issues, quality of the product and service of the heating system. Since Sydkraft covers the total aspects of the plant, it called Total Heating System. Sydkraft own this plant on the basis on contract. Usually, these contracts are for 10 years and sometime even longer. At the end, either these contracts are renewed or the heating plant is buy back by the respective companies.

Another non-technical definition of total heating system lies in the type of customers. It has one-plant one-customer criteria. It means that in most of the cases total heating system plant supplies heat to a certain company or industry. Mainly total heating system is meant for serving heat to the industries and industrial process, which receive heat from these system installed and maintained near the company (customer of heat), by Sydkraft. Industry doesn't want to invest and be involved in the heat production business. Rather the company wants to concentrate in their core business and invest the money, which would have been invested in the heating plant. On the other hand Sydkraft, which is pioneer in running heating system, can better operate and provide heat service to these companies. So, it can be said that companies are involved in the business in which they are good to.

In some of the cases the Total Heating System supplies heat to households too. But the supply of heat is done through a contractor who acts like agent between heat producer and household customer. Staffanstorp Total Heating System is the above type, where the customers are households of Staffanstorp city and gets heat through a single contractor. This is unlikely in District Heating System where heat producer directly supplies heat to households. In the case of Total Heating System the contractor (an individual or an organisation) buys heat from the heat producing company on the contract basis and supply to households.

At Sydkraft, heat operations are growing strongly. The focus on Poland, Denmark and Norway will continue both within Total Heat and through the acquisition of district heating operations and of CHP companies.

The Heating Systems are made up of four components[20]:

- Heating devices that produce heat
- Heat transfer devices to transfer heat from the source to the customer
- Heat delivering devices, such as heat exchangers, heaters, ovens, and kilns etc.
- Heat recovery devices

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[19] Bergnan, Håkan. (Sydktaft). (2002, September 9) Telephonic Interview.

[20] JIN Foundation. (2001). http://www.northsea.nl/jiq/2-2001.pdf [2002, July 7]

The system also includes a number of other support systems, such as sensors and controls, material handling, processes for atmosphere supply and control, emission control, safety and other auxiliary systems[21].

2.4 Environmental Performance Evaluation of THS

First of all author should mention that it is difficult to present the general environmental status of the Total Heating System. This is due to the fact that the various plants are not identical. In fact, they differ from each other to a great degree. Different total heating system plants have different sizes, different production capacities, technology, processes etc. The biggest difference comes from the age of the plants and their past maintenance and operation. Sydkraft had taken over these plants in different years and in different plant conditions, and thus they differ from each other. Due to these differences it is not feasible to generalise the environmental status of the total heating system plant. Different plants have different environmental status and performance.

However, based on some collected information from different plants and common environmental issues, as well as activities of these plants, it has been an objective to present a general environmental status in the overall total heating plants under Sydkraft. Sydkraft has accomplished several environmental improvements in the total heating systems. Things such as efficiency improvements of the boilers, operational improvements of other equipment, achievement in pollution reduction, and better customer service are being pursued in these plants.

At present, dust pollution are the most common and most serious problems across the total heating system plants. Several complaints have been received from neighbours and nearby communities at many plants. Since most of the heating systems are in the residential areas because of their small size and utility, Sydkraft's operation is vulnerable to the community complaints. Sometimes when the problem is critical, the regional environmental regulatory authority gives notice to these plants after checking the environmental status itself or based on the community complaints. The main reason for high dust emission is the unburnt matter and particles in the furnace. It happens when the combustion chemistry like ratio of fuel to air, is not appropriate, or fuel and air are not mixed properly, or the boiler is not efficient etc. Another reason for the high dust level is lack of better pollution control equipment like ESP (Electrostatic Precipitator), multi cyclone, bag filters etc. In some of the heating plants, even though there is some pollution control equipment it is not working properly probably due to poor operation and maintenance and/or due to poor condition of the equipment. ESP is expensive to install in all these plants because these plants are very small, and due to small production capacity it's not always economical to have equipments like ESPs. In some plants cyclones are not in good condition and some of them are even too outdated to be used for achieving high performance level. In some places, much work has been done to control the dust and also make improvements but still there are plants that need to be focused upon and have appropriate measures taken.

Noise is another big problem, which generates from the motors, pumps, blowers, air compressors and other equipment. It is a nuisance in the vicinity since, in some places, people live only 100 or 200m from the plant. Plants that are away from the community areas don't have this problem. Plying of trucks that bring fuels and other items to the plants also creates noise in some areas. Measures have been taken in several plants to reduce the noise level. One method is the replacement of poor equipments. These replacements are not done only because of the noise problem but also for other advantages. Some of the noise generating devices are covered with acoustic materials, and in some

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[21] Oit. Directorate of Environment. (1999). http://www.oit.doe.gov/bestpractices/process_heat/pdfs [2002, June 29]

places where the plants have gone for total renovation, the attempt was made to move the plant to isolated places to reduce the noise and pollution impact on the surrounding environment.

The emissions of NOx, SO2, CO, CO2 etc. from the heating system are normal emissions and NOx, falls into the environmental legal net. The amount of pollutants emitted into the atmosphere from the individual THS plant is not high enough to cause a significant environmental impact. But grand total emissions from the entire Total heating system plant in Sweden can give a picture of real significant environmental impact, which is given in Figure 6. Since Sydkraft owns more than 2000 small total heating systems, it becomes very necessary to see the cumulative environmental impact and its significance. The resource consumption in the form of fuels i.e. renewable and non-renewable both, is very significant. The total figure of Sydkraft's overall consumption is big, which itself demand attention to the efficiency of the plants and related environmental impacts. Water consumption is also a significant issue in these plants. Finally, generation of solid waste mostly in the form of bottom ash and some oil sludge can't be neglected. On the basis of Sydkraft's corporate environmental report, it can be said that improvements are being made almost continuously in reduction of resource consumption, reduction in waste generation, reduction in some specific emissions etc. But it is difficult to tell about the amount of improvements made in Total Heating System alone. Seeing the overall improvements of the whole group, it can be assumed that some improvements are being made at THS plants also, as Sydkraft is investing lots of money for the environmental improvements in these plants.

At total heating system plants several environmental improvements have been made after Sydkraft took over the plant. In general, emissions of different gases, especially CO and NOx were reduced due to better combustion efficiency. Sydkraft also has an objective to achieve a real annual improvement corresponding to 100 tons of sulphur and nitrogen oxides each year. There is a reduction in water consumption in many plants due to stoppage of leakages and the installation of better water treatment facilities. Energy efficiency increased by taking care of energy losses and wastage and also by improving the insulation of several heating equipment units. Energy recovery is made possible from the flue gas by installing equipment like gas condensers. Bad cyclones where replaced by better multi cyclones and also by ESPs wherever feasible. Complete new plants were erected where the takeover plant conditions were too bad and beyond repair. These plants were completely created from the ground up, with all the latest technology, which renders high level of environmental performance that would have been not possible by just repairing or replacing some equipment in those poor old plants. However, this work has cost an enormous amount of money to Sydkraft and also has required strong commitment from the management. Synergies between plants have been established to use the resources efficiently. As an example, unburnt woodchips from the less efficient heating plants are being sent to plants that have better technology and efficient combustion processes to reuse the resources to the maximum level[22].

Environmental communication with different stakeholders has improved by identifying important stakeholders and establishing better dialogue with them. Numbers of environmental goals have been set by the management for the total heating system plants based on the corporate environmental policy and overall management strategy. Some of the goals are[23]:

- An increase in the energy efficiency of the plant
- Less resource consumption

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[22] Lindin, Carl U. (2002, August 15) Telephonic interview.

[23] Lindin, Carl U. (2002, August 15) Telephonic interview.

- Less consumption of oil
- Reduction in water consumption
- Less air emissions
- Less ash deposit in the dumping site – increase the reuse of ash
- Protection of water bodies from the plant pollution etc.

Sydkraft has also launched a programme to certify all the daughter companies by ISO 14001 standard including total heating systems. Some are already certified and several plants have gone through the certification audit early this year. Many environmental programmes are in the process of implementation in these plants. Regular environmental audits are made to check the compliance of the environmental activity and also to find areas of improvements. In some places audits are based on ISO standard and in the rest of the places it is just general environmental audits.

3 Environmental Performance Evaluation (EPE)

This chapter answers the first two research questions. It presents the definition of the environmental performance evaluation (EPE) based on the literature review. Mainly, the ISO standard definitions of EPE are covered, and the basic framework for performing the environmental performance evaluation is presented. Then, the chapter describes the potential benefits of performing EPE at the organisation, and specifically at the total heating system plant. Finally, it presents the developed EPE framework based on Plan-Do-Check-Act cycle. The methodology of performing EPE is described along with the process of evaluating environmental performance based on the changes made by Sydkraft.

3.1 Introduction

Environmental performance has become one of the many important measures of business success not only in the local context but also at the international level. Currently, EPE is being subjected to an international standardization effort by the ISO through its ISO 14001 series (shown in Figure 7), in particular with the standards ISO –14031 Environmental Management - Environmental Performance Evaluation Guidelines and ISO 14032 Environmental Management – Examples of Environmental Performance Evaluation.

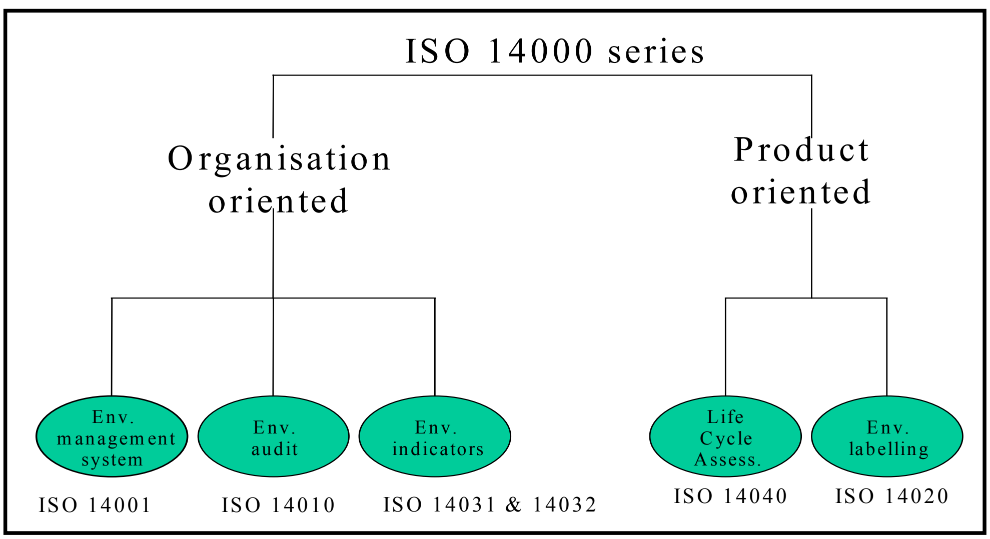

Figure 5 The ISO 14000 Standard series (Source: www.inem.org 2001 & Brorson, T 1999)

EPE is a management tool or process for helping an organization measure and improve environmental performance on an ongoing basis. The assessment and actual improvement is compared to target EP criteria. The overall EPE process provides organizations with a means to procure and assemble reliable and verifiable information, which they can report to stakeholders. EPE is the process of reviewing an organization's environmental aspects to see if objectives are being met.

EPE is defined as the "process to measure, analyse, assess, report, and communicate an organization's environmental performance against criteria set by its management"[24]. EPE is usually conducted by the organization on a continuous basis. Since EPE is an ongoing process it is usually most cost- effective for the organisation to establish continuous monitoring systems of the most important and/or variable environmental parameters.

According to Kuhre[25], EPE can be represented considering information flows and relations taking within an organisation. The performance evaluation is placed in the middle. Negative aspects that are subject to the evaluation are placed on the right and the positives on the left. The most important aspects are included: emissions to air, water and land. The figure highlights how both positive and negative aspects must be included. Internally, the communication is important to assist employees in fulfilling their responsibilities. Externally, it is needed to communicate the performance to interested stakeholders.

The process of environmental evaluation is based on suitable indicators. An indicator is a tool to measure and express the impact of various actions of the organization on the environment. The indicator is really the heart of the entire EPE process. There are two types of indicators defined by the ISO Standard. Environmental performance indicator (EPI) is a category that applies to both the management and operational systems. Environmental management indicator (EMI) and Operational performance indicator (OPI) are two subcategory of EPI. Indicators that apply to the state or condition of the environment are termed Environmental condition indicators (ECI), which is another category of indicator.

3.2 Benefits

EPE improves overall management and operational performance and is, therefore, good business. The greatest benefit is the environmental improvement of the organization. Communication of environmental information is facilitated by conducting EPE. EPE can also help to identify opportunities for the prevention of pollution and point out strategic business opportunities. It is the ongoing, focused evaluation of the environmental performance of an organization. It is a method to measure the results of the organization's management of the environmental aspects of its activities, products, or services. EPE is based upon saying, "what gets measured gets managed"[26]

The information generated by EPE can assist an organization to determine any necessary actions to achieve its environmental performance criteria and also to identify environmental aspects. The information generated from the EPE process may assist an organization to[27]:

Improve the environment: Minimizing the impacts and aspects evaluated; there is an immediate positive effect on the environment.

Improve organizational efficiency and profitability: As an outcome of the EPE process, improvements in the productive processes could occur which would result in better efficiency and/or cost savings.

Help with cost/expense management: As a consequence of a better resource allocation, management also benefits with better control of costs and expenses. An EPE can help track environmental expenses,

[24] ISO .(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO.

[25] Kuhre, W Lee. (1998). *ISO 14031Environmental Performance Evaluation*. New Jersey: Prentice Hall Inc. p. 3.

[26] ISO .(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO

[27] Kuhre, W Lee. (1998). *ISO 14031Environmental Performance Evaluation*. New Jersey: Prentice Hall Inc. p. 13-19.

cost savings, financial gains and expenses. Some indicators can even be linked to the expenses and consequently directed to cost management.

Help determine proper resource allocation: An EPE can provide management with information on the key areas where resources should be allocated in order to improve their environmental performance.

Determine if environmental performance criteria are met: As data and information are generated during the EPE, management should be aware if the environmental goals, targets and objectives are being met. Otherwise, the EPE process is worthless. The evaluation should provide qualitative and quantitative information for the understanding of the impacts.

Understand the impacts on the environment: This is one of the most important benefits of an EPE. If it is not achieved, at least partly, the EPE process is worthless. The evaluation should provide qualitative and quantitative information for the understanding of the impacts.

Achieve and demonstrate compliance with regulations: Through an EPE, an organization will be able to identify how well it is meeting environmental regulatory requirements.

Basis for continuous improvement of an existing environmental management system (EMS): As the ongoing EPE permits a comparison directly to environmental performance criteria, and assuming the results of the EPE are used to make corrections where necessary, the continuous improvement of the EMS is encouraged.

Improve community and customer relations: As the information resulting from the EPE is communicated externally, at least partly, it can help to improve the relations with community and customers as the company is demonstrating its interest for helping the environment. An EPE is a proper platform for this communication and also for the elaboration of environmental reports.

Raise awareness within the organisation: As the EPE results and findings are relayed to others within the organization, the level of environmental awareness is increased.

Perform benchmarking: Assuming that the information from the EPE process is properly established, and that other organizations are willing to communicate their performance, then an EPE is potentially an excellent instrument to foster benchmarking within the organizations on their environmental performance.

Support environmental labelling programs: As direct monitoring of environmental performance is done through the EPE, it is easy to track compliance with stringent criteria set in the labelling programs.

Environmental indicators, which are an integral part of EPE process, summarize extensive environmental data to a small amount of significant key information. It ensures a quick assessment of the main improvements as well as weak points of the corporate environmental protection for the decision-makers. One of the main strengths of environmental indicators is the fact that they quantify important developments in corporate environmental protection and make them comparable from year to year. Environmental indicators can also help companies compare themselves with different companies to demonstrate weak points and optimisation capacities[28].

[28]Federal Environment Ministry- Bonn et Federal Environmental Agency – Berlin. (1997). *A guide to Corporate Environmental Indicators*. Bonn/Berlin: BMU/UBA.

3.3 Environmental Performance Evaluation Model

EPE, as detailed in the International Organisation for Standardization (ISO) standard, follows basically a **"Plan-Do-Check-Act**" management model. From the literature review of the few examples of EPE process in the production companies, it was found that the Plan-Do-Check-Act cycle can be useful for the EPE process at the heating system plants, which gives a general idea how the process should run in a closed loop. This ISO cycle can be applied to any evaluation process because it is practical, implement able and productive. The environmental performance evaluation at the total heating system can be done with this model, which starts with the planning of EPE and talks about how to implement and then reviewing the EPE process to make it more effective. This model will be used for identifying the environmental improvements at the case study plant in this research work. Also, this proposed EPE model can be helpful in identifying improvements at other total heating system plants as well as for evaluating the environmental performance continuously in those plants.

Figure 8 shows the EPE model, which was designed by superimposing two structures, the ISO standard Plan-Do-Check-Act model, and self made model presented in Annexure 2 and also shown in the 'DO' part of the proposed model. 'PLAN' and 'REVIEW' part of the model is the same as the standard ISO model, but the 'DO' section, after superimposing it with the self-made model, becomes different from the ISO model. The self made model is based on the process for identification of the environmental improvements made by Sydkraft in the total heating system plants. It shows the process of identifying the improvements starting with 'Diagnostic' and then measuring the past environmental status with the help of set environmental indicators, and then comparing with the present status. Before going for the measurement of present status, it also identifies the changes made at the plant level for achieving certain environmental improvements. New indicators can be added to the final set of indicators based on the changes made in the THP, which can be used for other plants because basic operation and process of most of the heating systems are the same. For the final set of indicators some selection can also be made from the initial set of indicators based on its relevancy, depending upon the changes made in the plant. There are no criteria for the selection as it can be done by the project team itself by analysing the relevancy of the indicators.

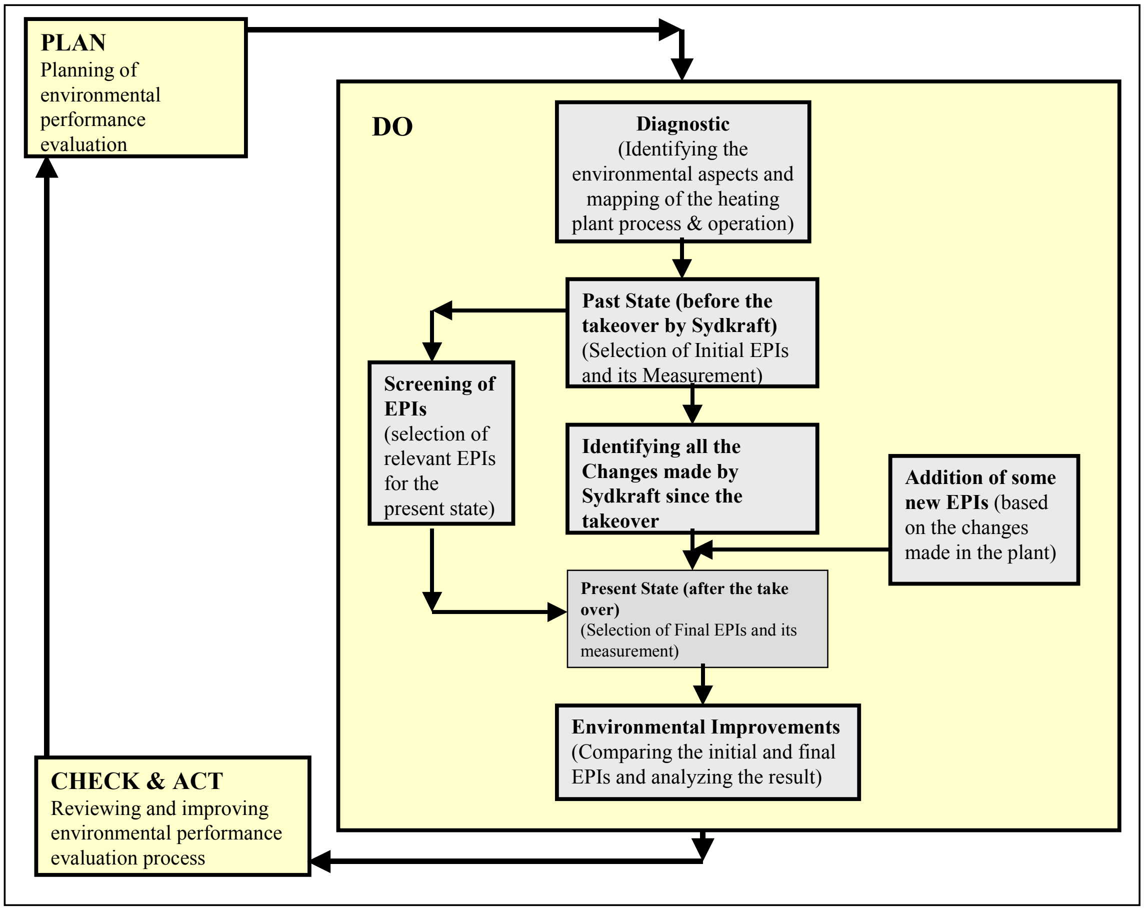

Figure 6 Proposed Environmental Performance Evaluation Model

Environmental performance evaluation (EPE), which is an internal management process based on indicators, is an effective system to compare an organization's past and present environmental status. The established environmental indicators are helpful in time series analysis (comparison with the indicators of previous periods). This comparison can help to identify the environmental improvements made in the particular period and track the environmental performance based on environmental performance criteria. In the Total Heating System plants the environmental performance evaluation can be accomplished based on the above model by comparing its past (period before 2000) environmental status with the present (2000 onwards) environmental status. The measurement and evaluation of environmental performance can be done with the help of suitable environmental indicators.

According to the ISO Standard for EPE, first planning is done, which is followed by implementation in the form of measurement and analysis. Then it comes regular checking and reviewing of the whole process for the continual improvement of the EPE system.

3.3.1 Plan

Primarily, planning starts from the decision of the management to seek environmental performance evaluation. First it is important to set the scope of the performance evaluation. Is it going to cover the entire plant at one time or part-by-part according to the significance of the operation and its impacts on the environment? Setting the scope of the work is necessary to give strong focus on the activity involved and the result obtained. If the whole operation is taken for the evaluation and appropriate measures are not considered, then the EPE could become a non-productive process. Depending on its capabilities and resources, the initial scope of an organisation's EPE may be limited to those elements of its activities, products and services given highest priority by management. In the future, the initial scope of EPE can be widened to address elements of an organization's activities, products and services that have not been previously addressed. Planning is thus important to prioritise the evaluation of the environmental aspects from different operations.

