JOINT MANAGEMENT OF ENERGY AND ENVIRONMENT IN INDUSTRY

Cleaner Production, Environmental Management Systems and Energy Management Facilitating Sustainable Development in Industry

PH.D. THESIS.

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Preface

An old saying, printed on the door to my office has been helpful in moments when I had problems:

> *"Theory is when you know everything but nothing fits together.*
> *Practice is when everything works out but no one knows why.*
> *In this room theory and practise unite, nothing fits together and no one knows why"*

When I was a child, my Uncle Knut always addressed me "The Professor". Eight years ago Mikael Backmann at the University of Lund asked me to jointly arrange a Nordic Ph.D. course. The courage to start this Ph.D. process was born from those two events.

I have written this thesis as a contribution to facilitate Sustainable Development in Industry. I hope that colleagues from corporate and environmental organisations; consultants; universities and governmental organisations will find my experiences and recommendations useful.

As a part of this overview, the aim of this thesis is to help society contribute to fulfilling its obligations within the Kyoto Protocol on reduction of CO_2 emissions. Thus reducing their contribution to the *"Greenhouse Effect."*

To tackle this, for me, big task, I would first like to express gratitude to my advisor Professor Dr. Donald Huisingh. He has supported me scientifically, encouraged me and supervised my work. He has been the leader in the supporting team for the creation of this thesis. A very special thanks to my local advisor, Professor Dr. Helge Brattebø, at the Norwegian University of Science and Technology (NTNU Trondheim), who has given extremely valuable advice on the structure and theories of this thesis. A very special thanks for supporting my work, to my advisor Drs Leo Baas at the Erasmus University in Rotterdam. Then thanks to everyone else connected to the Erasmus University's International Ph.D. program in Cleaner Production Cleaner Products, Industrial Ecology & Sustainability, especially to colleagues from the Centre for Environmental Studies at Erasmus University: Professor Dr. Wim Hafkamp, dr. Gerard Zwetsloot and the students in the Ph.D. programme. This thesis would have never been produced without the criticisms, support and follow up from this team. Special thanks to Carol LeBlanch for renting a Ford Fiesta big enough to carry the 12 first-year students to the Pub for late evenings at our first intensive in Holland. Thanks also to Alejandro Lorea-Hernandez from Mexico, Leo Heileman from Trinidad, Don Wong Shin from Korea and Michel Schilperoord from the Netherlands for interesting and funny exchanges of cultural experiences and events during the intensive courses.

On behalf of all readers and myself, we thank you a lot for this good work. My colleague Cecilia Askham from England has asked valuable questions in addition to working tirelessly on improving the English in this thesis. Then there is a large group of colleagues, especially Johan Thoresen and Bjørnar Sæther, but also Egil Erstad, Ingunn Saur Modahl, Elin Økstad, Mie Vold, Ole Jørgen Hanssen, Anne Rønning, Knut Aarvak and Gerd Klavestad, who have provided valuable scientific and practical support.

An extra special gratitude to my beloved wife Kathrine Bay, who has always encouraged me to proceed and has frequently discussed scientific aspects of the thesis. Without this support, this thesis would never have become a reality. Great thanks to my children Asgeir, Ola, Tonje, Synne Sofie and Øyvind for being so supportive. Thanks to Tonje and Asgeir for comments like: *"I do not understand this!"* A lack of time for my family has hopefully come to an end by the presentation of this thesis.

My friends, especially my fellows in the club for sport and pleasure, Jeløen Squash and Ball (JSB), Jon Ivar, Harald, Olav, Geir and Jan, deserve great thanks for helping me to maintain the mental space required for completing this thesis. Thanks to the author Ari, who helped me to design this preface.

Completing this thesis has improved my knowledge, visions and approaches to environmental management challenges. I have gained a higher level of scientific skills and, hopefully, I have succeeded in adding some value to the Sustainable Development process and will thereby, help improve future living conditions for all humans and other species.

Fredrikstad, Norway,
November 1999

Audun Amundsen

Abstract

Abstract in English

"Joint Management of Energy and Environment in Industry. Cleaner Production, Environmental Management Systems and Energy Management Facilitating Sustainable Development in Industry."

This thesis is designed to help industry operationalise its contribution to the AGENDA 21 (sustainable development generally) and the Kyoto protocol (the reduction of the greenhouse gas CO_2 in particular). The thesis begins with AGENDA 21 and the Kyoto protocol and studies these in light of industry's potential contribution to sustainable development. As part of Norway's response, the Norwegian Parliament has decided upon policies that, in practice, mean a 6% reduction in Norway's CO_2 emissions before 2012 (compared to the 1996 level). Norway's consumption increased by 6.7% from 1992 to 1996. Industry is responsible for a substantial part of this increase. There is little relation between political policies and the increase in industry's CO_2 emissions. Industry's role in the follow-up to the Kyoto protocol and to Agenda 21 has been substantiated to only a small degree (both in Norway and in other countries). This thesis aims to operationalise the requirements for sustainable development in order to reduce greenhouse gas emissions from industry. In order to realise the objectives of this thesis, a multidisciplinary scientific approach was taken. Thermodynamics, organisational learning, ecology and sociology were used. The term eco-efficiency[1] is used for a set of criteria that define a company's environmental performance.

Experiences from industry were gathered from 932 Scandinavian companies. In particular, food-processing companies were studied in depth. Existing environmental methods used in industry are evaluated and criticised.

Experiences from cleaner production and the effective use of energy effective were investigated. What are the driving forces for environmental work in industry? The thesis shows that these are primarily associated with short-term profit, but also with expectations of future market requirements. Experience shows that the companies' most important criterion for implementing an environmental improvement option is a payback time on their investment of three years, or less.

Industrial use of Cleaner Production and energy analysis has been evaluated. The results show, among other things, that:

[1] The term "Eco-efficiency" was introduced and defined by OECD (1998).

1) profitable improvement measures are carried out;
2) the improvement measures are of great benefit to the environment;
3) greater focus on energy economising produces a greater number of profitable options and reduces greenhouse gas emissions;
4) the existing methods do not produce systematic, continuous activities on the development and implementation of environmental improvement options in companies;
5) to further develop eco-efficient companies (as they are proposed by OECD environment ministers) there is a need for research, technological development and demonstration (RTD) to develop criteria and methods for use in industry.

Environmental Management has been introduced in hundred of Norwegian companies during the period 1996 to 1999. Experience has shown that little weight is placed on improvements in energy efficiency in Environmental Management. The untapped potential for energy savings in industry has been identified in this thesis.
A new method for environmental work in industry has been developed. This is an integrated environmental and Energy Management system, which includes the systematic and continuous improvements of Cleaner Production. It is suggested that Life cycle Analysis and eco-efficiency should be included as part of this method. Design criteria for renewable energy and minimal use of exergy are also proposed. A handbook is included in the appendix in order to guide industry in implementation of these approaches.

The author uses this opportunity to make recommendations, which are based upon his international experience and knowledge of environmental management in industry. National and local incentives are required to stimulate industry to move towards energy, environmental and eco-efficiency. Proposals for suitable incentives are made.

This thesis will be examined at the Centre for Environmental Studies at Erasmus University in Rotterdam (EUR). Professor Dr. Donald Huisingh from EUR and University of Lund has been the main supervisor for this thesis, but Drs Leo Baas from Erasmus University and Professor Dr. Helge Brattebø from the Norwegian University of Science and Technology (NTNU Trondheim), have acted as additional supervisors.

Abstract in Norwegian

"Integrert forvaltning av energi og miljø gir reduserte CO_2 utslipp fra industrien"

Doktoravhandlingen søker å operasjonalisere industriens bidrag i forbindelse med oppfølging av AGENDA 21 om bærekraftig utvikling generelt og om Kyoto avtalen og reduksjon av drivhusgassen CO_2 *i industrien spesielt.*

Avhandlingen tar utgangspunkt i AGENDA 21 og Kyotoprotokollen og studerer disse i lys av industriens mulige bidrag til bærekraftig utvikling. Som Norges oppfølging, har Stortinget gjort vedtak som i praksis betyr 6% reduksjon av Norges CO_2 utslipp før år 2012 i forhold til 1996 nivå. Forbruket i Norge økte med 6,7% fra 1992 til 1996. Industrien står for en vesentlig del av denne økningen. Det er liten sammenheng mellom politiske vedtak og industriens økning i CO_2 utslipp. Industriens rolle oppfølgingen er i liten grad konkretisert, både i Norge og i andre land.

Avhandlingen sikter mot å operasjonalisere kravene til bærekraftig utvikling for å oppnå reduksjon av drivhusgasser i industrien. For å finne løsninger. tar kandidaten en multidisiplinær vitenskapelig innfallsvinkel. Termodynamikk, organisasjonslæring, økologi og samfunnsvitenskap er benyttet. Begrepet øko-effektivitet[2] innføres som et sett kriterier for å definere bedrifters miljøprestasjon.

Erfaringer fra industrien er undersøkt i 932 skandinaviske bedrifter. Spesielt er det gjort dybdestudier av næringsmiddelbedrifter. Eksisterende metoder som anvendes i industriens miljøarbeid evalueres og kritiseres.

Erfaringer fra renere produksjon, miljøledelse og energieffektivitet er undersøkt.

Hva er drivkreftene bak industriens miljøarbeid? Avhandlingen viser at dette først og fremst er knyttet til kortsiktig profitt, men også forventede framtidige krav fra markedet. Erfaringene viser at bedriftenes viktigste kriterium for å gjennomføre miljøtiltak er maksimum tre års tilbakebetaling på investeringene.

Industriens bruk av tekniske miljøanalyser og energianalyser er evaluert. Resultatene viser bland annet: 1) at lønnsomme tiltak er gjennomført i bedriftene 2) tiltakene har stor miljøgevinst 3) større fokus på energiøkonomisering gir flere lønnsomme tiltak og mindre utslipp av

[2] Øko-effektivitet er en oversettelse av "Eco-efficiency", introdusert og definert av OECD (1998).

drivhusgasser 4) metodene gir ingen systematisk, kontinuerlig aktivitet for utvikling av miljøtiltak i bedriftene 5) For å videreutvikle øko-effektive bedrifter slik de er foreslått av 23 OECD miljøverministre, er det er behov for F&U for å finne kriterier og metoder til bruk i industrien.
Miljøstyring er innført i et hundretalls norske industribedrifter i de siste tre år. Erfaringer fra bedriftene viser at energi blir lite vektlagt i miljøstyring. Et uutnyttet potensiale for energiøkonomisering i industrien er identifisert i avhandlingen.
I avhandlingen er det utviklet nye metoder for industriens miljøarbeid. Et integrert miljø- og energistyringssystem som også inkluderer systematisk og kontinuerlig forbedring av renere produksjon, livsløpsanalyser og øko-effektivitet foreslås. Design-kriterier for fornybar energi og minimum forbruk av exergi er også foreslått. For å forenkle implementering av de vitenskapelige resultater i industrien, har forfatteren vedlagt en håndbok.

Forfatteren benytter anledningen ut fra sin internasjonale erfaring og kunnskap om miljøarbeid i industrien, til å komme med ikke vitenskapelige anbefalinger avslutningsvis i avhandlingen. Nasjonale og lokale virkemidler for å utvikle industrien til energi- miljø- og øko-effektivitet er foreslått.

Avhandlingen forsvares ved Senter for Miljø og Utvikling ved Erasmus Universitet i Rotterdam. Professor Dr. Donald Huisingh fra Universitetet i Lund har vært hovedveileder, mens Drs Leo Baas fra Erasmus Universitet og Professor Dr. Helge Brattebø fra Norges Tekniske Naturvitenskaplige Universitet i Trondheim, har fungert som støtteveiledere.

Abstract in Dutch

Samenvatting

De industrie staat voor een geweldige uitdaging om zijn bijdrage te leveren aan het realiseren van AGENDA 21 (Duurzame ontwikkeling) en het Kyoto protocol (de reductie van broeikasgassen zoals CO_2).
Het proefschrift begint dan ook met AGENDA 21 en het Kyoto protocol en bestudeert deze overeenkomsten in het licht van de potentiële bijdrage van de industrie aan Duurzame ontwikkeling. Als onderdeel van het Noorse antwoord heeft het Noorse parlement besloten tot een reductie van 6% CO_2 emissies vóór 2012 (vergeleken met het niveau van 1996). De consumptie in Noorwegen is met 6,7% gestegen in de periode 1992 tot 1996. De industrie is voor een substantieel deel verantwoordelijk voor deze toename. Tot nu toe is het overheids-beleid weinig effectief in het reduceren van de CO_2 emissies door de industrie. De industrie beperkt zich in de uitvoering van het Kyoto protocol en AGENDA 21 tot een geringe bijdrage (zowel in Noorwegen als in andere landen). Dit proefschrift beoogt de vereisten voor Duurzame ontwikkeling te operationaliseren om broeikasgas emissies door de industrie te reduceren. Om de doelstellingen van dit proefschrift te realiseren, is een multidisciplinaire wetenschappelijke benadering ontwikkeld. Thermodynamica, leerproces in organisaties, ecologie en sociologie zijn gebruikt. De term eco-efficiëntie[3] wordt gebruikt voor criteria die de milieu prestatie van een bedrijf definiëren.

Ervaringen in de industrie zijn in 932 Scandinavische bedrijven verzameld. In het bijzonder zijn de voedselverwerkende bedrijven diepgaand bestudeerd. De bestaande, in de industrie gebruikte, milieumaatregelen zijn geëvalueerd en bekritiseerd.

Ervaringen met Schonere productie en het effectief gebruik van energie zijn onderzocht. Wat zijn de drijvende krachten bij het integreren van het milieu in de industrie? Het proefschrift toont aan, dat deze primair worden geassocieerd met korte termijn winst, maar ook met verwachtingen van toekomstige markteisen. De ervaring leert, dat het belangrijkste bedrijfscriterium om een optie te implementeren die het milieu verbetert, de verwachting is, dat de investering zich in drie jaar of minder terugbetaalt.
Het gebruik van methoden voor Schonere productie en energie analyse in de industrie is geanalyseerd. De resultaten tonen onder andere aan dat:
winstgevende maatregelen ter verbetering worden uitgevoerd;

de uitgevoerde maatregelen van groot belang zijn voor het milieu;
een betere focus op bezuiniging van energie een groter aantal winstgevende opties genereert en broeikasgas emissies reduceert;
de bestaande methodes in de bedrijven geen systematische, continue aktiviteiten voor de ontwikkeling en implementatie van milieuverbeterende opties genereren;
de noodzaak bestaat tot onderzoek, technologische ontwikkeling en demonstratie, om criteria en methoden voor gebruik in de industrie te ontwikkelen met als doel de ontwikkeling van eco-efficiënte bedrijven (zoals zij worden voorgesteld door de Ministers van Milieu in OECD landen) te bevorderen.

Milieumanagement is in een honderdtal Noorse bedrijven geïntroduceerd in de periode van 1996 tot 1999. Ervaring toont aan, dat er weinig aandacht is voor de verbetering van energie-effiency in milieumanagement. Het onaangeroerde potentieel voor energiebesparing in de industrie is in dit proefschrift geïdentificeerd.

Er is een nieuwe methode ontwikkeld om milieu-aspecten in de industrie aan te pakken. Dit is een geïntegreerd Milieu- en Energiemanagement systeem, dat de voortdurende verbetering inhoudt door een systematische Schonere productie aanpak. De suggestie wordt gedaan om Levens Cyclus Analyse en Eco-efficiëntie als onderdeel van deze methode erbij te betrekken. Ook worden ontwerp-criteria voor duurzame energie en minimaal gebruik van exergie voorgesteld.

Een handboek wordt in een bijlage toegevoegd om de industrie in de implementatie van deze benaderingen te ondersteunen.

De auteur maakt van deze gelegenheid gebruik om aanbevelingen te doen, die zijn gebaseerd op zijn internationale ervaring en kennis van milieumanagement in de industrie. Zowel nationale als lokale stimulans is vereist om de industrie te motiveren in de richting van energie-, milieu- en eco-efficiëntie. Er worden voorstellen voor geschikte stimulerende maatregelen gedaan.

Het proefschrift, ontwikkeld bij het Erasmus Studiecentrum voor Milieukunde, zal worden verdedigd op de Erasmus Universiteit in

[3] De term "Eco-efficiëntie" werd geïntroduceerd en gedefiniëerd door de OECD (1998)

Rotterdam. Professor Dr. Donald Huisingh van de Erasmus Universiteit en de Universiteit van Lund is de promotor van dit proefschrift.

Drs. Leo Baas van de Erasmus Universiteit en Professor Dr. Helge Brattebø van de Noorse Universiteit van Wetenschap en Technologie (NTNU Trondheim) hebben het onderzoek mede begeleid.

Table of contents

Summary

Keywords: Sustainable Development, Kyoto Protocol, Cleaner Production; Environmental Management Systems, Energy Management; Environmental Performance Indicators, CO_2, Eco Efficiency, Industry, Food Processing Industry.

The scientific structure

The purpose of this thesis is to propose ways industry can make improvements in its management in order to make contributions to fulfilling their obligations to reduce CO_2 emissions as required in the Kyoto-Protocol. Norwegian industry and in particular the food processing industry is used as the prime example. Another objective of this thesis is to clarify industrial contributions for fulfilling requirements under AGENDA 21. To realise these objectives, it has been necessary to create a multidisciplinary thesis. Both theory and empirical data are utilised. The conclusions and recommendations are found in a retroduction[4] between theory, methodologies and empirical data.

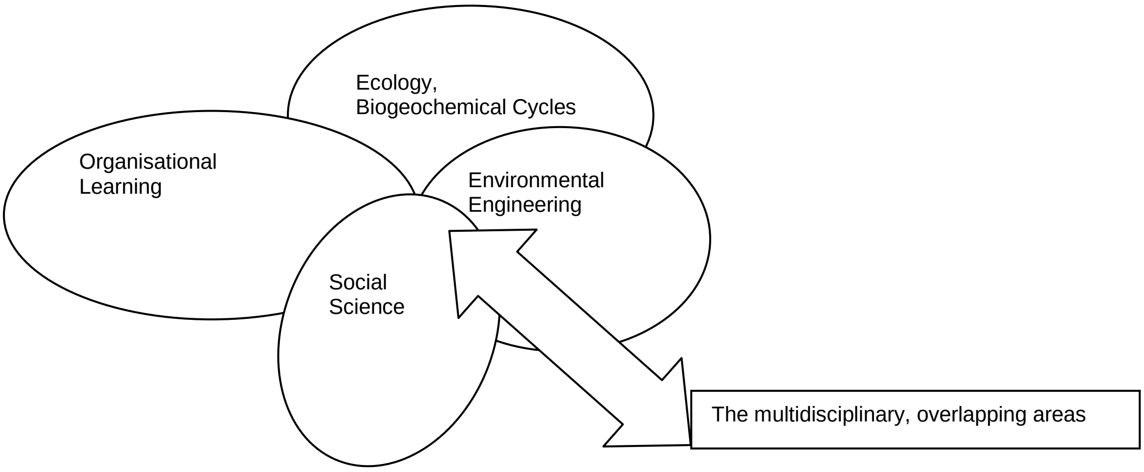

Figure S1 Illustrates the main scientific disciplines, or perspectives used in this thesis. (Copy of Figure 2.3)

The theories of organisational learning, the laws of thermodynamics and dynamics in nature are utilised as illustrated in Figure S1. Cleaner production methodologies, environmental management systems, energy management systems, eco-efficiency[5] and performance evaluation are utilised as the theoretical frames.

[4] Retroduction makes possible a research process that is characterised by the linking of evidence and theory in a continually evolving, dynamic process (Ragin 1994).

[5] World Business Council for Sustainable Development and OECD have initiated an Eco-efficiency concept. The definition is (BCSD 1993):
"Eco–efficiency is reached by delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's carrying capacity." Eco-efficiency is connected to a set of criteria outlined in Chapter 8 in this thesis.

Evidence from industrial case studies is utilised to create images. The data consist of qualitative information from 112 industrial case studies and quantitative data from 820 companies.

Additionally, surveys of several hundred companies, completed by other people, have been consulted. The emphasis of the thesis work is on the Norwegian food industry.

In the retroduction between the images and the frames, the joint management of energy and the environment in industry is discussed. The conclusion is a result of the retroduction. Figure S2 is a diagrammatic representation of the scientific organisation of the thesis. The recommendations for consultants, corporate leaders, academics and the government, are based on the conclusions and the author's 25 years of experience from sustainable development and cleaner production in industry, worldwide.

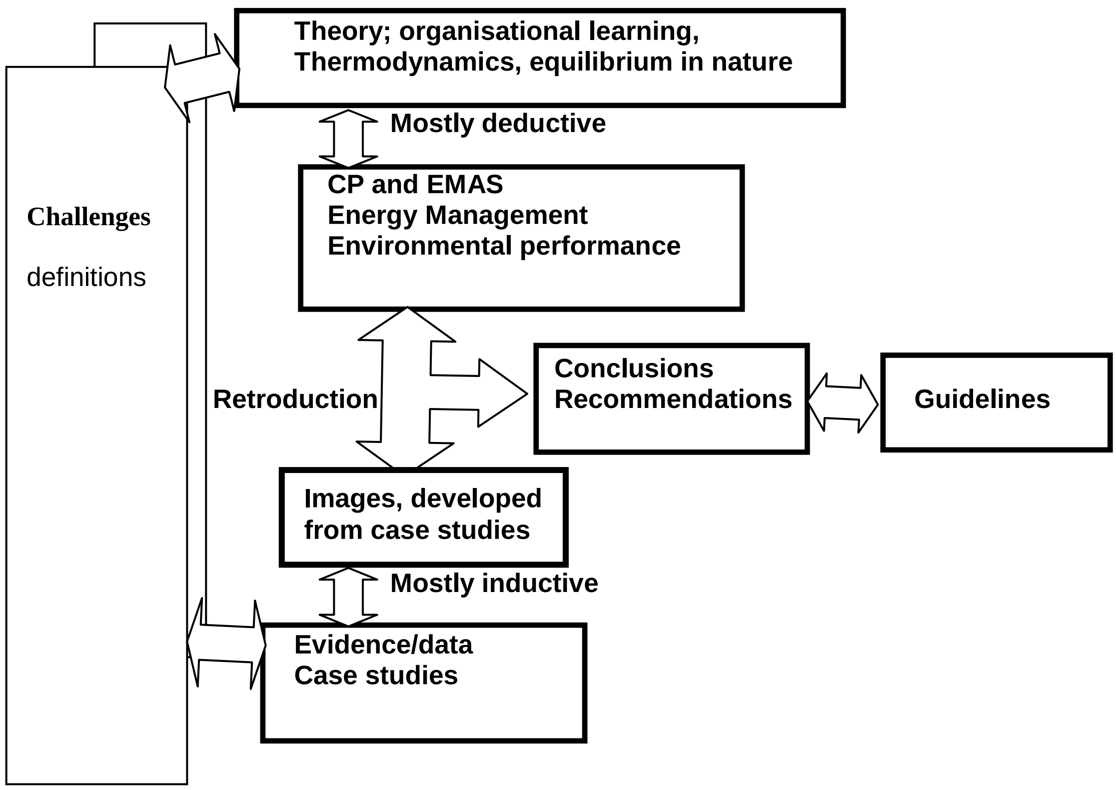

Figure S2 The selected research model for the thesis. The figure is a diagrammatic representation of the scientific organisation of this thesis. The problem definition is based upon both relevant theory and empirical data. The analytical framework is built on theory. Images are constructed from the empirical data. A retroduction (interaction) between analytical frames and images provide the basis for development of conclusions and recommendations. (Derived from Ragin 1994, and Jacobsen 1995) (Copy of Figure 2.7)

Conclusions

- Cleaner Production Assessments, in the way that they have been performed in 280 Norwegian companies, facilitate:
  1. implementation of waste reduction options with a payback time of less than three years;
  2. benefits to the environment.