Management commitment is crucial for the successful implementation of the EPE process. It should identify and provide the right amount of resources in the form of finance, physical resources and human resources. Environmental costs and benefits should be analysed by the management before proceeding with the implementation. The planning can also be based on what information is needed for analysis of financial effects related to environmental performance. The management commitment regarding the EPE can also be displayed or conveyed by incorporating the importance of environmental performance in the environment policy and the company's business strategies.

The organisation should base its planning of EPE on the significant environmental aspects that it can control and over which it can be expected to have an influence. It should also base its planning on its environmental performance criteria and the purpose of the evaluation which it is pursuing. The views of interested parties are important too to plan the EPE.

3.3.2 Do

This is the implementation phase of the process. In this phase environmental aspects and elements are selected for the measurement and analysis. Suitable indicators and matrices are attached with different environmental aspects, which helps in their measurement. Data is collected, calculated and analysed and the result is well reported and communicated to the various interested parties. Implementation is to be done in a number of steps.

Diagnostic

Diagnostic is useful to understand the types of activities and operation going on in the organization. It will help to know the environmental aspects and status of the plants, which will be important for identifying and selecting environmental indicators. The proper diagnostic is important to identify necessary elements of the organization and its environmental aspects.

The overall type and the business of the organization should be properly understood. The study of the production process, its operation with the help of process flow charts and energy and material balance measurement is necessary to identify environmental impacts (refer to Figure 9). Reviewing of an organization's documents and reports could be helpful. Site survey is usually done to have a glance of the company's operation in practice, which assists in understanding the environmental status and any problem in the organization. Interview with company's employees, different stakeholders and other interested parties could be helpful to get the overview of the environmental status of the company and the demand of the surrounding environment.

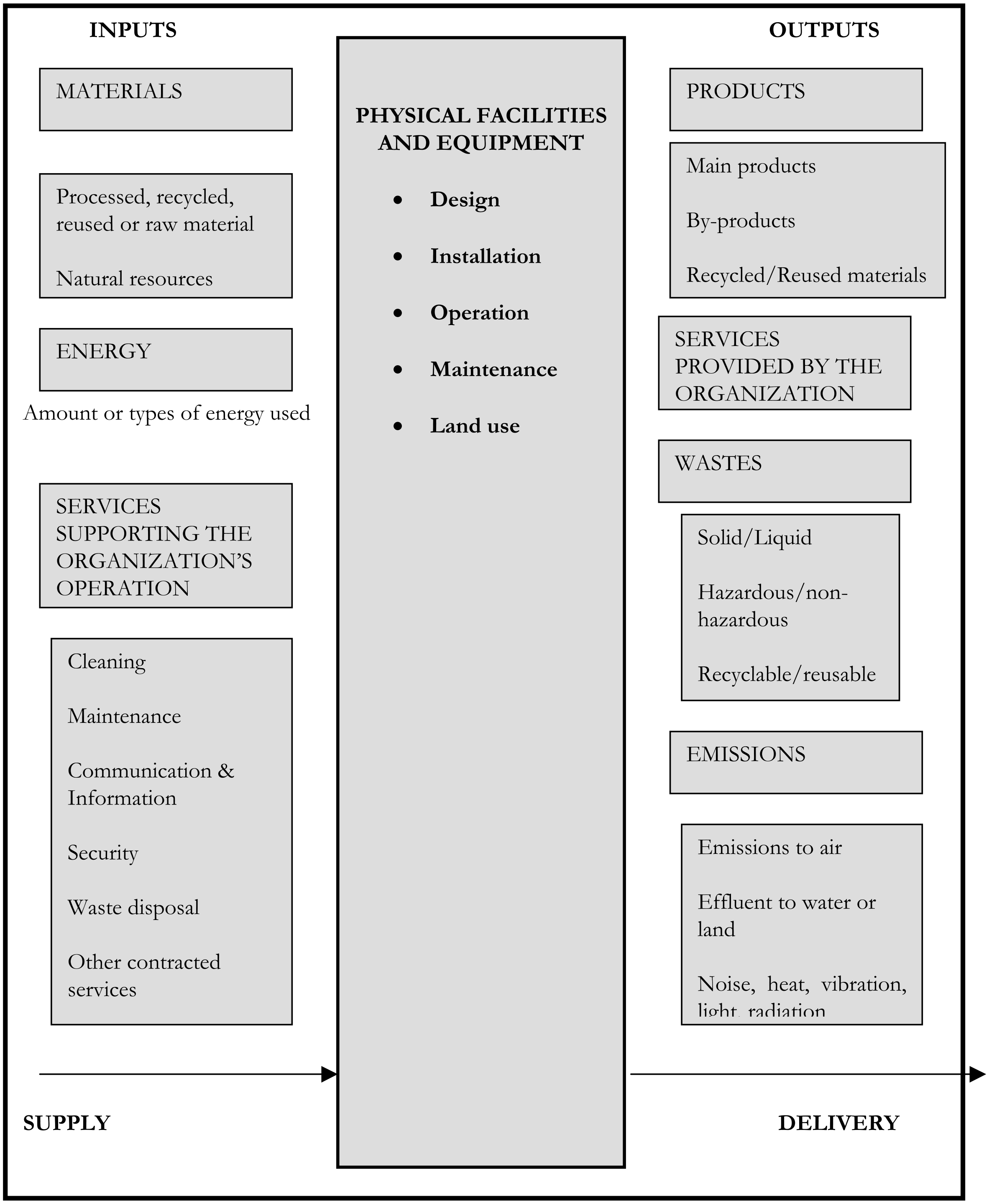

Figure 7 The organization's operations in general (Source: ISO, 1999)

At Sydkraft, the diagnostic could be based on some literature review of environmental performance evaluation and environmental indicators of the heating system. Some of the company's documents and reports are reviewed. Especially, the environmental reports prepared by the company for the environmental legal authority should be reviewed and analysed. It can help in identifying some aspects related to emissions and discharges and other environmental status of the Total Heating System.

Information can also be collected from surveys of the plant and interviews of personnel from corporate level to the operation level. Technical analysis like studying the process flow chart, mass balance, energy balance, and looking into the operation of the pollution control equipment will reinforce the quality of the diagnostic work.

Identification of the organizational aspects is an important input in an EPE. This can be done by identifying activities, products and services of the organisation, the specific environmental aspects and the relative significance associated with them, and the potential impacts related to significant environmental aspects. Some of the methods are given[29]:

- Use information about the condition of the environment to identify activities, products and services of the organization that may have an impact on specific conditions.
- Analyse the organization's existing data on material and energy inputs, discharges, wastes and emissions and assess these data in terms of risk.
- Identify the views of interested parties and use this information to help establish the organization's significant environmental aspects.
- Identify activities of the organization that are subject to environmental regulation or other requirements, for which data may have been collected by the organization.
- Consider the design, development, manufacturing, distribution, servicing, use, re-use, recycling and disposal of the organization's products, and their related environmental impacts.
- Identify those activities of the organisation having the most significant environmental costs or benefits.

Selection of Initial Environmental Performance Indicators (EPIs)

Indicators for EPE should be selected by organisations as a means of presenting quantitative or qualitative data or information in a more understandable and useful form. It helps to convert relevant data into concise information about management's efforts to influence the organization's environmental performance, the environmental performance of the organization's operations, or the condition of the environment. An organization should select a sufficient number of relevant and understandable indicators to assess its environmental performance. The number of selected indicators for EPE should reflect the nature and scale of the organization's operations. There are two well-defined criteria i.e. ISO Standard and German Standard for selecting indicators.

[29] ISO .(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO.p.

According to the ISO, elements to consider for the initial selection of environmental indicators are presented in Box 4[30].

Box 4 ISO Elements for the Selection of Environmental Indicators (Source: ISO, 1999)

- Overall business strategy
- Full range of activities, products, services
- Significant aspects that it can control and over which it can be expected to have influence
- Environmental policy and environmental performance criteria
- Environmental costs and benefits
- Information about local, national, regional, global environmental conditions
- Information needed to meet legal and other requirements
- Cultural and social factors
- Understanding of the views of interested parties
- Financial, physical, human resources needed and organisational structure

Similar to the efforts by the ISO EPE Standard, individual countries such as Germany, have also defined a series of characteristics/principles that a corporate system made up of environmental indicators should posses (in a special guide[31], hereinafter referred to as the German Document):

Comparability: allow comparisons to be made and reflect changes of environmental impacts

Target orientation: pursue improvement goals that can be influenced by the company

Balance: represent the environmental performance accurately and provide a balanced illustration of environmental problem areas and improvement potentials.

Continuity: in order to compare indicators, they must be established with the same data collection criteria in every period, refer to comparable intervals and be measured in comparable units

Timelines: should be determined in short enough intervals

Clarity: must be clear and comprehensible for the user and correspond to the user's information requirements

Other EPI issues that different sources such as the EPE Standard and the German Document[32] address include the number of environmental indicators that should be employed for an EPE, as well as possibility of using EPE and EPIs in an organization with or without an EMS.

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[30] ISO .(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO. p.

[31] Federal Environment Ministry- Bonn et Federal Environmental Agency – Berlin. (1997). *A guide to Corporate Environmental Indicators*. Bonn/Berlin: BMU/UBA.

The information conveyed through indicators for EPE can be expressed as absolute or relative measures; corporate, site, and process indicators; quantity and cost related indicators; indexed form[33]. Indicators for EPE may be aggregated or weighted as appropriate to the nature of the information and its intended use. Aggregation and weighting should be done with care to ensure verifiability, consistency, comparability and understand ability. Absolute measures are data or information, such as tonnes of contaminant emitted. Relative measures or calculations are data or information compared to or in relation to another parameter, such as tonnes of contaminant emitted per tonne of product manufactured, or tonnes of contaminant emitted per unit of sales turnover. Indexed describes data or information converted to units or to a form which relates the information to a chosen standard or baseline, such as contaminant emissions in the current year expressed as a percentage of those emissions in a baseline year. Aggregated data are of the same type but from different sources, collected and expressed as a combined value, such as total tonnes of a given contaminant emitted from production of a product in a given year determined by summing emissions from multiple facilities producing that product. Weighted data or information is modified by applying a factor related to its significance.

Determining process indicators is especially important for the main source of consumption of resources and the main cause of emissions, which is more applicable in the case study plant. Site and corporate indicators, on the other hand, serve as a general performance information tool for environmental management over a longer period of time as well as internal information. Environmental indicators are usually quantity related, i.e. in physical measurements such as kilograms, tonnes, items, etc. Due to the increasing relevance of cost aspects in environmental protection, cost related indicators could be developed at the same time. The advantage of cost related environmental indicators is the fact that environmental issues are translated into costs and revenues, which is the management language and easy for managers to understand[34].

Indicators for EPE are necessary for management to have sufficient information to understand the progress of environmental management and activities at the company level against some set environmental performance criteria. Indicators for EPE can be divided into two different categories[35], environmental performance indicators (EPIs) and environmental condition indicators (ECIs). EPIs can be further divided into operational performance indicators (OPIs) and management performance indicators (MPIs). The management of the organization includes the policies, people, planning activities, practices and procedures at all levels of the organization, as well as the decision and actions associated with the organization's environmental aspects. Efforts and decisions undertaken by the management of the organization may affect the performance of the organization's operations, and therefore may contribute to the overall environmental performance of the organization.

MPIs or Management performance indicators should provide information on the organization's capability and efforts in managing matters such as training, legal requirements, resource allocation and efficient utilisation, environmental cost management, purchasing, product development, documentation, or corrective action which have or can have an influence on the organization's environmental performance. MPIs should assist evaluation of management efforts, decisions and actions to improve environmental performance.

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[32] Federal Environment Ministry- Bonn et Federal Environmental Agency – Berlin. (1997). *A guide to Corporate Environmental Indicators*. Bonn/Berlin: BMU/UBA.

[33] Federal Environment Ministry- Bonn et Federal Environmental Agency – Berlin. (1997). *A guide to Corporate Environmental Indicators*. Bonn/Berlin: BMU/UBA. p.

[34] Federal Environment Ministry- Bonn et Federal Environmental Agency – Berlin. (1997). *A guide to Corporate Environmental Indicators*. Bonn/Berlin: BMU/UBA. p.

[35] Kuhre, W Lee. (1998). *ISO 14031 Environmental Performance Evaluation*. New Jersey: Prentice Hall Inc. p.

MPIs can be used to track the implementation and effectiveness of various environmental management programmes. It also helps in the management actions, which influence the environmental performance of the organization's operations, and possibly the condition of the environment. It can track the efforts, of particular importance to the successful environmental management of the organization. Environmental management capabilities of the organization, including flexibility to cope with changing conditions, accomplishment of specific objectives, effective co-ordination, or problem-solving capacity can be tracked by MPIs. MPIs can check the compliance with legal and regulatory requirements, and conformance with other requirements to which the organization subscribes. It helps in estimating the financial costs and benefits. MPIs can help to predict changes in performance, identify root causes where actual performance exceeds, or does meet, relevant environmental performance criteria.

OPIs or Operational performance indicators should provide management with information on the environmental performance of the organization's operation. It is usually related to input materials in the form of processed, recycled, reused or raw materials, and also input of energy and services. OPIs also relates to the design, installation, operation and maintenance of the facilities and equipment of the organization. Output is in the form of products, by products, recycled and reused materials, services, all types of wastes and emissions like emissions to air, effluent to water or land, noise, vibration, heat, radiation, light resulting from the organization's operations. It also covers the delivery of the product and other output resulting from the organisation's operations.

ECIs or Environmental condition indicators provide information about local, regional, national or global condition of the environment. The condition of the environment may change over time or with specific events. While ECIs are not a measure of impact on the environment, changes in ECIs can provide useful information on relationships between the condition of the environment and an organization's activities, products and services. The interrelations between MPIs, OPIs, and ECIs are shown in Figure 11.

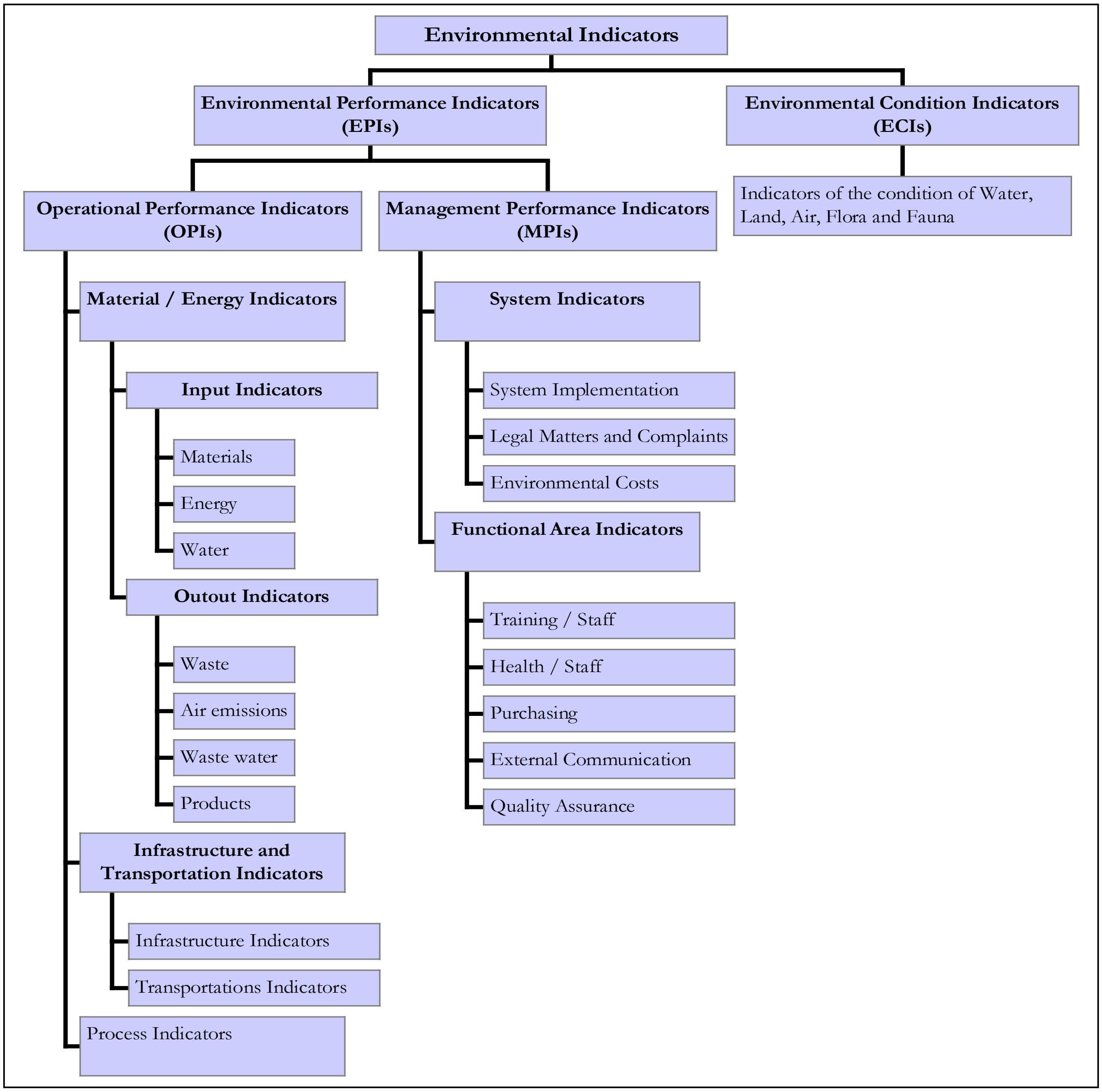


Figure 8 Classifications of Environmental Indicators (Source: Federal Environment Ministry – Bonn et Federal Environmental Agency – Berlin, 1997, in combination with ISO, 1999)

Indicators can be further divided into the following types[36]

Absolute and relative. Absolute indicators are the primary focus from an ecological point of view. However, to measure efficiency, absolute indicators must be examined in proportion to valid reference figures. In this way, they can reflect the environmental performance relative to the size or production capacity. At the same time, relative indicators can be defined in two forms: quotas or ratios. Quotas (or proportions) are used to determine a subgroup's proportion of the total or, put in other words, its

[36] Federal Environment Ministry – Bonn et Federal Environmental Agency – Berlin. A guide to Corporate Environmental Indicators, 1997.

share. Ratios relate absolute indicators to the operational units from which they are caused. In the German Document, an environmental indicators matrix for obtaining possible ratios was developed as shown in Table 2.

Table 2 Environmental Indicators Matrix (Source: Federal Environment Ministry – Bonn et Federal Environmental Agency- Berlin., 1997).

Basic data	Reference figure	Product output	Materials input	Energy input	Water input	Employee	Workdays	Working hours	Building space	Sale	Production costs
Materials input		X									
Packaging		X	X								
Cleaning agents									X		
Energy input		X				X			X		
Water input		X				X					
Waste		X	X								
Waste water		X			X						
Air emissions		X		X							
Transportation		X				X					
Occupational accidents						X	X	X			
Complaints							X				
Training						X	X				
Environmental Costs										X	X

Corporate, site or process indicators. Indicators at process level are well suited as planning, controlling and monitoring instruments for the department concerned. Determining these indicators is especially important for the main source of consumption of resources and the main cause of emissions. Site and corporate indicators serve as general performance information tools for environmental management as well as to provide internal information.

Quantity and cost related indicators. Indicators are usually quantity related, that is, physical measurements such as kg, tons, items, etc. But, since there is an increasing relevance of cost aspects in environmental protection, cost related indicators can be developed simultaneously.

Aggregated. Indicators in which the data or information is of the same type, but comes from different sources, collected and expressed as a combined value.

Weighted. Indicators in which the data is modified by applying a factor related to its significance.

Data Collection and Measurement

Data should be continuously collected by the organization to provide input for calculating values for selected indicators for EPE. Data collection procedures should ensure data reliability. The collection should be supported by quality control and quality assurance practices that ensure the data obtained are of the type and quality needed for EPE use. Data collection procedures should include the appropriate identification, filing, storage, retrieval, and disposition of data and information.

Data can be collected from different sources. It could be from its own monitoring and measurement, or interviews and observation, or from the regulatory report. Inventory and production records can also provide some important data for the indicators measurement. Environmental review of the whole process and operation, audit, or assessment reports can give good information. Data can be also collected from suppliers, subcontractors, customers, government agencies and other interested parties.

Data collection follows the measurement of selected indicators based on their matrices. The collected data should be converted into information describing the organization's environmental performance. Some measurements can be done directly by just summing or doing some simple mathematical applications. However, some are based on complex formulas and if the straight data is not available then it can be done by some theoretical calculations. Conversion factor table and other databases help in the measurement of those environmental indicators. Information describing the organization's environmental performance can be developed using calculations, best estimates, statistical methods and graphical techniques, or by indexing, aggregating or weighting.

Identifying Changes Made

The next task is to identify all the changes made in the total heating system by Sydkraft. It covers all types of changes, from technological to operational, to the substitution of resources or fuel. Installations of pollution control equipments to reduce the pollution from the process, and making improvements in good housekeeping are some of the changes at the plant level. Site visit and technical analysis are the crucial things to identify and get understanding about the changes made. Studying the company's documents and interviewing organization's personnel and representatives can also aid in identifying the changes.

Mapping work can be done to identify basically five major changes, especially in the energy generation plant, i.e. **Management Strategy**, **Cleaner Technology, Substitution of Fuel or Raw Material, Installation of Pollution Control Equipment, and Good House Keeping.**

a) Management Strategy
Since most of the Total Heating Systems were under control of other organizations, it is important to know about the new management and its strategy. It is necessary to know the difference between the present and past management and its operation. What business concept does Sydkraft have in acquiring these Total Heating System plants? What is the management strategy of the organization regarding these heating plants? It is important to know about the change in the environmental goal and the objective for these companies. The planning of the organization to handle all the environmental matters of the heating system plant may be a major driving force for the present and future environmental activities.

b) Cleaner Technology

Change in the process of production by introducing new technology may be one of the major reasons for the environmental improvements made by Sydkraft. Most of the Total Heating System plants have gone through complete renovation in technology. In the rest of the heating plants many technological improvements have been made in compliance with the Sydkraft's management strategies. It is important to know the type of technological changes which have been made, the new equipment installed and modifications made in the existing technology. Technology implemented especially for increasing the energy efficiency of the furnace and boiler is useful to understand. Pollution abatement equipments are important to know about regarding the technological changes. It will help to understand which type of change leads to what type of environmental improvements.

c) Substitution of Fuel

Sydkraft's corporate environment policy states that there should be a shift towards the renewable fuel from the non-renewable or fossil fuel. Presently, at Sydkraft, the major part of the electricity and heat is produced by nuclear, bio fuel and natural gas. In the Total Heating System plants fuels like bio fuel and natural gas are the major fuels, and the share of bio fuel is increasing gradually. In the past fossil fuel like oil, and coal etc. were used as the main fuel, which resulted in high emissions in all its forms. Shift towards the renewable fuel improved the environmental performance of these plants, so the identifying shift in fuel and its type is important to analyse the environmental improvements.

d) Raw Material

Identification of the different types of resources and their consumption may be useful for analysing the environmental improvements. Other than fuel, water is the main resource, which is consumed in large amounts to transfer heat from the production unit to the customer. Changes in its consumption due to different reasons could be useful to know. There may be changes in the use of different chemicals to treat water for different purposes. Knowing the consumption of resources and the changes made in its use can help to understand the improvements made for the efficient use of resources.

e) Installation of Pollution Control Equipment

Introduction of state-of-art pollution control technology and equipment in the Total Heating System plants is one of the most important changes done by Sydkraft. Equipment were installed to control the quality of feed water to boiler and to treat wastewater in some plants. Some pollution control equipment was installed for trapping pollutants in the flue gas. There is some equipment to recover the heat or energy from the water/wastewater and flue gas by the process of condensing, and other operations. Mapping of all the changes made regarding these types of equipment and operations could be useful for the study.

f) Good House-keeping

Identification of the changes made regarding Good Housekeeping are also crucial. It is simple, economical and the most effective way to achieve improvements. It is important to know the amount of improvements made by Sydkraft regarding the housekeeping of these heating plants. Some questions like how the resources are stored and used and how the different types of wastes are handled may be useful to ask. Changes in housekeeping can surely help to identify some of the environmental benefits.

Selection of Final EPIs

After identification of all the changes made at the plant level, review of the initial environmental indicators should be done. Most of the indicators will remain the same, since it has to be compared in two periods (past and present) to identify the environmental improvements. Some new indicators can be added to the initial list, based on the changes made at the plant level. Data for the final indicators would be collected in the same way as was done for initial indicators, described above. Data collection is followed by the calculation of the values for these indicators. The measurement is based on the matrices selected for the indicators, which will help in analysing the environmental improvements.

Analysis

Analysis starts with the comparison of the measured values of initial and final environmental indicators. In the analysis, comparison of EPIs should also be done with the organization's environmental performance criteria. These criteria could be the organization's environment policy, management strategy and its objectives and targets etc. The values of each indicator, which are measured and calculated, need to be compared with the corresponding one. The difference between the corresponding values will give the improvements. It is not necessary that all the comparisons will show positive changes and improvements. Comparison between some of the indicators might show negative change or no improvement as well. But these things could also be highlighted with the explanation of their importance for the overall improvements. If there are no improvements in certain areas, it can be combined with other bigger improvements to project the overall positive environmental improvement in the company. The comparison may indicate progress or fall in environmental performance. The results of this comparison may be useful to understand why certain environmental performance criteria have not been met.

Another part of analysis could be comparing the environmental performance internally and externally with the performance of another organisation as a benchmark. Either it can be compared with the organisation within the Sydkraft group and/or with some other organisation in the same business.

The information describing the organisation's environmental performance and the results of the analysis could be reported to the management, to support appropriate management actions to improve or sustain the level of environmental performance. Environmental performance reporting and communicating provides useful information describing an organization's environmental performance. It may be reported or communicated to interested parties within and outside the organization, based on the needs of management's assessment and its audiences.

3.3.3 Review and Improve

Once the environmental improvements are identified, analysed and reported or communicated to the management and other interested parties, then comes the work of reviewing and improving the whole EPE process. It can be done after identifying the improvements made by Sydkraft in the particular Total Heating System plant. This will help in improving the EPE process for other total heating plants as well. EPE should also be done regularly at the plant level to keep track on the environmental aspects and impacts and identify the improvements. It will help organization to regularly monitor the environmental status and its improvements. This process will be more successful when the organization's EPE and its results are reviewed periodically to identify opportunities for improvement in the overall process. Review may contribute to management actions to improve the management and operational performance of the organization, and it may result in improvements of the environmental conditions.

Primarily, the review of EPE can include certain things[37]:

- The cost effectiveness and benefits achieved from the evaluation process
- Progress to meet environmental performance criteria
- Appropriateness of environmental performance criteria
- Appropriateness of selected indicators for EPE
- Data sources, data collection methods and data quality

[37] ISO .(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO.

4 Case Study in Sydkraft Värme Syd AB

Selection criteria for the case study total heating system plant are described in this chapter. Justification for selecting the Staffanstorp total heating system plant has been based on a matrix. Then, the process of the Staffanstorp plant is presented along with the past state (before its takeover) environmental status. Thus it answers one of the sub research questions about the past environmental status. The process of development of environmental performance indicators is described in section 4.5. Based on the indicator development process, and past environmental status, a set of initial indicators is developed and finally, measured.

4.1 Selection Process

The selection of the case study plant was made on the basis of a self-made selection matrix. Table 3 presents the matrix with different parameters utilized on the basis of the requirements of this research study. Primarily, two steps were covered in the whole process. The first step was to make a list of plants that were being considered for the evaluation based on defined criteria, since Sydkraft owns more than 2000 Total Heating System plants across Sweden, of which about 800 belong to Sydkraft Vårme Syd AB, the subsidiary company of Sydkraft. Semi-structured interviews were conducted based on some conceptual framework and the feasibility (mainly based on the available time) of utilizing the plant for the study. Some factors, which were covered while choosing the plants for the selection process were: plant should be running on different fuels, the year of the takeover by Sydkraft, is it new or old plant with complete renovation, etc.

The second step was to analyse all the selected plants based on six criteria and make a final selection of one Total Heating System Plant for the research project. The criteria for the selection of the case study plant are given in the selection matrix presented in Table 3. All the eight listed plants were analysed on the basis of the selection criteria, and one, which was best suited, was finally selected for the research study. These criteria were formulated on the basis of the purpose of the study and feasibility regarding the time limitation of the study. For the study, the prime requirement was the availability of data. So, presence of the environmental department for easy access to the environmental information was taken as one of the criteria. Another feasibility for data availability was judged on the basis of the past and present records of required data. Environmental monitoring frequency was reviewed to measure the availability and reliability of the environmental data. Installed capacity criterion was utilized to get an idea of the size of the plant, which helped in the study due to a greater scope of selecting indicators and analysing the performance in the bigger plant. Legal compliance criterion was important to know the area of environmental concerns and performance based on the applicable environmental regulations imposed on the plant.

Table 3 Selection Criteria Matrix for the THS plants

Sl no	**Plant**	**Installed Capacity**	**Environmental Department /Coordinator**	**Legal Compliance**	**Environmental Data Record**		**Technology in use**	**Environmental monitoring**
					Before Takeover	At Present		
1	Sävelundsverket	31 MW	Yes	Yes	No	Yes	NA (not available)	More than once/year
2	Staffanstorps	24 MW	Yes	Fly Ash	Few data only	Yes, in different	2 Natural gas boiler & 1 Bio fuel boiler	Once/Year Measureme

				NOx SO_2 Wastewater quality Noise	through Environmental Report made for reporting to the regional legal authority	forms & Well recorded	6 MW from Bio fuel boiler & 18 MW from Natural gas 3 Gas Condenser for recovering heat from the flue gas Reverse Osmosis Water treatment plant Cyclones Gas scrubber Ash handling unit	nts by monitoring agency Few online measurements
3	Pharmica	9.9 MW	Yes	No	No	No	NA	NA
4	Trellex	4 MW	Yes	Dust emissions Noise	No	Yes	10 GWh Steam boiler 10 bar Natural Gas	1/year
5	Skånemejerier	16 MW	Yes	Dust emissions NOx	No	Yes	20 GWh Steam boiler 16 bar Gasol & Oil	1/year
6	Jabo I Tranemo	> 10	Yes	Yes	No	Yes	NA	NA
7	Rörvik	< 10	Yes	Yes	No	Yes	NA	NA
8	Malmöhus Fastigheter, Lund	19	Yes	No	No	No	NA	NA

Based on the above criteria, the case study plant (Staffanstorp's THS) was selected. The selection process was divided into three stages, as shown in Figure 12. These stages are based on the selection criteria, which are different for different stages. All the listed plants are compared with the criterion of the plant production capacity greater than 15 MW. From the 8 plants listed, four plants passed the comparison test. So, at the first stage of selection, 4 THS plants were short-listed. Then comes the second stage, where one of the screening criteria was variance in the technology and different types of pollution control equipment in use. Another criterion was the availability of the present environmental data. Based on these two criteria, three plants were selected, which is the second stage of the process. At the final stage (3rd stage), availability of the past data and the number of applicable environmental legal compliances were taken as the criteria for selecting the case study plant. Staffanstorp total heating system plant was selected after passing these final criteria requirements.

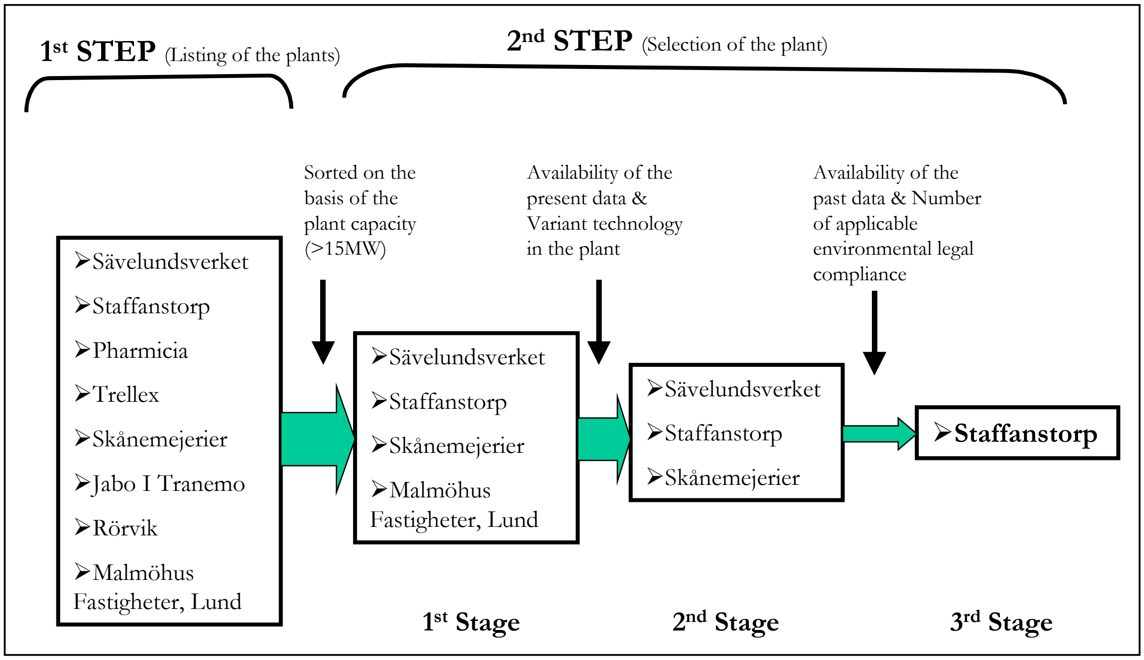


Figure 9 Selection Process for the Case Study Plant

Based on the selection process, the Staffanstorp plant was found suitable for the study and for the testing of the developed EPE model. This plant has high production capacity with different types of boilers. It also has many units of pollution control equipment, which gives a broader area in which to work and evaluate the environmental performance. It also has an environmental coordinator responsible for measuring and recording environmental data as well as evaluating the performance based on environmental compliances. The most important criterion of the selection process, which suited the Staffanstorp plant, was the availability of the required past and present environmental data.

4.2 Introduction of Staffanstorp THS

The Total heating system at Staffanstorp was commissioned in 1996. It was basically meant for supply heat to the communities of Staffanstorp in order to heating their houses and for other purposes. Staffanstorp Kommun is the owner of the plant and the distribution system. In June 1999, the plant and distribution system was leased to Sydkraft Värme Syd AB, which is the subsidiary of Sydkraft AB. Sydkraft, has the total responsibilities of Production, Operation, Maintenance, Up-keeping etc. The compliance with different environmental requirement likes renewal of consent to operate, yearly environmental reporting of the plant to the regional regulatory authority are taken care by Sydkraft. At present, there are approximately 477 households connected to this heating system. In addition to that there is an old Sugar Industry, which is buying the heat from this plant.

The total production capacity of the plant is approximately 18 MW, 13 MW from Natural Gas and 5 MW from Bio fuel (wood chips). But the plant has the permit to produce up to 24 MW i.e. 18 MW from natural gas and 6 MW from bio fuel[38]. It has 3 gas boilers, and 1 bio fuel boiler. One of the gas

[38] Sydkraft Värme Syd AB .(1999). Plant report. Malmö: ÅF-Energy Consultant Syd AB.

boiler remains in standby and is used in the case of emergency, extra load or during the maintenance of the two other regular boilers. The gas for the gas boiler is supplied by one of the daughter company of Sydkraft called Syd Gas. The bio fuel (wood chips) comes from a storage belonging to one of the bio fuel plant in Malmö, which also prepares the bio fuel in the form to be used in the plant and also maintain its quality. The heating plant is well automated. The degree of automation of the plant can be imagined by the realization that there are no personnel to run and operate the plant. Everything is done automatically, which completely supported by computerisation. The efficiency of the plant increased with the automation and so too the environmental performance. Sydkraft owns the production system, i.e. the plant and the distribution network up to the households. The customer looks after the system of heat exchanging and heat supply inside the house. The business of selling and buying the heat is not in the purview of Staffanstorp plant; instead it is done by the Sales Department of Sydkraft.

The production unit mainly consists of furnaces and boilers, which is the main source of environmental pollution. It has some pollution control equipment to control the pollution directly and indirectly. Another significant environmental impact is water consumption, since it is being used in large amount for the heat exchanging and transporting from the production unit to the customers. Fuel for boilers and furnaces is one of the biggest resources used in the plant; its quality, quantity, and efficiency of its combustion are the most important things impacting the environment. Since the plant capacity is higher than 4.5 MW, it comes into the net of legal compliance, which makes it necessary to measure and report environmental compliance to the regional regulatory authority.

4.3 Analysis of the Plant Process

The analysis of the total heating system process describes the process, equipment wise. It takes up the different equipment and explains its function and operation. The basic designs of all the boilers are same except the gas boilers are installed horizontally and the bio fuel boiler is kept vertically. The operation arrangement is done in such a way that the bio fuel boiler runs all the time, even in the summer when the demand is low. Gas boiler operation depends on the demand for heat from the customers. The capacity of each boiler is 4 MW. In two of the gas boilers 0.5 MW is recovered from the flue gas, and more than 1 MW is recovered in the case of the bio fuel boiler. Thus the total production capacity of the plant is 18 MW.

Natural Gas Boiler

The boiler has two types of tubes, flame tube and convection tubes. In the flame tube, red-hot flame travels inside the tube and water covers it from all around. The gas is fired in the flame tube by the burner, which mixes the primary air and natural gas from different inlets. The flame from the flame tube travels to the convection tubes, which is also surrounded by water. Heat travels in the tube in the form of convection current and it is transferred to water flowing on the outer surface. The flue gas then goes to the flue gas cooler where the remaining heat is recovered in the form of hot water and the flue gas is emitted through the stack. Water heated in the flue gas cooler is fed into the feed water input line to the boilers. The temperature in the gas boiler is approximately 960 ^{0}C and the temperature of the hot water coming out of the boiler as an output varies from 95 – 99 ^{0}C. This hot water then goes into the main pipeline, which acts as a heat transporting system to the customers.

Bio Fuel Boiler

The bio fuel boiler arrangement has two parts, a furnace and a boiler, shown in Figure 13. The fuel is burned in the furnace and the hot flue gas enters the boiler, which almost has the same design as the gas boiler. Fuel in the form of small wooden chips is fed into the furnace with the help of an automatic crane. The furnace has several platforms in the form of steps, which move the fuel down from the first step to the last step by the help of hydraulic cylinders. As the fuel slides down slowly over different platforms, it gets spread out and burns properly. This is done for better mixing the air and fuel at every place so that the combustion is proper. Air is supplied in the form of primary air from the bottom of the furnace. Secondary air is fed through a number of nozzles from the sides and from top of the furnace. The furnace temperature is around 960 ^{0}C. Ash is drained out from the bottom. Flue gas from the furnace passes to the boiler, which contains water tubes in a vertical position. Heat transfers take place from flue gas to the water in the tube and then gas goes off the boiler to cyclone. Temperature of the boiler is approximately 124 ^{0}C and the final hot water that goes to the customer from this unit has the temperature of 95 – 99 ^{0}C. The cyclone removes the coarser dust particles from the flue gas and then the gas passes to the gas condenser. In the condenser, the gas is cooled and scrubbed by water spray to remove fine dust particles and some harmful gases. Finally, the treated flue gas is vented off through the stack.

Overhead Tank

Water that returns from the customer end after transferring heat through the heat exchanger, varies in temperature, volume, and pressure. To manage the expansion and pressure of the water in the distribution system due to varying temperature, an overhead tank is installed, which is attached to the inlet water stream to the plant. The tank also acts as degassed water storage. The static pressure in the system is kept stable by a pump.

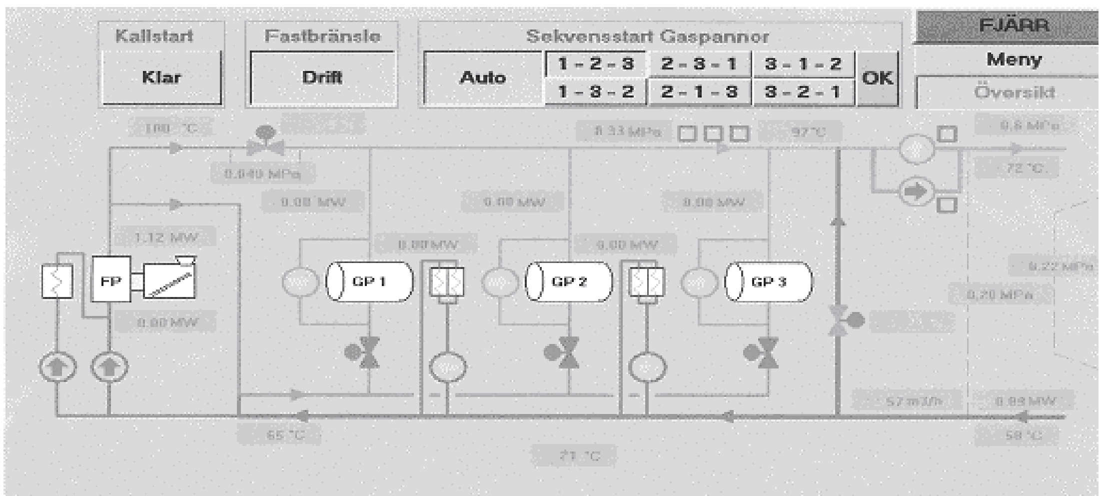


Figure 10 Flow Diagram of Staffanstorp Plant (Source: Sydkraft's total heating system, Staffanstorp, 2002)

Cyclone

A cyclone is a pollution control equipment with a cylindrical body stem and conical bottom. There is no moving part in this piece of equipment. It works on the centrifugal principle where the flue gas from the boiler enters cyclone tangentially along the surface. Due to centrifugal force the heavier particles move towards the surface and finer particles towards the centre. Heavier particles slide down along the surface due to the gravity through the conical bottom, and clean air is carried out from the top.

Gas Condenser

The gas condenser is attached to the bio fuel arrangement. It recovers heat from the flue gas and also removes some fine particles of dust, which the cyclone is unable to trap. This equipment scrubs some harmful gases also. In the equipment the flue gas enters from the top and water is sprayed from the spray nozzles. Water suppresses the gases and particulate matter and then the gas is condensed on the surface of the water tube. Water tubes are made of stainless steel with aluminium fins all around for a better heat exchange. The gases condense on the surface of these tubes and transfer heat to water flowing in the tube. Cooled gases vent out through the stack and thus the gas condenser works.

Gas Cooler

This is a sort of heat exchanger to recover heat from the flue gas of the natural gas boiler. It is like a shell and tube heat exchanger in which water flows in the tube and the flue gas in the shell side. The temperature of the flue gases going in to the gas cooler is approximately 85-87 ^{0}C, and after exchanging heat, the temperature comes down to 55-59 ^{0}C.

Water treatment Plant

The water treatment plant is basically for treating the feed water to the boiler. This treatment plant removes the hardness of the water, which causes scales on the surface of boiler tubes and other parts. It also filters particulate matter that can become sediment at the bottom of the boiler and cause erosion to the boiler equipment.

The water treatment process in total has two types of treatment equipment. The first one is filter to filter the fresh water to remove sediments and suspended matter. Next is the reverse osmosis process, which further filters the water to remove finer matter and also some ionic compounds[39] that cause hardness and form scales. It has two parallel arrangements combined together.

Ash Handling Unit

The purpose of the ash-handling unit is to carry ash from the bio fuel boiler and transport and dispose of it in a proper way. There are three outlets at the bottom of the bio fuel boiler to the ash-handling conveyor. The ash-handling device is a simple conveyor, which transports ash mixed with water. It is an inclined conveyor that moves the ash up on the inclined plane and water flows down by gravity. It is shown in Figure 14. Thus the ash is separated from the water. The ash-handling unit is also meant for removing the ash from the cyclone. The ash, which is collected in an ash collection bin, is carried to a landfill or dumping site once a week. The frequency of ash transportation to the dumping site clearly indicates that the amount of ash coming from the boiler is not huge, and so there is no big environmental impact.