- In a study of 67 Norwegian Companies, it was documented that energy advisors positively influence the results with regard to energy savings and environmental improvements.

- Based upon data from 67 Norwegian and 22 non-Norwegian companies (from Sweden, Denmark and Iceland), Cleaner Production Assessments, in the way they were performed, are not sufficient to create systematic, continuous environmental improvements in companies.

- Within 22 Nordic food-processing companies, weaknesses were found after performing a CP assessment. These were due to the lack of long-term thinking connected with initiatives to help stimulate companies to achieve a more consistent contribution to eco-efficiency.

- It was found that EPIs for exergy/anergy and renewable energy were not applied as strategic tools in companies. Studying the limitations to fulfilling the eco-efficiency concept in the 22 companies, the following conclusion was made:
  "CP assessments, EMS and Energy Management, as currently done within the subject companies, was not sufficient to ensure a consistent improvements in corporate eco-efficiency".

- While studying 13 Norwegian EMAS registered companies, in the spring of 1998, it was found that neither energy nor Energy Management was emphasised, to a high level, in the Environmental Statements in the food-processing Industry. Joint management of energy and environment should be done in order to obtain energy efficiency improvements as integral to EMAS implementation.

- Benchmarking against energy related EPIs, connected to networking among 540 Norwegian companies, helps company leaders to compare their performance with others in the same sector and thus helps them to be motivated to reduce their energy consumption over a time span of three years.

- Energy Management, as shown in Figure S3, applied in the food-processing industry, contributes significantly to improving energy efficiency**.**

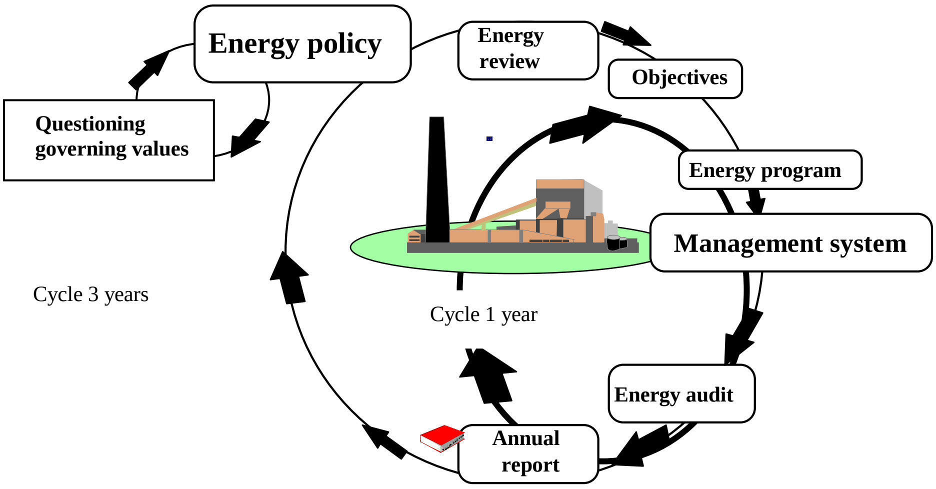

Figure S3 The Main Components of Energy Management applied to EMAS. A double-loop (the big circle) cycle has a three-year cycle to follow EMAS requirements and a single-loop (the small circle) cycle to allow creation of yearly improvement programs. An extra cycle connected to the Environmental Policy illustrates that new insight by open confrontation and testing should be developed. (Copy of Figure 7.8, developed in this thesis.)

- Energy efficiency management in the food-processing industry contributes significantly to improving energy efficiency. Short-term profit and future market expectations are the main driving force in companies, thus the programs created limited long-term thinking. Low temperature energy sources have a large potential for corporate improvements in energy efficiency, but are not currently utilised as fully as could be done. A payback time of less than three years is a typical criterion for implementing improvement options. If the option also results in reduced emissions to the environment, this is considered by corporate leaders to be an extra benefit.

- Case studies in 10 Norwegian food processing companies, where energy efficiency management was integrated in implementation of EMAS (as shown in Figure S4), were efficient in obtaining improved results in energy conservation measures and also in securing continuous efficiency improvement activities. Such integration can be facilitated according to the guidelines provided in Appendix 2.

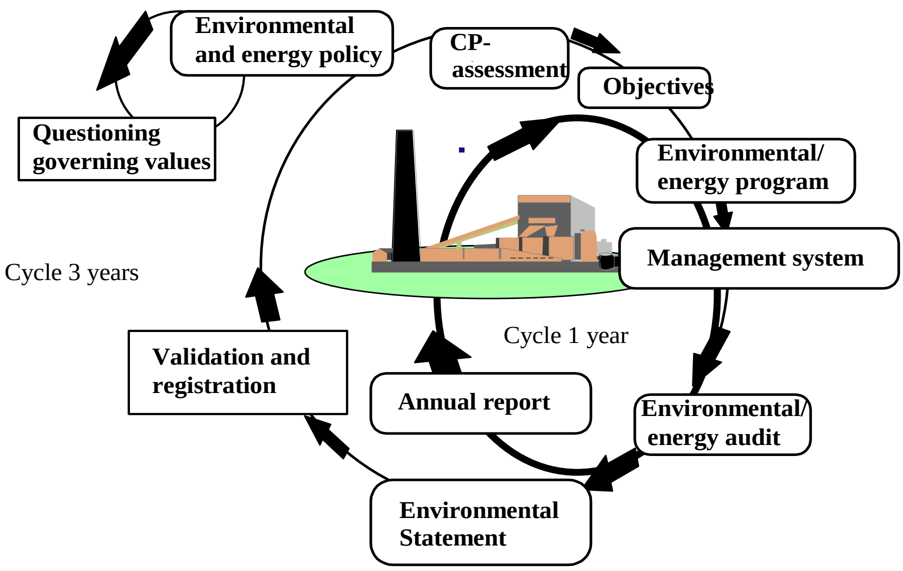

Figure S4 The Main Components of successful integration of Energy Management, EMS and Cleaner Production assessments. A double-loop (the big circle) learning cycle has a three-year cycle to follow EMAS requirements and a single-loop (the small circle) learning cycle to encourage creation of yearly improvement programs. An extra cycle connected to the Environmental and Energy Policy illustrates that new insight by open confrontation and testing should be developed. (Copy of Figure 7.9, developed in this thesis.)

Recommendations

Today's energy consumption by Norwegian industry is approximately 77 TWh per year (NOU 1998 p. 77). From experience, this author sees the possibility of saving 15 % of this energy. This can be achieved by improvement options using developed technology, which have a payback time of less than 5 years. This would mean an energy saving potential of 12 TWh. To put this in to perspective, two planned natural gas power stations in Norway (Kollsnes and Kårstø) yearly would produce 5,6 TWh with CO_2 emissions at 0.5 million tonnes. (NOU 1998, p. 269). To realise this energy saving potential, governmental programmes will be necessary. Some suitable governmental programmes are suggested in the following.

Recommendations for industry

The following advice is aimed at companies that will be in the front line of the eco-efficiency, paradigm shift and will be required to produce environmentally sound products.

Join a benchmarking, energy efficiency network.

Networking and benchmarking among companies helps motivate corporate leaders to reduce their energy consumption per unit of product.

What are the principle opportunities for the company (supporting initiatives, supervisors, network, web based learning. etc.)?
This thesis does not prioritise “best options” for this question. However, it can be stated that networking and benchmarking among companies leads to lower energy consumption, per unit of product over a time span of three years.

Being a member of the voluntary Norwegian Industrial Energy Efficiency Network (IEEN) provided benefits. These were:

- a lower energy consumption per unit of product was achieved over a time span of three years;
- benefits to the environment.

Joint management of energy and environment
An improved method, integrating CP assessments, Environmental Management Systems and Energy Management is suggested. Utilisation of this improved method is supposed to provide industry with short-term profitable options and help to ensure continuous activities on environmental performance. The method, shown in Figure 7.9, is based on double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87) and secures also identification of long-term profitable options.

Corporate leaders wishing to comply with their responsibilities for energy efficiency and eco-efficiency, should consider renewable energy sources and a minimum of exergy consumption.
Which criteria and indicators should be considered when combining energy efficiency with eco-efficiency? An important issue for indicators is to distinguish between long-term and short-term objectives. The short-term criterion is typically profit. Long term indicators should consider physical laws (the first and second laws of thermodynamics and equilibrium in nature). Important design criteria in process modifications, or design, should include:

> *“Utilisation of the highest feasible proportion of renewable energy sources to fulfil the energy requirements”*

and

> *“Utilisation of the lowest feasible proportion of exergy consumption to fulfil the energy requirements”*

These criteria are not commonly used in industry today. They should be used in all societal sectors, including industry. Governmental programmes, information and taxes on energy are recommended measures to stimulate corporate leaders to implement the design criteria.

Utilise Environmental Performance Indicators connected to eco-efficiency improvements.

Two more EPIs should be used to help industry to evaluate their performance against eco-efficiency. These two EPIs are related to energy and eco-efficiency. However:

- Many firms have developed targets and EPIs for reducing their intensity of material use and energy consumption.
- Renewable energy is included in the OECD eco-efficiency criteria.
- The European Green Table[6] recommends that a life cycle perspective should be used in helping companies make systematic improvements in SD.

The European Green Table[83] recommends that a life cycle perspective should be used in helping companies make systematic improvements in SD.

In order to meet the challenge from the OECD ministers on reducing environmental impacts from industry, eco-efficiency indicators need to be identified and developed. These indicators need to be transparent, comprehensive indicators of eco-efficiency. They are needed as part of a broader set of sustainable development indicators. The author recommends that industry calculates energy related, eco-efficiency indicators based on the following principles:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency.*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the energy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency.*

Recommendations for national governments

From the author's experience, governmental measures such as, taxes, technical and management training and information, financial support and "SD laws and regulations" will be required to stimulate industry to achieve eco-efficiency. This may be facilitated through governmental initiatives such as:

Future strategy for the government

To overcome the future Eco-efficiency challenges, the following recommendations are made as help to ensure improvements:

[6] European Green Table (EGT) is an independent foundation established by Norwegian Industry leaders in 1989. Companies and Government Bodies from Europe participate in the foundation. The purpose of the EGT is to support and strengthen the role of market mechanisms in the ongoing process towards SD.

A. to facilitate utilisation of design criteria and performance indicators on maximum utilisation of renewable energy sources and minimising exergy consumption, a double-loop joint management system for energy and environment as presented in chapter 7 (Figure 7.9) should be implemented in the companies;
B. increase the market demand for environmentally sound products;
C. increase the profit and motivation for the companies by “carrots” from the government;
D. eco-efficient production and products should be forced on the companies by law;
E. EMAS and ISO 14001 should require compliance with the Eco-efficiency criteria;
F. CP assessments should be utilised in the environmental review phase of EMAS;
G. utilisation of Life Cycle Assessment (LCA) is a future challenge for companies. These will help to put focus on the most important environmental burdens in the product chain;
H. utilisation of Industrial Ecology and co-operation with the factories’ stakeholders (including the local community) are future challenges in order to secure co-operation among companies within a limited geographical area. Such co-operation can give new opportunities for co-operation on transport, renewable energy production and utilising of low temperature energy sources;
I. utilisation of waste heat in the production process (beyond what gives short-term profit) should be emphasised in companies. Referring to the company leaders description of to-days practice, only options with less than three years of payback are implemented. The payback period has to be extended to 5-10 years.

Improve EMS, strengthen the requirements in EMAS and ISO 14001.

EMS implementations in industry should be improved by:

- organising the components systematically, as a double-loop learning system, as shown in Figure 7.9.
- improving policy instruments in order to verify internal and external factors;
- utilising CP assessments as one component within EMAS;

Requirements should be made to utilise the improved policy instruments, set scope for all the work to be done and secure implementation as follows:

- Short-term improvements: so that energy efficiency is dramatically improved;

- Long-term improvements: comprehensive options to realise improved eco-efficiency (OECD 1998) in all corporate activities.

The following should be required as verification in an improved EMS:

- yearly reporting of energy and materials efficiency;
- yearly reporting of toxic use reduction and improvement in workers health and safety.

The reporting should include proper EPIs to show compliance to the Rio Declaration, the Kyoto protocol and the OECD, eco-efficiency concept.

Recommend proper EPIs for industry

In order to meet the challenge from the OECD ministers (OECD 1998) on reducing environmental impacts from industry, eco-efficiency indicators need to be identified and developed. These indicators need to be transparent, comprehensive indicators of eco-efficiency improvements. They are needed as part of a broader set of sustainable development indicators. The author presents the following energy-related, eco-efficiency principles to be used in calculating EPIs:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency.*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the energy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency.*

From the author's experience, stimulating measures from the government, such as taxes, will be required for industry to take these new criteria into account in all of their corporate activities.

National Program on Joint Management of Energy and Environment.
A program to encourage co-operations to make improvements in energy efficiency and in other environmental aspects

With the goal of overcoming limitations to environmentally friendly production and products, the government should start a National Program on Joint Management of Energy and Environment. An objective for this network should be to increase eco-efficiency in industry. The network program should provide industry with information, supervision and financial support on how to implement eco-efficient improvement options. A voluntary network of companies should be established within the program. The network should have the resources to:

- provide information about the network;

- provide relevant technical and non-technical information on eco-efficiency and SD;
- provide help to establish and utilise relevant EPIs for each company;
- provide help to identify profitable environmental improvement options;
- provide financial assistance for implementing the improvement options, by necessary “carrots”7 to utilise low temperature energy sources;
- perform benchmarking for different industry branches on EPIs relevant for eco-efficiency and SD;
- make the results of the comparative benchmarking work available in usable form to help industries help themselves to make ongoing improvements;

so that industry can benefit from participation.

An improved method, integrating CP assessments, Environmental Management Systems and Energy Management is suggested. Utilisation of this improved method is supposed to provide industry with short-term profitable options and help to ensure continuous activities on environmental performance. The method, shown in Figure 7.9, is based on double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87), which facilitates identification of long-term profitable options. This improved method, should be highlighted in future governmental programmes.
The potential for corporate energy savings can make an important contribution to fulfilling the Norwegian obligations within the Kyoto protocol. This could be realised with big economic profits for industry and savings in raw materials, waste treatment, and emissions to the environment. Properly designed governmental programs, based on double-loop learning, are necessary as catalysts to foster and continue to support continuous improvement activities in companies.
The program should provide practical guidelines on joint management of environment and energy to facilitate the implementation in industry. If companies follow this, it will help them on their journey towards eco-efficiency. A proposal for guidelines on the integrated management of energy as part of its implementation of EMAS, is presented in Appendix 2.

Database for case studies

The State Pollution Control Authority and Oestfold Research Foundation[8] have published a database of CP case studies (Amundsen and Koren 1998[9]).

[7] ”Carrots”, means support from the government, typically 1) training programs, seminars etc. 2) governmental programs which use external advisors to help industry to identify potential improvements or 3) financial support in order to encourage the company to implement potential improvements.
[8] The author is employed in this research foundation.

This database can be utilised from industry, consultants, government and universities as an idea generator in industry. This database could be expanded to also include eco-efficient improvement options, long term plans, policies etc. The purpose of this would be to inform industry about such possibilities and about enhanced profitability and improvements in eco-efficiency. The State Pollution Control Authority is hereby challenged by the author to initiate this type of program.

Future research

Referring to the above-suggested future governmental strategy, the author suggests further research. This research should identify limits and governmental measures necessary in order for all companies to implement option in order to achieve consistent contributions to Eco-efficiency.

Recommendations for local governments.

From the author's experience, stimulating measures by local government (such as prices for local goods and provision of information) will be required to help catalyse industry to achieve eco-efficiency. This can be performed through measures such as:

Pricing waste for disposal

Prices charged by local government for goods and services such as water and waste disposal, should be dear enough to encourage industry to utilise integrated, waste minimisation approaches and reduce its consumption of water and energy. The higher the prices charged, the higher the number of profitable improvement options that the companies will find and utilise.

Environmental Performance Indicators (EPIs)

Municipalities can stimulate industry to produce and to apply EPIs for, for instance, energy, exergy, renewables, freshwater, wastewater and solid waste management, providing industry with easy to understand, monthly and yearly information integrated in their utility bills. This information should contain figures on how much of the municipality's goods each particular customer has purchased in the last time period. These figures should also be compared to figures from earlier periods. Industry can use those figures for EPIs on, for instance, waste disposal per unit of product produced, or waste recycled per unit of product produced. These EPIs will help industry measure their own progress.

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[9] http://www.sto.no/rp_internett/index_en.html

Sustainable energy production and consumption programme.

Local energy supply companies should, in co-operation with environmental authorities, develop plans for sustainable energy production and consumption. Renewable energy sources and the utilisation of low temperature energy sources, should be identified, prioritised and implemented.

AGENDA 21 programmes

Local governments should design and implement their AGENDA 21 programmes in co-operation with industry, trade associations chambers of commerce, academic institutions and NGO's. These programmes should foster eco-efficiency in all corporate implementation plans and should be incorporated with regional programmes for industrial ecology and regional infrastructure programmes to foster and support regional improvements in eco-efficiency.

Technical and non-technical assistance programmes

Local governments should set up technical and non-technical assistance programmes to support companies in continuing their improvement efforts towards Sustainable Production.

INTRODUCTION

Chapter 1 The challenge

The need for this thesis, *"Joint Management of Energy and Environment in Industry",* arises from obligations to fulfil international agreements, like the World Commission for Environment and Development (WCED 1987), the Rio Declaration (UNCED 1992) and the Kyoto Protocol (1997). In this thesis, it is argued that increased energy efficiency in industry can enable Norway to fulfil its obligations. This chapter states the hypotheses and the research questions upon which the thesis is based.

Background

The man-made greenhouse gases.

Many scientists view the possibility of climate change as a result of rapidly increasing greenhouse gas emissions, as the most serious environmental problem facing the world today. The most important measure of possible climate change is the global mean temperature, which has risen by 0,3 - 0,6 ^{o}C during the past 100 years (Figure 1.1). There is great uncertainty associated with the effects of further temperature increase, but probable effects are changes in precipitation patterns, more frequent occurrence of extreme weather conditions, displacement of climate zones and a rise in sea level of 15-95 cm. This could have serious consequences for world agricultural production and for populations living in low-lying areas, many small islands will also disappear.

Carbon dioxide (CO_2) contributes more than 50 per cent of the increased greenhouse effect (IPCC 1990); chlorofluorocarbons (CFCs) contribute 25 per cent; methane (CH_4) 15 per cent and nitrous oxide (N_20) 5-10 per cent. These gases act as a one-way filter in the atmosphere. Most of the radiation from the sun penetrates the filter, warming up the Earth's surface. Some of the warm, infrared radiation from the Earth's surface escapes out through the atmosphere. However, it does not penetrate the filter to the same extent therefore, some of the energy is "temporarily trapped". The result is a gradual heating of the lower part of the atmosphere. This effect can be compared to a car parked in the sunshine with its windows closed, or to a greenhouse. The most important international negotiations and agreements, briefly described in the following, set a frame for necessary actions.

International action

Three important international actions form an important foundation for this study. In the following text, brief overviews of the three actions are presented:

World Commission

In 1987, the World Commission for Environment and Development (WCED) issued its analysis and recommendations in 'Our Common Future' (WCED, 1987), where the following aspects were highlighted:

> *"Sustainable development should be the objective for the world community and for individual nations, where sustainable development is defined as development that meets the needs of the present without compromising the ability of future generations to meet their needs.*
> *Poverty and environmental destruction form a vicious circle, so the initiatives to solve environmental problems cannot be successful unless a wider perspective is adopted that includes causes of and remedial action against world poverty.*
> *Economic growth is necessary to solve global problems of poverty and equity, and growth is a decisive factor in hindering environmental problems. But economic growth must be given a new and sounder content that does not involve burdens, which exceed the critical loads of natural systems.*
> *Recommendations for new conventions and for international follow-up action to secure sustainable development are suggested."*

The WCED-report has led to follow-up activities with three objectives:

- *first* to put forward and implement remedial action on environmental and developmental problems;
- *second* to unite all nations in a common understanding of our common problems;
- *third* to define the roles of industry [10], public institutions and non-governmental organisations in future environmental improvement actions.

The UN Conference on Environment and Development

This author has studied the report from the conference in Rio de Janeiro 1992 (UNCED 1992) and the follow up documents and decisions from the Norwegian government and parliament. Frames or guidelines have been identified from these in order for the thesis to be in accordance with the conference decisions.

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[10] cf. ICC - International Chamber of Commerce's Business Charter for Sustainable Development issued by ICC's Executive Board in 1990.

Paragraphs relevant to this thesis are found in Chapter 31: SCIENTIFIC AND TECHNOLOGICAL COMMUNITY. Fragments from this chapter are referred to in the following:

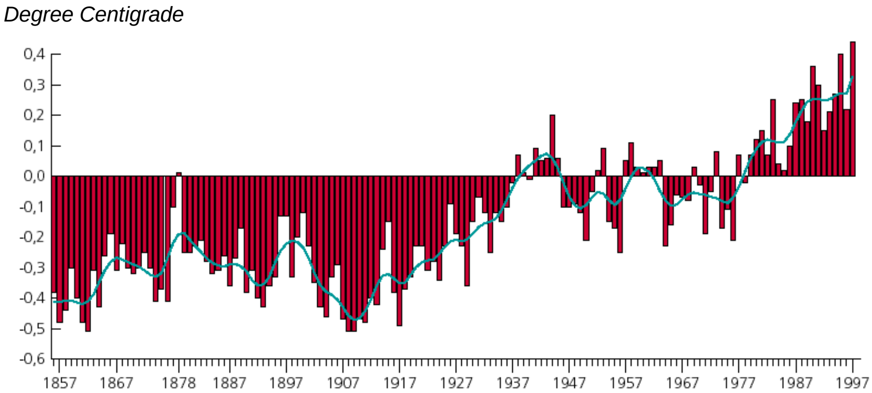


Figure 1.1. The figure shows changes in global mean temperature compared with the normal value for 1961 – 1990. (SSB 1998, p. 48)

> *" 31.1. The present chapter focuses on how to enable the scientific and technological community, which includes, among others, engineers, architects, industrial designers, urban planners and other professionals and policymakers, to make a more open and effective contribution to the decision-making processes concerning environment and development. "*
>
> *...*
>
> *"Existing multidisciplinary approaches will have to be strengthened and more interdisciplinary studies developed between the scientific and technological community and policy makers and with the general public to provide leadership and practical know-how to the concept of sustainable development."*
>
> *"Basis for action":*
>
> *"31.7. Scientists and technologists have a special set of responsibilities which belong to them both as inheritors of a tradition and as professionals and members of disciplines devoted to the search for knowledge and to the need to protect the biosphere in the context of sustainable development."*
>
> *"Activities"*
>
> *"b) Capacity-building*
> *........ guidelines, including on appropriate principles, should be developed for and by the scientific and technological community in the pursuit of its research activities and implementation of programmes aimed at sustainable development."*

The Norwegian Parliament has declared it's agreement with the RIO principles and developed a Norwegian follow-up plan. (Report No.13, 1992-93)[11]. The review Rio+5 (Lafferty et al. 1997) evaluated actions performed in the five years after Rio. Lafferty et al. argues that the implementation and practical results since the RIO conference are low and should be speeded up. This author has the objective of contributing to achieving the goals in the above challenges of the RIO Declaration.