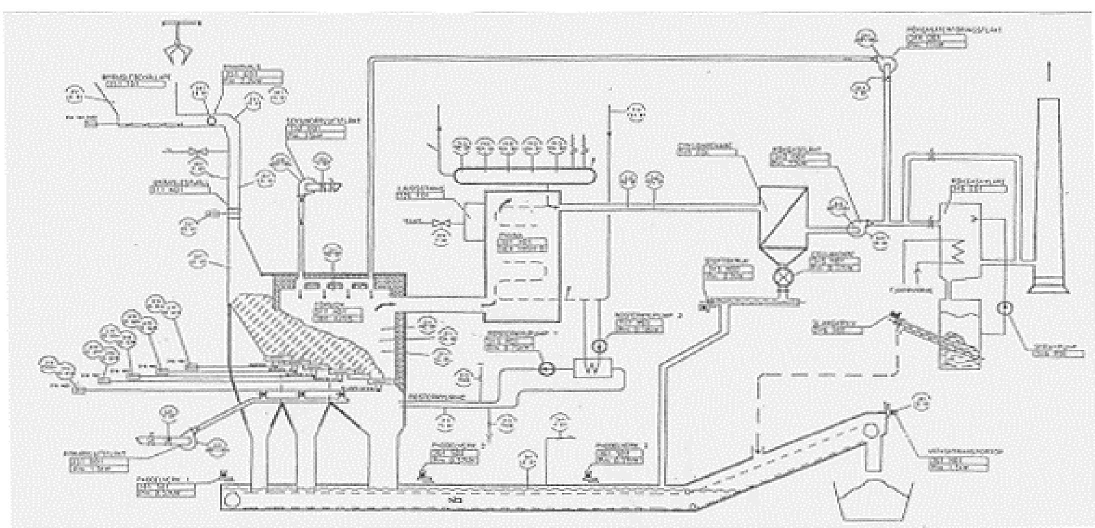


Figure 11 Schematic Diagrams of the Bio fuel Boiler and the related processes (Source: Sydkraft's total heating system, Staffanstorp, 2002)

[39] It is one of the state of material made of more than one molecules

4.4 Identification of the Past Environmental Status

In the past days at the Staffanstorp plant, there was a problem of high level of flue gas from the stack. It was due to the low stack height and also the stack was not properly designed according to the flow and the velocity of the flue gas. Due to improper height of the stack, the smoke and dust didn't spread and dilute properly in the air. It plunged towards the ground and created a problem in the nearby areas.

Another problem of high level of dust in the flue gas was due to poor condition of the boiler. The maintenance was not properly done and that led to degradation of the boiler. This resulted in water leakages, corrosion of tubes and shell, clogging of tubes and formation of scales on the tube surface. The formation of scales prevented the efficient transfer of heat from the flue gas to water in the tube. Poor maintenance also led to improper combustion of fuel, which resulted in increase in pollutants in the form of particulates and gases in the flue gas[40].

It will not be an exaggeration to say that the whole plant was deteriorating in the past due to the lack of management commitment and poor maintenance. This caused the boilers and other equipment to deteriorate rapidly, which resulted in poor efficiency of most of the equipment, and that led to poor environmental performance. The plant was not fully automated, which led to inefficient functioning of equipment, and the overall plant.

Water chemistry of the plant was not good. Water is the next biggest resource, after fuel, needed in the heating plant. Water is used in the boiler to receive heat from the fuel combustion and transfer to the required place. Quality of water is very important in the boiler as the efficiency of the boiler depends on it. Also the operation and working life of the boiler largely depend on the water quality. The water wasn't softened enough to get rid of its hardness, which formed scales on the heating surfaces. Improper filtration led to accumulation of sediments in the boiler, which reduces the heat transfer by reducing the heat surface area and by thickening the heat transfer surface.

The yearly average amount of fresh water consumed in the past was 55, 000 litres. Water is used as feed water for the boiler where fresh water is added as a make up water. The amount of make up water depends on the water loss, which usually happens due to water leakages and evaporation losses. Leakages can be stopped to save water, if the problem is addressed properly. In the past leakages were the main causes of high water consumption. The water consumption figure was higher compared to the other plant of the same capacity.

Another problem was energy loss. It is assumed on the basis of the condition of plant maintenance in the past that heat loss was also one of the major problems. Heat losses take place from the insulation in the plant and especially from the insulation of the heat distribution lines to the customer. This loss can lead to a major environmental problem, as it is a loss of energy, which leads to huge loss of the fuel and other resources.

4.5 Analysis of Inputs/Outputs and related Environmental Aspects

4.5.1 Material and Energy Flow

Process mapping and the study of the material and energy balances are helpful to understand related environmental aspects and impacts. The amount of material going in the process as an input can

[40] Anderson R. (2002, July 24) Personal Interview

indicate, which are the significant environmental aspects in terms of resource consumption. The amount of emissions and waste coming out could give the real pictures of what is happening and what could be done to improve the environmental performance of the certain activity.

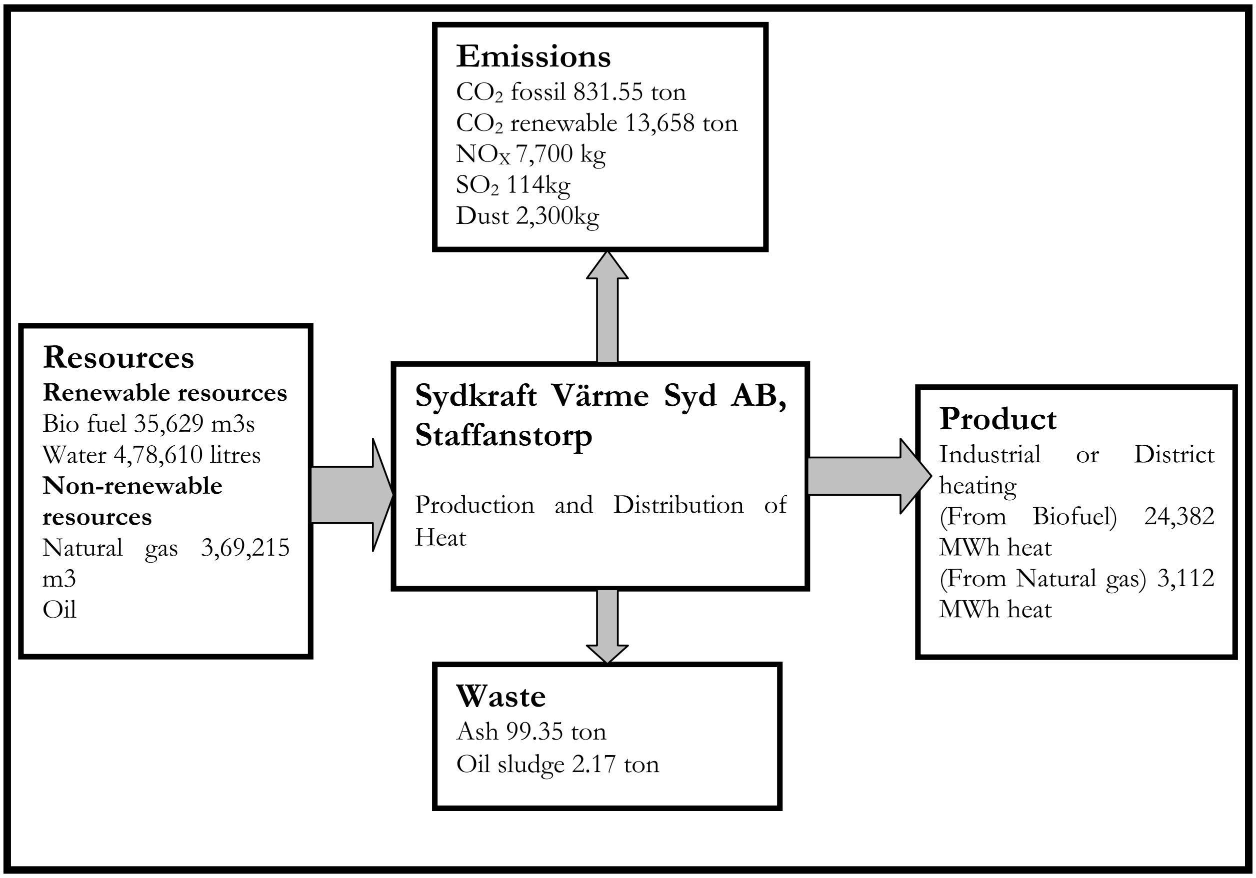
In the total heating system plant at Staffanstorp, the only product is the heat produced for district and industrial heating for the Staffanstorp city. The product is measured in two forms, heat produced by the biofuel in a year and heat produced by natural gas in the whole year shown in Figure 15. Corresponding to the production, the two main input materials are there. 35,629 m3s of biofuel and 369,215 m3 of natural gas were consumed in the year 2001[41]. Water is also one of the main resources used at the heating or energy plant. Since the water is recycled numbers of times in these types of plants, the total amount of water consumption is difficult to assess. The only quantity of water, which is measured, is the fresh water consumption every year. Figure 15 also gives the useful message about the water consumed in the process. The performance can be seen with the efficiency of water use and reduction in fresh water consumption. Oil is being used in the oil fired mobile boiler depending on the requirement. Mainly it is brought into operation during the yearly shutdown of the plant for the maintenance and overhauling.

CO_2 from the renewable and non-renewable fuel is the major emission. Other significant emissions are NO_x and SO_X. Sulphur is emitted from the combustion of natural gas as it contains small trace of sulphur. But there is no emission of sulphur dioxide from the biofuel combustion. Another significant emission from the process is the dust emission from the biofuel boiler. Dust emitted in the air through stack is fine, as the coarser particles are captured by the multi cyclone installed on the flue gas line from the boiler.

Ash separated in the cyclone from the flue gas goes into the bottom of the cyclone and is taken out and transported to the ash collection bin. The amount of ash of itself is not significant, but if it is compared to the capacity of the plant, then it can be taken as a significant aspect. Since an oil boiler is used sometime, oil sludge comes out as a waste (2.17 ton in 2001), which is important to consider as one of the environmental impacts by virtue of its nature and type.

[41] Brandeby, K. (2002). Staffanstorp Fjärrvärmeanläggning document. Malmö: Sydkraft Värme Syd AB.

Figure 12 Material and Energy balance at Staffanstorp Plant for the year 2001.



4.5.2 Evaluation of Environmental Aspects and Impacts

Environmental aspects are effectively managed by environmental management system (EMS), which is the part of overall management system that includes organizational structure, planning activities, responsibilities, practices, procedures, processes and resources for developing, implementing, achieving, reviewing and maintaining the environmental policy[42]. This management system identifies the environmental aspects where it is applied and makes relevant programmes and procedures to control the impacts. Several total heating system plants, including Staffanstorp, are already in the process of implementing environmental management system (EMS) and certifying on the ISO Standard. The environmental aspects (shown in Table 7) identified at the Staffanstorp total heating system plant cover environmental impacts ranging from the resource use to common pollution in air and water. These aspects help in identifying some of the environmental problems, which a production unit like Staffanstorp has. Process mapping, input and output balance, and the past environmental status helped in the identification of aspects at Staffanstorp.

Environmental aspect evaluation is done on the basis of the evaluation framework used by Sydkraft Värme Syd AB for its aspect evaluation. This framework is developed by Sydkraft Värme Syd AB and Sydkraft. According to the evaluation model, evaluation of identified environmental aspects is based on two criteria. One is "consequences," which tells about the intensity of the impact caused by the particular aspect. Another criterion is "probability," which tells about the chances of occurrences.

[42] ISO.(1999). *ISO 14031 Standard: Environmental management- Environmental performance evaluation- Guidelines*. Switzerland: ISO.p. 2.

Different consequences of the impact have different Environment Load Unit[43] (ELU), which has its corresponding scale "C" from 1-10, shown in Table 4. Environmental Load Unit is the product of yearly emission or consumption quantity and the EPS (environmental priority strategies) of the corresponding environmental aspect. The EPS system, (EPS stands for Environmental Priority Strategies in product design) was developed to meet the requirements of an everyday product development process, where the environmental concern is just one among several others[44]. EPS[45] is basically developed by Chalmers University of Technology. EPS indices are based on certain principles like Environmental Philosophy, Causality principle, and Precautionary principle. The emission load of pollutants is referred to the EPS indices given in the Environmental System Analysis report of the Chalmers University and the corresponding EPS index was selected.

The scale of consequences of an environmental aspect depends on its ELU. Higher the consequence higher is the scale (C), which shows the degree severe ness and significance of the impact. So, as ELU increases the scale goes up.

Table 4 Criteria for different points based on the intensity of consequences (Source: Sydkraft Värme Syd AB, 2002)

Consequences	**ELU/year (Environmental Load Unit)**	**Scale (C)**
Very small impact	< 100	1
Small impact	100 - 1000	2
Average environmental impact	1000-10000	3-4
Employees or other interested parties concern	10 000-50 000	5-6
Complaints from employees and other actors	50 000- 1 000 000	7-9
Stringent environmental law and demand from customers	>1 000 000	10

Probability is categorized on the basis of the frequency of occurrence of the impact in a particular period. The higher the frequency of an occurrence of any impact (based on the past experience), the higher the probability. As the frequency goes up, the scale (S), which is defined from 1-6, increases. So,

[43] Environmental Load Unit is the measure of the environmental impact. This unit is developed by the Chalmers University, Sweden.

[44] The development of the EPS system was started during 1989 on a request from Volvo and as a co-operation between Volvo, the Swedish Environmental Research Institute (IVL) and the Swedish Federation of Industries. Since then it has been modified several times during projects, which have involvied several companies, like in the Swedish Product Ecology Project (Ryding et. al 1995) and the Nordic NEP project (Steen et.al, 1996). The last modification is made within the Centre for Environmental Assessment of Products and Material Systems, CPM (http://www.cpm.chalmers.se).

[45] Steen. B. (1999). *A systematic approach to environmental priority strategies in product development (EPS). Version 2000 – General system characteristics.* Sweden: Chalmers University of Technology, Technical Environmental Planning.

the higher the probability, the higher the corresponding scale. The matrix between the probability, frequency and scale (S) is given in Table 5.

Table 5 Criteria for different points based on the frequency of occurrences (Source: Sydkraft Värme Syd AB, 2002)

Probability	**Frequency**	**Scale (S)**
	Less than once in 10 years	1
Very small probability	Once in 10 years	2
Small probability	Yearly or if any accident to human happen	3
Not very often or seldom	Monthly	4
It can happens only starting and stopping the operation	Weekly	5
It can happen during the normal operation (all the time happening)	Daily	6

Evaluation of the aspect is done on the basis of its ELU and the corresponding scale of consequences and probability. On the basis of the ELU and frequency of its occurrence, the aspect is referred to Table 4 and Table 5 respectively and the corresponding scale is selected. Product of the scale of consequences and probability are taken. The value of the product is compared with a standard value for selecting the significant aspects. It is defined on the basis of Sydkraft's evaluation process, that if the product of C*S is 20 or more, "20 or more" then the environmental aspect will be considered a significant aspect. An aspect, which doesn't have any ELU, is assigned to the category of average impact or less than that based on the experience and history of the plant. An aspect, which falls under the emergency and safety category, is directly taken as a significant aspect. The complete matrix for selecting significant aspects is presented in Table 6. The identified significant environmental aspects are listed in Table 7 with its related activity.

Table 6 Evaluations of Environmental Aspects and Impacts at Staffanstorp Total Heating Plant (Sydkraft Värme Syd AB, 2002)

Evaluation of Environmental Aspects and Impacts of the Staffanstorp Heating Plant									
Activity	**Aspects**	**Unit**	**Values**	**EPS index**	**ELU**	**Consequences (C)**	**Probability (P)**	**C*P**	**Significant**
Building plant	use of resources					3	6	18	
Transporting									
Goods	emissions to air, water or ground					3	6	18	
Hazardous goods	emergency &safety					3	4	12	
Storage of									
Oil	emergency &safety					2	2	4	
Biofuel						1	6	6	
Combustion of fuel									
Natural gas	use of resources	kg	5800	1.1	6380	4	5	20	X
Bio fuel	use of resources	MWh	28663		9000	4	6	20	X
Oil	use of resources	kg	18000	0.5	9000	4	5	20	X
Consumption of electricity	use of resources	MWh	717	18.6	13336.2	5	6	30	X
Noise generation	local problem					2	6	12	
Use of chemicals	use of resources					1	6	6	
Use of Asbestos, Hg, PCB	emergency &safety	kg							
Consumption of water	use of resources	kg	12 830	0.003	38.49	1	6	6	
Handling the emissions to air									
NOx	emissions to air	kg/year	7700	2.13	16401	10	2	20	X
CO	emissions to air	kg/year		0.33		10	2	20	X
CO2	emissions to air	ton/year	888	108	95904	10	2	20	X
Dust	emissions to air	kg/year	2300	36	82800	10	2	20	X
Handling the emissions to water	emissions to air, water or ground	m3				1	6	6	
Ash handling	emissions to air, water or ground								
Waste transportation	emissions to air, water or ground					2	6	12	
Handling of other waste									
Hazardous	emergency &safety					3	6	18	
Oil sludge	emissions to air, water or ground & emergency and safety					3	6	18	
Distribution of heat	use of resources		8 km of pipes			1	6	6	
Heating services at households	use of resources					2	6	12	

Table 7 Environmental Aspects at Staffanstorp Total Heating Plant

Activity	Aspects	Significant / Not significant
Building plant	use of resources	not significant
Transporting		
Goods	emissions to air, water or ground	not significant
Hazardous goods	emergency &safety	not significant
Storage of		
Oil	emergency &safety	not significant
Biofuel		not significant
Combustion of fuel		
Natural gas	use of resources	**significant**
Bio fuel	use of resources	**significant**
Oil	use of resources	**significant**
Consumption of electricity	use of resources	**significant**
Noise generation	local problem	not significant
Use of chemicals	use of resources	not significant
Use of Asbestos, Hg, PCB	emergency &safety	not significant
Consumption of water	use of resources	**significant**
Handling the emissions to air		
NOx	emissions to air	**significant**
CO	emissions to air	**significant**
CO2	emissions to air	**significant**
Dust	emissions to air	**significant**
Handling the emissions to water	emissions to air, water or ground	not significant
Ash handling	emissions to air, water or ground	not significant
Waste transportation	emissions to air, water or ground	not significant
Handling of other waste		
Hazardous	emergency &safety	not significant
Oil sludge	emissions to air, water or ground & emergency and safety	not significant
Distribution of heat	use of resources	not significant
Heating services at households	use of resources	not significant

4.6 Initial Environmental Indicators

4.6.1 Identification of Indicators

Based on the evaluated environmental aspects, analysis of the process of the heating system, input and output analysis, initial environmental performance indicators is developed to measure the performance of the past environmental status and keep track of the environmental impacts.

Particular importance was placed on the operational performance indicators, as these are the most relevant to the heating process. While selecting the OPIs, emphasis was given to the quantity of the material being consumed or emitted and released. Most of the indicators selected are the operational performance indicators and few are management performance indicators. More emphasis is given to the quantity indicators like CO2 emission in kg, waste quantity, quantity of resource consumption, etc. than to cost incurred to control and treat pollutants. The cost of the material or its value in the economic terms was not considered in the selection of indicators even though they play a significant role in the selection of the process units. The investment indicator, which is a MPI is the only cost-based indicator taken in the initial set of EPIs. However, the preference towards absolute indicators was overlooked since these types of indicators are not as helpful as relative indicators in measuring the efficiency of the process (relative indicators allow comparison of environmental performance among companies irrespective of sizes, places and technology used, provided the product remains the same)[46]. Since the purpose of this research is to help Sydkraft's Total Heating System plants start up a process of systematic EPE, the use of relative indicators is regarded as a better instrument for these companies than the indicators expressed in absolute terms.

The initial set of EPIs selected is primarily based on the company's environmental aspects described in the environmental aspect table. Described environmental aspects are collected from the plant and evaluated regarding their significance. The evaluation is done based on the criteria developed by Sydkraft, which has been described in previous section. All the significant aspects are covered in the process of developing environmental indicators. Development of initial indicators also depends upon the past environmental status of the total heating system plant. The mapping of the heat production process also supports the process of indicator development. Process of both the boilers, i.e. bio fuel and natural gas, are thoroughly analysed and other processes related to their operation, especially, the pollution control processes, are also reviewed. Inputs for the indicator development are also taken from the heating plant process inputs and outputs as well as from the applicable regulatory compliances. Further, the information given in the yearly environmental report and the parameters measured and reported are considered as a base for identifying environmental indicators.

Table 8 presents the initial EPIs for the given environmental aspect. From the total set of indicators, most of them address the significant environmental aspects within the process phase. Detailed explanation of the EPIs with their indices is presented in the table.

[46] Roberto Lopez Chaverri. Development OF Environmental Performance Indicators. (2000). IIIEE

Table 8 Set of proposed Initial Environmental Performance Indicators (EPIs)

Environmental Aspects	**Proposed EPI**	**Unit**	**Explaination/Considerations**
Use of Resources	1. Total non-renewable fuel consumption per unit of energy produced	M3/MWh	• Two boiler run on natural gas, it contributes significantly to the total production • It is useful to measure the amount of non renewable fuel consumed to see it share in the total fuel for the production • It can also give idea about the degree of compliance with the company's environment policy to shift to renewable resources
	2. Total renewable fuel consumption per unit of energy produced	M3s/MWh	• Bio fuel (wood chips) used for the bio fuel boiler is considered as a renewable fuel • Major part of the production is from bio fuel, so it is useful to know the consumption rate. It can also tell the efficiency of the fuel use.
	3. Energy (electricity) consumption per MWh of heat produced	MWh (electricity) /MWh (heat)	• As there are numbers of electric driven pieces of equipment in the heating system, the ratio of energy consumed in the plant to the output (MWh) would help to compare the performance in this aspect.
Emissions of CO2	4. Amount of CO2 emitted per unit of energy produced from the renewable fuel	Kg/MWh	• As bio fuel is used in boiler, there are consequent carbon dioxide (CO2) emissions originating. The amount of emissions per MWh of energy produced would provide an idea to the company operating its boilers efficiently or to use some flue gas cleaning process.

	5. Amount of CO_2 emitted per unit of energy produced from the non-renewable fuel	Kg/MWh	• As natural gas is used in boiler, there are consequent carbon dioxide (CO_2) emissions originating. The amount of emissions per MWh of energy produced would provide an idea to the company either to use more environmentally friendly fuel or operate its boilers efficiently or to use some flue gas cleaning process.
	6. Amount of CO emission per unit of energy produced	Kg/MWh	• As fuels are used in boiler, there are consequent carbon mono oxide (CO) emissions originating. The amount of emissions per MWh of energy produced would provide an idea to the company operating its boilers efficiently, especially the combustion efficiency, or to use some flue gas cleaning process.
Emissions of NOx	7. Amount of NOx emitted per unit of energy produced	Kg/MWh	• As fossil fuels are used in boiler, there are consequent nitrogen oxides (NOx) emissions originating. The amount of emissions per MWh of energy produced would provide an idea to the company to operate its boilers efficiently.
Emissions Dust	8. Amount of fly ash emitted per unit of energy produced	Kg/MWh	• The level of fly ash is related with the environmental regulation. So, it is necessary to control the emissions from the boiler operation. Indicators like this would help to know how much dust is generated per unit of the product. It will also help in measuring the loss of unburnt fuel in the furnace, which is also an economic loss.
Generation of Waste	9. Amount of bottom ash emitted per unit of energy produced	Ton/MWh	• Most of the time amount of bottom ash generated is directly proportional to the amount of un burnt material in the combustion process. • This indicator can give some idea about the combustion efficiency and the amount of material loss.
Water Consumption	10. Water consumed per unit of energy production	Litres/MWh	• As the heating system uses huge amount of water for transporting heat to the required place, this indicator would help relate the total water consumption with respect to

			energy produced. • This would be also helpful in comparing the performance of other heating systems regarding efficient use of water and its consumption. • The main reason for water wastage is the leakages in the system, so this indicator can give the status of the water leakages.
Combustion Efficiency	11. Emission of Oxygen from the furnace or boiler	Kg/MWh	• Amount of oxygen in the furnace gives an idea about combustion efficiency. The supply of primary and secondary air in the combustion chamber is crucial. • The measurement of the emission of oxygen would be helpful to keep control on the fuel combustion.
Energy Recovery	12. Amount of Energy recovered from the gas cooler or condenser	MWh of energy produced from those equipments	• There are 3-gas condensers for condensing the flue gas and recover energy from it. Keeping in mind the production capacity of the plant, the amount of energy recovered from the condensers is significant. • Indicator for the measurement of the amount of energy recovered would be an important indicator for the plant management to reduce the energy wastage and use it more efficiently.
Regulatory Compliance	13. Number of Non-Compliance	Number of Non-Compliance/year	• It is a MPI that tells the status of the operation of the plant how much it is in compliance with relevant environmental regulation.

Management Commitment	14. Environmental investment made per year	Amount of SEK/ year	• It shows the management commitment to improve the environmental performance of the plant and its operation. • A company that is able to plan its projects effectively on environmental work is most likely one that will succeed in achieving an improved environmental performance year after year. Therefore, monitoring the economic resources allocated for these environmental projects is key as it will point out which company is making efforts to improve its performance and is prepared to face the economic investments required for the improvements.

4.6.2 Measurement of Indicators

Measured values for the initial set of environmental indicators are given in Table 9. Information is collected from different sources to measure and calculate the above indicators. Data was taken from the company's official and unofficial documents. Sydkraft records certain information to operate and track the performance of the plant. Some information is recorded online, like temperature of the water, flow etc., and figures like quantity of the fuel, waste generation etc. are recorded manually by the plant authorities. Data from these sources were referred while doing the measurement. Company's environmental report was also referred for the emissions figure, which it sends to the regulatory authority. All the required data were collected on the Excel sheet in the form it was received (Annexure 3). It is then calculated according to the indices, which are mostly in the relative terms, though a few are in the absolute terms.

The past status means the period before Sydkraft took over the plant. It covers the period from 1996 to 1999. The values calculated for the indicators are the average values over this period. Most of the values are measured from 1997; as for the year 1996 there was not enough information to calculate. Wherever the data was available from 1996, it is used for calculating the values. Most of the indicators are relative indicators measuring the values in respect to energy produced in the certain period. Only a few of them are absolute indicators and it was not feasible to convert them to relative indicators. Measurement of the indicators for the fuel consumption is based on the data from 1996 to 1999. CO2 emission indicator also covers the data over the same period. But CO emission indicator, energy recovery indicator, oxygen emission indicator didn't take any data from the year 1996, as it was not available.

CO2 emission was calculated with the help of an Excel package designed by Pricewaterhousecoopers. The package is a sort of small calculating software based on certain formulas and pre-fed values. It takes default emission factors for different fuels and calculates the CO2 emission on the basis of quantity of fuel consumed. The Excel format is given in Annexure 3. The result can vary on the quality of the fuel, which depends upon the region and technology, but this package gives average values for the CO2 emission. CO emission measurement is based on the monitoring and measurement done by the monitoring agencies hired by Sydkraft. In the case of non-compliance indicator, no significant number of non-compliances was found, so instead of some quantitative result, just a qualitative result was obtained.

Data availability for the period of 1996 to 1999 was crucial for the measurement of the initial indicators. Since the plant was under different management, much information was either never covered or not transferred during the change of ownership. Some of the data for the indicators between 1996 and 1999 was not available. Due to this, it was not possible to calculate the average value for this period, and for a number of the indicators an average was calculated from a different set of years within the period mentioned. For example, in the case of electricity consumption by the plant due to unavailability of data, the value of 1999 was taken as average value for the past state.

Most of data received from the company were not in the form of the desired units. So, required conversion factors were used to convert those data into the form of indices for the selected initial indicators.

Table 9 Measurements of Initial (1996-1999) Environmental Indicators

Measurements of Initial Environmental Indicators			
Serial no.	**Selected Indicators**	**Indices**	**Average (1997-1999) measured values**
1	Total non-renewable fuel (natural gas) consumption per unit of energy produced	**m3/MWh**	24.99 m3/MWh
2	Total renewable fuel (bio fuel) consumption per unit of energy produced	**m3s/MWh**	1.02 m3s/MWh
3	Electricity consumption per MWh of heat produced	**MWh(electricity) /MWh(heat)**	29.42
4	Amount of CO2 emitted from the renewable fuel (bio fuel) per unit of energy produced	**Kg/MWh**	413.99 kg/MWh
5	Amount of CO2 emitted from the non-renewable fuel (natural gas) per unit of energy produced	**Kg/MWh**	56.18 kg/MWh
6	Amount of CO emission per unit of energy produced	**Kg/MWh**	125.43 kg/MWh
7	Amount of NOx emitted per unit of energy produced	**Kg/MWh**	0.31kg/MWh
8	Amount of fly ash emitted per unit of energy produced	**kg/MWh**	0.18 kg/MWh
9	Amount of bottom ash emitted per unit of energy produced	**Ton/MWh**	0.0035 ton/MWh
10	Water consumed per unit of energy production	**Litres/MWh**	2.06 litres/ MWh
11	Emission of oxygen from the furnace or boiler (combustion efficiency)	**Kg/MWh**	19.24 kg/MWh
12	Amount of Energy recovered from the gas cooler or condenser	**MWh of energy produced from these equipments**	1260 MWh
13	Number of Non-Compliance	**Number of Non-Compliance/year**	(Not Available in the given form) Comliance problem with dust emission, some complaints from the community
14	Environmental investment made per year	**Amount of SEK/ year**	Not Available

5 Review of the Status after Transfer to Sydkraft

This chapter addresses two sub research questions. It presents the description of the changes made at the plant by Sydkraft. It covers the changes made from technological to management level. Present environmental status of the Total Heating System plant is also covered in this chapter. Based on the initial set of indicators and the present environmental status, the final set of indicators is developed and measured, and is given in section 5.3.

5.1 Changes made at the Plant Level[47]

Sydkraft made a number of changes in the plant. Technological changes like replacing inefficient equipment with efficient equipment, making some change in the existing equipments etc. were carried out in the past few years. Changes were also made for increasing the energy and resource efficiency. Installation of pollution control equipment was done at a different part of the heating production process.

Stack height was increased to avoid the dusting problem in the nearby areas. The height is recalculated on the basis of flow and the velocity of the flue gas in it, and thus modified. Further, the diameter of the added part is slightly reduced towards the top to increase the velocity of the flue gas. This helped the flue gas to get more height and disperse and dilute in the air.

Measures have been taken to control leakages in the distribution network. The state of the art water treatment plant, which works on the reverse osmosis principle, is an absolute condition to maintain an acceptable water quality. Even though these changes were made, there is an increase in overall water consumption over the past few years and this is a contradiction to the changes made.

New water treatment plant was installed replacing the old type plant. This works on the reverse osmosis principle and the setup is less bulky and more efficient. It treats water, which is fed to the boilers and distribution system. Its task is to remove the hardness and other impurities, to get rid of scales on the heat transfer surface and reduce the heat transfer.

Parts of the heat distribution piping in the Staffanstorp city were changed last year. The old tubes were heavily corroded and damaged, and that resulted in heat losses and risk for uncontrollable leakage. New and better quality tubes are replacing the old ones. Some old piping, connection pipes to customers, suffered from damage by handling during the installation process. This will cause leaks after a number of years, and this particular problem is the most probably the root cause of the huge water loss.

The exhaust boiler for the bio fuel unit was replaced. The old one had the material damaged due to high thermal stress, which resulted from the particles sedimentation (200-300mm) at the bottom of the boiler, and poor water chemistry. Poor water chemistry can lead to accumulation of sediments in the boiler and scale formation on the heat transfer surface. The attempt was made to eliminate these problems in the new exhaust boiler in combination with a water treatment plant. Also, the old boiler was small in relation to the capacity of the bio fuel furnace, which was one of the main reasons for poor heat recovery from the fuel and high dust level from the stack. The new boiler resulted in an

[47] Anderson R. (2002, July 24) Personal Interview.

increase in energy recovery and stable and improved combustion, which helped in more heat recovery from the same amount fuel, as well as reduction in dust level due to better combustion.

A degassing unit was installed in the heating plant in the year 2000. In this, steam flows in from a auxiliary boiler and is released through the nozzles placed at the bottom of the tank. Nozzles are kept submerged in the water to be degassed. Steam rises to the surface of the water in the form of bubbles and it causes the water to boil. Steam helps to remove gases like O_2, CO_2 and other dissolved gases, which are corrosive in nature and can damage the boiler equipment and affect its performance. The degassing unit directly or indirectly helps prevent leakages, by stopping the corrosion, reduce heat loss and deliver safe and quality heating service to Sydkraft customers.

5.2 *Present Environmental Status*

The description of the present environmental status of the plant is presented on the basis of the described past environmental status. It gives the idea of the status of the past problem in the present state and also shows the degree of improvements regarding those problems. Fly ash emissions status is described with the improvements achieved. Condition and operational efficiency of the heat exchanger is presented along with the position of water leakages and return water temperature problem. However, site survey of the plant and the review of its environmental report were also useful in understanding the present environmental status of the total heating plant.

Dust level from the Stack

The dust level of 20 mg/ MJ given by the regulatory authority was set in consultation with the Staffanstorp heating plant owner in the beginning. This value is based on the energy content of the fuel, which is crucial because then it depends on the quality of the fuel. According to Sydkraft, the limit is too low as it should be somewhere around 40 mg/ MJ based on the same calculation. Sydkraft's justification of increasing the limit doesn't nullify the pro-active approach of the company, but it says that the present value is not practical in the existing condition of the technology and the quality of the fuel. Doing all the possible changes and optimising the plant to a large extent can hardly help the company to reduce the level by 5 – 10 mg. In the wintertime when the demand of heat is high and the plant almost runs at its full capacity, the level of dust is approximately 25-30 mg/MJ, which is low compared to summer when it is higher than 40 mg/MJ.

Problems in the Heat Exchanger

At present, one of the biggest problems is the temperature of the returning water from the customer end. It is around 55-60 ^{0}C, but the preferred temperature is around 40-45 ^{0}C. The main reason lies at the distribution end due to poor maintenance of the heat exchangers. Formation of scale is the main cause for poor performance of these heat exchangers. Higher scale formation reduces the heat transfer rate, so for delivering the same amount of heat it needs higher flow of hot water.

Another cause may be the malfunctioning of the temperature and flow regulator. The infectivity of the regulator to sense the temperature is the problem. High flow of the hot water to deliver the same amount of heat causes the regulator to open more, which is crucial for the temperature of the return water to the heating plant.

Old type Heat Exchanger

Functioning of the old type heat exchanger is another reason for the above-discussed problem. Shell and tube heat exchangers, which are presently used in many places, are not so efficient as plate type heat exchangers. In the plate type exchanger, the flow of the water is laminar, which results in better efficiency and heat recovery. The plate type heat exchanger is the modern type in use in most places.

Absence of a flow meter to measure the amount of water flowing through the heating system in the households could be one of the reasons for the negligence of the customers resulting in poor performance of the heat exchanger. Suppose there is a flow meter installed in a house, which will measure the flow of water through it and make the customer pay accordingly, then it can have some impact on the customer to identify the problem and look after the performance of the heat exchanger and save money.

Heat Supply to Old Sugar mill

Heat is being supplied to a industrial site, which is situated in the Staffanstorp city. The distribution channel to this plant is not in good condition. The local system is old, resulting in heat loss at several places. Even the heat exchangers at the factory end and at the intermediate stage are not very efficient, and the temperature regulators as well.

Water Leakages

There are some problems of water leakage from the distribution network. It is guessed that most of the leakages are happening in the secondary system in the city, taking heat from the primary system attached to the production plant. Pipes are damaged due to contract mishandling. In the middle of the pipes there is a copper tube covered with mineral wool working as an insulation, and a plastic covering on the top. When any damages happen to the plastic covering, water leaks to the copper tube through the wool bed, which causes corrosion, and thus damages the copper tubing. This results in water leakages from the distribution-piping network.

Gas Condenser

The gas condenser on the bio fuel unit is not functioning effectively. Due to the improper design of the condenser, the gaps between the fins on the tube are getting chocked, which reduces the heat transfer from gas to water in the tube. Tubes are made of stainless steel and the fins are made of aluminum, which are more susceptible to corrosion and damage at the high temperature. Ideally gas should pass through the condenser from bottom to top, which will result in better heat exchange and will also get rid of the accumulation of dust on the tubes.

Temperature of the Return Water

The temperature of the return water is critical, as the performance of the whole plant depends on it. At present the temperature of the return water is around or above 55 ^{0}C, but ideally it should be around 40 ^{0}C. High temperature creates a problem in the process of heat transfer from the boiler and other systems, which results in a significant amount of energy loss. High temperature is also hampering the performance of the gas condenser. Gas condensers, even the improved one in the heating system plant, cannot work effectively if the temperature of the return water from the customers is as high as 55 ^{0}C.

5.3 Final Environmental Indicators

5.3.1 Identification of Indicators

Table 10 shows the list of all the final indicators proposed for measurement of present environmental status, which is the period from the year 2000 until now. It contains the same 14 indicators listed in the initial set of indicators and also 6 newly proposed indicators based on the changes made and present management strategy.

Table 10 Set of final Environmental Performance Indicators (EPIs)

Environmental Aspects	Proposed EPI	Unit	Explanation/Considerations
Use of Resources	1. Total non-renewable fuel consumption per unit of energy produced	m3 /MWh	As earlier
	2. Total renewable fuel consumption per unit of energy produced	m3s /MWh	As earlier
	3. Energy (electricity) consumption per MWh of heat produced	MWh (electricity)/ MWh (heat)	As earlier
Emissions of CO_2	4. Amount of CO_2 emitted from the renewable fuel per unit of energy produced	Kg/MWh	As earlier
	5. Amount of CO_2 emitted from the non-renewable fuel per unit of energy produced	Kg/MWh	As earlier
	6. Amount of CO emission per unit of energy produced	Kg/MWh	As earlier
Emissions of NO_x	7. Amount of NO_x emitted per unit of energy produced	Kg/MWh	As earlier
Emissions Dust	8. Amount of fly ash emitted per unit of energy produced	kg/MWh	As earlier
Generation of Waste	9. Amount of bottom ash emitted per unit of energy produced	Ton/MWh	As earlier
Water Consumption	10. Water consumed per unit of energy production	Litres/MWh	As earlier
Combustion Efficiency	11. Amount of Oxygen in the furnace	% of Oxygen	As earlier
Energy Recovery	12. Amount of Energy recovered from the gas cooler or condenser	MWh of energy produced from those equipments	As earlier

Regulatory Compliance	13. Number of Non-Compliance	Number of Non-Compliance /year	As earlier
Management Commitment	14. Environmental investment made per year	Amount of SEK/ year	As earlier
New Indicators based on the changes made in the plant			
Management Commitment	15. Environmental training for employee or contractor conducted	Number of people trained/year	• Not only the training in environmental issues is relevant, but also the possibility of putting in practice the knowledge acquired by participating directly in projects related to environmental improvements. Therefore, an indicators such as this one, would allow the company's management monitor how much time is spent by their staff on projects that would lead to an overall improvement of the company's performance.
Noise Generation	16. Intensity of noise generated	Db(A)	• Indicator to monitor the noise level in the boiler and other equipments. Mainly, pumps and motors create high noise. • It is good to measure and reduce the level of noise because it produce nuisance the working environment.
Compliance of the Environmental Policy	17. Frequency of breakdown of the bio fuel boiler	No. of breakdown/ year	• As the bio fuel is a better fuel in compare to fossil fuel, the operation of its boiler is crucial. More breakdowns will push the reliance on the fossil fuel boiler, which is not as environment friendly bio fuel operation. • Indicator would help to measure the dependency on the less environment friendly process.
Wastage of Energy	18. Temperature of the return water	Degree Celsius	• Temperature of the return water is very crucial because the efficiency of several equipments and also the whole heating system depends on it. If the temperature is high then

			the system loses significant amount of energy from different points. It is an absolute indicator for the measurement of temperature of the return water, which could be useful to keep track on the energy wastage.
Emergency & Risk	19. Number of Emergency Measures taken	Number of Emergency drill conducted/year	• Sometimes hazardous waste and oil sludge generates in the plant, which poses some risk to human health, air, water or ground. This type of MPIs gives the idea that how much the plant management is prepared to handle any environmental & safety emergency and risk. • Indicator is not addressing the amount of hazardous material generated, as there is lack of information. • Number of emergency measures taken in the plant is related to the number of emergency drill conducted to be ready to handle the emergency crisis.
Resource consumption	20. Use of Chemicals per unit of energy produced	Kg or ton/MWh	• There are some chemicals used for water treatment for the boiler. It is used to remove the hardness of the water and the particulate matter. An indicator would help the company to use the chemicals efficiently.

5.3.2 Measurement of Indicators

A final set of indicators is meant for measuring the present (2000-2002 June) environmental status of Staffanstorp heating system plant. It has been named the final set of indicator because these indicators, including the proposed new indicators, can be used in the future for EPE in other plants as well. For the measurement of the final set of indicators, the period from the year 2000 and 2002 was taken. Even though Sydkraft took over the plant in June 1999, it sounds practical to measure the performance from the year 2000. Since the plant was not under Sydkraft for almost half the 1999, it took time for Sydkraft to rearrange the operation and management of the plant. Also, once there is a change in the management, it takes time to make changes and achieve some improvement. The present status is not the only period after the changes made by the Sydkraft, but it includes the entire period from the year 2000. It also considers the period before Sydkraft made any changes and also the performance during the period of change in the process, technology, management etc.

The values for the indicator measuring the present environmental status are the average value from 2000 to June 2002. In some cases it took the average value only up to 2001, as the information is missing for the year 2002. The calculation for CO2 in both the cases (renewable, non-renewable fuel) is done with the help of the CO2 emission Excel package by Pricewaterhousecoopers. This is a standard format in which the consumption figure of fuel is fed and CO2 emission is calculated based on some default emission factor and values. The detailed description can be seen in section 4.6.2. Numbers of values were calculated from different units to fit into the desired units. In some cases the efficiency of boiler and furnace is used when the values were given in the reference to MJ of energy content in the fuel. In the case of return water temperature value, the present value, which was collected during the visit to the plant, is taken as a value for the present status. The investment figure was achieved over 2000 and 2001 both; the yearly average value is taken for the relevant indicator. Also, regarding the training of 20 employees, it is not known how many employees were trained each year, so the yearly average value is taken for the year 2000-2001.

The list of final indicators meant for measuring the present environmental status, is presented in Table 11. It shows the measured values of all the indicators based on the above-described calculations. The table also shows the units in which the values are measured and qualitative measurement for some of the indicators.

Table 11 Measurements of Final (2000-June 2002) Environmental Performance Indicators

Measurements of Final Environmental Indicators			
Serial no.	**Selected Indicators**	**Indices**	**Average (2000-2002 June) measured values**
1	Total non-renewable fuel (natural gas) consumption per unit of energy produced	**m3/MWh**	15.37 m3/MWh
2	Total renewable fuel (bio fuel) consumption per unit of energy produced	**m3s/MWh**	1.29 m3/MWh
3	Electricity consumption per MWh of heat produced	**MWh(electricity)/MWh(heat)**	28.88
4	Amount of CO2 emitted from the renewable fuel (bio fuel) per unit of energy produced	**Kg/MWh**	488.98 kg/MWh
5	Amount of CO2 emitted from the non-renewable fuel (natural gas) per unit of energy produced	**Kg/MWh**	35.87 kg/MWh
6	Amount of CO emission per unit of energy produced	**Kg/MWh**	77.6 kg/MWh
7	Amount of NOx emitted per unit of energy produced	**Kg/MWh**	0.28 kg/MWh
8	Amount of fly ash emitted per unit of energy produced	**kg/MWh**	0.08 kg/MWh
9	Amount of bottom ash emitted per unit of energy produced	**Ton/MWh**	0.0035 ton/MWh
10	Water consumed per unit of energy production	**Litres/MWh**	5.48 litres/ MWh
11	Intensity of noise generated	**Db(A)**	Not available
12	Frequency of breakdown of the bio fuel boiler	**No. of breakdown/year**	12 times/year
13	Temperature of the return water	**Degree Celsius**	58 Celsius
14	Emission of Oxygen from the furnace or boiler (Combustion efficiency)	**kg/MWh**	16.97 kg/MWh
15	Amount of Energy recovered from the gas cooler or condenser	**MWh of energy produced from those equipments**	1008 MWh
16	Number of Emergency Measures taken	**Number of Emergency drill conducted/year**	(Not available) Automatic valve to stop the gas flow, smoke detectros and fire alarm installed, smoke ventilation
17	Number of Non-Compliance	**Number of Non-Compliance/year**	(Not available) Still above the 20 mg/MJ but improved in compared to past status
18	Environmental investment made per year	**Amount of SEK/ year**	SEK 618,100 (Total SEK 1,236,200 since year 2000)
19	Environmental training for employee or contractor conducted	**Number of people trained/year**	(approximately 10 employees/year) Around 20 employees trained uptil now
20	Chemicals used per unit of energy produced	**Kg/MWh**	0.015 kg/MWh (calculated only on the basis of 2001)

6 Analysis

In order to test the developed EPE model and find an answer to the final sub research question, the initial and final environmental indicators are compared. After the comparison, differences between initial and final indicators are analysed and the result is presented in the form of environmental performance in five different categories. Finally, the yearly trends of different parameters are also compared to Sydkraft's overall performance trend.

6.1 Comparison of Initial and Final Indicators

The initial and the final indicators are measured based on their indices (Unit /MWh). The initial list of indicators was selected according to its relevancy to the heating system operation in the past. Mostly the focus was on the performance of emissions and amount of waste generated, as it was mandatory to report to the regulatory authority for the legal compliance. However, the final set of indicators contains all initial indicators in addition to some new ones added to it based on the changes made in the plant. Addition of new indicators was done based on EPE standards and also on information required for the holistic analysis of environmental status. The idea for new indicators also came from the present management's strategy and the measurement done to track the present operational performance of the system. Some of the indicators were taken considering the importance of parameters in the present for overall environmental and safety performance.