[11] Approved from the Parliament 1997

Kyoto

On their web-site the Norwegian Government recently published[12]:

"On 23 April 1998, the Norwegian Government submitted a Report to the Norwegian Parliament (Parliament) on national implementation of the Kyoto Protocol and a Proposition to the Parliament on green taxes. These provide a good starting point for a coherent Norwegian climate policy. It will be a major challenge to develop patterns of production and consumption that can reduce emissions of greenhouse gases, and we can only succeed in this task if all sectors play their part. All industrial countries will inevitably have to respond to the threat of climate change. Furthermore, early response can also give Norwegian industry a clear competitive advantage. It is therefore, important to start as soon as possible. According to the Kyoto Protocol, Norwegian emissions of greenhouse gases may not be more than one per cent higher in the period 2008-2012 than in 1990. In practice, this means that Norway must reduce its emissions by about six per cent from the 1996 level to meet its commitment. Without the introduction of new measures, it has been calculated that emissions will rise by 23 per cent from the 1990 level in this period. According to these calculations, Norway must reduce its proposed emissions by a total of 12.3 million tonnes by 2010…".

(Minister of the Environment, Guro Fjellanger)

This statement is given in detail in the "Norwegian implementation of the Kyoto Protocol"[13] approved by the Norwegian parliament (Report No. 29, 1997-98).

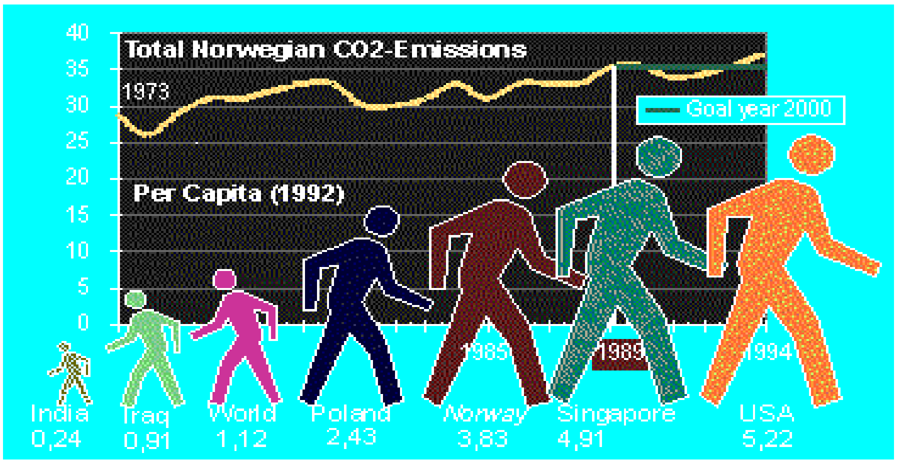


Figure 1.2. The figure illustrates man-made CO_2 emissions in selected countries. 1973-1997. (Source: Grid Arendal 1998b)

Emissions of carbon dioxide.

Figure 1.1 illustrates the fact that the global mean temperature has increased over the last years. The increasing temperature is closely connected to the CO_2 emissions. According to the IPCC (Intergovernmental

[12] WEB page, www.odin.dep.no (1998)

Panel of Climate Change)(IPCC 1990) about 50% of the increased temperature is caused by carbon dioxide.

Figure 1.2 shows the CO_2-emissions per capita as tons of carbon per person for some countries in 1992. (Grid Arendal, 1998b). According to this figure Norway has a relatively high emission per capita. Figure 1.3 shows the man-made CO_2 emissions in Norway by source, 1973-1997 (Grid Arendal 1998b). The figure illustrates increasing emissions, beyond the national goal decided by the Norwegian Parliament. The figure also shows that industry is a part of the problem. For this author, it is clear that the situation calls for action.

Concluding the present situation

According to the Kyoto Protocol, Norway can increase her total emissions of greenhouse gases by one percent compared to the 1990 level. However, the emissions already increased by seven percent from 1990 to 1996. Therefore, Norway needs a substantial reduction in emissions to achieve the targets given in the Kyoto protocol she has signed.

The present situation calls for a different approach in the future than has been used in the past. As Figure 1.3 illustrates, industry is one area to concentrate upon. For this reason, this thesis deals with the challenges and opportunities for corporate Environmental Management as a tool to focus on energy efficiency.

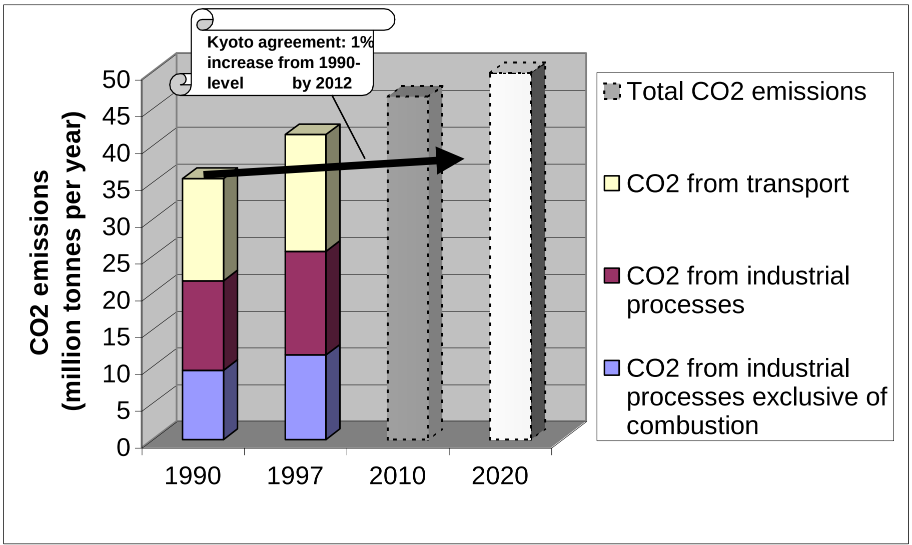


Figure 1.3 Manmade CO_2-emissions in Norway by source. 1973-1997 compared with the National goal of Norway according to the Kyoto Protocol. However, the emissions already increased by seven percent from 1990 to 1996. Therefore, Norway needs a substantial reduction in emissions to achieve the targets given in the Kyoto protocol she has signed. (Derived from SSB 1998b)

[13] The author's translation to English

Vision and objectives

Vision

Building on the World Commission Report, the Rio Declaration, the Kyoto Protocol, and the national follow-up plans for these documents, this author's vision is to contribute to the strategic operationalisation of the principles contained within them. This contribution is made by developing and testing scientifically based, guidelines for industry on Energy Management.

Objective

Based on relevant theory and experience documented in this thesis, the author's objectives are to contribute to the aforementioned descriptions of the challenges given in the Rio Declaration and the Kyoto protocol connected to industry by:

- analysing how improvement systems for integrated Energy Management in industry, can be effectively implemented;
- designing this Energy Management system so that it fosters "continuous improvements";
- designing an Energy Management system so that it is suitable to be integrated within Environmental Management Systems;
- detailing how this Energy Management system should be designed in order to contribute to "Sustainable Development".

Another objective is to inform readers about the lessons the author learned as an advisor and a supervisor for more than 100 companies, worldwide. The author has assisted those companies in implementing cleaner production by establishing environmental management systems and Energy Management systems. It is the author's hope that corporate leaders, governmental leaders, consultants, NGO's and others, can benefit from these lessons. Some of these lessons are documented in this thesis, but part of the content comes from the author's position as an observer of relevant environmental measures in industry worldwide.

Why focus on Energy Management related to environmental issues?

What are the reasons for a thesis on *"Joint management of energy and the environment in companies"*? The author suggests three reasons:

1. The Norwegian national obligations related to the Kyoto protocol emphasise that many energy efficiency measures must be taken by Norwegian society;

2. The importance of systematic corporate Environmental Management as a follow up of Agenda 21 (in parallel with the efforts from the government to focus on energy efficiency) is rapidly increasing;
3. In industry, energy and environment have traditionally been separate. People from different departments have had responsibility for the management of energy and environment. Management of energy has been connected to environmental impacts in insignificant ways only.

Framework for the thesis.

This thesis and Sustainable Development

This thesis is written from a perspective of promotion of societal practises to facilitate the transition to Sustainable Development (SD).

Energy efficiency in industry is an important part of SD. Energy Management is one important task prioritised by the Norwegian government. It is an important challenge to develop efficient management tools, which will secure a minimum of energy consumption.

Macro-, meso- and micro-scale

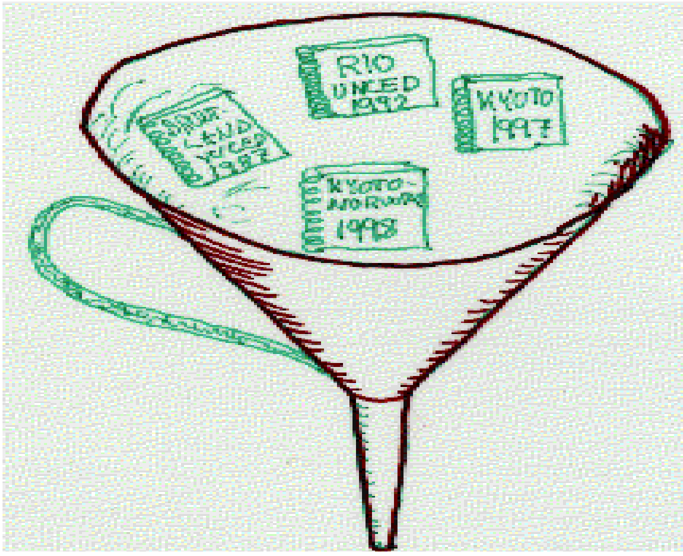
To achieve government targets, many activities must be performed. Efforts focused upon the macro-[14], meso-[15] and micro-scales[16] have to be addressed. The approach in this thesis is limited to the micro-scale. The perspective of, and reality for, the employee and managers in the factory are pin pointed. However, governmental programmes, on a macro-scale, sometimes have a link to the micro-scale. An example here is an employee in a factory dealing with a project on energy efficiency. The program is initiated by an external advisor and financed by the Ministry of Energy.

Limitations of the thesis

- Limitation 1: To study Energy and Environmental Management in Norwegian and Nordic industry.
- Limitation 2: To study Energy and Environmental Management on the micro-scale.

Energy and Environmental management on a company level is the main issue in this thesis. Human efforts within organisations depend not only on the "in-factory" actions, but also on the influence of external stakeholders. On the macro-level, many stakeholders play important roles; governmental programs on CP are one example. Results from such a Norwegian CP Program are included in this thesis.

[14] Macro-scale means effects (measures or options) on the society level.
[15] Meso-scale means effects (measures or options) on, for instance, a group of factories.
[16] Micro-scale means effects (measures or options) on the company level.



The Norwegian Goal:
Six % reduction of CO_2 emissions before the year 2010 compared to 1996.

Figure 1.4. The design process for the hypotheses and research questions. The WCSD report "Our common future" (WCED 1987), the Rio Declaration (UNCED 1992), the Kyoto protocol and the Norwegian implementation plans (Report No. 29, 1997-98) have been put in a funnel as illustrated on the Figure, to extract relevant challenges connected to the scope of this thesis: *Joint Management of Energy and Environment in Industry.*

Hypotheses and research questions

The WCED report "Our common future", the Rio Declaration, the Kyoto protocol and the Norwegian Parliament's follow up plans have been put in a funnel to extract relevant challenges connected to the scope of this thesis: *Joint Management of Energy and Environment in Industry.* Figure 1.4 illustrates the design process. The following hypotheses are stated and labelled with the letter H and consecutive numbers. Research questions connected to each hypothesis are also stated.

H1 hypothesis:

"Performing Cleaner Production assessments in Norwegian industries helps them to reduce their environmental burdens by making process and procedural improvements. Such process improvements have short payback periods."

To test the H1 hypothesis, the author performed research to determine (R1):

- Does performance of CP assessments in Norwegian industries help them to reduce their environmental burdens, and what is the average payback period for such improvements?

H2 hypothesis:

"When a Cleaner Production Assessment is performed, the relative importance given to energy efficiency improvements in the company is dependent upon the skills and interests of the external advisor."

To test the H2 hypothesis, the author performed research to determine (R2):

- What is the relative importance of energy savings on economic and environmental results?
- What is the effect of external financial support for energy audits on implementation of energy efficiency improvements?
- To what extent does project manning influence the results of and the integration of, energy conservation into corporate environmental management activities?

H3 *hypothesis:*

"Performance of Cleaner Production Assessments is sufficient to create systematic, continuous improvements in companies"

The research question (R3) connected to the H3 hypothesis is:

- Does performance of cleaner production assessments stimulate corporate management to continue on the journey of environmental improvements?

H4 hypothesis:

"CP assessments, EMS and Energy Management helps companies to achieve a more consistent contribution to eco-efficiency[17]"

Research questions R4:

To test this hypothesis, research questions were developed and grouped in three categories that correspond to the historical stages of the development of tools and systems for CP. The research questions are:

GROUP A *CP assessments*

- What are the driving forces in companies and what is the need for external assistance to make them become effective in fostering continuous improvements?
- Do companies focus on short-term profitable options, or also on long-term options?

[17] World Business Council for Sustainable Development and OECD have initiated an Eco-efficiency concept. The definition is (BCSD 1993): *"Eco–efficiency is reached by delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's carrying capacity."* (OECD 1998). Eco-efficiency is connected to a set of criteria, described further in Chapter 8 in this thesis.

- Have profitable options been identified and evaluated?
- Have the improvement options been implemented?
- Are there specific types of CP options, which provide big savings?
- Is making a contribution to “sustainable development” important for companies?

GROUP B *Environmental Management System (EMS)*

- What is the driving force for implementing an EMS, and what are the obstacles for the implementation of such systems?
- Is EMS necessary and sufficient to gain continuous environmental improvement activities?
- Are corporate activities better organised and more effective if they are implemented within companies with an EMS, compared to those that do not have EMS systems?
- Is employee involvement stronger in companies with an EMS, than in companies without one?

GROUP C *Future needs*

- Are CP assessments and EMS necessary, but insufficient to catalyse implementation of sustainable production in participating companies? Has the introduction of CP, CP assessments and EMS led to product improvements? Do the companies use Life Cycle Analysis (LCA) to improve their products?
- Do the companies use EPIs to measure their improvements?
- To what extent do CP assessments, EMS and Energy Management help companies to achieve a more consistent contribution to eco-efficiency?

H5 *hypothesis:*

"EMS implementation in industry contributes significantly to improved energy efficiency"

Research questions (R5):

- Is Energy Management emphasised in the Environmental Statements of the Norwegian EMAS registered companies (all branches)?
- Is Energy Management focused upon within an EMAS implementation in the food-processing industry in Norway?
- Is energy mentioned in their annual reports?
- Are energy related EPIs reported in EMAS reports in the energy intensive food-processing industry?

H6 *hypothesis:*

"Benchmarking energy related EPIs and co-operation, through networking among companies, help companies reduce their energy consumption over a time span of three years"

Research question (R6):

- Are benchmarking with EPIs and co-operation through networking among companies effective ways to help industry to obtain decreased energy consumption per unit of production?

H7 *hypothesis:*

"Energy Management in the food processing industry contributes significantly to improved energy efficiency."

Research question (R7)

- Does Energy Management facilitate implementation of energy efficiency options?
- Do companies that have implemented Energy Management approaches, obtain reduced energy consumption per unit of production?

H8 *hypothesis:*

"Energy Management in the food processing industry contributes significantly to improving eco-efficiency".

Research questions (R8):

- Are managers of small and medium sized food processing companies familiar with exergy and anergy?
- Do they consider the share of exergy and anergy before choosing their source of energy?
- Do companies know the consequences and the costs of utilising low temperature energy-sources?
- Are managers of small and medium sized companies familiar with renewable energy sources versus non-renewable sources?
- Do they consider the share of renewable energy before choosing the source of energy?

H9 *hypothesis:*

"Integration of Energy Management in EMS-systems (e.g. EMAS and ISO 14001) is efficient in facilitating the implementation of energy conservation measures and ensuring continuous improvements.

Research questions (R9):

- Are there similarities in Energy Management and Environmental Management Systems (EMS)?

- Is integration of Energy Management in EMS-systems (like EMAS) efficient in obtaining improved energy efficiency and in helping to ensure that the company continues on the improvement journey?

Chapter 2 Research Methodology

Summary

In order to test the research hypotheses, a research model was developed. This model was developed from two methods, one presented by Charles C. Ragin in his “Constructing Social Research”, (Ragin 1994). This method has both a theoretical approach and an empirical approach. Representation of social life is developed in the crossroads between the theoretical and empirical approaches. The second method used in this thesis is the model of The Foundation for Scientific and Industrial Research at the University of Trondheim (SINTEF model). This model is based upon two approaches, one problem based and the other theory based. Practical results can be obtained using both approaches.

The scientific model for this thesis is shown in Figure 2.7.
The design of the parts and chapters of the thesis is presented in Figure 2.8.

Research strategy

The research strategy used in this thesis is primarily qualitative research. The similarities that exist between a relatively small number of cases are examined. The research strategy is further discussed in this chapter.

Multidisciplinary science

Arguing for an unusual scientific method and using a multidisciplinary scientific approach, the author has utilised approaches from old scientists. Starting with Albert Einstein, who once wrote:

> *"We cannot solve problems by using the same kind of thinking we used when we created them."*[18 19]

Proceeding with Thomas S. Kuhn, who elaborated upon the differences between “Normal Science” and “Revolutionary Science” in his book “The Structure of Scientific Revolutions”, (Kuhn 1970). The first type works within a specific, scientific paradigm, while the other type identifies the flows in our current ideas and approaches and proposes alternative visions and paradigms, which in turn leads to a scientific revolution.

[18] http://kirstine.fys.ku.dk/~raben/einstein/

Hacking (Hacking 1985) interprets Kuhn as follows:

> "Once a specific science has been individuated, Kuhn argues, it characteristically passes through a sequence of *normal science – crisis – revolution – new normal science.* "Normal science" is chiefly puzzle solving activity, in which research workers try both to extend successful techniques, and to remove problems that exist in some established body of knowledge. Normal science is conservative, and its researchers are praised for doing more of the same, better. But, from time to time the anomalies in some branch of knowledge get out of hand, and there seems no way to cope with them. This is a crisis. Only a complete rethinking of the material will suffice, and this produces a revolution".
>
> In 1972, Kuhn defined the scientific paradigm as a quintessential theory or meta-theory[20], that unifies and reconciles preceding theories, which at an earlier stage even may have appeared to be contradictory. The unifying power of the paradigm often is rooted in an extended and completely different definition of the system- or problem borderline than used by the individual, proceeding theories".

The author agrees with Einstein and Kuhn on the necessity of finding new approaches to new challenges (as those presented in Chapter 1 on reduction of CO_2 emissions).

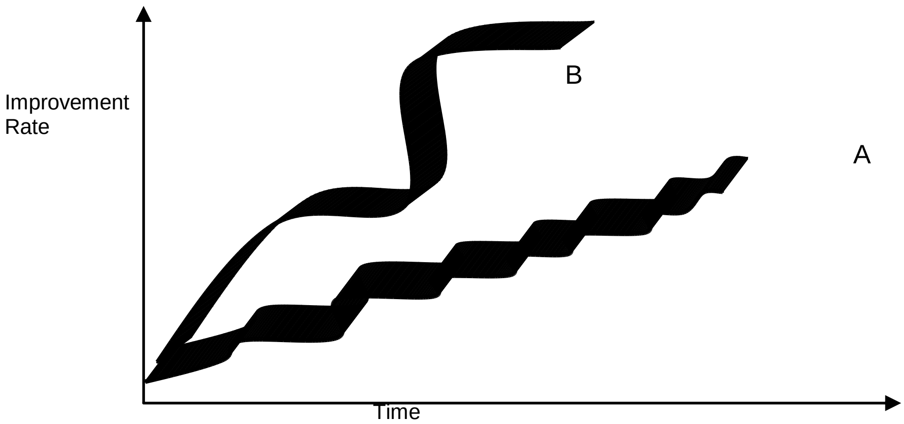


Figure 2.1. The figure illustrates alternative improvement strategies in industry. Curve A describes the usual "one step at a time" model, frequent small improvements. Curve B describes more radical improvements that occur infrequently.

Figure 2.1 describes two alternative improvement strategies by describing improvement rate as a function of time. Curve A describes the *usual "one step at a time"* model. Curve B describes more radical improvements. The main point is that the B curve ends at a higher improvement rate than that in curve A. How is it possible to obtain improvements of category B? This author's answer is through application of insights gained through

[19] Peter Senge has an equivalent expression; "Today's problems come from yesterdays solutions" (Senge 1990, p 57)

multidisciplinary science because they can stimulate new problem solving approaches. Multidisciplinary approaches are important for the investigated challenges and suggested solutions in this thesis.

The World Commission emphasised a multidisciplinary approach as part of the solution (WCED 1989) so did also the Rio Declaration (UNCED 1992, chapter 31.1).

Figure 2.3 groups the main scientific disciplines or perspectives used, and shows the overlapping field in which this thesis has been developed.

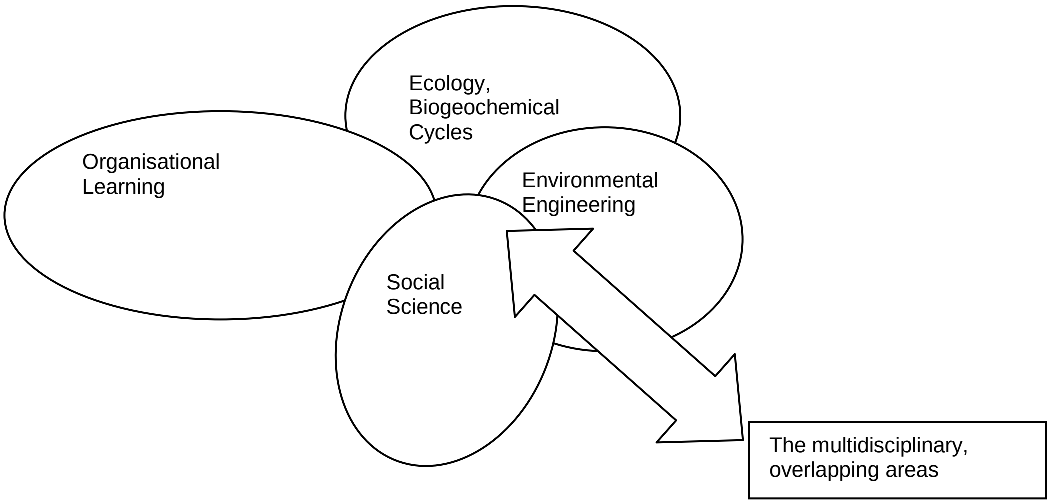


Figure 2.3 Illustrates the main scientific disciplines, or perspectives used in this thesis.

Research models

In order to a find a research model suitable for a multidisciplinary approach, two research models are presented, and a concluding model is selected.

Model 1: Social research

Charles C. Ragin presents, in his “Constructing Social Research”, (Ragin 1994, p.57-74) an approach useful in the construction of social science research. The simple model of social science research is referred to in Figure 2.4.