Since the measuring units of corresponding indicators are the same, the values can be directly compared with each other. Measured values either increase or decrease depending upon what is being measured and its performance. In the case of emissions, if the value goes down in the final indicator, it is termed a positive change, since reduction of emissions is beneficial for the environment. This is the case in waste generation and resource consumption. If the final value goes up in the case of energy efficiency or productivity, it is termed a positive performance. Thus the result of the comparison depends on what is being compared and in what form, which is shown in Table 12.

No comparison has been made in the case of new indicators given in the final set of indicators. This is due to unavailability of information regarding these new indicators in the period before Sydkraft took over the THS. Explanation about the importance of the new indicators is given in the next section. It will also explain the type of measurement done by these indicators and how it can be useful to track the environmental performance of the system in a better way. Fifteen indicators are compared based on their values in the past state and present state. The final set of indicators contains 21 indicators including 6 new indicators added to the existing initial set of indicators.

The compared value is written in the extreme right column of the table. In most cases, the result of the comparison is in a quantitative form and it also has the same unit for the corresponding indicators. In the case of new indicators, which are not listed in the initial set of indicators and for which there were no values in the past state, no comparison has been made. Present values of these indicators are measured and placed in the present status indicators. The environmental performance column gives only the difference between present and past status indicators. The values are shown in either a positive or negative way. This is explained in the next section. This section also gives an explanation of the meaning of the increases and decreases in certain values and the related environmental improvement. Together with this, it highlights the fall in environmental performance, which is a part of the complete picture of environmental performance evaluation in any organisation. Identification of the shortfall will help management to understand where improvement is needed in the future. In the area where no improvement or fall in performance is registered, an explanation is given regarding the importance of that measurement and why it should be continued in the future.

Table 12 Comparison of Initial and Final Environmental Indicators

Comparison of Environmental Indicators				
Selected Indicators	**Indices**	**Past state (1996-1999)**	**Present state (2000-2002 June)**	**Environmental performance (Improvements & shortfall)**
Total non-renewable fuel consumption per unit of energy produced	**m3/MWh**	24.99 m3/MWh	15.37 m3/MWh	**9.62m3/MWh reduction** in fossil fuel consumption
Total renewable fuel consumption per unit of energy produced	**m3s/MWh**	1.02 m3s/MWh	1.29 m3s/MWh	**0.27m3s/MWh increase** in renewable fuel consumption
Electricity consumption per MWh of heat produced	**MWh(electricity) /MWh(heat)**	29.42	28.88	**0.54 reduction** in power consumption
Use of Chemicals per unit of energy produced	**Kg or ton/MWh**	Not available	0.015 kg/MWh	Not Applicable
Amount of CO2 emitted from the renewable fuel (bio fuel) per unit of energy produced	**Kg/MWh**	413.99 kg/MWh	488.98 kg/MWh	**74.99 kg/MWh increase** in CO2 emissions from bio fuel
Amount of CO2 emitted from the non-renewable fuel (natural gas) per unit of energy produced	**Kg/MWh**	56.18 kg/MWh	35.87 kg/Mwh	**20.31kg/MWh decrease** in CO2 emission from natural gas
Amount of CO emission per unit of energy produced	**Kg/MWh**	125.43 kg/MWh	77.6 kg/MWh	**47.83 kg/MWh reduction** in CO emissions
Amount of NOx emitted per unit of energy produced	**Kg/MWh**	0.31kg/MWh	0.28 kg/MWh	**0.03 kg/MWh reduction** in Nox emissions
Amount of fly ash emitted per unit of energy produced	**kg/MWh**	0.18 kg/MWh (5333 kg/month)	0.08 kg/MWh	**0.1kg/MWh reduction** in fly ash emissions
Amount of bottom ash emitted per unit of energy produced	**Ton/MWh**	0.0035 ton/MWh	0.0035 ton/MWh	**No change** in the waste generation

Selected Indicators	Indices	Initial state	Present state	Environmental performance
Water consumed per unit of energy production	**Litres/MWh**	2.06 litres/ MWh	5.48 litres/ MWh	**3.42 litres/MWh increase** in water consumption
Emission of oxygen from the furnace or boiler (combustion efficiency)	**Kg/MWh**	19.24 kg/MWh	16.97 kg/MWh	**2.27 kg/MWh reduction** in oxygen emissions
Amount of Energy recovered from the gas cooler or condenser	**MWh of energy produced from these equipments**	1260 MWh	1008 MWh	**252 MWh decrease** in the energy recovery over last few years
Number of Non-Compliance	**Number of Non-Compliance/year**	(Not available) Comliance problem with dust emission, some complaints from the community	(Not available) Still above the 20 mg/MWh but improved in compared to starting few years	(Not applicable) Improvements can't be shown based on indicator but there is an improvement in dust level compliance
Environmental investment made per year	**Amount of SEK/ year**	Not available	SEK 618,100 (Total SEK 1,236,200 since year 2000)	Not applicable
Temperature of the return water	**Degree Celsius**	Not available	Around 58 Celcius	Not applicable
Frequency of breakdown of the bio fuel boiler	**No. of breakdown/year**	Not available	12 times/year	Not applicable
Intensity of noise generated	**Db(A)**	Not available	Not available	Not applicable
Number of Emergency Measures taken	**Number of Emergency drill conducted/year**	Not available	(Not available) Automatic valve to stop the gas flow, smoke detectros and fire alarm installed, smoke ventilation system	Not applicable
Environmental training for employee or contractor conducted	**Number of people trained/year**	Not available	(approximately 10 employees/year) Around 20 employees trained uptil now	Not Applicable

6.2 Environmental Improvements

The environmental improvements are identified on the basis of the comparison made in section 6.1. In the comparison the difference between the past and present state values is analysed. Initial indicators measure the average values for the past state, which covers the period from 1996 to 1999. The period after Sydkraft took over the plant, i.e. from 2000 until present, is the present state and the final indicator does its average measurement. Wherever there was no data available from the past state, no improvement has been shown. Also, in the case of new indicators, no performance analysis is done, as these indicators were not part of the initial set of indicators, so there is no past state measurement. However, explanations are given regarding its selection in the final set of indicators and its importance in the measurement of environmental performance.

6.2.1 Resource Consumption

This analyses the intensity of the different resource consumption values at the Staffanstorp heating system plant. It presents the performance of the resource use in the comparison between the past and present state. It describes the environmental performance based on increase or decrease in the resource use in the past few years, in respect to per unit of heat produced. Resources like natural gas, bio fuel, water, electricity, and chemicals are covered.

Non-Renewable Fuel

The consumption of non-renewable fuel has gone down in the past few years, which can be a sign of improvements. From the comparison, it was found that the difference is about 9.62m3/MWh between the past and present state. There is a significant reduction of natural gas consumption since the takeover in 1999. The decline is not in an absolute term because the capacity of gas boilers remained the same and the capacity of the bio fuel boiler seems to increase and so also the bio fuel consumption. There is an increase in the efficiency of natural gas boiler that pushed down the consumption of gas per MWh of energy produced. Due to proper maintenance and high automation, the efficiency of the gas boiler increased slightly. This helps in less gas consumption for producing the same amount of heat. Decline in fossil fuel consumption, without changing the output, complies with Sydkraft's environment policy and also with its management strategy to decrease the use of fossil fuel in the future.

Renewable Fuel

There is no major improvement in the combustion efficiency of the renewable fuel (bio fuel). The comparison shows that there is an increase in the fuel consumption of about 0.27m3s/MWh. This increase seems to be due to a drop in the natural gas consumption as well as an increase in heat production, which is either balanced by increased combustion efficiency of bio fuel and/or increase in bio fuel consumption. The combustion efficiency increas may be due to replacement of the old boiler by Sydkraft. Before Sydkraft took over the plant, the bio fuel boiler was smaller in size than was required. This resulted in poor boiler efficiency, which means poor energy transfer to water from the flue gas and loss of energy in the form of high venting flue gas temperature. It led to high fuel consumption to deliver the same amount of heat produced. The new exhaust boiler has more space for better heat transfer and for appropriate flue gas velocity to trap the fly ash.

On the other side, it's good to increase the consumption of renewable fuel, replacing the fossil fuel but without compromising the efficiency of the fuel use. It would be better to replace the fossil fuel by bio fuel at Staffanstorp plant gradually. Indicators like m3s/MWh will help to measure the efficiency of the bio fuel in comparison to the heat production. It can also check the reliance on bio fuel if combined and compared with the indicator for measuring the fossil fuel consumption. Increased use of bio fuel with improved efficiency complies with the organisation's environmental objectives to shift to reliance on renewable fuel.

Electricity Consumption

There is a reduction in electricity consumption in the plant operation, which can be termed a significant improvement. The amount of electricity used in a small plant like Staffanstorp is not huge but in comparison to its size and its production capacity, it becomes a significant aspect to watch. Since the indicator is the ratio of electricity consumed to the heat produced (MWh of electricity consumed/MWh of heat produced), the value of this indicator is just an absolute number without any unit. The difference between present and past state is 0.54, which shows an improvement. The reason for this reduction in the electricity consumption is not clear, but it is assumed that one of the reasons could be the use of more efficient equipment. After the takeover, several changes have been made in equipment and also some of this equipment was totally replaced with better units. Another strong reason for this improvement seems to be the high level of automation of the plant, which leads to the efficient use of electricity. But since the improvement is minor, some sound energy reduction projects could be undertaken in the future to work in this area more effectively.

Water Consumption

The average water consumption per production from the year 2000 to June 2002 is 5.48 Litres/MWh. Average water consumption before 2000 was 2.06 litres/MWh, which was quite low in compared to the present average consumption. The water consumption has gone up significantly in spite of changes made by Sydkraft in terms of installing a new water treatment plant and preventing leakages by changing some of the distribution-piping network. The consumption is going up continuously every year, which is shown in Figure 16. The projected water consumption for the current year is 2110 Kilolitres, which is 1631 Kilolitres more than the consumption in 2001. It is said that the reason for the high water consumption in last few years is the leakage in the secondary system. The secondary system is the part of the heat exchange system in the heat distribution network, which takes heat from the primary section and transports it to the customers. There is some water recovery by the gas condenser, which recovers some water by condensing moisture in the flue gas from the burning of bio fuel. But the water losses through leakages are so high that it nullifies the quantity of water recovered from the condensing units. Much work has been done to prevent the leakage in the distribution line but there is still much more to be done. According to Sydkraft there is a large scope of activity to stop leakages in the old distribution system and conserving water as well as heat. The proposed indicator (Litres/MWh) can be useful to keep track of water usage and to measure water wastage as well as its recovery.

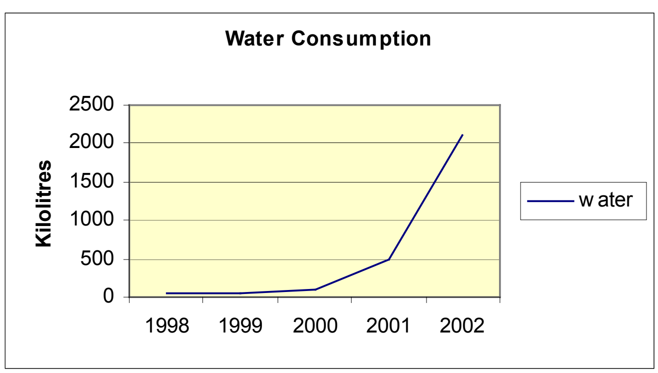


Figure 13 Water consumption at Staffanstorp THS

Chemical Consumption

Since there was not enough information about chemical consumption in the period before Sydkraft took over the plant, no environmental performance can be shown. An indicator, kg of chemical used/MWh of energy produced can be useful to measure and track the use of chemicals in the process. It's important to measure the amount of chemicals used regularly, as chemical use is always termed a negative aspect on an environment due to different types of impact. Reduce the chemical use in any process, and better will be the environmental performance of that system. At Staffanstorp, mainly two chemicals are being used, i.e. sodium hydroxide (NaOH) and sodium chloride (NaCl). These chemicals are used for treating water to make it suitable for the boiler, by removing its hardness and sedimentary particles before feeding into the boiler. In the year 2001, total chemical use was 407 kg, which is comprised of 7 kg of NaOH and 400 kg NaCl.

6.2.2 Emissions

In this section, the analysis of the emissions is presented. The analysis is based on incline or decline of emissions over the past and present states. Description of NOx, Fly Ash, CO_2 emissions from renewable and non-renewable fuel, and CO emissions are presented. Sulphur dioxide emissions were not covered because there are no significant SO2 emissions at the Staffanstorp heating plant.

NOx Emissions

The values showing NOx emissions levels are not practically monitored and measured. It is theoretically calculated based on the air supply in the furnaces and boilers, and measuring the oxygen quantity in the flue gas. But these calculations can also show the performance of NOx emissions reduction. Reduction in NOx emission measured by the selected indicator between past and present state is about 0.03 kg/MWh. This is a total reduction in NOx emissions from both bio fuel and natural gas. It is not a significant improvement but the emission is well within the regulatory limit, which is 100 mg/MJ (for bio fuel), and 80 mg/MJ (for natural gas). Reduction in NOx emission relates to the improvements in combustion efficiency in the boilers and the furnace. Emissions of NOx and CO are interrelated. Increase in CO may lead to decrease in NOx and vice versa. Since there is a reduction in CO emissions too, it shows that there is a significant improvement in the combustion of fuel and the boiler efficiency.

Dust Emission

There is an improvement in reduction of dust emissions from the Staffanstorp plant. This improvement has also eliminated the complaints from the people living in the city of Staffanstorp. It was one of the problems in the early days. However, the dust emission from the plant is still higher than the limit (20mg/MJ) set by the regulatory authority. Comparison between the past and present state shows that the dust level came down by 0.1 kg/MWh of the heat produced.

The reason behind the reduction in dust level is the improvement in the combustion of bio fuel. Better combustion resulted in less unburnt particles and less emissions. Dust emissions at Staffanstrop are from the bio fuel boiler only, as another fuel is natural gas. The old bio fuel boiler was small in compared to the capacity of the furnace, which resulted in damaging the boiler and also increasing the velocity of the flue gas. This resulted in poor energy recovery and high level of dust from the stack. Replacing the old boiler with the bigger boiler removed these problems to a great extent. According to Sydkraft, the emission figure of 20mg/MJ set by legal authority is not practical and not properly calculated to the capacity of the furnace and boilers. The company is negotiating with the regulatory agency to increase the limit, since there is no problem presented by the present level of dust emission. The author also supports this argument, as he himself saw the very low level of emissions from the stack during his visit to the plant.

CO2 Emission from Non-Renewable Fuel (Natural Gas)

There is a significant reduction in CO_2 emissions from natural gas at Staffanstorp, as presented in Figure 17. According to the calculation based on the proposed indicator (kg CO_2/MWh), CO_2 emission has gone down by 20.31 kg CO_2/MWh, since the takeover in 1999. The past state value is calculated on the basis of the yearly emission in 1999. The present value is based on the average of the yearly values from 2000 to June 2002. An improvement of 20.31 kg CO_2/MWh is a big achievement for a plant of the Staffanstorp size. Better combustion efficiency in the natural gas boiler seems to be the major reason behind this achievement. The achievement also describes an increase in the boiler efficiency by its proper maintenance and operation. Positive environmental performance like CO_2 reduction in the Total heating System plant can improve the overall environmental performance of Sydkraft.

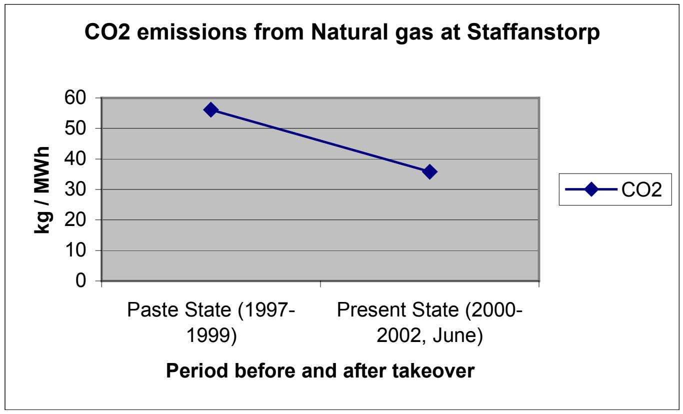


Figure 14 CO2 emissions from Natural gas

CO2 Emission from Renewable Fuel (Bio Fuel)

Usually, the carbon dioxide emission from the bio fuel combustion is taken, as zero or almost negligible. This calculation is based on the Net Carbon concept, which is the difference between CO_2 emissions from the bio fuel and the amount of CO_2 absorbed by the plant in its life span. However, in the study the Net Carbon concept is not taken because the author wanted to show the performance of the bio fuel combustion and the boiler efficiency. Carbon dioxide emissions from the bio fuel are increasing. At the time of takeover (1999), the average yearly CO2 emission was 11,076 tons and in the year 2001 it was 13,6581 tons. As the consumption of bio fuel has risen continuously through 1999 to 2001, CO2 emission has also gone up. So, there is no improvement in CO2 emission in an absolute term. The yearly CO2 emissions calculated according to the indices of the indicator, which is kg of CO2/MWh, also show no improvement from 1999 to June 2002.

Figure 18 shows the trend in CO2 emissions over the past, and present state. There is no improvement in CO2 emissions from the past (before the takeover) to the present state (after the takeover) average values. Average CO2 emission before Sydkraft took over the plant was 413.99 kg/MWh. Average emission in the present state is 488.98 kg/MWh, which is the average of the emissions from 2000 to June 2002. So, an increase of 74.99 kg CO_2/MWh over the past few years was registered. One reason for this increase could be the increase in the bio fuel consumption. The indicator, kg CO_2/MWh, can be useful to measure the emissions of CO2 from other plants as well as to evaluate the combustion efficiency of the bio fuel from time to time.

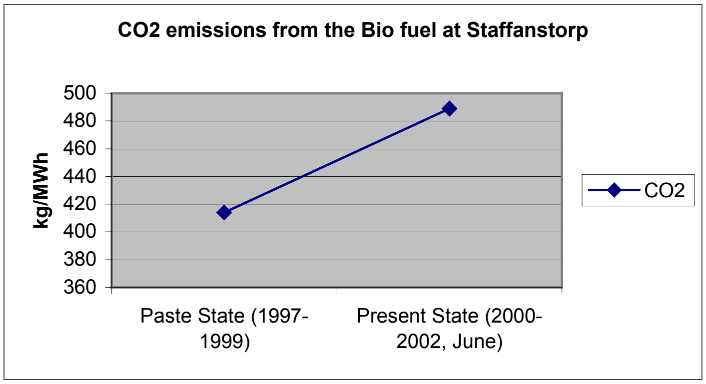


Figure 15 CO2 emissions from Biofuel

CO Emissions

Carbon monoxide is calculated in the form of kg/MWh. This indicator does not show any improvement in the local environment but it is more related to the running performance of the furnace and boiler. Tracking the performance of CO can be useful to control other emissions from the combustion process. Significant reduction can be seen in the given form. There is a decline of CO emissions over the period between 1997 and 2001. An increase in CO emission was experienced in 1998, but due to better combustion efficiency and perhaps balancing the NOx generation, it went down to 74.41 kg/MWh in 2000, which has been the lowest until the present time. According to the indicators set for past and present states there is an improvement in reduction of CO emission by 47.83 kg/MWh.

6.2.3 Waste Generation

Bottom Ash

Since there is no significant generation of other wastes except the bottom ash from the bio fuel furnace, so only bottom ash figures are reviewed. There is no reduction in bottom ash generation according to the indicator ton/MWh. Even though the bio fuel exhaust boiler has been changed to a bigger and better boiler and combustion efficiency has gone up, there is no indication of reduction in the bottom ash from the boiler and furnace. Earlier, it is highlighted that there is an increase in bio fuel consumption over the past few years. Increase in bio fuel consumption increased the bottom ash generation. But increase in bio fuel and ash generation was not proportional because better combustion chemistry reduced the generation of ash to a certain extent.

6.2.4 Energy Efficiency

In this section, energy efficiency in the plant was analysed. The analysis is performed based on the amount of energy recovered in the past and present states with the help of gas condenser. The gas condenser recovers heat from the boiler flue gas, thus saving a significant amount of resources. Energy efficiency analysis also covers the combustion efficiency of the fuel based on the quantity of oxygen in the flue gas. Return water temperature in the heating plant is crucial for the overall energy efficiency of the plant, since efficiency of the heat transfer at different places depends on this temperature. Reliance of the heat production on fossil fuel is also briefly covered.

Energy Recovery

According to the selected indicator there is a decrease in energy recovery from the gas condenser units. The indicator is an absolute indicator (MWh), which measures the total amount of energy recovered in the three condenser units. The average recovery in the past state was 1260 MWh and the average recovery in the present state is 1008 MWh, which shows a decline of 252 MWh in the energy recovery. So, there is no improvement in energy recovery from the gas condenser. However, it is a significant area to keep track of in the future because much energy can be recovered from a gas condenser.

Combustion Efficiency

The combustion efficiency of the furnace and boiler depends mainly on the amount of air supplied and on the fuel and air ratio in the combustion chamber. The amount of oxygen emitted through the flue gas could be an effective measurement for the combustion efficiency. If more oxygen is coming out of the stack it means that either there is an excess supply of air in the furnace or air/fuel mixture is not proper. So, the lower the O2 level in the flue gas, the better the combustion. There is minor improvement in the combustion of the fuel at Staffanstorp plant. The improvement is measured in the form of a selected indicator, i.e. oxygen emitted (kg/MWh). The comparison of the value of the past and present state indicators show a slight improvement of oxygen reduction over the years from 1997 to 2001 of 2.27 kg/MWh.

Return Water Temperature

No improvement can be shown in this area as, there is no comparison made due to unavailability of return water temperature data before Sydkraft took over the plant. This is a new indicator, which can track the heat transfer efficiency in the system and can support further improvements in the overall plant performance.

At present, the return water temperature is 58^0C. This temperature is too high for the return water, which should be around 40^0C. High temperature reduces the heat transfer. Return water temperature of 58^0C means that the heat transfer is not taking place in a proper way at the customer end, which is the cause for high temperature of the water returning to the plant. High temperature also affects the efficiency of the gas condenser. Even the boiler efficiency depends on the temperature of water entering the boiler, and return water is reused again as a boiler feed, which affects its performance. So, Sydkraft can further improve the plant efficiency by looking at the performance of the return water with the help of the proposed absolute indicator.