Referring to Ragin, the conclusions and recommendations have to be developed by:

1. Identifying general patterns and relationships.
2. Testing and refining theories.

Ragin (1994) defines some important expressions in the model as follows;

[20] Meta- means above or beyond as in metaphysics (Senge 1990)

- "Deduction is the process of deriving more specific ideas or propositions from general ideas, knowledge, or theories and working out their implications for a specific set of evidence or specific kind of evidence (Ragin 1994,p.186).
- Induction is the process of using evidence to formulate or reformulate a general idea. The process of constructing images (via the synthesis of evidence) is mostly inductive. Generally, whenever evidences used as a basis for generating concepts, as in qualitative research, or empirical generalisation, as in quantitative research, induction has played a part (Ragin 1994,p.188).
- Retroduction is the interplay of induction and deduction, and is central to the process of scientific discovery. The process of constructing representations from the interaction between analytic frames and images involves retroduction (Ragin 1994,p.191)".

According to the model of Ragin, images are built up from evidence found in the empirical data. The evidence is systematised, grouped, evaluated and presented as images. These images are primarily inductive. An analytic frame (another approach) defines a category of phenomena and provides conceptual tools for differentiating phenomena within the category. Retroduction has deep historical roots, according to Sæter (1998); Aristotle, Pierce and Hansson are among the most noted contributors to this tradition. Retroduction represents an attempt to overcome the pitfalls of a purely inductive or deductive research process. Inductive research processes should be utilised in the future for the greening of industry, Sæter (1998).

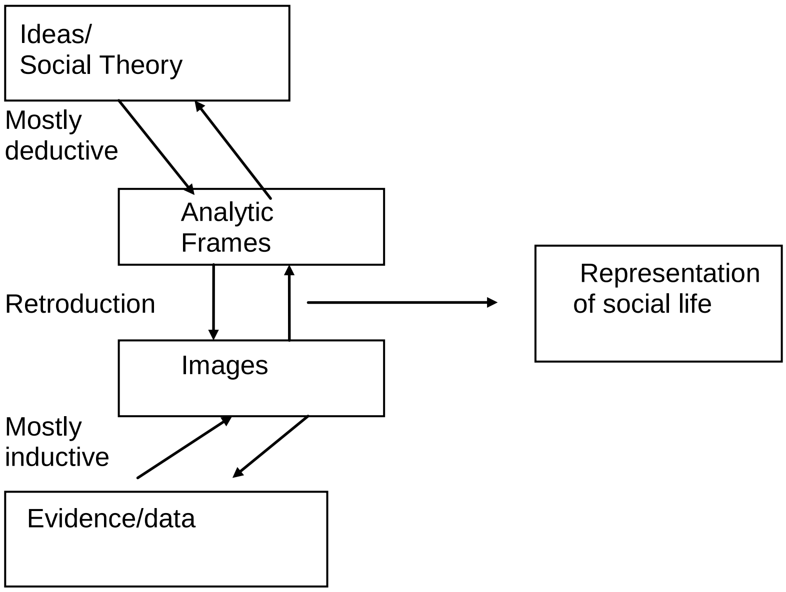


Figure 2.4 The Ragin model, called a "Simple model of social research" (Ragin 1994, p. 57). The model shows the interaction between theory and evidence/data utilising a retroduction.

Retroduction makes possible a research process that is characterised by the linking of evidence (induction) and theory (deduction) in a continually evolving, dynamic process (Ragin 1994). The retroduction in this thesis ends in a tested and refined method for joint management of energy and environment. This approach is illustrated in Figure 2.4.

Model 2: Applied Science

According to Jacobsen (Jacobsen 1995), The Foundation for Scientific and Industrial Research at the Norwegian University of Science and Technology, in Trondheim (SINTEF) defines applied science as:

1. A systematisation of existing technology and organising of research work in a suitable framework for a wide range of applications.
2. Research work directed towards concrete problem areas in trade and industry.

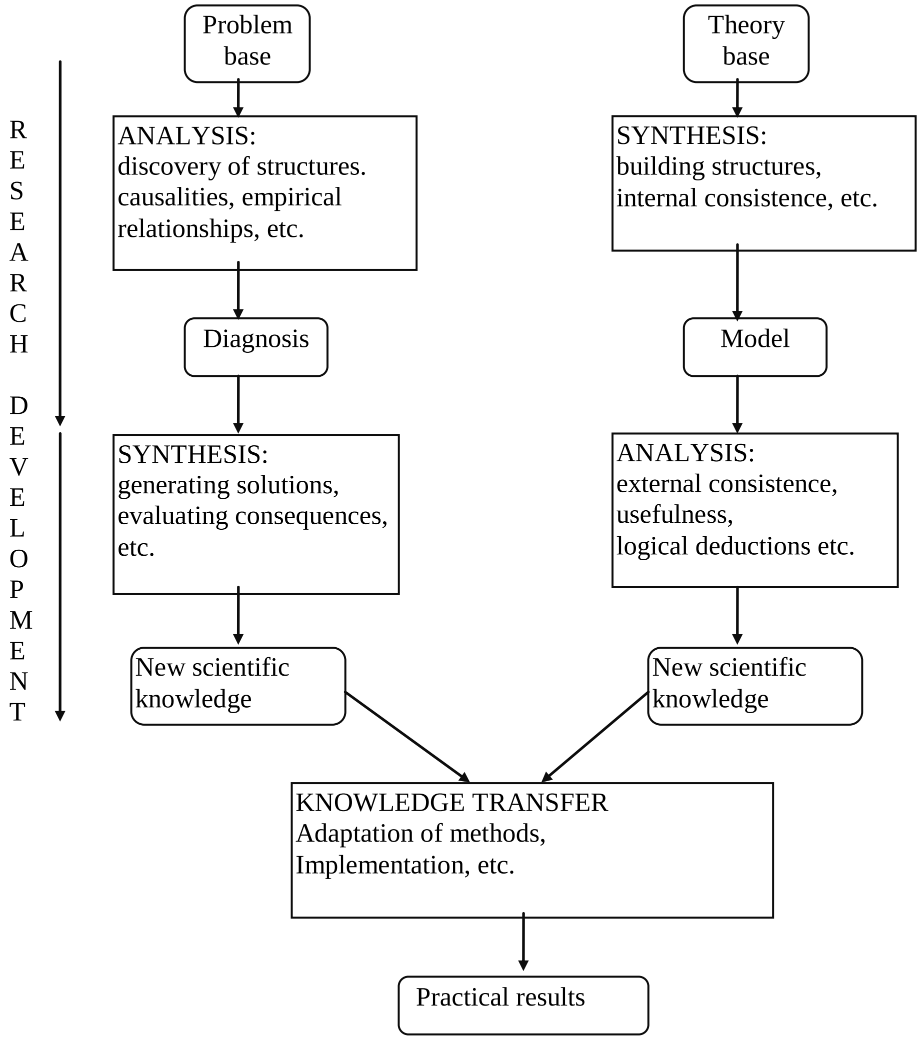


Figure 2.5 The model from The Foundation for Scientific and Industrial Research at the University of Trondheim (SINTEF). This model is based upon two approaches, one problem based and the other theory based. The practical results are found using both approaches (Jacobsen 1995 p 14). Outputs are practical results and recommendations for future activities to "solve" the problem.

A transition from points 2 to 1, above, will result in knowledge of needs and utilitarian values; while a transition from 1 to 2 will result in knowledge of how to convert a problem into a solution.
These principles are presented diagrammatically in Figure 2.5. (Jørgensen 1992).

Selected research model

Referring to the objective of this thesis outlined in Chapter 1, this author's approach is to utilise both multidisciplinary theories and images built upon the case studies from industry. Many models and tools for environmental performance in industry are utilised today. These models are connected to Cleaner Production, Environmental Management Systems (EMAS and ISO 14001), Energy Management and Environmental Performance. The author has built a research design in line with these two models, applying Ragin's model and the SINTEF-model to this research.

In this thesis, the main elements in the model are:

- The model begins with problem definition; clarification of challenges, hypotheses and research questions;
- The scientific method for testing the hypotheses is divided into two approaches:
    1. The theoretical approach which consists of relevant theory and an analytical framework;
    2. The evidence approach which consists of empirical data and images.

Figure 2.6 presents the selected model. The following paragraphs explain the applied content in each part of the model and the interaction between the parts. Results from the interaction (retroduction) of the two approaches are presented in Chapter 13.

Problem definition

Problem definition has to be done based on the background and the challenge the researcher faces. In this thesis the problem definition is presented in Chapter 1:

1. global warming is a big challenge in the world today;
2. the Norwegian Government has approved a plan to decrease the emissions of carbon dioxide from Norwegian societal activities;
3. the carbon dioxide emissions currently continue to increase;

4. the author uses a funnel (see Figure 1.4) to limit the scope of the thesis, and postulates that integrated management of energy and environment is a good way to meet this challenge;
5. proper hypotheses are stated as a starting point for the research to be performed.

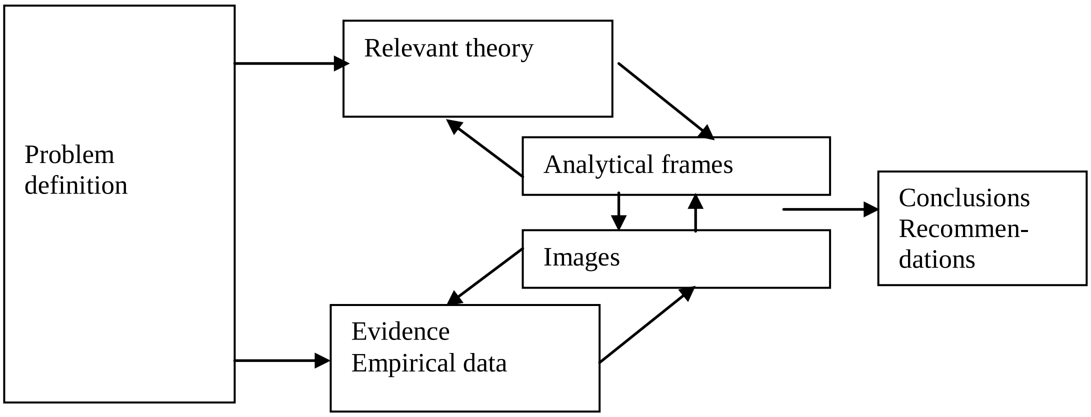


Figure 2.6. The figure shows a diagrammatic representation of the scientific organisation of this thesis. The problem definition consults both relevant theory and empirical data. The analytical framework is built on theory. Images are constructed from the empirical data. An introduction (interaction) between analytical frames and images gives conclusions and recommendations as output. (Derived from Ragin 1994, p. 57 and Jacobsen 1995 p 14)

Relevant theory

Theories from multidisciplinary perspectives as shown in Figure 2.3 are reviewed. The reviewed literature is from social science, organisational learning, thermodynamics and ecology

Analytical Frames

In order to develop relevant analytical frames, the author has evaluated and chosen tools and systems that are relevant to the investigated challenges. These tools and systems are: Supervision of environmental improvements in industry, CP methodology, Environmental Management Systems (EMS), Energy Management, Environmental Performance Indicators (EPIs), Benchmarking and Environmental Reporting.

Evidence, empirical data collection design

The evidence in this thesis consists of:

1. Quantitative research from 280 Norwegian case studies from different branches of industry;
2. Qualitative research performed on 67 Norwegian case studies: 11 pulp & paper companies and 56 food-processing companies. The data were derived from Cleaner Production implementation;

3. Qualitative assessments performed within 22 food-processing companies from Denmark, Sweden, Iceland and Norway. The 22 companies were followed for a period of 4 years;
4. Quantitative research on 540 Norwegian case studies from different industry branches;
5. Qualitative research on 13 Norwegian case studies from different industry branches;
6. Qualitative research including in-depth interviews of 10 Norwegian food-processing companies.

All together, the data consists of qualitative data from 112 industrial case studies and quantitative data from 820 companies. In collecting data, longitudinal data on continual improvement, or lack of it, was emphasised.

Images

Images are built up from evidence found in the empirical data. The images are primarily inductive. An analytical frame defines a category of phenomena and provides conceptual tools for differentiating phenomena within the category. The evidence (case studies) was systematised, grouped, evaluated and presented as images.

Retroduction

Retroduction makes possible a research process that is characterised by the linking of evidence (induction) and theory (deduction) in a continually evolving, dynamic process (Ragin 1994). In most research methodology textbooks, the idea is that theories (hypotheses) are developed in isolation from evidence and then tested against evidence particularly collected for that purpose. The reason that this author chose a different approach is:

(1) Many researchers work differently from the standard methodology described in most textbooks. They might, like this author, utilise their own previously published work, other researchers work, or data from previously published statistics.

(2) It excludes the researchers who use evidence to refine ideas in a more grounded way.

(3) It assumes we have well developed theories that we can easily shape into hypotheses. In the multidisciplinary approach chosen in this thesis, a group of different scientific approaches, often contradictory, exist. It is therefore complicated to pick the right approach to be sure that all of the important aspects are included. This explains the need for "double-fitting" ideas and evidence that is central to the notion of retroduction. Referring to Ragin (1998): *"From a strict philosophy of science*

(falsificationism) point of view, retroduction is all wrong. This is another reason why I emphasize the representational side of social research. All social scientific "results" are theory-infused and knowledge-dependent constructions, which we hope will prove useful. Only time and experience provide real tests of our results."

In the process of retroduction, the hypotheses[21] presented in the introduction of this thesis is tested and utilised to state conclusions and recommendations.

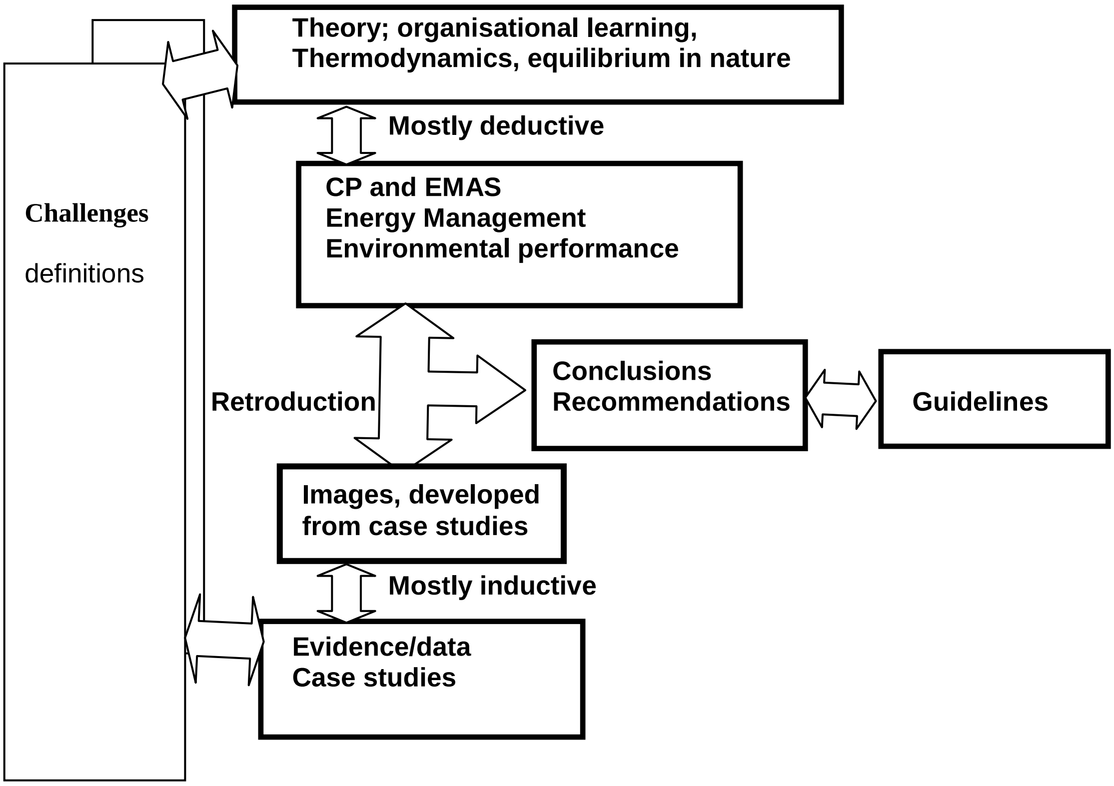


Figure 2.7 The selected research model for the thesis. The figure is a diagrammatic representation of the scientific organisation of this thesis. The problem definition is based upon both relevant theory and empirical data. The analytical framework is built on theory. Images are constructed from the empirical data. A retroduction (interaction) between analytical frames and images provide the basis for development of conclusions and recommendations. (Derived from Ragin 1994, p. 57 and Jacobsen 1995 p 14).

Conclusions and recommendations

Conclusions based on the retroduction and recommendations are outlined in Chapter 13. To facilitate the application of the conclusions and recommendations, guidelines for joint management of energy and environment are presented, with regard to the target group. (See Appendix 2). The research model developed for this thesis is shown in Figure 2.7.

[21] "A hypothesis is best understood as an educated guess about what the investigator expects to find in a particular set of evidence", Ragin 1999 p. 14.

Structure of the thesis

As a result of this research model, the text of the thesis is divided into five parts:

INTRODUCTION: the introduction contains the problem definition, hypotheses, research questions, and research strategy;

Part A of the thesis is divided into two sections, the theory and the analytical framework. The theory is based upon organisational learning, the carbon cycle and thermodynamics; relevant for successful implementation of CP and Energy Management. Methodology on supervision, CP, EMS, Energy Management and EPI are presented as a final section in part A;

Part B of the thesis contains the empirical data and images derived from the data. The images developed from the empirical data are discussed and conclusions based upon the empirical data are presented;

Part C of the thesis contains the retroduction, an analysis of the information presented in parts A and B. This is performed by 1) a test of the hypotheses and 2) developing a model suitable for the joint management of energy and the environment in industries. Finally, in part C, conclusions and recommendations are developed;

APPENDICES. Appendix 1 contains a questionnaire used in one of the empirical projects. Appendix 2 presents guidelines developed to facilitate the application of the conclusions and recommendations.

The structure of the thesis is shown in Figure 2.8.

Summing up this Chapter

The selected research model is presented in Figure 2.7. This figure represents the research strategy. The diagrammatic representation of the relationships of the different text elements of the thesis, are presented in Figure 2.8. First, there is an introductory part where the challenge is defined and argued. Hypothesis and research questions are then presented. Four parts follow this:

Part A: Theory and methods (analytic frames) which are relevant for this thesis and which also build upon the theory.

Part B: Evidence consisting of empirical data and images developed from the data.

Part C: Retroduction, presentation of a refined method, conclusions and recommendations

APPENDICES: Appendix 1 presents an example of a questionnaire utilised to get data from case studies in 25 Nordic factories. This questionnaire, together with the reports listed in the references, completes the data from the case studies. A guideline for joint management of energy and environment in industry is presented in Appendix 2. This is present in order to facilitate implementation of the conclusions and recommendations in industry.

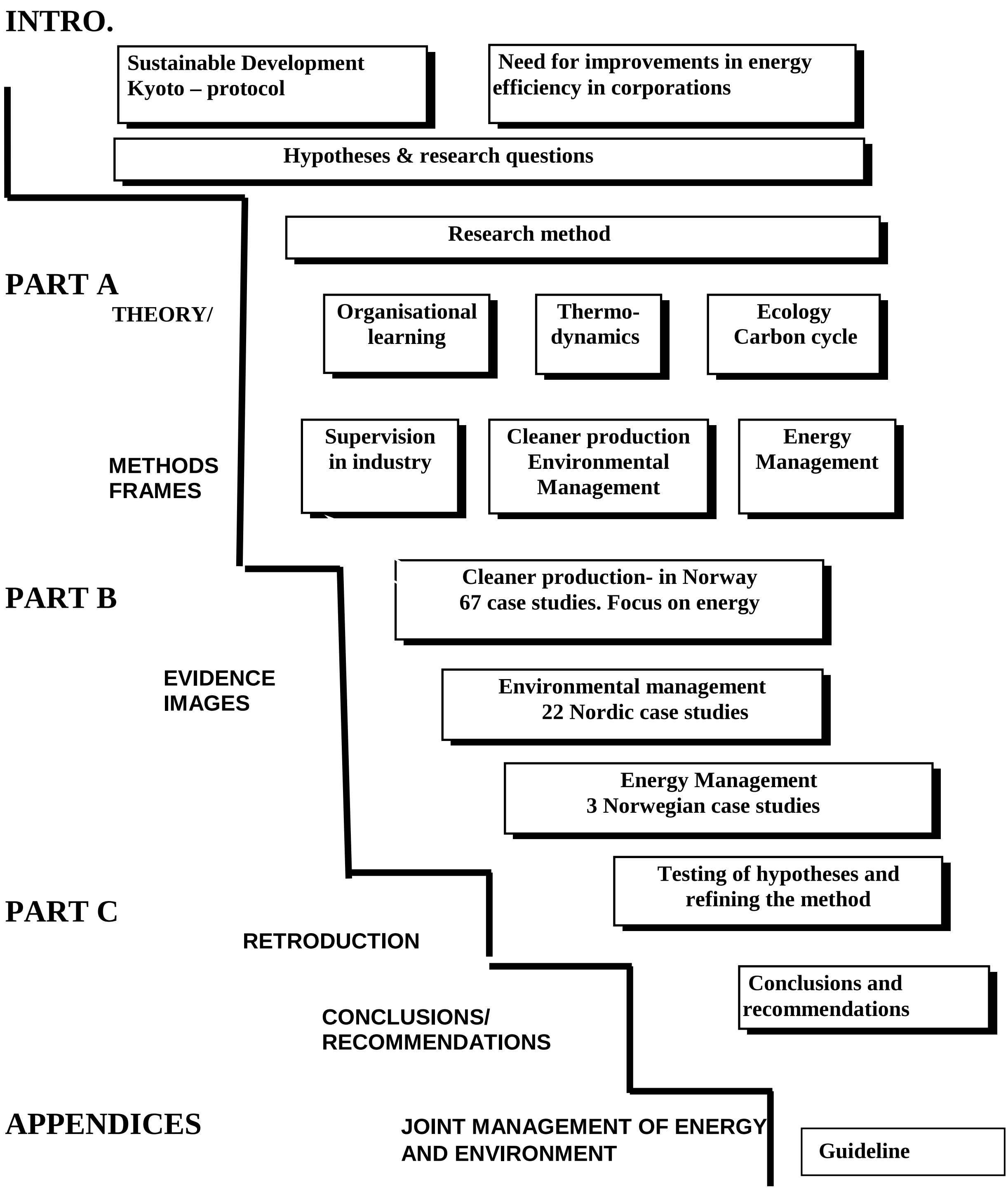


Figure 2.8 Structure in the parts of this thesis

PART A THEORETICAL CONCEPTS AND MODELS

Chapter 3 The theory of Thermodynamics and the Biogeochemical Cycles in the Ecosystem

Summary

This chapter forms an important part of the multidisciplinary theory in this thesis. Referring to the introductory chapter, even a reduction in use of electricity produced from waterpower might reduce carbon dioxide emissions (and thus their contribution to the greenhouse effect). If that quantity of electricity could be transferred to another place where fossil fuel is the current alternative, there could be a net reduction in carbon dioxide emissions.

Combustion of fossil fuels makes a significant contribution to carbon dioxide emissions. In this chapter, the laws of thermodynamics and the carbon cycle are applied to the burning of fossil fuels. Based on the laws of thermodynamics and the biogeochemical cycles represented by the carbon cycle, the quality of energy is presented. The conclusions are:

1) That it is important to increase energy efficiency at all phases in the products life cycle. Energy should be seen in the perspective of a Life Cycle assessment of the product.

2) That it is important to increase the usage of renewable energy as a percentage of total energy in the industrial system, in order to reduce the formation of greenhouse gases, and

3) In order to use the right quality of energy, the concept of implications of exergy[22] should be considered before the energy source is chosen. 'Right quality' means a minimum of exergy consumption due to the physical need for exergy. A requirement for low exergy content will facilitate the utilisation of local and low temperature energy sources. This can result in decreased consumption of fossil fuel and in: decreased emissions of carbon dioxide/unit of production.

With an understanding of “the greenhouse effect” and the carbon cycle on a macro-level, this chapter clarifies the future challenges for industry on a meso- and micro-level. Energy and the environment are closely connected, the challenges on a macro-level have to be sorted out on a meso- and micro-level.

[22] “Exergy is energy which, in a specified environment, can be transferred to all other types of energy”

The theory and conclusions presented in this chapter form an important foundation for joint management of energy and environment.

Physical laws

Industrial and societal development that includes nature has to consider certain physical laws. Frequently, in these approaches, certain laws and limits are neglected. The first and second laws of thermodynamics are examples of the most important laws related to energy consumption. The carbon cycle, as one important part of the material cycle in the ecosystem related to energy consumption, should also be emphasised in industry and considered in the design phase of products, processes and services. Governmental Policies to promote sustainable energy consumption should consider these physical limitations.

First law of thermodynamics

The first law of thermodynamics deals with the accounting of energy between a closed system and the environment. It describes the fact that energy is neither created nor destroyed. It may change form or pass from one place to another. (Holter m. fl 1979, p.21). This can be stated as:

$$\Delta U = \Delta Q + W \qquad \text{(First law)}$$

If we have a closed system transferring energy to the environment as heat, described as:

ΔQ

and the system gives off energy to the environment, as

W

This causes a change in the system's internal energy,

ΔU[23]

When energy is lost from the system into the surroundings for example when wood burns, the reaction is called *exothermic*. When energy from outside is put into a system to raise it to a higher energy state, the reaction is called *endothermic*.

Referring to Holter (Holter m. fl 1979, p. 22), the first law is quite reasonable to understand; energy can not disappear, only change form. The first law tells us that energy may change quality. Referring to Sonntag and Van Wylen (Sonntag and Van Wylen 1982, p 170), the first law states that during any cycle that a system undergoes, the cyclic integral of the heat is equal to the cyclic integral of the work. The first law however does not place restrictions on the direction of flow of heat and work.

Second Law of thermodynamics

The second law, for open systems, incorporates the fact that processes proceed in a certain direction, but not in the opposite direction. The process is irreversible. If we transfer heat ΔQ to a system, for a marginal heat transfer dQ, we get:

$$dQ = T\,dS$$

Where S is the entropy[24] and T is the temperature.

The second law of thermodynamics states that the entropy in the environment increases in all real processes:

$$\Delta S_{total} \geq 0 \qquad \text{(Second law)}$$

A hot cup of coffee cools by virtue of heat transfer to the surroundings, but heat will not flow from the cooler surroundings to the hotter cup of coffee (Sonntag and Van Wylen, p.170). This example is evidence of the second law of thermodynamics. Figure 3.1 illustrates the second law.

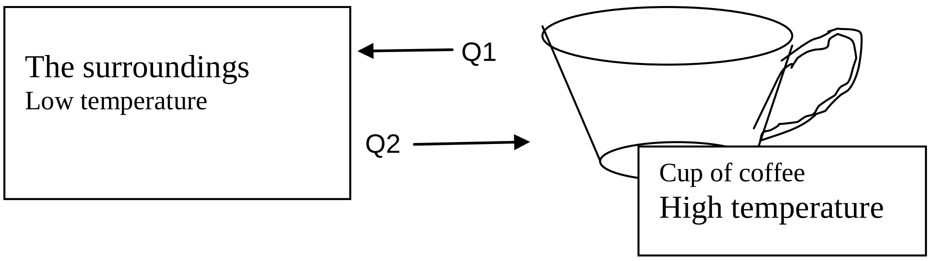


Figure 3.1 An example illustrating the impossibility of completing a cycle by transferring heat from a low temperature body to a high temperature body.

To understand the underlying physical and chemical boundaries and challenges in this process, the following statement should be considered:

> *"All real processes increase a system's disorder at the molecular level."*

and

> *"All real processes increase the entropy"*

This statement is another way of expressing the second law (Holter et.al.1989, p.22 and Nørretrander 1991 p.22).

---

[23] Δ U relates to the system's molecular movement and conditions

[24] Entropy (S) for reversible processes is defined by the equation $dS = (dQ/T)_{rev}$ (Sonntag and Van Wylen 1982, p 203 and 215).

To understand what heat really is, James Clerk Maxwell launched Maxwell's demon in 1867 (Nørretrander 1992 p. 20-27). Maxwell stated that the molecules in a gas do not move at the same speed. Some molecules move at a very high speed, some with a low speed. Most molecules have a speed near the average speed. If two gases are mixed, one with a high temperature and one with low temperature at some time the molecules will obviously have different speeds. Maxwell's idea was to separate the molecules and make the process reversible. His idea is illustrated in Figure 3.2. The demon let molecules with high speed go to the right and molecules with low speed to the left (from Nørretrander 1992 p 32). Maxwell's idea has not been scientifically proven. If such a sorting were possible, the second law of thermodynamics would be proven to be false. An open process would then be reversible, and the heat exchange towards the hot cup of coffee in Figure 3.1 would have been possible.

This story is useful in order to understand the nature of heat and how it cannot be fully utilised with our present technological capability.

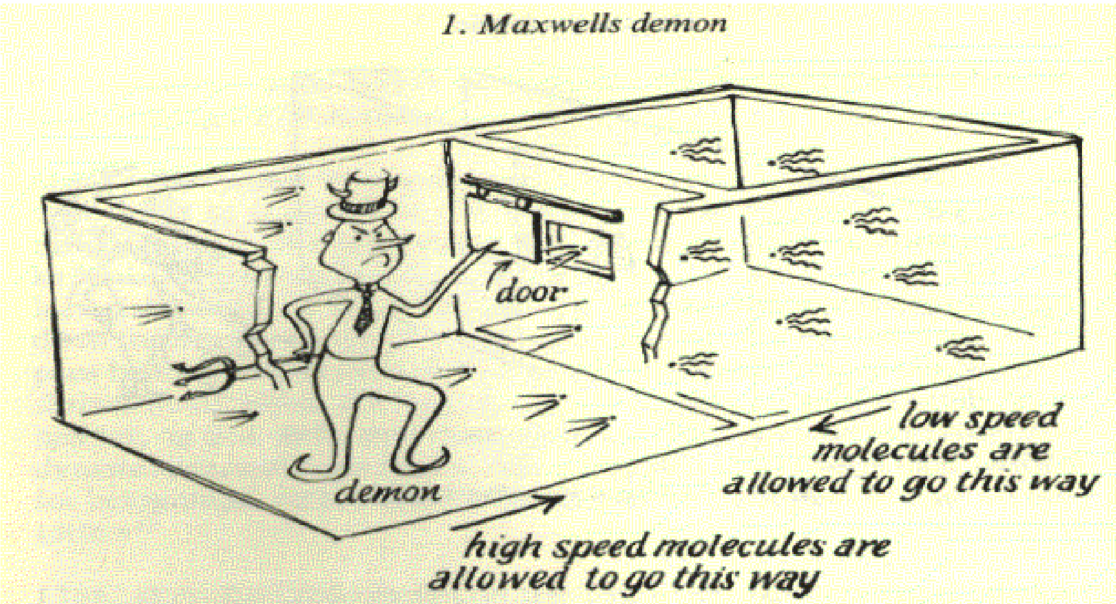


Figure 3.2. A visualisation of Maxwell's demon. The demon, which knows the speed of the molecules very well, allows molecules with high speed to go to the right and molecules with low speed to go to the left. The demon uses a door to perform the sorting (from Nørretrander 1992 p 32).

Exergy and anergy

The second law tells us; each time we use energy, it will be less available for subsequent uses. If energy is used to perform work (or produce power), a loss of heat will occur. The loss of heat has no potential to do work or produce power. Lost work (LW) occurs. The relationship is given as follows:

$T\,dS = dQ + dLW$ (Sonntag and Van Wylen, p.214).

Where:

T = temperature;

dS = the marginal change in entropy;

dQ = transfer of heat;

dLW = the marginal lost work.

The possible energy available for transformation into mechanical energy, or work, decreases. Heat is one type of energy that is not available for all purposes. If we have heat available and would like to run an electric motor we need electricity, we have to transform the heat into electricity.

To describe the ability of the energy source to do work (or to produce power), the terms exergy and anergy, are introduced into thermodynamics. According to Holter, the German physicist Baher (Holter et.al.1989, p.22-27) gives this definition:

> *"Exergy is energy, which in a specified environment, can be transferred to all other types of energy"*

and

> *"Anergy is energy which cannot be transferred to exergy"*

Referring to Nørretrander (1992) and the previous paragraph, the following should be added to the above statement:

> "*with our present technological capability."*

Therefore:

Energy = exergy + anergy (Baher 1966)

With this definition, the second law could be reformulated:

> *"By all irreversible processes, exergy transforms to anergy"*

The exergy is the part of the energy available for practical use (e.g. in rotating movements).

> *"Exergy represents the share of energy which has potential to perform work."*

A reservoir of water above sea level contains pure exergy because the potential energy can be transformed into 100% mechanical energy.

Another important point is that the share of exergy depends on the temperature of the surroundings. A reservoir at sea level, when no gravity forces or salt gradients are present, contains exergy only if it has a higher temperature than the environment. From this follows:

> *"Anergy can give no work and is not a resource."*

In some situations, it is quite common to use more energy than needed. One example is the heating of air inside buildings. Figure 3.3 shows a Sankey diagram utilised to analyse the exergy/anergy situation connected to heating an industrial facility by hot water. Oil is the energy source. The temperature levels occurring in the process are also illustrated.

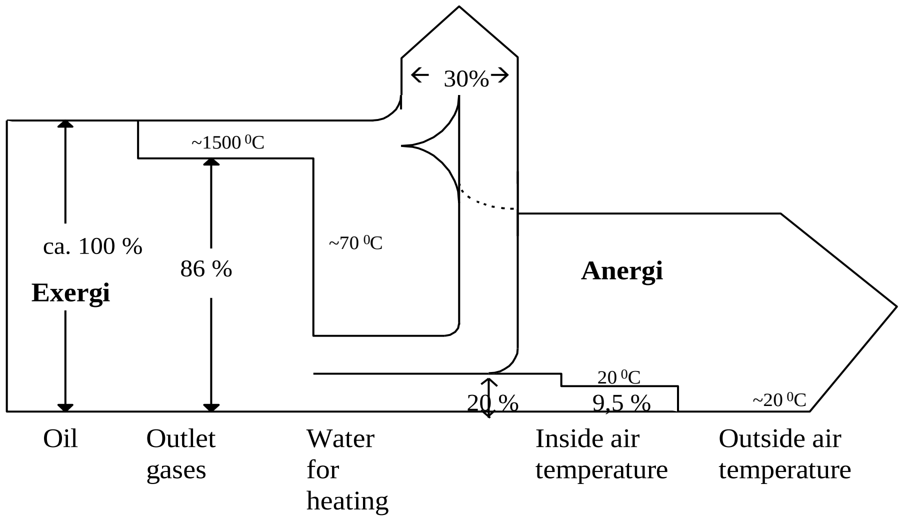


Figure 3.3. A Sankey diagram showing the exergy/anergy situation connected to heating a building with hot water. Oil is the energy source. The temperature levels occuring in the process and the exergy pecentage levels are illustrated.

Technologies for reduced share of exergy

In the following text, some technologies applicable for analysing reduced share of exergy in industry are briefly presented.

Exergy analyses

Exergy analysis is the combination of the first and second law of thermodynamics. It is defined as the maximum amount of work potential of a material or a form of energy in relation to the surrounding environment. Therefore, in an exergy analysis, the losses represent the real losses of work (Cornelissen 1997). Exergy analyses is a developed tool ready to be utilised. The tool is designed for all industrial processes. The purpose of exergy analysis is to evaluate industrial processes in order to identify how and where in the process a quantified amount of energy is being lost. The present energy consumption and exergy ratio are evaluated against the theoretical, physical minimum, which is required to run the process. From this evaluation, optimal design, or improvement options can be identified. Cost/benefits should be analysed before the options are implemented.

Cornelissen (1997) describes, in his Ph.D. thesis, how Life Cycle Assessment (LCA)[25] and Exergy Analyses should be combined. According to his thesis, to determine the efficiency of a system, all kinds of interactions between energy and material flows outside the system's boundaries should be taken into account, not only processes that occur within the system. Only then can the actual performance of the system and its impact on the environment be evaluated. The objective nature of exergy can serve for various applications, from pinpointing the losses within a process to a global estimate of the environmental impact of a certain industry.

The cumulative exergy consumption during the life cycle allows evaluation of the degree of thermodynamic perfection of the production processes. This can also be used to assess the whole process chain. Cornelissen (1997) developed a method, called the Exergetic Life Cycle Assessment (ELK), and showed how to perform this analysis. Several processes were assessed using this method, among them a heat exchanger.

Conserving Energy by Application of Pinch Technology

Linhoff of Leeds University in the United Kingdom developed pinch technology in 1978 (according to the Centre for Environmental Technology Exchange (APEC 1999). It was first put into practical use in 1984, by Linhoff March Co. Pinch technology is a method of using the overall thermal balance of a process to theoretically predict its minimum energy consumption, the construction costs of the plant using a heat recovery system, and other information. These predictions are then employed as targets for the design or renovation of the process. The purpose of pinch technology is to analyse the energy usage conditions of entire plants and groups of plants and optimise the effective use of heat in the plant processes.

Improved heat recovery and reduced consumption of high pressure and high temperature steam can be achieved. The result of this is a reduced use of exergy.

Equipartition of Forces

Sauar (Sauar et al 1996), at The Norwegian University of Science and Technology (NTNU Trondheim), has developed a new principle for process design and optimisation. They call it the "*Equipartition of Forces*". It is a method aimed at reducing the entropy production of a total system, given a

[25] Life Cycle Assessment (LCA) is the analysis of the continuous chain of processes, leading from natural resources to final products, their use and discard and the assessment of their influence on the environment.

specified flux, (transfer duty) and a specified contact or transfer area in the apparatus. Sauar et al (1996) states that an increase in the internal entropy of a system reduces the maximum available work. A new design principle for optimum production of a given set of fluxes with minimum dissipation of energy is suggested in this article. Ratkje and Sauar (Sauar et al 1996) suggest that the equipartition of driving forces rather than equipartition of entropy production rates should be applied to obtain a specified separation (i.e. mass fluxes). The principle can be used for the design of new process equipment, and also to evaluate improvements of existing equipment.

Energy and exergy conservation

The author divides practical improvements in industrial energy efficiency into three main groups. The first group (Group 1) is discrete measures dedicated to energy efficiency. Group 1 measures can be categorised by very low (payback time of less than one year) or zero investments. These groups of options are typically minor housekeeping measures, improved routines for turning off lights, closing refrigerator doors, optimising temperature levels, less water usage per unit time for cleaning equipment etc. Group 2 measures may include, for example, insulation, improved boiler control systems, variable speed drives on electric motors, electric motor revolution control on, waste heat recovery, low temperature heat pumps[26] for maximum utilisation of waste heat, high temperature heat pumps[27], or co-generation of heat and power. Group 2 measures can be categorised by the scale of investments, beginning and moving through low cost engineering/operational improvements, higher cost improvements, investment in new plant with improved performance and finally, investment in new facilities incorporating fundamental changes in basic technology. The key feature of Group 1 and 2 measures is that their primary purpose is to reduce energy use and energy expenditure. Group 1 and 2 measures are broadly suited to the cost benefit assessment necessary for the determination of BAT[28].

Group 3, industrial energy efficiency measures, is less straightforward and connected to Energy Management as a system for continuous improvements. This group of measure is a management measure and is described in Chapter 7 in this thesis.

[26]Heat pumps which typically utilise waste heat at a temperature level from 5 ^{o}C to hot water at a temperature on maximum 70 ^{o}C.
[27] Heat pumps which typically produce hot water at a temperature from 90 to 110 ^{o}C.
[28] BAT = Best Available Technology

Ecosystem, Biogeochemical Cycles

With an understanding of “the greenhouse effect” and the carbon cycle on a macro-level, the following paragraphs clarify the future challenges for industry on a meso- and micro-level.

Introduction and limitations

Ecology is important for understanding the structure, organisation and function of nature and is, according to Smith and Smith (1998 p.3), the scientific study of the relationship between organisms and their environment. *Environment* includes not only the physical but also the biological conditions under which an organism lives. Organisms interact with their environment within the context of an *ecosystem*. The *eco* part of the word relates to the environment. The *system* part implies that the ecosystem is a system. A system is a collection of parts that function as a unit. A heatpump is a system, components of the pump, such as the compressor, are also systems. The ecosystem consists of two basic interacting components, the living, or biotic, and the physical, or abiotic.
Interaction of organisms with their physical environment, interaction within the same populations and interactions between populations came together in the concept of community. The community involves the biota only and is not further studied in this thesis, the author refers to “Elements of Ecology” (Smith and Smith 1998).

Interaction of the biotic community with the abiotic world gives us the ecosystem as one important part of ecology. The living world depends upon the flow of energy and the circulation of materials through the ecosystem. A necessary requirement for the existence of mankind is a rational understanding of the abiotic world as a frame for our existential values. This understanding should be the basis for a nature and environmental ethics for mankind in order not to exceed the capacity of nature. Energy and materials flow through the ecosystem together as organic matter; one cannot be separated from the other. The continuous cycling of elements, driven by the one-way flow of energy, keeps ecosystems functioning. The biogeochemical cycles, the grand cycles (explained in the next paragraph) are an important part of the ecosystem. In the following, the cycles connected to energy consumption and production are addressed. The emphasis is on the carbon cycle, since it is closely connected to energy flow and since Energy Management and environmental management are central to this thesis.

The grand cycles

All elements flow from the non-living to the living and back to the non-living components of the ecosystem in a more or less cyclic path known as the *biogeochemical cycles*. Carbon (C), nitrogen (N), sulphur (S), phosphorus (P) and hydrogen (H), are important biochemical building blocks of life. These elements are incorporated into plants and animals, thanks to the interplay of solar, biological and geochemical processes. Each of these five elements moves from one chemical state to another and from one physical location on the earth's surface to another in closed loops, or "cycles". Many other elements such as Fe, Ca, Mg, Na, Mo, Mn etc. have similar "cycles". Human activities are substantially modifying these cycles.

The carbon cycle

Carbon is so closely connected to energy flow that the two are inseparable (Smith and Smith 1998). In this thesis, the carbon cycle is emphasised since Energy Management and environmental management are central to this thesis.

Figure 3.4. lists the most important anthropogenic releases that lead to the ''greenhouse effect". As stated in the introduction to this thesis, the average temperature in the world has increased significantly in the last 20 years (Figure 1.1). Findings published by IPCC (1996) suggest an increase in the average global temperature of between 1 ^{o}C and 3,5 ^{o}C by 2100. Fifty percent of the greenhouse effect is caused by carbon dioxide (IPCC 1990,p.9).

The 1995 report (IPCC 1995), concluded that the industrial sector accounts for more than a third of the global CO_2 emissions from fossil-fuel combustion (excluding the power generation sector)(IPCC 1999). The report also concluded that the burning of fossil fuels, land-use practices, agriculture, and other human activities have greatly increased the atmospheric concentrations of greenhouse gases (carbon dioxide, methane, and nitrous oxide) (IPCC 1999).

Some researchers disagree that this is a problem, they argue that the change in greenhouse gases is a frequently occurring phenomenon. Some argue that CO_2 is absorbed by sinks, which may be natural (e.g. forests, oceans, sediments) or anthropogenic (e.g. buildings, furniture, paper). In1995 according to statistics of Norway (SSB, 1998 p.50), the natural sink in Norwegian forests was estimated to be 13.6 million tonnes CO_2 per year, which corresponds to about one third of the total anthropogenic emissions from Norway in 1995. This author, however, argues in line with the IPCC. If there is a small percentage of chance for increased unbalance caused by humans, leading to the greenhouse effect, then we should, in the name of future generations, act as if it is a big problem and invest major efforts to reduce the emissions that may contribute to such effects. The "precautionary principle" should be applied in all human activities.

Component	**Important sources**
Chlorofluorocarbons, (CFCs) and Hydrofluorocarbons, (HCFCs)	Cooling fluids
Carbon dioxide, (CO_2)	Combustion of fossil fuels, change in land use and deforestation
Nitrous oxide (N_2O)	Agriculture, fertiliser production
Methane (CH_4)	Agriculture, landfills, production and use of fossil fuel
Perflourocarbons (PFCs and CF_4 and C_2F_6)	Aluminium production
Sulphur hexafluoride (SF_6)	Magnesium production

Figure 3.4. Man made impacts on the greenhouse effect. These activities are increasing the carbon dioxide concentration in the atmosphere and are changing the global climate. (Derived from SSB 1998, p. 49)

Referring to the book "Industrial ecology and Global Change" (Socolow et.al. 1997), the carbon cycle is explained as follows:

> *"In the carbon cycle, carbon dioxide is removed from the atmosphere and reduced carbon is incorporated directly into plants by the process of photosynthesis. A portion of the sunlight that drives photosynthesis is stored as chemical energy in the plant. Unlike the nitrogen cycle, the carbon cycle involves no intermediary stages, which is why we call the carbon dioxide in the atmosphere a nutrient reservoir but the diatomic nitrogen in the atmosphere is a bio-unavailable reservoir. The reduced carbon returns to carbon dioxide by respiration while the plant is alive and as part of the process of decomposition once the plant has died. The decomposition is accomplished by microfauna, bacteria and fungi, acting upon plant litter and fine roots."*

Ayres (Socolow et.al. 1997, p.127) describes the two key chemical reactions (each the reverse of the other[29]) as:

$$CO_2 + H_2O + \text{sunlight} \rightarrow CH_2O + O_2 \rightarrow \text{photosynthesis}$$

(CH_2O = plant proxy)

and

$$CH_2O + O_2 \rightarrow CO_2 + H_2O + \text{energy} \qquad \text{respiration, decomposition}$$

Figure 3.5 shows the human additions to the pre-industrial global carbon cycle. The units are million metric tons carbon per year. In pre-industrial

[29] In quantifying the rate of carbon exchange between the biosphere and the atmosphere, one must distinguish gross primary productivity from net primary productivity. The process of photosynthesis is accompanied by a substantial amount of reverse reaction - nearly simultaneous respiration that releases some of the incident energy to support plant metabolism. Gross primary productivity measures the rate of photosynthesis, and net primary productivity measures the actual rate of increase of the stock of organic carbon. Net primary productivity is generally the quantity of greater interest, because it measures the build-up of plant matter during a growing season."

times the concentration of carbon dioxide in the atmosphere was roughly constant (Socolow et.al. 1994 p. 132), but it has been rising for more than a century. In the middle of the last century, about 280 of every million molecules in the atmosphere were carbon dioxide molecules (280 parts per million by volume, or 280 ppmv). Today the value has risen by 25%, to about 355 ppmv. The current rate of increase is about 0.4 percent per year.