Bio Fuel Boiler Breakdown

After Sydkraft took over the plant, the yearly average breakdown of the bio fuel boiler can be taken as 12. All instances are not complete breakdowns, but some small interruptions as well, in the operation of the boiler. Numbers of short interruptions happened due to different small problems. Quality of bio fuel sometimes disrupted the operation of the boiler. There were other reasons also, which affected the normal operation. An indicator Number of breakdown/year could be an effective tool to keep track of the operation of the bio fuel boiler and the overall plant's environmental status. Measurement of numbers of breakdowns can be useful to identify their cause and to take appropriate action to reduce these causes in the future. More bio fuel boiler breakdown translates to more dependence on the fossil fuel (natural gas) boiler. This interrelation and increase in the use of the gas boiler may lead to poor overall environmental performance of the THS plant. Since there is no information available from the past status, no performance analysis was done in this case.

6.2.5 Management Performance

Since few management performance indicators (MPIs) are selected for the environmental performance evaluation of the Staffanstorp plant, the description is given highlighting their importance in EPE process. Due to lack of data from the past state (before its takeover), no performance analysis has been presented. However, the explanation is given regarding the importance of these indicators for performing EPE, and the usefulness of MPI indicators in achieving environmental improvements in the future.

Non-Compliance

There was no major problem for the company regarding the compliances with applicable environmental regulations. Regulations with which the company has to comply are dust emission, NOx emission, wastewater generation, and solid waste (both hazardous and normal). Among these, dust emission is the most significant. Before Sydkraft took over the plant, there was a problem regarding the dust level emission from the stack, which created some problems for the people living nearby. There were a few complaints from the neighbouring community regarding the dust pollution. After changing the bio fuel furnace, dust level declined significantly. Still, the emission is not within the limit (which is termed impractical) of 20 mg/MJ set by the regulatory authority, but better exhaust boiler and greater stack height have almost removed the dust problem. The total heating plant is negotiating with the regional regulatory authority to increase the dust limit to 40 mg/MJ.

Environmental Investment

There was no information regarding the environmental investment in the past state and thus no comparison has been made in this case. Sydkraft made some investments in the plant after the takeover but that was not truly an environmental investment according to Sydkraft; instead it was more related to the maintenance and other operations. The investment figure was about SEK 1,236,200.00 i.e. approximately SEK 618100/year. Since these investments produced some environmental improvements in the heating system plant, it can be said that it was a sort of environmental investment by the management. An indicator for measuring the environmental investment can be useful to evaluate the management performance regarding the environment in terms of money invested every year. It may also show the management commitment towards improving the environment, which can bring about these environmental improvements from time to time.

Emergency Measures

Due to the lack of information about the emergency measures in the past, it is not possible to do an analysis and show any performance record. At present, the company has some precautionary procedures to prevent disasters. In case of an accident there are certain emergency plans. There is no storage for natural gas and oil, as the gas flows directly from its source to the plant. If anything happens in the gas system an automatic main valve closes to block the flow of gas into the building, and at the same time a valve for gas ventilation opens. In case of fire, there is an automatic fire alarm with smoke detectors connected to an SOS-alarm and the fire brigade alarm. There is also an automatic system for smoke ventilation connected to the fire alarm. The moment it senses the intensity of smoke, it opens to diffuse the smoke inside the plant. The emergency indicator can help in evaluating and keeping track of the emergency and safety issues to prevent any environmental damage.

Environmental Training

There is no information regarding the environmental training of the employees in the period before Sydkraft took over the plant. Since 2000, some of the employees have gone through the operational and environmental training. Twenty employees, a group representing nearly half of the workforce, have gone through some sort of environmental awareness program.

In an organization, it is necessary to train employees on the environmental issues and activities. Their awareness and the working approach at the workplace is linked with the performance of the organization. Awareness level of the employees can increase the level of performance by adding to other changes. Indicator such as number of employees trained/year could be helpful in tracking the management performance regarding training, and increasing the employee awareness.

6.3 Staffanstorp's THS environmental performance trend within Sydkraft AB

Few comparisons have been made between the environmental performance of Staffantorp's THS plant and Sydkraft. For this author's comparison, the past and present state criteria are not taken for the THS plant. It is done on the basis of comparison of trends in different parameters, based on yearly data from past few years. Increase and decrease in trends of different parameters in the Staffanstorp plant are compared with the corresponding trends at Sydkraft. Reliance on non-renewable fuel for heat production, consumption of renewable fuel, emissions of dust, emissions of NOx and CO2 etc. are compared between Staffanstorp total heating plant and Sydkraft. This comparison is done to show the trend of Staffanstorp plant in different areas of environmental performance. Its trend is compared to Sydkraft's overall group performance to see Staffanstorp's compliance with the corporate strategy and approach. Comparison like this can also help to identify the gap in management's commitment and action. Some comparisons are also made with Syd Värme AB, the subsidiary of Sydkraft involved in heat production and distribution.

Heat Production from Different Fuels

While comparing the heat production from bio fuel and natural gas in Staffanstorp, it can be seen (in Figure 18) that there is a significant decline in the heat production from natural gas over the past few years. At the same time sifting the production towards bio fuel is gradually taking place to cover the same amount of production. This substitution from non-renewable to renewable is in compliance with the Sydkraft's overall strategy.

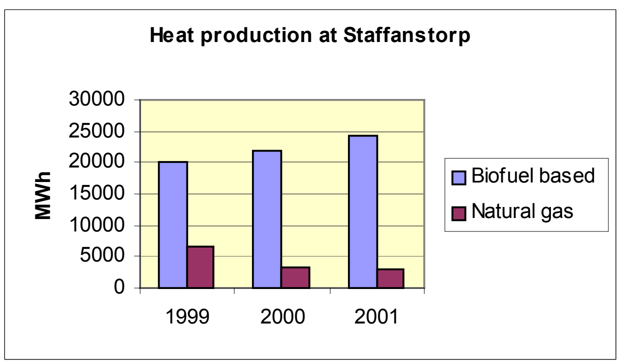


Figure 16: Heat production at Staffanstorp

The trend of decline in heat production from fossil fuel and increase in heat production from bio fuel is the same in the overall Sydkraft group, which is shown in Figure 19. This shows that Sydkraft is reluctant to decrease the reliance on fossil fuel. Increase in bio fuel consumption in Sydkraft is not significant; instead, it has been fluctuating over the last few years. The Total heating system plant in Staffanstorp seems to be sharing the same group vision and showing the compliance with the group's environmental policy and objectives to reduce the consumption of non-renewable resources. From Figure18 & 19, it can be said that heat production is gradually shifting from fossil fuel to renewable fuel at Staffanstorp and Sydkraft alike.

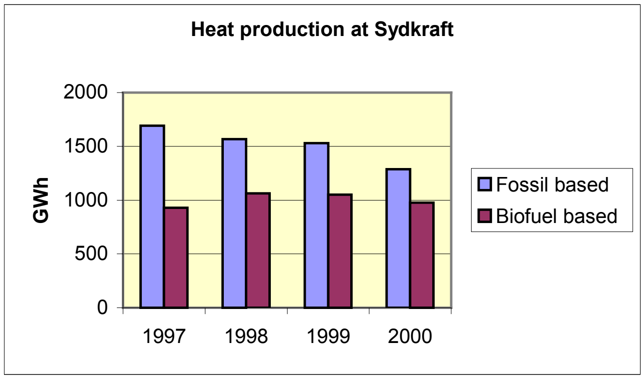


Figure 17 Heat production at Sydkraft

Comparison of Consumption of Natural Gas

Figure 20 shows that there is a significant drop in natural gas consumption in the Sydkraft group and at Staffanstorp heating plant. The overall decline in fuel consumption between 1998 and 2000 at Sydkraft and Staffanstorp was 102 GWh and 2726 MWh respectively. From the comparison it is found that at Staffanstorp the consumption of natural gas after 1998 went down more sharply than at Sydkraft.

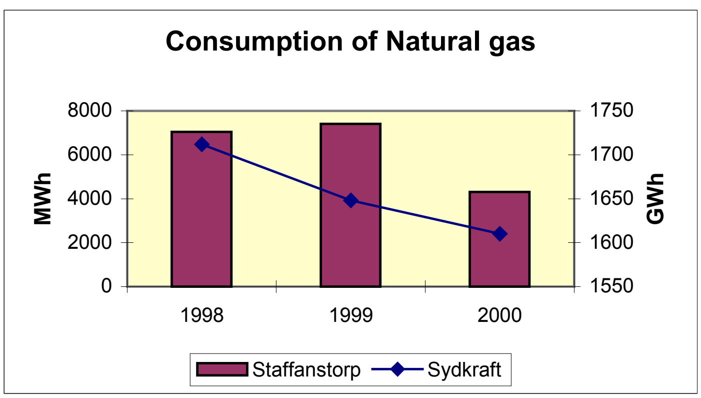


Figure 18 Comparison of Natural gas Consumption

Comparison of Fly Ash Emissions

According to Figure 21, at Sydkraft the level of dust emissions is rising even though there is a reduction in emissions in most of the individual units. The main reason seems to be the continuous addition of total heating systems in its portfolio of heating system plants. Usually, acquisition of Total Heating System plants decreases the environmental performance level of the whole group. This is because at the time of acquisition the condition of the total heating plants is poor and needs major change and investment to improve the level of their environmental performance to that of other units in the Sydkraft group.

At Staffanstorp, the environmental performance of the plant was not good at the time of acquisition in 1999. Changes in operation, changes in the process, and installation and replacement of some pollution control equipment brought down the dust emission level. Figure 21 shows the continuous decrease in dust level from 1998 to 2000. From this comparison it can be said that at Staffanstorp there is an improvement in reduction of dust emission. This reinforces the claim made by Sydkraft about the investment made in total heating system plants to achieve environmental improvements.

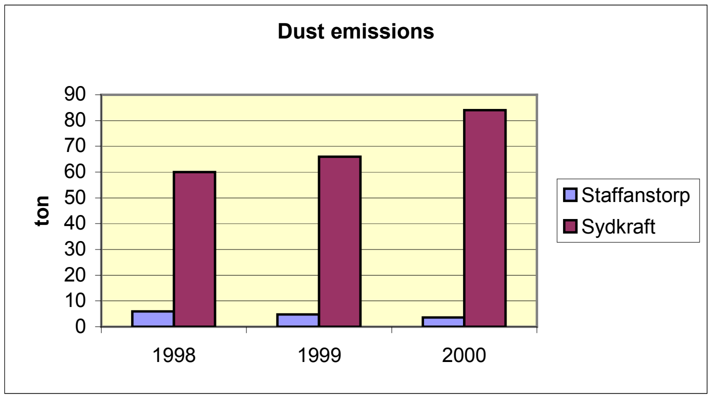


Figure 19 Comparison of Dust emissions

Comparison of NOx Emissions

The trend of NOx emission in Figure 22 shows reduction in the emissions at Staffanstorp and in overall Sydkraft. At Staffanstorp there is a reduction of 2502 kg from 1998 to 2000. The emissions went down in Staffanstorp due to better combustion efficiency, which also keeps balance between the CO and NOx emissions, as both are interdependent on each other. Decline in NOx emission over the past few years can also be seen at Sydkraft. The emission of NOx at Staffanstorp is well within the regulatory limits applicable to the plant.

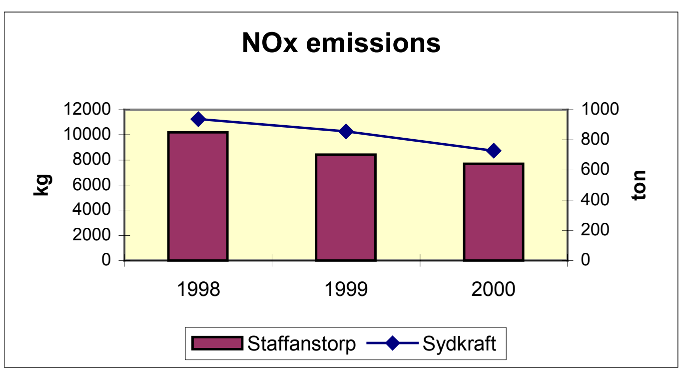


Figure 20 Comparison of NOx emissions

Comparison of CO_2 Emissions from Fossil Fuel

Comparison in carbon dioxide emissions between Staffanstorp and Sydkraft can be shown in Figure 23. There is a decline in the emissions of both Sydkraft and Staffanstorp over the past few years. The CO_2 emissions at Staffanstorp have decreased gradually from 1999 to 2001. The big dip in the year 2000 was due to the increase in the efficiency of the gas boiler, and also due to the decline in the natural gas consumption. The decline of CO_2 emission in the overall Sydkraft plant is predicted to be due to decline in the fossil fuel consumption over the past few years. Sydkraft is continuously trying to substitute the non-renewable fuel with renewable fuel. From Figure 26, it can be seen that the performance of the Staffanstorp total heating plant is in compliance with Sydkraft's vision of reduction of fossil fuel use in the future.

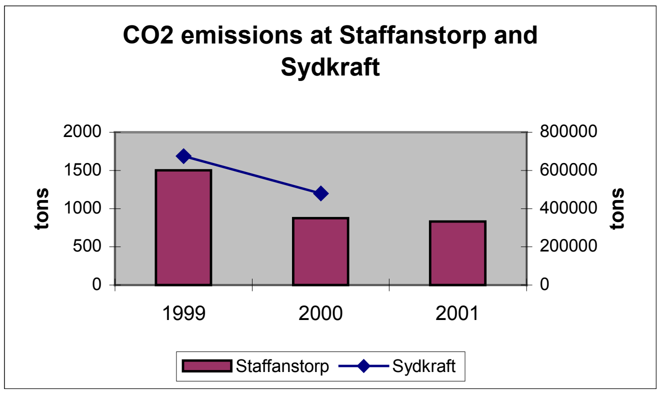


Figure 21Comparison of CO2 emissons

Comparison of Fuel Consumption with Sydkraft Värme Syd AB

Figure 24 shows that the ratio of bio fuel to natural gas consumption at Staffanstorp is higher than at

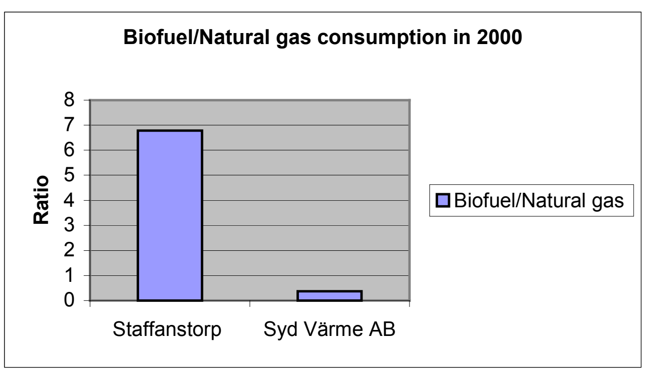


Figure 22 Ratio of Bio fuel to Natural gas consumption

Sydkraft Värme Syd AB. Bio fuel is used as a main fuel for the heat production at Staffanstorp. During the summer when the heat demand is very low, gas boilers are shut down and all the required heat is supplied from the bio fuel boiler. This shows the commitment of the Staffanstorp plant to use renewable fuel and achieve better environmental performance. The heat production in this plant from bio fuel is almost 6 times more than the heat produced by natural gas. In the year 2000, the ratio of bio fuel to the natural gas use was 6.79, whereas it was 0.37 in overall Syd Värme AB. So, it can be said that the Staffanstorp heating system is ahead in the shift towards renewable fuel compared to the overall Syd Värme AB group.

Comparison of Emissions with Sydkraft Värme Syd AB's Heating System

At Sydkraft Värme Syd AB, emissions from the district heating system are higher than those of the total heating system. The difference between the district heating and the total heating is significant in the case of NOx emissions in compared to dust emissions. So, it can be stated that even though the capacity of the total heating system is less than that of the district heating system, numbers of small total heating plants are boosting their dust emissions to a significant level. The THS plants need further changes in their processes and operations to bring down the dust emissions level.

Comparison of CO2 emissions with overall Sydkraft Värme Syd AB

In the comparison of the CO_2 emission in the overall Sydkarft Värme Syd AB group, the emissions at the Staffantstorp heating plant is negligible. The emissions at Staffanstorp also account a tiny part of the total heating system emission in the entire group. Figure 23 shows the share of the CO2 emission in the total heating system in Sydkraft Värme Syd AB, as well as in the overall Sydkraft Värme Syd AB emissions.

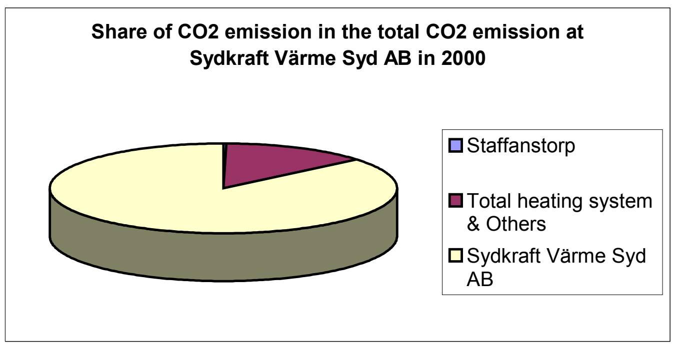


Figure 23 Presentation of the share of the CO2 emissions in Sydkarft Värme Syd AB

7 Conclusions and Recommendations

The primary goal of this thesis was to investigate how the environmental performance evaluation of the Total Heating System at Sydkraft can be performed, so that a similar EPE process might be used for other heating plants as well. Another purpose of the study was to identify the environmental improvements achieved at the plant since the Sydkraft takeover. This chapter summarises the findings made in Chapter 6, and gives recommendations based on the analysis and the present environmental status described in section 5.2.

7.1 Conclusions

The difference between the district and the total heating system is narrow. The reason for the difference lies in the type of customer. It has been found that the concept of Total Heating System may be clear with Sydkraft's management, but it is not clear with the employees related to these system units. Even though the Total Heating System Plants are small, due to their large number (i.e. more than 2000) in Sydkraft, it becomes very significant to look upon its environmental status and cumulative environmental impact. In total, the environmental impact from the entire total heating system is greater than from the big energy plants in the group. The dust problem from the total heating system plant is one of the major environmental problems, which most of these plants are facing. The primary concern is to operate these plants in such a way that the impact on the environment could be reduced. Another reason to give importance to the performance of the total heating system is that the overall group's environmental performance depends on the performance of these plants also, and sometimes-negative performances of these plants can undermine the major improvements in the overall Sydkraft group.

- Environmental performance evaluation is an effective tool to monitor and measure the environmental status of an organization.

EPE is defined as the, "process to measure, analyse, assess, report, and communicate an organization's environmental performance on an ongoing basis. It helps an organization to assess and understand its impact on the environment by evaluation of its environmental aspects and impacts. EPE can also help the organization's management to determine whether it meets its environmental goals, targets and objectives. Well-planned EPE will help improve overall organizational efficiency as well as profitability. Methodology for conducting EPE is well defined on the basis of international standard by ISO, which is given in the ISO guidelines- ISO 14031 and ISO 14032. EPE based on these guidelines can be applied to any organization irrespective of its size, type and businesses locations.

It can help Sydkraft to determine its ongoing performance in meeting environmental criteria based on its environmental policy, objectives, and targets. It can improve the resource efficiency, overall organizational efficiency, minimize the environmental aspects and impacts etc. EPE can facilitate continual improvement of environmental performance and help Sydkraft reduce environmental impacts from their total heating system.

- Total heating system can monitor and measure its environmental status based on EPE criteria and evaluate the performance by the help of proposed EPE model.

The proposed model will help to do the EPE in different steps, which will cover the ISO cycle of "Plan-Do-Check-Act." The implementation of the environmental performance evaluation can be done by the implementation model given in Annexure 2. It should start from the diagnostic of the organization and its process. This is followed by the indicator development and its measurement in two different periods. Finally, comparison is done based on the initial and final values of the indicators, and environmental performance can be analysed and reported. Since total heating systems in Sydkraft are already going for Environmental Management System (EMS) based on ISO 14001 standard, implementation of EPE process will work as a complimentary to EMS and help in evaluating the performance of EMS and other environmental activities.

The most important thing of an EPE process is the environmental indicator selected to evaluate the performance. Basically there are two types of indicators, ECIs and EPIs. EPIs are further divided into management performance indicators (MPIs) and operational performance indicators (OPIs). EPE in companies is more focussed on EPIs rather than ECIs. Within the EPIs, more emphasis is given to operational performance indicators than to management performance indicators, as OPIs are more related to environmental impacts from the processes and operation. Compared to cost-based indicators, quantity-based indicators are more often used in companies because of the ease of measuring and calculating. Even though most of the organisation uses the absolute indicators, relative indicators are more appropriate and can give better performance measurement. The ISO standard does not provide and specific guidelines as to how an EPI should be selected and which EPI should be used for which company.

- Final Environmental Indicators for the Total Heating System

Based on the analysis of the environmental aspects, material and energy balances, and a process mapping set of final indicators are developed for the measurement of environmental status in the total heating system. These indicators help in collecting meaningful data and in determining values regarding the aspects of operation, products and services, which have a significant impact on the environment. Evaluation can be performed based on the proposed EPE model by analysing the data collected for different indicators. Table 13 presents the list of final indicators, which virtually covers the operation of the total heating system plants.

Table 13 Final selected EPIs

Serial no.	Proposed Environmental Indicators
1.	Total non-renewable fuel consumption per unit of energy produced
2.	Total renewable fuel consumption per unit of energy produced
3.	Electricity consumption per MWh of heat produced
4.	Amount of CO2 emitted per unit of energy produced from the non-renewable fuel
5.	Amount of NOx emitted per unit of energy produced
6.	Amount of fly ash emitted per unit of energy produced
7.	Amount of bottom ash emitted per unit of energy produced
8.	Water consumed per unit of energy production
9.	Intensity of noise generated
10.	Frequency of the breakdown of the bio fuel boiler
11.	Temperature of the return water
12.	Amount of Energy recovered from the gas cooler or condenser
13.	Number of Non-Compliance
14.	Environmental investment made per year
15.	Environmental training for employees or contractor conducted

- The environmental performances of the Total Heating Systems were poor when Sydkraft took over these plants.

The basic problem of the total heating system plants is their small size, which makes them less attractive investments. Most of these plants are very small and are supplying heat to one industry or small group of households. With this small-scale type plant, it is not always economically and technologically feasible to make investments in its process and operations. Equipment such as an electrostatic precipitator (ESP) can bring down the dust level, which is the biggest problem for the total heating system. But due to the high cost of an ESP, it is not economically feasible to install this equipment. Sometimes it is also difficult to allocate full-time human resource as well as other resources for the environmental management of these small units.