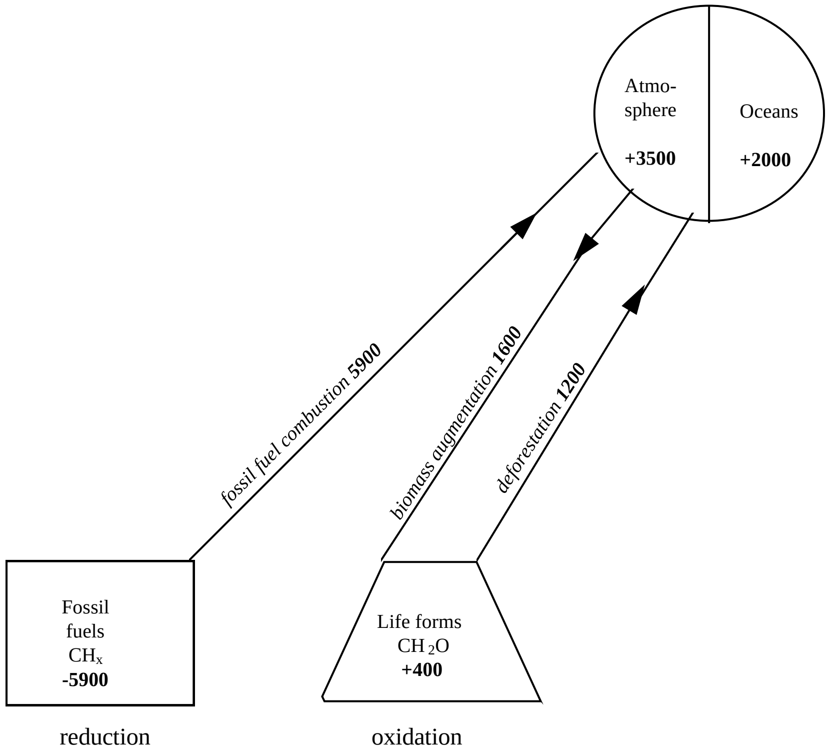


Figure 3.5 Human additions to the pre-industrial global carbon cycle. Units: million metric tons carbon per year. (From Socolow et.al. 1994 p. 133)[30]. Changes in reservoir stocks are shown by entries inside the boxes and sum to zero. Human impacts, dominated by the combustion of fossil fuel and deforestation, lead to an increase in carbon dioxide in the atmosphere and bicarbonate in the oceans. The estimates shown here assume the “missing carbon” is in land plants. The chemical structure of fossil fuel is stated as CHx to emphasise that the ratio (x) of hydrogen atoms to carbon atoms in fossil fuel is variable, ranging from 4 for natural gas to less than 1 for coal. The rate of combustion of fossil fuels and the rate of increase in the atmospheric stock are known accurately; the other estimates are highly uncertain.

Referring to Ayres (Socolow et.al. 1994), it is not yet possible to accurately assess the significance of human beings in the disturbance of the global nitrogen cycle - either in absolute terms, or relative to the disturbance of the global carbon cycle. The disturbance of the global carbon cycle is probably leading to global warming, and the disturbance of the global nitrogen cycle is probably leading to global eutrophication.

[30] Changes in reservoir stocks are shown by entries inside the boxes, which add up to zero. Human impacts dominated by the combustion of fossil fuels and by deforestation, lead to an increase in carbon dioxide in the atmosphere and bicarbonate in the oceans. The estimates shown here assume the “missing” carbon is in land based plants (see text). The chemical structure of fossil fuels is stated as CHx to emphasise that the ratio (x) of hydrogen atoms to carbon atoms in fossil fuels is variable, ranging from four for natural gas to less than one for coal. The rate of combustion of fossil fuels and the rate of increase in atmospheric stocks are known accurately; the other estimates are highly uncertain.

Figure 3.5 also illustrates that fossil fuel combustion and deforestation are responsible for the two most important increments to the pre-industrial flow of carbon dioxide from the land to the atmosphere. Their sum is about 7100 million metric tons per year. An important illustration of the incompleteness of environmental science today is that we cannot fully account for the fate of this additional flow. We can infer from Figure 3.5 that 3500 million metric tons of carbon per year, is accumulating in the atmosphere. Therefore, about 3600 million metric tons of carbon per year must be accumulating either in the oceans or in terrestrial biomass. The oceans appear to take up about 2000 million metric tons of carbon per year (Ayres in Socolow et.al. 1994 p. 134). The remainder, 1600 million metric tons of carbon per year, is called the “missing carbon” which can be in one of two places. Either the “missing carbon” has gone into the oceans, which would mean that the carbon sequestering processes are misunderstood, or the “missing carbon” is accumulated in terrestrial biomass elsewhere (i.e. at sites other than the sites of deforestation, where small changes in total terrestrial biomass are very difficult to detect). From Ayres (Socolow et.al. 1994 p. 134), the missing carbon may be going into the temperate forests of North America and Russia, increasing their stocks of biomass in spite of increased timber and wood pulp harvesting.

The principal human activity disturbing the carbon cycle (fossil fuel use) has long been the subject of innovations in technology and policy designed to reduce environmental impact.

Combustion of Fossil Fuels

There is a huge reservoir of buried, dispersed, organic carbon. Some of this has been aggregated by geological processes and transformed by heat and biological activity to form coal, petroleum, and natural gas. Humans are adept at finding and extracting these buried hydrocarbons wherever large amounts are in one place. We are commercialising such resources at increasing depths below the earth’s surface, and at increasing depths offshore. Extraction and combustion of these fuels has contributed significantly to altering the atmospheric CO_2 balance. The basic combustion equation connected to pure carbon is:

$C + O_2 = CO_2$ (Sonntag and Van Wylen 1982, p. 453), However, coal combustion delivers less energy with each carbon atom than oil does, and oil less than natural gas. The reason for this is that different fossil fuels have different chemical bonds with hydrogen. Coal has less than one hydrogen atom per carbon atom, oil has about two, and natural gas (which is largely methane) has almost four. Energy is released from the oxidation of both carbon and hydrogen. As one example, the basic combustion equation for propane is:

$C_3H_8O + 5O_2 \rightarrow 3CO_2 + 4H_2O$ (Sonntag and Van Wylen 1982, p454),

Hence, an intermediate term strategy for reducing carbon transfer to the atmosphere from fossil fuels is to shift fossil fuel use away from coal and oil towards natural gas (provided leakage of unburned natural gas to the atmosphere can be kept to a minimum). A Norwegian company, Norsk Hydro, is planning to build a natural gas-based power station for electricity production[31]. They will utilise new technology. The carbon dioxide produced by the plant will be pumped into oil reservoirs offshore, below the ocean floor. The idea is to use non-renewable resources, but not to add carbon dioxide to the atmosphere, thus minimising the contribution to the greenhouse effect.

Williams (Socolow et.al. 1997, p.132) suggests that five to ten percent of global biomass oxidation could be arranged to occur within energy conversion facilities that produce electricity and gaseous and liquid fuels. This would permit leaving an equivalent amount of fossil fuel below ground. Without human intervention, this biomass oxidation would occur in a dispersed manner (decay on the forest floor, for example), releasing energy in forms too dilute for current technology to harness. The biofuels industry could be based on renewable plantations, where carbon dioxide released through combustion would be absorbed from the atmosphere through new plant growth. This could be an approximately carbon neutral system.

Another long-range strategy, explored by the author's colleagues (Saur et.al 1996), is to substitute biomass for coal in the reduction process in the silica and ferro-silica production processes. Only small modifications to the kiln are required. In Brazil for example, a ferro-alloy plant uses nearly 100 % biocarbon (and no coal) as reduction material in their process (Saur et.al 1996).

[31] See for instance: http://www.energionline.com/avis/reportasje/002121198.html

Renewable energy sources

Renewable energy derived from resources such as the sun, wind, and water flow, generally do not cause changes to the grand cycles in their production phase. In a life cycle perspective the situation is different. Life cycle analyses calculating the depletion of energy-sources in the entire life cycles might change this picture somewhat. The construction and waste phase of renewables will generally cause pollution. For this reason, a life cycle analysis should be performed connected to selection of the energy source. The purpose and the net consumption per unit time should be carefully considered in conjunction with life cycle analyses before the energy source is chosen. In some cabins in Norway, solar power is used as the source of power for lighting. Some of these solar energy systems never capture the equivalent amount of energy to that which was necessary to produce the equipment in the first place. This is because they are utilised only a very few hours per year.

However, renewable natural energy sources can be converted into usable energy in several ways. There are a number of technologies for conversion of renewable energy such as hydropower and biomass that are well developed in Norway, where 99% of electrical energy is produced from hydropower and private houses are commonly heated by wood. Other conversion technologies, such as wind turbines, solar energy for domestic hot water, photovoltatics, electricity from waves on the ocean, are already well developed. Although geothermal energy is produced from geological, rather than solar sources, it is often included as a renewable energy resource. Finally, heat pumps should be mentioned as a technology with a high potential. This technology is well developed and can be utilised at a high rate. Increased use of heat pumps is one of several alternatives, which can reduce the amount of electricity used for heating purposes. A new Norwegian heat pump, developed by the Norwegian University of Science and Technology/SINTEF (Nekså et.al. 1998), use CO2 as a working fluid. CO_2 is one of the few non-toxic and non-flammable working fluids that do not contribute to ozone depletion or global warming, if leaked to the atmosphere. Tap water heating is one promising application for a trans-critical CO_2 process. The temperature glide at heat rejection contributes to a very good temperature adaptation when heating tap water, which inherits a large temperature glide. This, together with efficient compression and good heat transfer characteristics of CO_2, makes it possible to design very efficient systems. An efficiency factor of 4.3 is achieved for the prototype when heating tap water from 9 to 60^{o}C, at an evaporation temperature of

0^oC. The results lead to a seasonal performance factor of about 4 for an Oslo climate, using ambient air as heat source. Thus, the primary energy consumption can be reduced with more than 75% compared to electrical or gas fired systems. Another significant advantage of this system, compared to conventional heat pump water heaters, is that hot water with temperatures up to 90^oC can be produced without operational difficulties.

For further information on renewable energy applied to Norway, see Salvesen, (1996, p.4-66), CADDET (1998b) and CREST (1998).

Renewables have however, not achieved the highest profit rate and market penetration of which they are expected to be ultimately capable. In general, renewables loos the competition to “cheap” energy based upon oil, gas and coal. Market penetration could be accelerated by governmental policies on energy prices as one important measure.

Relevant Points for this Study

Energy efficiency research in Norway, over the last few years, has revealed that it is possible to compare different production methods according to their consumption of energy. It is also possible to calculate how much the different processes should use, and from this, predict how an energy efficient process could be designed and implemented. The following methods can be utilised: Exergetic Life Cycle Assessment, (Cornelissen 1997), Sankey diagrams (illustrated in Figure 3.3), Pinch Technologies (APEC 1999) and Equipartition of Forces (Sauar et al 1996).

When designing an energy efficient system[32], the following questions are important:

- How far are we from a theoretical minimum of energy consumption per unit of production?
- How can we obtain optimum exergy efficiency?
- How can energy supply systems made to be profitable, in the short term?
- How can energy supply systems made to be ecologically sound in the long term?
- How can different stakeholders, including the government, stimulate industry to make the “right” choices?

[32] Energy system means in this context the support equipment necessary to supply energy, e.g. steam, hot water, or electricity, oven, heat exchanger, ventilation system etc., required to support a certain defined energy consumption in a geographical area.

Figure 3.6 lists the possibilities according to profit and type of energy source. Often, more than one possibility occurs inside the cells containing profitable options.

Known profitable energy resources	Unknown profitable energy resources
Known not profitable energy resources	Unknown not profitable energy resources

Figure 3.6 Four main categories of energy sources. The diagram shows the groups of possible choices. (Holter 1989)

In the process of choosing between the energy sources acceptable in economic terms, industry still has a dilemma. The right energy source and energy system must be chosen. From the author's experience, there is no focus on this dilemma in industry, or in the companies hired to design equipment for industry. This is the reason for developing design criteria emphasising exergy and for stating the research question R8, "testing the know-how on exergy in industry".

To know which energy sources and which energy systems are best from an eco-efficiency[33] perspective (OECD 1998) Sustainable Energy Performance Indicators (SEPI)[34] should be developed and utilised.

There are four main dilemmas in trying to select the most appropriate type of energy supply (see Figure 3.7).

CRITERIA FOR CHOOSING

To select the appropriate energy supply as presented in Figure 3.7, the following criteria are useful. Considering the lowest possible carbon dioxide emissions, the first design criterion applies.

> ***Utilisation of the highest feasible proportion of renewable energy sources to fulfil the energy requirements***

If a minimum of carbon dioxide is to be emitted in a situation where you have limited renewable energy sources available, the first and second laws of thermodynamics should be taken into consideration. The second design criterion should be:

[33] Eco–efficency is defined in Chapter 8.

Utilisation of the lowest feasible proportion of exergy consumption to fulfil the energy requirements

Applying this criterion, however, the author suggests that principles like Exergetic Life Cycle Assessment (Cornelissen 1997), Sankey diagrams (illustrated in Figure 3.3), Equipartition of Driving Forces (Sauar et al 1996) and Pinch Technology (APEC 1999) should be utilised.

THE DILEMMA

On the left side of Figure 3.7, the carbon dioxide emissions are high due to utilisation of fossil fuels. If a minimum of carbon dioxide emission is the goal, then the left portion of the figure should be avoided, as far as possible.

Low share of renewable energy Low share of exergy	High share of renewable energy Low share of exergy
Low share of renewable energy High share of exergy resources	High share of renewable energy High share of exergy resources

Figure 3.7. Four main dilemmas when choosing the type of energy supply

Looking at the right side of Figure 3.7, this refers to the sustainable approach. In order to benefit from these approaches, we should carefully design energy consumption according to the following criterion:

Utilisation of the lowest feasible proportion of exergy consumption to fulfil the energy requirements

This criterion will tell which is the best choice.

TWO EXAMPLES

1. If the need is to support lights and electrical machinery, it is a physical need for a high level of exergy. Possible choices lie in the bottom two cells. “Best choice” (The most sustainable energy source) is on the bottom right in Figure 3.7.
2. If the need is to heat a building, low temperature and low exergy share is sufficient. While the possible choices are all four cells, the most sustainable and energy efficient choice is the upper right cell.

[34] Referring to literature like the European Green Table’s, “Environmental Performance Indicators in Industry” (Økstad 1997), questions on 1) level of Exergy/anergy, or 2) level of renewables are not considered in the methodology. This is the reason for introducing the SEPI term.

“The less sustainable choice”, is in the bottom left cell, however this cell corresponds to the most common choice currently used in heating Norwegian buildings. Referring to Sjøvold (Sjøvold et al. 1994), electrically powered heaters for buildings are in common use for both living and business purposes. In industry, the picture changes somewhat, but in older industry (older than a decade) oil, or electricity are the most common energy sources.

Conclusions

Considering physical laws, such as the first and second laws of thermodynamics, important design criteria should be:

> ***“Utilisation of the highest feasible proportion of renewable energy sources to fulfil the energy requirements”***

and

> ***“Utilisation of the lowest feasible proportion of exergy consumption to fulfil the energy requirements”***

To apply the theory and conclusions presented in this chapter in industry, organisational learning is important. This is outlined in the next chapter.

Chapter 4 Humans learning in organisations

> A human being with both feet on the ground, doesn't move[35]
> (Bringsvaer 1972)

Content of this chapter

This chapter describes one of the disciplines that is the theoretical bases for this thesis. The chapter begins with a presentation of the requirement for human learning and continues by presenting theoretical approaches regarding organisational learning. It is an important challenge for industry to utilise this, in order to achieve improvements related to environmental issues. Understanding the theoretical basis of organisational learning is important in order to achieve Cleaner Production, for performing Cleaner Production Assessments, and for optimal implementation of Environmental Management Systems and Energy Management programmes. It is important to utilise current theory and experience of organisational learning in order to move towards sustainable development. Developing this chapter, the author has been challenged and inspired from a Ph.D. thesis on "Joint Management" and learning organisation (Zwetsloot 1994).

Central questions

The most important challenges pertaining to improvements in industry with regard to environmental issues are not only the technical issues, but also non-technical issues such as:

> *"How do organisations learn about environmentally related issues?"*

and

> *"How do people in organisations learn and then act differently based upon the lessons learned?"*

Assumptions and limitations

One assumption is the belief in human being's subjective constitution. This approach assumes that all human action is more or less, based on a personal theory or abstraction. Everything human beings do, or, on purpose, don't do, is based on a, more or less verbalised, personal theory of action (Argyris and Schön 1978, p. 4). Schulman (1995 p. 158) put it this way:

> *"the first requirement for effective teaching is that the pupil must have a stake in the outcome."*

[35] My wife would like to add here; a man with both feet on the ground probably has his car in the workshop.

Teaching and learning

The process of teaching and learning is affected by many variables. These variables occur in the subject, the context of learning, the teacher and the pupil, as well as the interaction among them. The pupil is not simply a passive object onto which the teacher can project already developed ideas. Rather, the pupil is actively involved in the learning process. This view, elaborated by Dewey (1916), maintains that

> *"The organism is not simply receiving impressions and then answering them. The organism is doing something; it is actively seeking and selecting certain stimuli."* Dewey emphasised that *"the primary subject matter of knowing is that contained in learning how to do things of a fairly direct sort." (p.205)*

Schwartz (1979), in discussing education in the classroom, also commented on the importance of the active involvement of the pupil. Citing the contribution of 18th-century historian and philosopher Biambiattista Vico, he argued:

> *"This is the true process by which students learn: they cannot own their knowledge until they have 'made' it, worked it over, put their mark on the data, imposed their own order upon it, and altered it to fit with what they already have learned".*

Of course, the more factual the knowledge, the less it is open to being 'altered'.

Knowing the subject and transmitting the ideas is clearly an important precondition to teaching. However, these skills should not be confused with the entire process. Schwartz (1979) put it as follows:

> *"In the light, the problem of the transmitting functions is not that it is '-progressive' or even unproductive, but simply that it does not go far enough into the educational process. When the facts are told, the notes taken down, the 'truth' laid out, the work is only just begun. The hardest part remains."*

Learning in organisations

Need for change

In a market full of competitors, a company's situation is often very uncertain, turbulent and rapidly changing. In Western culture the requirements from shareholders force industry leaders to keep maximising the profit as rule number one. The market requires dynamic improvements of the products and services. Market demand for eco-efficient products and services is increasing[36]. This fact tells industry leaders rule number two; *"listen to market demands"*. In Chapter 10 in this thesis, data collected from industry leaders supports these two rules as the most important ones. Industry leaders act according to these two rules. Fortunately, the market increasingly also requires eco-efficient[37] products and services. The need for differentiation in skills and knowledge inside the company increases. The organisation must adapt to changes through learning.

Production is run with a minimum of employees. Dynamic economic pressures, force competing companies into this situation. The staffing level in a good and economically healthy company is very limited. Especially for small and medium sized companies, there are inadequate staffs for developing "new" projects. The hours of work for the workers and those in a position of responsibility are very often directly connected to the day's production. Starting the journey towards cleaner production[38] means change. Figure 4.1 describes part of this journey, starting with three phases: present situation, change and future situation. (Amundsen 1993)

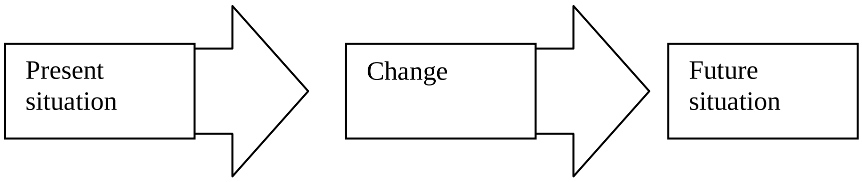


Figure 4.1. The main phases of organisational change. (Amundsen 1993)

To achieve change, effort and time are required. It is important to obtain a continuous learning process. The phases shown in Figure 4.1 can be effectively integrated into double-loop learning, as described later in this chapter.

To obtain sustainable changes in an organisation, both top down and bottom-up approaches should be utilised. These approaches are described later in this chapter.

Five parts of a learning organisation

In *The Fifth Discipline*, Peter Senge (Senge 1990) describes the five parts of a learning organisation broadly. Each part has an essential role to play in developing the right atmosphere for learning and for growth to take place.

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[36] As one example, there has been increasing demand for milk produced by farmers using no pesticides or synthetic fertiliser. The market share for "organic farmed milk" in Copenhagen is 20% at present. This change has required new skills both from the management and workers during the past ten years. The production process was improved.

[37] Eco-efficient products (OECD 1998) are further described in Chapter 8 of this thesis.

[38] Referring to a quote from Professor Donald Huisingh (1990): *"Cleaner Production is a journey, not a destination".*

Senge clarifies the first four critical disciplines for successful organisational learning as follows:

1. Personal mastery.

Senge recognises that mastery means achieving a special level of proficiency. Here there is a need for continuous clarification of one's personal vision and a deepening of the understanding of it. It becomes the focus of energy and the basis upon which priorities are established. Employees have to develop patience and ability to make observations and analyses. A gap between the reality of today and tomorrow's vision needs to be closed by actions to achieve the goal. Reducing expectations should not do this. This can be seen in Figure 4.2.

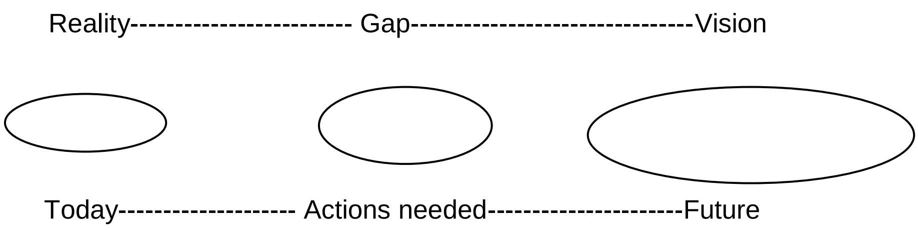

Figure 4.2 The gap between reality and vision and the actions needed to close this gap.

2. Mental models.

These are assumptions, generalisations, patterns or images that influence how we understand the world. They are the precursors to actions.

3. Building shared visions.

It is a clearly recognised fact, derived from empirical evidence all around us, that leadership has inspired organisations over the years by presenting a shared picture of the future, which we wish to create.

4. Team learning.

In an organisation the power of the team to enhance learning is great. The team may be at its best when it is purposely selected for a set tenure. It will help to bring about the fundamental shift of thought needed to break with the past and provide a giant step forward.

In the *fifth discipline,* Peter Senge (1990) stresses that system thinking should be a central discipline in organisational learning. System's thinking is about interrelated actions which provide a conceptual framework, or a body of knowledge, that makes the pattern clearer. It is vital that the five disciplines develop as an ensemble. Senge presents the learning dilemma that confronts organisations (1990 p. 23): *"We learn best from experiences but we never directly experience the consequences of many of our most important* *decisions".* Senge addresses 11 elements, which clarify the parts of the fifth discipline (1990 p. 57-67). The first of these elements is this author's favourite: *"Today's problems come from yesterday's solutions."*

The essence of the discipline of system thinking (Senge 1990, p. 71) lies in a shift of mind:

- seeing interrelationships rather than linear cause effect chains and;
- seeing processes of change rather than snapshots.

This author would like to connect this essence of system thinking to Cleaner Production (CP) and Sustainable Development (SD).

"CP and SD are a journey, not a destination" (derived from Huisingh 1990). This expression is in line with Senge's *fifth discipline,* system thinking. Obtaining CP and SD is indeed not a snapshot, but part of a process of change.

Development of employees and conditions for human learning

Referring to Ken Heap (1998) pre-conditions for change and innovation are applied know-how, involvement and action. Implemented improvement options depend on these three main factors. Figure 4.3 illustrates this.

Organisations that find, develop and motivate talented people to a common goal will be winners in the competitive market in which they operate. This applies whether the common goal is maximum profit, or minimum environmental impact. Why is it that some companies manage to build and retain a stock of talented people? Does it have to do with conditions of work, which mitigate against some less technologically advanced industries, or with salary and working conditions? The answers are often none of these. According to Bain (Bain 1995), the answers are related to:

- excitement of the work place;
- involvement in the future;
- feeling of belonging within the organisation.

Comparing these three main issues from Bain (1995) and the know-how, involvement and action (Heap 1998) from Figure 4.1, we recognise involvement as a most important common issue. Connected to an organisation, this author will emphasise involvement as most important, but the remaining four issues are also important preconditions for innovation and change. All conditions are important in order to provide a state of continuous learning, or, as some writers put it, "a learning organisation".

A learning organisation consists of

- teaching humans in the organisation;

- for this reason the organisation develops;
- the organisation continuously changes and learns.

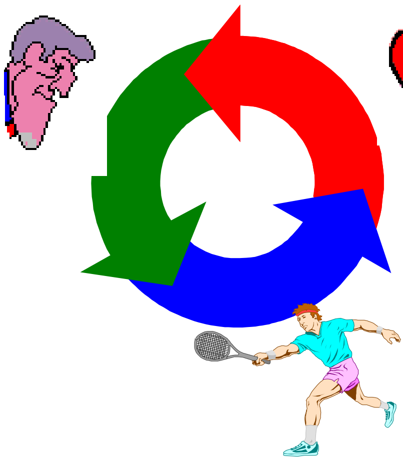

Figure 4.3 Preconditions for change and innovation. Know-how, involvement and action are the three main factors. (Heap 1998)

Learning is not about cramming the mind with even more facts, it has to do with study, practice, feedback and change.
What is required in order to develop superior people and to give added value for the company?
Creation of an environment for continuous learning is crucial. This, of course, involves the leader and the top management, who have to be active catalysts in involving employees at all levels within the company.

Top-down and bottom-up strategies.

In organisational learning, both top-down and bottom-up approaches (Argyris 1985 p. 95-97) have been utilised in industry.
Thoresen tested these approaches in a Norwegian factory (Thoresen 1998 p.4), and concluded:

> *"Results from a pilot survey comprising 450 employees, at all levels in Peterson Moss AS, has underscored the need to combine a 'top-down' perspective in planning and development activities with a 'bottom-up' perspective and increased employee participation. It has been found especially important to include foremen and group leaders at the bottom of the management ladder more closely in this planning and development process."*

Applying top-down and bottom -up approaches, the organisation of an improvement project, must involve top, middle and lower management, as well as employees from throughout the organisation. People directly connected with production: production leaders, technically responsible persons, maintenance persons and operators in the production process should be involved. The time available for learning activities and changes is often very limited. Changes usually cause stress, whatever the type of change. However, the company's success in the market is necessary for people in the organisation to have a job and an income in the future. Changes that will improve the company's position in the market are, despite a higher level of stress, of interest for people in organisations. The situation after the change is implemented may also mean better working conditions, e.g. automatic machinery is doing the hard work, or quality is improved so that product quality, worker health and safety and profitability are all improved.

Most industrial companies are subjected to considerable uncertainty, competitive turbulence and external changes. Authority must be delegated to employees at all levels in the organisation. This and employee participation in planning and development processes are essential factors in the process of preparing for, and taking advantage of, such uncertainty and change. However, many companies have little experience with delegation of responsibility and employee participation. An organisation model (with its balanced 'bottom-up'/'top-down' action) seems to be a good foundation for a successful organisation's culture and for the design of an integrated management system. It is a good foundation for breaking loose from bureaucratic control.

Based upon this thesis writer's experience, the requirements emphasised by Warren Bennis (1989) and Heap (1998), referred in the former paragraph, also go for employees working on environmentally related issues. The managers should, through a bottom-up and top-down strategy, seek to develop the staff on all levels. Defining the limits in responsibility and authority connected to each person is important in this work. If the manager requires responsibility but no authority, results do not occur.

Single-loop and double-loop learning

The advantageous effects of feedback on performance and motivation have been widely recognised by researchers from the early 1950s (Ashford & Cummings, 1983). Feedback processes have been widely recognised as important potential means of learning in organisations. In the early years the focus was put on the effects of feedback on individuals. Most discussions also tended to ignore individual differences, a perspective that later proved to be much too narrow. The reason for this is that the perception of feedback may be biased according to the receiving individual's characteristics. Thus important information may be distorted depending on the relationship between the sender and the receiver (Ashford & Cummings, 1983; Ilgen et al., 1979).

Argyris and Schön (1978, p.2), describes organisational learning as a process of detecting and correcting error. Error is defined as any feature of knowledge or knowing that inhibits learning. When this learning process enables the organisation to carry on its present policies, or achieve its present objectives, it may be called single-loop learning. Single-loop learning is like a living room thermostat that learns when it is too hot or too cold and turns the heat on or off. The thermostat receives information and performs *corrective actions* (Agryris and Schön 1996 p 21). Morgan (1997) illustrates single-loop learning as shown in Figure 4.4. A simple thermostat however, is unable to determine what level of temperature is appropriate to meet the preferences of the inhabitants of a room and to make adjustments to take account of this. When an organisation is capable of questioning the underlying policies, goals and programs, double-loop learning occurs. Double-loop learning is when an organisation challenges its own actions, assumptions, policies, norms or objectives. There is active confrontation of discrepancies that may be found between espoused and real actions, assumptions etc. New insight by open confrontation and testing and treatment of errors are important characteristics of double-loop learning (Argyris and Schön, 1996 p. 20-25); Morgan, 1997 p.85-89). The different elements of double-loop learning are illustrated in Figure 4.5.

How to succeed in implementing double-loop learning?

Argyris and Schön (1996 p. 73-175) states that there are two models of behaviour that either oppose (model I), or encourage (model II) double-loop learning. Model I state that people need to control their own actions. They feel good when they manage to attain the desired results. They strongly dislike to lose - or feel that they lose - control. There is a need to control tasks to be done by other people, decide what to tell people and what information must be distorted in order to save somebody's face. In Model II people are helped to produce valid information, make informed choices and develop an internal commitment to these choices. The model requires that one strive to develop employees with as much motivation and as deep a sense of organisational stewardship as possible. Senge (1990, p.206) called for a '*shared vision'* and emphasised that this is vital for the learning organisation because it provides the focus and energy for learning.

To make their models operational in an organisation, Argyris and Schön (1996, p. 120), have developed a detailed description of social attitudes, characterising the two models in Table 4.1. The information in this table, illustrates that an organisational culture satisfying model I is very much different from a culture that satisfies model II. This means that making an organisational change from model I to II require major changes in management style, organisation and responsibility structure, degree of employee participation, organisational competence etc. The implementation period often takes several years. This means that strong management initiative and support are required, along with a broad set of systematic, long-term and organisation-wide activities.

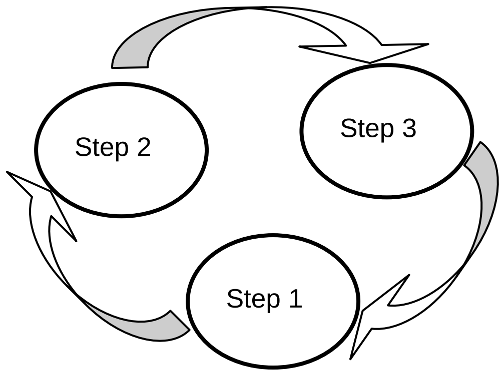

Figure 4. 4 *Single-loop learning* rests in an ability to detect and correct error in relation to a given set of operating norms. (Morgan 1997, p.87).

Step 1 = the process of sensing, scanning and monitoring the environment.

Step2 = the comparison of this information against operating norms.

Step 2a = the process of questioning whether the operating norms are appropriate.

Step 3 = the process of initiate appropriate action.

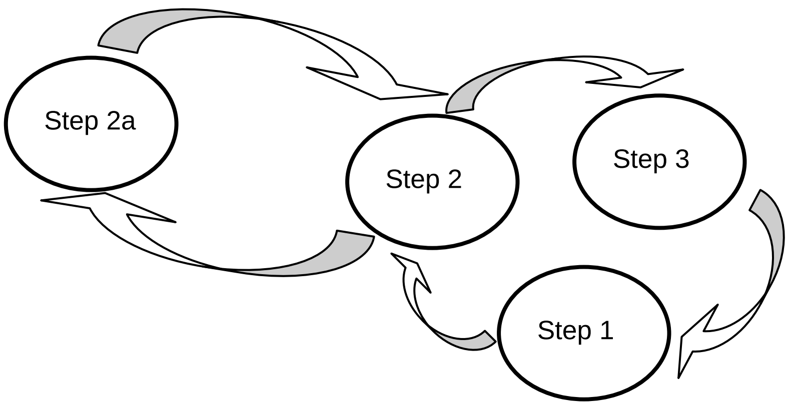

Figure 4.5 *Double-loop learning* depends on being able to take a “double look” at the situation by questioning the relevance of operating norms. (Morgan 1997, p.87).

Thoresen (1998, p. 20) stresses that the learning loop should be co-ordinated and scheduled with the budget system in the company. One main point here is that if an organisational change requires investments, proposals of these investments should be proposed to the management before the next year budget or the long-term budget is decided. This suggestion is important to show involved people a follow-up of their efforts and activities.

Table 4.1. Model I and II behaviour characteristics. Model I opposes, and model II encourages double-loop learning (From Argyris and Schön, 1996, p.120)

Model I Social Virtues	Model II Social Virtues
Help and support: Applaud and praise to others. Tell others what you believe will make them feel good about themselves. Reduce their feeling of hurt by telling them how much you care, and - if possible - agree with them that the others acted properly.	**Help and support**: Increase the other's capacity to confront their own ideas, to create openness of mind and to stand face to face with their own hidden suppositions
Respect for others: Leave the responsibility to others and do not confront their reasoning or actions.	**Respect for others**: Expect a considerable ability in others for self-reflection and self-judgement. This needs to be without being so upset that they loose efficiency and understanding of their own responsibility and choices.
Strength: Advocate your position in order to win. Keep your own position in the battle against others. Regard the feeling of vulnerability as a sign of weakness.	**Strength:** Advocate your position and combine this with investigation and self-reflection. The feeling of vulnerability when being challenged is a sign of strength.
Honesty: Tell other people no lies, or tell others all you think and feel.	**Honesty:** Encourage yourself and others to tell whatever they fear to tell. Do not use distorted information.
Integrity: Stick to principles, values, and beliefs.	**Integrity:** Advocate your principles, your values and your beliefs in a way that encourages an evaluation of them. Invite others to do the same.

Referring to Thoresen (Thoresen 1998 p 6), performance indicators may be used for planning, scenario evaluation, developing objectives, control and information purposes. They may be:

- direct measures of performance (e.g. quantifying production rate, pollution rate or product quality characteristics), or
- measures of some intermediate performance characteristics related to ultimate performance (e.g. CO_2 emission as an intermediate measure of global climate consequences, or measuring the degree of creativity as an intermediate measure to predict future company performance).

Double-loop learning requires an opposition or reference of ideas for comparison. Level of performance cannot be effectively questioned without good longitudinal benchmarking data. Own progress, or lack of it, can be benchmarked. In Chapter 11 examples of benchmarking from 540 Norwegian companies (related to energy consumption per unit produced) are described.

One problem according to Thoresen (1998, p.52), is that many cause-effect (or dose-response) relationships between process output characteristics and end effects are uncertain, unknown, or cannot be measured. Thus, when selecting indicators for intermediate measures, valid descriptions of the end effects of interest should be emphasised. The monitored indicator level must give a correct description of performance at the time of measurement. Poor indicator validity, or reliability may lead to unsatisfactory, or even counterproductive, remedial action.

It is essential that the gap between goal and performance exceed the tolerance of the instruments, or practices, used for monitoring.

Learning in organisations in the future

Future organisations

The R&D projects at Massachusetts Institute of Technology, (MIT) on future organisations called, "Inventing the Organisations of the Twenty First Century", project changes in the way successful business will be organised in the next century. They found that the following should be emphasised:

1. Inventing new organisational processes, especially those that take advantage of information technology;
2. The impact of ubiquitous information on the management of a company;
3. The role of organisational culture in organisational learning;
4. Managing the boundary-less corporation.

This author would like to stress the importance of workers' "wellbeing" both at work and in private, as one element in future organisational learning. In line with this Senge (1990, p. 312) exemplifies future challenges:

- Support personal mastery as a part of the organisation's philosophy and strategy.
- Make it acceptable for people to acknowledge family issues as well as business issues and to interject these into pertinent discussions, especially discussions involving time commitment.
- Where needed, help people to obtain guidance for how to make effective use of their family time.

Employees' "wellbeing" may increase their capacity both at work and at home. Future organisations should care about employee's wellbeing as described. Bain (1995) and others state that "involvement in the future" is one of the three most important factors in learning in organisations. Responsibility for nature and environmental issues, for future generations and one's own children and grandchildren, are, for most people, important cultural issues. Most people take this responsibility seriously, but have seldom had the opportunity to influence the future in their working career. Implementing EMS systems, or performing a Cleaner Production Assessment in companies, can often create enthusiasm among the people working on these issues. However, in order not to waste this enthusiasm, the management has to create an organisation that is truly a "Learning Organisation", based on "*learning by doing"*, the fifth discipline, double-loop learning and bottom up/top down approaches.

Networking

Networking among factories can be an efficient way to organise organisational learning. Industrial leaders working together in networks may exchange experiences and know-how in a very efficient way. Know-how is allowed to flow from inside to outside and vice versa. Besides meetings, computerised communications, telephone meetings etc, excursions and visits to each other's production lines are beneficial for the participants and help to develop effective information and problem solving communities.

Conclusions

This chapter examines organisational learning, dealing with the requirement for human learning and using this as a bridge to present-day theoretical approaches regarding human learning in organisations. Understanding learning in organisations, and the limitation of current learning theories in the understanding of interpersonal interaction, is essential for improving the efficiency of learning in organisations. The Dewian principle of *"learning by doing",* should be emphasised. Future challenges on environmental improvements will require formal competence, motivation for education and courses that are interactive with working. Securing employees' personal satisfaction, *"what's in it for me?"* is important in order to remove obstacles to organisational learning. Employees can improve their working capacity and creativity if they are well accepted by colleagues, or managers. Argyris and Schön (1978,1996) and Morgan (1997) emphasise the importance of performing organisational learning as a double-loop learning process. For big future environmental challenges on the companies' journey to sustainable development, methods related to Factor-10, Eco-efficiency, Industrial Ecology and Zero-outlet should be utilised. In this process double-loop learning should be emphasised. How to apply this to environmental issues in an organisation is presented in Chapter 6 "Cleaner Production Methodology". The author support utilising both bottom up and top down strategies to obtain an efficient journey to cleaner production. This is further described in Chapter 6. Besides utilising double-loop learning and the top-down/bottom-up approaches, employee satisfaction should also be emphasised by management.

If employees are well managed (utilising the requirements, approaches and methods described in this chapter) they show that they can handle uncertainty and complex problems in ways that by far exceed the capability of the individual employee. This author would like to connect system thinking in the way it is presented by Senge (1990) to Cleaner Production (CP) and Sustainable Development (SD). *"CP and SD are a journey, not a destination"* (derived from Huisingh 1990). This expression is in line with Senge's *fifth discipline,* system thinking. Obtaining CP and SD is indeed not a snapshot, but part of a process of change.

In the next Chapter, the theory of organisational learning is applied to supervision. The application of this theory to Cleaner Production, Environmental Management and Energy Management is presented in Chapters 6 and 7. The importance of evaluating performance in organisational learning is considered in Chapter 8.

Chapter 5 Supervisors – how should they approach interactional supervision?

Abstract

In the previous chapter organisational learning theory was presented. Organisational learning was stated to be among the most important challenges for helping companies to “solve” environmental problems. External and internal advisors, in their work for industry can play important roles in advising how this learning process can be facilitated. Interpersonal interactions and dialogues are essential for the development and change processes in an organisation. If these interpersonal interactions are co-ordinated through systematic supervision, effective and continuous learning can be achieved.

Shulman (1995) and Heap (1998) describes a method for supervising social workers. Their findings are similar to those of this author, who has applied this method to industrial employees and external advisors. Supervisor’s roles are focused in the context of organisational learning theory.

It is suggested that the Dewian principle of *“learning by doing”* (Dewey 1916, p. 22, 69-79) should be expanded to include *“learning by supervised doing”.* Interpersonal interaction and dialogue is essential for development and change processes in an organisation. If this interpersonal interaction is performed by systematic supervision, learning can be improved.

Introduction

Schwartz (1979), in discussing education in the classroom, also commented on the importance of the active involvement of the pupil. Citing the contribution of 18th-century historian and philosopher Biambiattista Vico, he argued:

> *“This is the true process by which students learn: they cannot own their knowledge until they have ‘made’ it, worked it over, put their mark on the data, imposed their own order upon it, and altered it to fit with what they already have learned”.*

This is the central conclusion of this chapter on the educational function of supervision. The staff members should be active participants in the learning process. The supervisor’s job is to present ideas and to monitor the way in which the worker relates to these ideas.

Central question

The most important challenge facing advisors working with organisations is how to contribute to progress, development and change. Important question is:

How can advisors best contribute to organisational learning and change?

Assumption

Should the advisor or supervisor[39] be an external or internal person?

The answer to this question depends upon many different conditions, according to the situation in the company. According to Shulman (1995), there is one underlying assumption for improvements in supervision:

"The belief that a number of common dynamics and core skills are central to all supervision processes."

Derived from Kadushin (1985, p. 24) a definition of supervision is:

"A supervisor is a company staff member or an external advisor to whom authority is delegated to direct, co-ordinate, enhance, and evaluate on-the-job performance of the supervisees[40] for whose work he or she is held accountable. In implementing this responsibility, the supervisor performs administrative, educational, and supportive functions in interaction with the supervisee in the context of a positive relationship."

This emphasis on the educational aspects of supervision has been combined, over the years, with a second emphasis on the administrative aspects of the work (Kadushin 1985 p. 20-21). The administrative aspect is about efforts to control and co-ordinate workers in order to get the job done.

Obstacles to worker-system interaction

Giving and receiving help is a complex human relationship, and there are a number of ways in which the process can go wrong. For example, people often hear and remember only what they want, or expect, to hear. To overcome this, is a challenge for the supervisor. In this work, it is useful to clarify the responsibility of the supervisor.

[39] Definitions to explain my terms:
Consultant: an external person, usually hired to do a limited and well-defined piece of work.
Advisor: an external or internal person who gives advice to the client on the possible choices and recommends one of them. An advisor may work together with the client in a way that transfer of know-how occurs efficiently.
Supervisor: an internal or external person performing an educational process in which a person with certain knowledge and skills takes the responsibility for training a person with less knowledge.

[40] **Supervisee** is the person (or persons) who is (are) supervised.

The definition of the term, “supervision” and the description of the general supervisory tasks of administration, education, and support are helpful in clarifying the responsibilities of a supervisor.

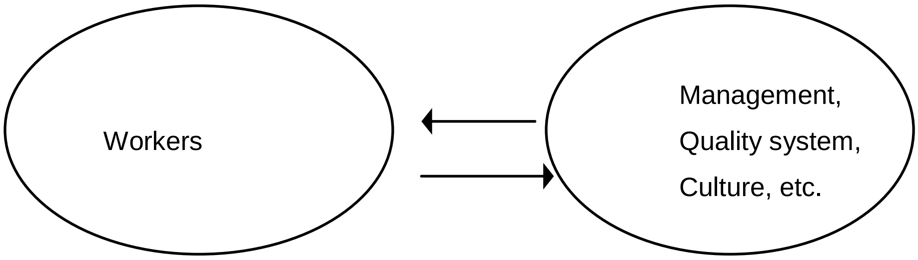

Figure 5.1. The Worker System Interaction depends on different factors in the company. (Derived from Shulman 1995, p.16)

Two elements in the model of a worker relating to the various systems of demand are shown in Figure 5.1. A third element for supervisor is added to this model, (Figure 5.3). The functional role of the supervisor may be best explained as mediating the engagement between the worker and the organisations with which he/she is working.

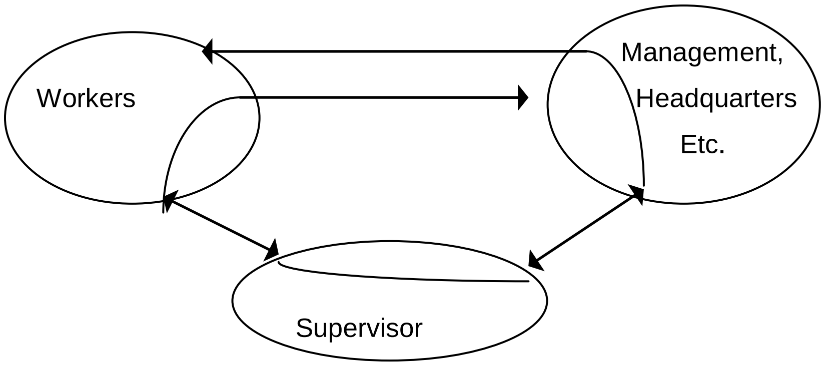

Figure 5.2. The figure illustrates the Mediating Function of Supervisors. The arrows illustrate the directions of communication (derived from Shulman 1995, p.20.)

According to the author’s experience, the issues of job stress and job manageability are crucial in supervision. This is always popping up in workshops.

The supervisor’s general tasks include administrative, educational, and supportive functions.

In the preliminary phase of supervisory work, a supervisor-preparatory empathy (tuning in) is essential. This can help to enter a new system, as well as to integrate a new worker into the system.

The next step examines the work phase in supervision: it combines a skill's model of the work phase with examples of problems common to this phase.

The model "Interactional Supervision"

The model described in Shulman (1995) and Heap (1998) consists of the four steps described in Figure 5.3.

1. Contracting phase
2. Tuning in phase
3. Work phase
4. Evaluating phase

Figure 5.3 The four main phases in external advising of corporations. (Derived from Shulman 1995, p. 35-256 and Heap 1998 41-299).

Contracting phase

The first phase of the model is a contract about the supervision. This includes when to start, the purpose, objectives, time span, reporting etc. This contract may include, and be combined with, development and implementation of an environmental management system (EMS), or a cleaner production (CP) assessment. If this is the case, these should be carried out in line with the traditions for EMS/CP assessments. The difference with this model is the way to perform the supervision.

Tuning in phase

Referring to Shulman (1995) and also this author's experiences, it is on the one hand important that the supervisor has know-how about the actual industry branch, the particular company and state of the art of the technology. The level of competence among employees and their ability to perform change in the organisation are also important pieces of information for a good supervisor to know. On the other hand, it is important that the supervisor has the relevant skills and puts focus on the employees' work situation. Typical issues to focus upon are: How much time does the employee have? Which skills does a person need as additional competence? How is the employee's attitude to extra work? What is the attitude of colleagues to helping on hindering the employees involved in the supervision process?