Usually the total heating system plants have problems of dust emission, poor combustion efficiency, heat losses, and sometimes noise problems. At Staffanstorp, high level of dust emission was the major problem at the time of takeover. The reasons for high dust emission were poor combustion chemistry and improper size of the boiler. Another major problem at the heating plant was poor water chemistry, which damaged the boiler and affected its performance. Poor energy recovery from the gas condenser resulted in energy loss.

Old type and inefficient heat exchanger at the customer end is another reason for energy losses. Due to poor maintenance of the heat exchanger, scale formation takes place on the heat transfer surface[48], which reduces the rate of heat transfer. Also, the improper functioning of the temperature and flow regulator reduces the efficiency of the heat exchanger and thus results in high temperature of return water to the plant. The gas condenser attached to the bio fuel unit is not functioning effectively. High return water temperature is one of the reasons. Water leakage problem in the heat distribution network is another significant problem at Staffanstorp.

It was felt that the technological and economical analysis was not done properly at the time of takeover. The equipment was not in good shape due to poor maintenance. The bio fuel boiler was corroded in number of places due to accumulation of sediments. The capacity of the old boiler was less than the capacity of the bio fuel furnace. The gas scrubber was not working properly due to design fault and high return water temperature, which still is the case. The water treatment plant was not efficient, which was the main reason for poor boiler water chemistry.

- Environmental improvements in the process and the operation were achieved in the total heating system after Sydkraft made some changes in the plant.

A number of changes such as, change in processes, technological changes, installation of pollution control equipments, change in management strategy etc. were made once it became part of Sydkraft group.

Reduction in dust emission is the major improvement achieved at the Staffanstorp plant. This virtually stopped the complaints from the nearby community, which was a major problem before Sydkraft took over the plant. There is a reduction in carbon monoxide (CO) emissions due to better combustion efficiency, which also controlled the emission of nitrogen oxides (NOx). Reduction in oxygen emissions shows that there is an improvement in the combustion process, which controls a number of other pollutants. The Carbon dioxide from the non-renewable fuel (natural gas) has significantly gone down in past few years. It is one of the major improvements achieved after the takeover of the Staffanstorp plant by Sydkraft.

[48] The surface through which heat is transferred, this surface touches two mediums, one which is providing the heat and other which is receiving the heat.

Overall efficiency of resource consumption at the Staffanstorp plant has gone up. There is a decrease in the consumption of non-renewable fuel (natural gas) and an increase in renewable fuel (Bio fuel) over the past few years. The increase in use of renewable fuel shows compliance with Sydkraft's environmental policy and organizational strategy. Electricity consumption in the plant has declined due to installation of energy efficient equipment and automation of the plant.

There are certain areas in the plant where no improvement has been registered. No reduction has been achieved in bottom ash generation from furnace and boilers. The amount of CO2 emissions from renewable fuel has gone up in compare to earlier days. There are some negative performances also after the changes made by Sydkraft. It is necessary in the EPE process to report all the positive and negative results simultaneously. It will help to understand which area is not doing well and will lead to proper action. The amount of energy recovery from the gas condenser and cooler has gone down from 1260 MWh/year to 1008 MWh/year over the last few years. Water consumption has gone up significantly due to leakages in the secondary system.

There are even a few areas where no improvements can be shown due to lack of information. Temperature of the return water from the customers end is very important for the performance of the gas condenser and boiler. Information was not available about the past state, and at present the temperature is around 58^0 C, which is too high for the efficient operation of the plant. Areas like environmental investment, noise pollution, emergency preparedness, and employee awareness cannot be analysed for their performance measurement due to the lack of information.

- Comparison of the environmental performance of a heating plant with Sydkraft's overall performance gave some idea where the plant stands today in respect to the group's vision and strategy.

In comparison to Sydkraft's performance in reducing the consumption of non-renewable fuel, Staffanstorp plant is doing well in complying with the organization's objectives. The use of non-renewable fuel (natural gas) at Staffanstorp has taken a steeper decline than the overall trend in this area at Sydkraft. Staffanstorp is also doing better in controlling the emissions of fly ash. NOx emission has registered better improvement in both cases. There is a decline in CO_2 emissions from the natural gas at the Staffanstorp plant, which is in compliance with the overall CO_2 emissions at Sydkraft.

7.2 Recommendations

Sydkraft is one of the big energy companies in Sweden. Since it is a proactive organisation in the field of environmental protection, it is easy for Sydkraft to implement the process for evaluating environmental performance in a small heating plant like Staffanstorp. In the Total Heating System, the environmental impacts from an individual plant may be fairly small, but it becomes quite significant when added to that of other total heating system plants. Environmental performance evaluation (EPE) of the entire Total Heating System plants should be taken by Sydkraft. This would give management information about the amount of environmental load borne by these plants. EPE would also help Sydkraft analyse the environmental performance of these plants systematically and give a proper basis for taking measures to improve. Since the performance of the THS is also added to the overall group's performance, it would help to improve Sydkraft's overall performance and image once the process was applied in these systems. It would also lead to resource savings and economic benefits.

EPE can provide a systematic framework to do the evaluation of the environmental status of the organisation's activities and operation. The biggest advantage of systematic evaluation is that it can be done for any period and it can help to compare parameters between two periods. EPE of a heating system will help improve the environmental performance, as it will continuously give the status of environmental performance, which will be helpful in taking action and implementing measures.

Proposed EPE model based on ISO Plan-Do-Check-Act cycle can be used, as it closes the loop of the evaluation process and can lead to continual improvement of the whole process. Even though the environmental performance evaluation model was helpful in obtaining the result in this research study, it is up to the company to make changes in its process and its use. The steps proposed to identify all the environmental improvements made by Sydkraft can be changed according to the suitability of the organisation's activity and the affectivity of the environmental management system (EMS). If the company already has an EMS in place, it would be easy to implement the EPE. It would need less resource and time, as the EPE would be based on the environmental aspects and impacts identified in the environmental management system.

The process of the selection of environmental performance indicators (EPIs) based on significant environmental aspects may be more useful than other criteria because it can be combined with EMS. EPIs selected and used were helpful in the measurement of environmental status and evaluation of the environmental improvements of the Staffanstorp plant. Here it is strongly recommended that final selection of EPIs should always be based on the relevancy to the organization and its objectives. Care should be exercised to establish the right type and number of environmental indicators for the EPE process. Indicators should be established to cover the entire operation of the organization. EPIs should cover the performance of management, operation, processes, and specific environmental activities in all areas. EPE for a plant of Staffanstorp's size, management commitment and action could be of great importance, as small size usually causes management to keep a low level of commitment.

There are hundreds of Total Heating System in Syd Värme AB. These plants differ in size and capacity. It is not practical to take a big heating plant and a small plant (e.g. < 1 MW) at the same level of EPE implementation. This means that the implementation strategy and approach should be different for big plants and small plants. It is recommended to make two sets of total heating system plants, one comprised of all the big plants (defined by Sydkraft) and the other group of small plants. Implementation of EPE should be taken in these two sets of plants differently and according to their feasibility. EPE in small plants could be taken slightly less intensively or on a small scale according to their available resources and the significance of their environmental aspects.

It would be useful to have a common set of environmental performance indicators (EPIs), which are promoted and used in other total heating system plants and district heating plants. This could be helpful in monitoring and comparing the environmental performance internally with other Sydkraft heating system companies and externally with the performance of other heating systems in Sweden or even in other countries. This condition could be a win-win situation for the small total heating system units. It could help the Sydkraft group to continuously compare different units within the group and take measures in the low performing plants. Relative indicators would be more effective in measuring the performance in the company and would also help in comparing the performance internally and externally. So, the company should try to use relative indicators instead of absolute indicators but, if relative indicators are not possible, then absolute indicators can be used for the measurement.

The analysis of the total heating system plant should be improved before a takeover. Proper technological and economical analysis of THS should be carried out. This would establish help to understand the true condition of the plant before its acquisition, leading to better evaluation of the value of the plant and the investment needed to improve its environmental performance to the desired level. Improper evaluation sometimes pushes the organization to improve the process and operation to achieve financial benefits, which itself takes so much resources that nothing is left at the end for investing in the environmental improvements.

For measuring the EPIs in an EPE process, the data availability and its quality are important. The data collection process at Staffanstorp and other total heating plant needed to be improved. The environmental department could take data collection work, or if the plant is too small the operation department should take the responsibility. Once the EPIs are developed, data related to all the indicators should be collected for an effective EPE process. The company should report and demonstrate EPE results both internally and externally. It may also develop some type of environmental report for Sydkraft Syd Värme AB or specifically for THS, which may be only for internal circulation.

For implementing environmental performance evaluation in the Staffanstorp heating system plant and other plants too, the company would need some type of institutional support. This process should be integrated with the company or group's normal operation and especially with the environmental management. Since Sydkraft's major decision-making disseminates from the group management to a different company's management, the decision to perform EPE can be made at the top level of the group.

EPE can be taken as a separate assignment for each plant, or it can be integrated into the environmental management system of the company. According to Sydkraft's corporate policy, all the concerns within Sydkraft must go for ISO 14001 certification in coming years. Staffanstorp has already gone through the certification audit in June 2002. It would be productive to combine the EMS with the EPE process, which would act as a complement to EMS. It would also be helpful in the evaluation of environmental aspects and environmental programmes controlled and implemented through EMS.

For the implementation of an EPE project, there can be a separate workforce or the group already involved in the implementation of EMS can undertake the task. There could be a special group, which would have responsibility to carry out EPE in all the companies in Sydkraft. EPE process should be carried out periodically, based on the systematic EPE model. The proposed model in this research study can be used for the evaluation process or some other suitable model could be used. If the total heating system plant already has an environmental department with environmental coordinators, it would be feasible to give the responsibilities of doing EPE to those environmental coordinators. It could result in better output, as these coordinators are more knowledgeable about their plant's environmental activities and problems. It would be useful to have these coordinators as the EPE project group in their own company.

The result of EPE done in the company should be communicated and reported internally and externally to concerned stakeholders. The plant employees should know the results of the environmental performance evaluation so that they can understand what is going wrong and what are the improvements. The corporate division of Sydkraft should also get the results of the EPE done at the plant level, in order to take necessary management action and implement measures for further improvements.

Some of the specific recommendations regarding Staffanstorp total heating plants:

- Water leakages from the secondary system in the distribution network should be addressed.

- Energy losses at the customer's end should be addressed in the future by improving the heat exchanger and the temperature regulators that will control the return water temperature.

- The water scrubber in the bio fuel process must be taken care of. Either it should be replaced by a better scrubber or some technical improvements should be done to improve its effectiveness.

- The possibility of installing an ESP or better multi cyclone could be explored on the basis of economic feasibility.

- It was found that the temperature is already being recorded in the plant but selecting it as an indicator for its measurement in the EPE system, would increase the accountability of the measurement and also lead to certain action.

- Management performance indicators should be given importance, as they can track the performance of the management regarding its commitment towards environment improvements. Environmental investments made per year, compliance with the applicable legal directives and numbers of employees trained are some of the MPIs, which can be helpful in evaluating the performance of the management towards the environmental initiatives and strategy.

- Indicators for measuring degree of compliance, number of emergency drills, emissions of oxygen, chemical consumption, can be omitted if the company thinks that these are not significant and just consume resources.

Further study is recommended, which can cover other Total heating system plants. Since this study was specifically based on one Total heating system plant at Staffanstorp, its outcome and implement able feasibility for another plant could be limited. However, study based on other plant covering different types of technology, processes and fuels would be more useful to standardise the EPE process for the Total heating system. The model or criteria for performing environmental performance evaluation can be further generalised for other units as well after considering more plants in the study. It will also help in developing more effective set of environmental indicators, which could be applicable in overall total heating system at Sydkraft.

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Abbreviations

EPA	Environmental Protection Agency
EPIs	Environmental Performance Indicators
MPIs	Management Performance Indicators
OPIs	Operational Performance Indicators
ECIs	Environmental Condition Indicators
EMS	Environmental Management System
ISO	International Organization for Standardization
ESP	Electrostatic Precipitator
CO_2	Carbon Dioxide
GWh	Gigawatt-hour
KWh	Kilowatt-hour
MWh	Megawatt-hour
NO_x	Nitrogen Oxides
CO	Carbon Oxides
SO_2	Sulphur Dioxide
THS	Total Heating System
CHP	Combined heat and power
EPE	Environmental Performance Evaluation
ISO	International Organization for Standardisation

Appendix 1

Examples of Environmental Aspects and their Indicators

Some potential and common environmental aspects are given in the Table with probable indicators to measure the aspects and keep track of them. These indicators can give some good ideas for understanding the types of indicators, which can be related to different environmental aspects. In the table, the indicators are presented in the form of absolute indicators, which can be developed into relative indicators based on the matrix given in Table 4.

Table 14 General Identification of Environmental Aspects and Indicators (Source: ISO, 1999)

Serial no.	Aspects	Types of Indicators	Categories	Indicators
1.	Achievement of environmental programmes	**MPIs** (Management Performance Indicators)	Implementation of policies and programmes	Number of achieved objectives and targets
2.	Environmental awareness			Number of employees/contracted individual trained
3.	Environmental aspects from suppliers/contractors services			Number of suppliers and contractors queried about environmental issues
4.	Compliance of environment regulations		Conformance	Degree of compliance with regulations
5.	Emergency measures			Number of emergency drills conducted
6.	Environmental investment		Financial performance	Amount of money spent in a year
7.	Savings from environmental performance			Return on investment for environmental improvements projects
8.				Savings achieved through reductions in resource usage, prevention of pollution or waste recycling
9.	Interested parties concern		Community relations	Number of inquiries or comments about environmentally related matters
10.				Number of environmental educational programmes or materials provided for the community
11.				Number of sites with environmental reports

12.	Resource consumption	**OPIs** (Operational Performance Indicators)	Material	Quantity of materials used per unit of product
13.				Quantity of processed, recycled or reused materials used
14.	Water consumption			Quantity of water used per unit of product
15.				Quantity of water reused
16.	Amount of hazardous material used			Quantity of hazardous materials used in the production process
17.	Energy consumption		Energy	Quantity of energy used per year or per unit of product
18.				Quantity of each type of energy used
19.	Wastage of energy			Quantity of energy generated with by-products or process streams
20.	Disturbing the land biodiversity		Physical facilities and equipment	Land area used to produce a unit of energy
21.	Equipment breakdown or failure			Number of hours of preventative maintenance to equipment per year
22.	Waste generated		Wastes	Quantity of waste per year or per unit of product
23.	Waste disposal			Quantity of hazardous, recyclable or reusable waste produced per year
24.	Emissions in the air		Emissions	Quantity of specific emissions per unit of product
25.	Wastage of energy in air			Quantity of waste energy released to air
26.	Discharges to water			Quantity of specific material discharged to water per unit of product
27.	Wastage of energy in water			Quantity of waste energy released to water
28.	Consumption of fuel			Quantity of fuel consumption
29.	Air pollution	**ECIs** (Environmental Condition Indicators)	Impact on Air, Water & Land	Concentration of a specific contaminant in ambient air at selected monitoring locations

30.	Water pollution			Concentration of a specific contaminant in groundwater or surface water
31.	Land contamination			Concentration of a specific contaminant in surface soils at selected locations in the area surrounding the organization's facility
32.	Disturbance in biodiversity			Population of a particular plant or animal species within a defined distance of the organization's facility

Appendix 2

Steps of the Implementation (DO) part of the EPE Model

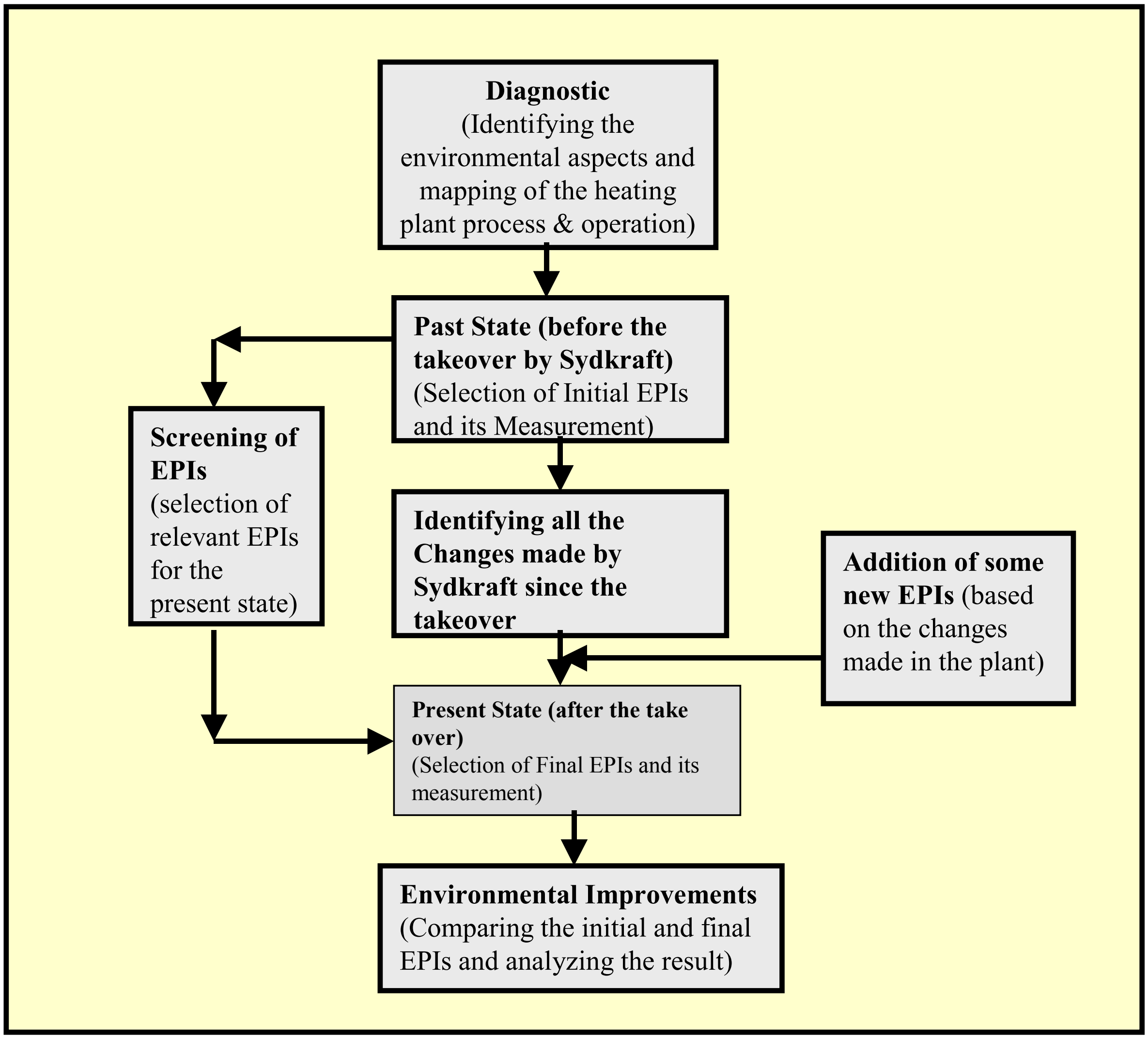

Figure 24 Steps of the Implementation phase of the EPE Model

Appendix 3

Excel Data Sheet for Environmental Indicators (EPIs) Measurement

Table 15 EPIs Data collection and measurement sheet

Aspects	Measurement						
	1996 (85% biofuel used)	1997 (85% biofuel used)	1998 (85% biofuel used)	1999	2000	2001	2002 (june)
Production	5 MW Biofuel & 13 MW Naturalgas	5 MW Biofuel & 13 MW Naturalgas	5 MW Biofuel & 13 MW Naturalgas	6540 MWh natural gas, 20216 MWh biofuel	3208 MWh natural gas, 21769 MWh bio fuel	24 382 MWh biofuel, 3112 MWh natural gas	11 903 MWh biofuel, 2494 MWh natural gas
Energy recovery from the gas condenser	NA	NA	NA	1260 mwh	1189 mwh	940 mwh	391 mwh
Use of Fossil fuels	1410571 m3 (15375mwh)	756 674 m3 (8619 mwh)	617 147 m3 (7035 mwh)	668 515 m3 (7404 mwh)	388 367 m3 (4309mwh)	369 215 m3	270 511 m3
Use of bio fuel	18591 m3s (18112mwh)	23 735 m3s (20 465mwh)	30 379 m3s (26 869 mwh)	26 904 m3s (21 300 mwh)	31 314m3s (25 427 mwh)	35 629 m3s	18 990 m3s
Emissions of CO2 from natural gas	NA	NA	NA	1503.05 ton	874.76 ton	831.55 ton	609.71 ton
Emissions of CO2 from bio fuel	NA	NA	NA	11076.81 ton	11667.3 ton	13658.1 ton	7242.4 ton
Emissions of CO from biofuel	NA	25 mg/MJ	34 mg/MJ				
Emissions NOx	natural gas 2200 kg/yr & biofuel 6190 kg/yr	natural gas 1240 kg/yr & Biofuel 7000 kg/yr	natural gas 1012 kg/yr & biofuel 9190 kg/yr	1070 kg/yr (natural gas) & 7350 kg/yr (bio fuel)	77 mg/MJ	600 kg/yr(natural gas) & 7100 kg/yr(bio fuel)	70 mg/MJ
Flyash or Dust in the air	5200 kg/yr	5160 kg/yr	6097 kg/yr	4875 kg/yr		2300 kg/yr	
Generation of Solid Waste	91 ton	99.4 ton	165.7 ton	21.76 ton	98.16 ton	99.35 ton	39.72 ton (up to march)
Oil Waste		0.05 ton	0.05 ton	1.51 ton	3.97 ton	2.17 ton	1.32 ton (up to march)
Water Consumption	NA	55, 000 litres uptake water	55, 000 litres uptake water	55, 000 litres uptake water	96, 900 litres uptake water	4, 78, 610 litres uptake water	21, 10, 000 litres uptake water
Emission of Oxygen (from biofuel)		4.35 mg/MJ	4.7 mg/MJ		4.38 mg/MJ (2.9 mg/MJ from gas)	3.6 mg/MJ	4.85 mg/MJ (4.15 mg/MJ from gas)
Electricity consumption	NA	NA	NA	787, 288	696 176	794 379	440 497
Breakdown of the Biofuel furnace / boiler	NA	NA	NA	NA	NA	NA	NA
Return temperature of the water	NA	NA	NA	NA	NA	NA	NA