Work Phase

The skills of the work phases in supervision have been grouped into general categories called *skill factors*. In the model of the work phase of supervision (Figure 5.4), all behaviours associated with the supervisor's efforts to deal with the worker's emotional responses are grouped in *empathic skills.*

In the work phase, it is important to stimulate the client's involvement and know-how in order to empower action. This is illustrated in Figure 5.4.

- *Tuning in phase*
- *Contracting*
- *Making a demand for work*
- *Pointing out obstacles and identifying ways of overcoming those obstacles*
- *Sharing data*
- *Project management*
- *Monitoring progress*
- *Making reports*
- *Providing dynamic feedback.*

Figure 5.4 Important skill factors in the work phase of supervision
(Derived from Shulman 1995, p. 79)

The focus in the working phase is on the educational function of supervision. Kadushin (1985) described educational supervision as a specific staff development, in which

> *"training is directed to the needs of a particular worker carrying a particular case load, encountering particular problems and needing some individualised program of education".*

His research suggests that educational supervision provides two of the main sources of satisfaction for both supervisors and staff members.

Educated, experienced personnel in industry do not wish to be told what to do by a consultant, or an expert. Co-operation with a supervisor who does not act as if "I know all the answers" actually increases quality and satisfaction for the client.

To create ownership to changes

All organisational learning will cause changes. One important factor will be who is the owner of the ideas connected to the changes. The committed person, or persons, is the insurance that the changes are implemented. One important key (commonly used in present day Norwegian culture) is to metaphorically transfer the option(s), which is necessary to create the change into a person's "baby". If the "baby's" owner(s) is employed in the organisation, the level of success is increased. If the "baby's" owner is an external consultant, good proposals will often not be realised.

The crucial and most critical aspect of a consultant or supervisor's role is to transform the task into a baby using enthusiastic arguments. A second crucial task is to help to create an owner for the "baby" within the organisation.

Requirement for effective learning related to supervision.

According to Shulman (1995), the first requirement for effective teaching is that the pupil must have a stake in the outcome. A worker who is to learn new skills or procedures must be willing to invest some effort, or emotion, into the process. In effect, workers should become co-partners with supervisors. By engaging in the activity together, they can have the same interest in its accomplishment and share in the resulting ideas and emotions.

This may seem a rather obvious idea, but its implications for teaching are often ignored. The supervisor must be clear about the usefulness of the content for the staff, or the connection will not be made. Orientation programs, which contain a large amount of material on, for example, the organisational structure of the company or the policy manual, may have little immediate meaning for the worker. As a result, little learning occurs.

In many situations, the connection between the content to be learned and the staff member's sense of urgency may be hard to perceive without extensive experience. Initial supervisory efforts must find this connection and help the staff understand clearly, why the information is important. At the start of the supervision session, a form of contracting takes place. The supervisor concentrates on helping the staff members connect the data to be learned with their own sense of need. The conversation is most important in the learning process. A supervisor may focus upon attributes listed in Figure 5.6.

The second essential requirement for effective learning is that the staff members should be actively involved in the investigation of ideas and in building their own models of reality (bottom –up strategy). No matter how much the supervisor may want to impart understanding to a worker, or to share quickly the results of his or her own years of learning, it should not be done. Holt (1972, p 164) described it this way:

> *"We teachers - perhaps all human beings- are in the grip of an astonishing delusion. We think that we can take a picture, a structure, a working model of something, constructed in our own minds out of long experience and familiarity, and by turning that model into a string of words, transplant it whole into the mind of someone else."*
>
> *"Most of the time, explaining does not increase understanding, and my even lessen it."*

Many educators seem to persist in believing that by speaking words they can transmit an idea, even though their own educational experience has taught them differently. The myth that words are magic - and that if they are spoken they are heard, understood, and remembered by the pupil - is still widely believed. If we think back to how we learned something new, we know that our ideas did not exist until we created them for ourselves. One example experienced by the author of this thesis illustrates that point:

- be curious;
- listen to the audience;
- be open minded, show respect;
- be warm;
- be understanding;
- be spontaneous;
- do not judge.

Figure 5.6. For a supervisor, conversation is the key to co-operation and engaging participants. Conversation is the key to co-operation and engaging participants. (Derived form Shulman 1995)

Operators working at the same place year after year, performing different functions get "blind" to improvements. For this reason an external supervisor, who has experience from other similar factories, can be useful. External persons can help employees to see what they have overlooked for years. An example from a plating shop that used cyanide in the production process illustrates this point. The production line consisted of several large vats, containing about 5 m^3 of liquid. These containers were supplied with different chemicals. To the cyanide container, they added 5 kg of cyanides every Friday, except for Fridays during Easter and summer holidays.
The author asked the operator, "If you added an amount of cyanide based on the production levels from the last week, would that be less than 5 kg?
*The operator gave the answer and **changed the procedure** for adding cyanide. The consumption of cyanide decreased by 20%: The operator had never questioned this procedure and was not aware of the hazard the cyanide can have outside the factory. What was changed in this case was an improved positive attitude by: 1) an improved operating procedure (as part of an environmental management system) and 2) added competence on understanding of reducing negative environmental impacts of the production process.*

1. We learn best when we can devote most of our energy in the learning situation to learning.
2. We learn best when learning is accompanied by positive satisfaction – when it is successful and rewarding.
3. We learn best if we are actively involved in the learning process.
4. We learn best if the content is meaningfully presented.
5. We learn best if the supervisor takes into consideration the supervisee's uniqueness as a learner.

Figure 5.7 Some important principles should be emphasised by the supervisor in interactional supervision. Kadushin (1985 p 149-224).

Referring to Kadushin (1985 p 149-224), some important principles should be emphasised by the supervisor. These principles are listed in Figure 5.7.

Evaluation phase

According to Shulman (1995), an evaluation is an objective appraisal of an employee's performance. It is one of the most important elements of the supervisor's role, and when handled well, an evaluation makes a major contribution to the employee's development and client services. One type of evaluation, called *formative evaluation*, provides ongoing feedback to workers in order to help form, shape or improve their job performance. Another type of evaluation procedure combines formative purpose with company assessment functions. In addition to providing feedback for the staff member's development, this evaluation process may be used as a basis for decisions about an employee. Decisions about proposed plans for future education and courses to supplement weak skills can be based on such evaluations.

Performance evaluation routines for employees may be routinely performed in companies. An external person should carry out the evaluation. An example from environmental systems is a yearly revision of the education program in the Environmental Management System (EMS) further described in Chapter 6. Approved procedures should be established and used to ensure periodic evaluations. The possibility for future educational programs, courses, or participation in relevant exhibitions, will secure co-operation from the workers. From the management point of view, such procedures will improve organisational learning.

Relevant Points for this Study

The author of this thesis search to develop environmental management as to obtain continuous improvements and enhanced organisational learning. The model of interactional supervision developed for social work should be utilised in connection with environmental management. The most important issue is that an advisor with proper skills and time available is involved.

Taking the cyanide story from the paragraph *"Requirement for effective learning related to supervision"***,** in the perspective of the *"Teaching and Learning"* paragraph in Chapter 4, learning requires the active creation of knowledge by the employee, using all resources available. Answering the central question in this chapter, the supervisor is a central resource he or she is responsible for creating conditions so the pupil must perform the construction of the idea, fact, or theory. The supervisor should secure that the learning process is done according to this.

Comprehension of the idea that knowledge does not exist for the employee until he or she creates it leads to major changes in thinking about the teaching-learning process. Teaching cannot be conceived of as simply handing over knowledge, or covering the agenda. Instead, the supervisor must concentrate on the interaction between the employee and the ideas to be learned. Priority must be given to continuous monitoring of the learning interaction processes. The supervisor must keep in touch with the employee's progress in constructing the ideas.

Another requirement for effective learning is that the employees must have structured opportunities for using the information presented. Environmental behaviour, for example, will become meaningful when a worker uses the ideas to understand the connection to his own neighbourhood. The doing part, the application of theory, strengthens the worker's understanding of its elements.

Practice skills development is another area in which the importance of 'doing' is most obvious. A worker learning a new skill is more likely to learn it if he, or she, can practice it while it is being taught. Employees developing group leadership skills can go only so far in their understanding of group skills before they are blocked in their learning by a lack of practical experience. When actual practical experiences are not easily available, group work on case studies may be useful. One example is a team established to create ideas for cleaner production solutions in a company. This team/group has to learn new methods (methods for Cleaner Production, Environmental Management and Energy Management are described in the next chapters), which they are supposed to perform. The group members have to co-operate and depend on each other to reach the target. Data must be collected and mass and energy balances established. Waste reduction idea-generation can then be performed. This must all occur before ideas for potential solutions can be evaluated, prioritised, reported and presented as a result of the group work.

The three essential requirements for effective learning, referring to Figure 4.3, are 1) perceiving an investment in the knowledge, 2) being actively involved in creating the ideas, and 3) the action, having an opportunity to practice the use of the information. Even with these requirements fulfilled, many obstacles can emerge to block the learning process. A good supervisor helps overcome these obstacles by developing the employee's mastery of the skills needed for effective work.

Kadushin (1985) emphasises five principles for effective learning, among them: *" We learn best if we are actively involved in the learning process"* and *"We learn best if the supervisor takes into consideration the supervisee's uniqueness as a learner."* Having these two principles in mind and adding the

Dewian principle (Dewey 1916) *"learning by doing"*, this author suggests *"learning by supervised doing"* as an improved principle.

Conclusions

Increased need for rapid changes in organisations, as well as an increased need for change in skills and competence, will require systematic use of supervisors in companies in the future. Expanded use of supervisors will be required in the future. The author's answers to the focused question of this chapter: "*How can advisors best contribute to organisational learning and change?"* are summarised in the following.

Supervisors should, in the context of the organisational learning theory, pay attention to double-loop learning, as outlined in Chapter 4 and shown in Figure 4.5. The supervisor should ensure that a system for double-loop learning is implemented in the organisation to help ensure continuous improvements effected within the company.

To achieve this, knowledge of human learning in organisations is essential. Learning in organisations, and the limitation of current learning theories in the understanding of interpersonal interactions, is essential for improving the efficiency of learning in organisations. The presented approach emphasises the practise of individuals and their personal abstraction of practice as a condition for learning.

It is suggested that the Dewian principle of *"learning by doing"* should be improved. *"Learning by supervised doing"* is suggested as an improved principle. Interpersonal interaction and dialogue is essential for development and change processes in an organisation. If this interpersonal interaction is improved by systematic supervision, learning effectiveness can be improved.

In the following three chapters, interactional supervision is linked to methods and systems for Cleaner Production & Environmental Management, Energy Management and Environmental Performance Indicators.

Chapter 6 Cleaner Production methodology

Summary

The concept of Cleaner Production (CP), the way it was launched and used in Norway, is presented in this chapter. Referring to the research methodology presented in Chapter 2, the concept of CP serves as the analytical framework for this thesis. This chapter contains a description of the development of the analytical framework for the analysis and implementation of CP in companies. This conceptual description serves as the normative frame and reference. The methods of CP and environmental management are discussed from the perspective of organisational learning, described in Chapter 4. Single- and double-loop learning is a proper way to optimise organisational learning, Argyris and Schön (1996). Improvements in the methodology of CP and EMS are suggested.

The empirical data from the companies, described in part B of this thesis, will be evaluated from the perspective of this chapter.

History

Most industrialised countries, in their efforts to reduce the impacts of pollution and waste generation, have historically tried to obtain success with the following four strategies (Backman 1988):

1. Dilution is the solution to pollution.
The diluting strategy based on high chimneys into the air and pipelines into lakes, rivers and the ocean. This strategy was used in the 1950's and the 1960's. The common opinion at that time was: if the pollution were spread over a large area, it would do no harm.

2. ***Pollution control is the solution to pollution.***
The filter and treating strategy based on end-of-pipe installations. In the 70's and the 80's, it was common opinion that this strategy was the solution to most environmental problems. However, it was realised that these solutions often transfer, or transform, one environmental problem to another.

3. Recycling is the solution to pollution
The recovery/reuse strategy started in the 1980's. A lot of environmentally friendly activities were realised and gave some results we appreciate today: reuse of paper, glass etc. However, this strategy does not deal with the production process, or problems themselves, but focuses only on used products and recovery of raw materials in waste products.

4. Pollution Prevention/Cleaner Production is the solution to pollution.

The CP strategy emerged in some countries beginning in the mid-1980's, and has become the main strategy in most industrialised countries in the 1990's. This strategy is based on sustainable production and products, and design for the environment. The environmental problems are primarily reduced by source reduction, i.e. the concept of CP.

Cleaner Production Methodologies

This paragraph contains a description of the development of the analytical framework for the analysis and implementation of CP in companies. This conceptual description serves as the normative frame and reference for this thesis. The empirical data from the companies, described later in this thesis, are evaluated against the analytical framework.

Experiences from studies done prior to writing this conceptual framework emphasise most work in CP has been dominated by case studies. Few efforts have been done to analyse the changes and reasons for changes within the organisations whether they are consequences for technology development or organisational and systemic changes within an organisation. Rene van Berkel Ph.D.-thesis: ”Cleaner Production in Practice” (Van Berkel 1996) does however, outline the concepts of CP and related approaches in a systematic way.

Definition

Referring to the definitions outlined in Hans Van Weenen Ph.D. thesis *”Waste prevention. Theory and Practice”* (Weenen 1990) I would like to focus on definitions relevant in Norway

US-EPA defined Waste Minimisation as follows (EPA 1988 p. 2):

> *"The reduction to the extent feasible, of hazardous waste that is generated or subsequently treated, stored or disposed of. It includes any source reduction or recycling activity undertaken by a generator that results in either (1) the reduction of total volume or quantity of hazardous waste or (2) the reduction of toxicity of the hazardous waste, or both, so long as such reduction is consistent with the goal of minimizing present and future threats to human health and the environment"*

According to Freeman (1990), various individuals and agencies use terms other than Waste Minimisation to denote the same approach. Freeman lists synonymous terms for Waste Minimisation (Freeman 1990 p.4) as follows:

Waste Minimisation; Waste reduction; Clean Technologies; Pollution Prevention; Environmental Technologies; Low and non-waste technologies.

Cleaner Production approaches

Van Berkel (1996) compiled the subsets of Cleaner Production practices as: “Pollution Prevention (PP)”; “Toxics Use Reduction (TUR)”; and “Design for the Environment (DfE)”. A comparative evaluation of their present coverage laid the foundation for an extended application of the CP strategy. Referring to Van Berkel, the content of CP is described at five levels: i.e. “strategy”; “approach”; “practice”; “option” and “measure”. The “*strategy*” encompasses the continuous environmental improvement of products and processes as reflected in the working definition. It is the highest level in the application. At the next level are the “*approaches*”, each addresses a possible “cause” category for industrial pollution. CP according to Van Berkel (1996), covers seven approaches:

1. *Service Approach*: this approach questions the material and energy efficiency of servicing and targets the inclusion of environmental consideration in the purchasing of trade articles (to be sold to customers),
2. *Chain Approach*: questions the co-ordination and co-operation in the production chain, with a view to facilitate the material exchange between producers in different stages of the production chain and to facilitate the co-ordinated application of environmentally-improved processes and practices in all stages of the production chain;
3. *Product Approach*: questions the physical design of the product and its use system in order to minimise the environmental burden over the life cycle of the product;
4. *Material Approach*: questions the material selection both with regard to product constituents as well as with regard to auxiliaries for the production and consumption, in order to minimise the environmental burden associated with the use of the materials in products and in production and consumption processes;
5. *Technology Approach*: questions the choice and operation of the technology used in the production, distribution and delivery of products and services in order to minimise the environmental burden caused by these processes;
6. *Operational Approach*: questions the planning, management and operation of the production processes with a view to minimise process waste and emission generation:

7. *Reuse Approach*: questions the generation of waste materials and energy losses with a view to closing material cycles or recovery of energy and/or useful constituents within the physical boundaries of the location where waste materials or energy losses actually occur.

Applying the third, practice, level of the concept of CP according to van Berkel, are the *"prevention practices*"; each specifies a category of - generally applicable solutions within one of the approaches listed above. Next, these are linked with a particular source and cause of industrial pollution, which results in "*prevention options"*. These are essentially alternative solutions to avoid or to at least minimise the causes of environmental burden in a particular process or product. Finally the "*prevention measures*" are the "feasible" prevention options. The prevention measures are the actual changes in products and processes and thus result in the practical implementation of CP.

Methodological framework

"CP assessments" are systematic, procedures with the objective of identifying ways to reduce or eliminate the generation of wastes and emissions. An assessment may be regarded as an "environmental improvement" cycle. In general, an assessment should aim to complete at least one environmental improvement cycle which can result in the implementation of the most obvious prevention options in the *short* term. It should also create conditions for the execution of new environmental improvement cycles to safeguard ongoing environmental improvements, in the longer term.

According to van Berkel, an assessment methodology consists of a "method", a "procedure" and "guidance & supervision". The "*method*" serves as the tool for the identification of CP options. The "*procedure*" organises the necessary activities for the implementation of CP. The "*guidance & supervision*" guides, informs and stimulates the responsible project team at the plant level.

The central element of the "method" is the examination and re-evaluation of the production process, product and/or service that causes the environmental impacts of concern. This re-evaluation consists of "*source identification*" (on the basis on a material balance or flow chart) followed by a "*cause evaluation*" -.

The Norwegian approach

In the following paragraphs, the CP strategy applied in Norway is introduced.

"Waste Minimization Opportunity Assessments" from the US-Environmental Protection Agency (EPA) in 1988 (EPA 1988), was one of the first complete assessment methodologies on CP, consisting of a "method", a "procedure" and "guidance & supervision". In 1989, this tool was applied by Oestfold

Research Foundation in Norwegian Industry[41]. (Amundsen 1990) and (Abrahamsen 1993)

Since those tests gave positive results (Amundsen 1991) (Amundsen and Huse 1991) (Amundsen and Vold 1991a), the Confederation of Norwegian Industry made a Norwegian handbook. In this Norwegian handbook (Amundsen and Vold 1991b), the Waste Minimisation of hazardous waste was expanded to CP which was defined as follows:

> *"Options in factories which change raw materials, the production process, operating practices or the product-specification with the purpose to eliminate or reduce pollution or waste at the source".*

The method is illustrated in Figure 6.1. The most important change from the USEPA-manual is that the definition goes for all types of waste or pollution, and is not limited to hazardous.

This method has been translated to many languages (Czech, Slovakian, Polish, Russian and Chinese), and was adopted within branch-specific manuals.

Based on practical experiences, the USEPA manual was changed and rewritten in the "Facility pollution prevention guide". (EPA 1992).

In this manual POLLUTION PREVENTION is described as:

> *"Pollution prevention is the maximum feasible reduction of all wastes generated at production sites. It involves the judicious use of resources through source reduction, energy efficiency, reuse of input materials during production, and reduced water consumption. There are two general methods of source reduction that can be used in a pollution prevention program: product changes and process changes. They reduce the volume and toxicity of production wastes and of end-products during their life-cycle and at disposal".*

This revised version, was based on experiences worldwide, including the author's contribution from Norwegian experiences (EPA 1992).

Some of the main changes in the new methodology:

1) The first phase of the project ends with a Pollution Prevention Program.
2) Energy conservation is focused on in a separate chapter.
3) Development of environmentally friendly products was focused, and practical guidelines in how to carry out the work were developed.
4) The number of work sheets was reduced in order to simplify the data collection phase.

The phases in the revised EPA- method are presented in Figure 6.2.

[41] Professor Dr. Donald Huisingh, University of Lund in Sweden, introduced the concept and experiences on Cleaner Production to Oestfold Research Foundation in 1989.

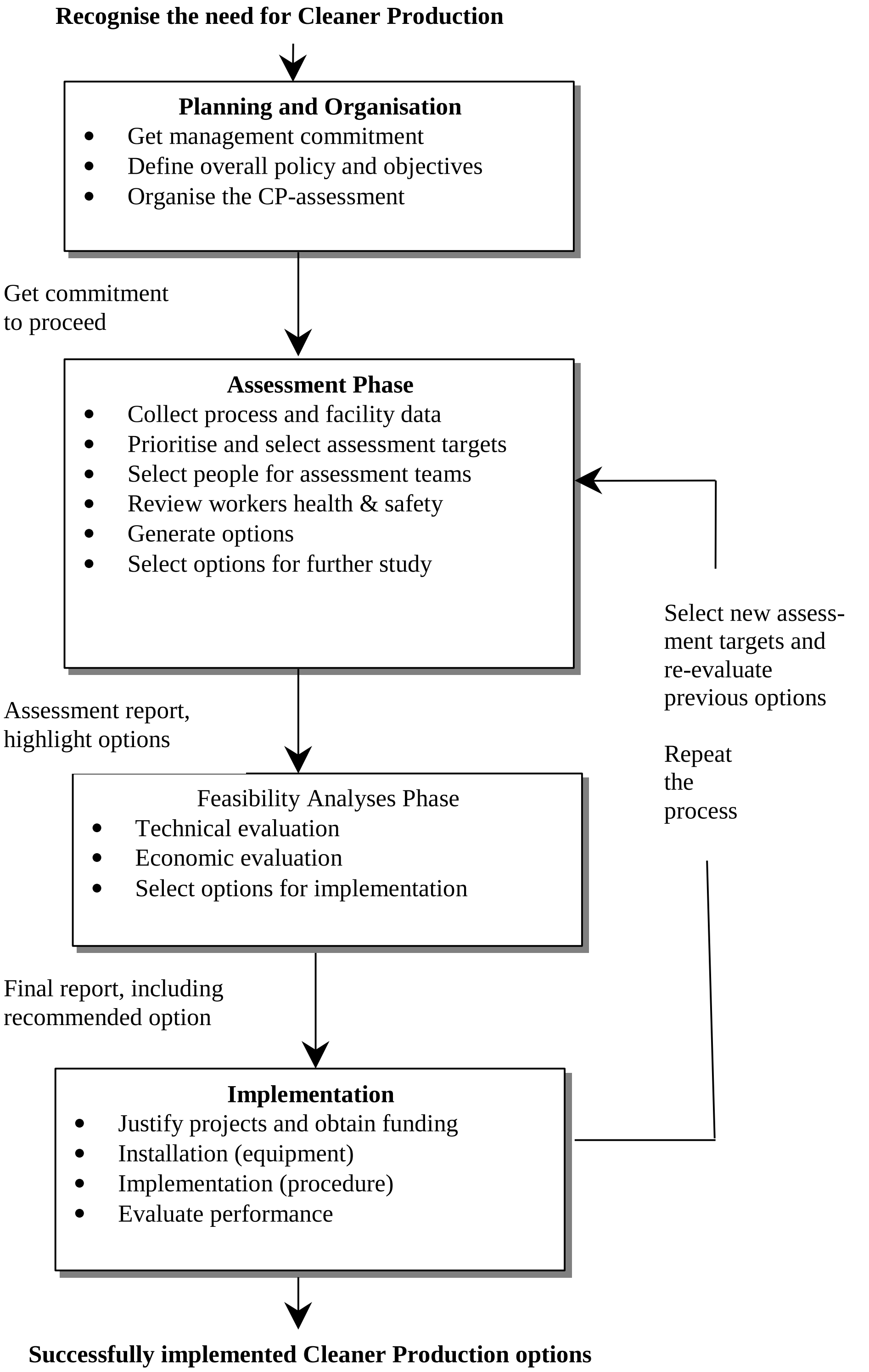

Figure 6.1. Phases in the implementation of CP in a company (Amundsen and Vold 1991b, p. 13, applied from EPA 1988). The most important change from the US-EPA manual is that the definition goes for all types of waste or pollution, and is not limited to hazardous.

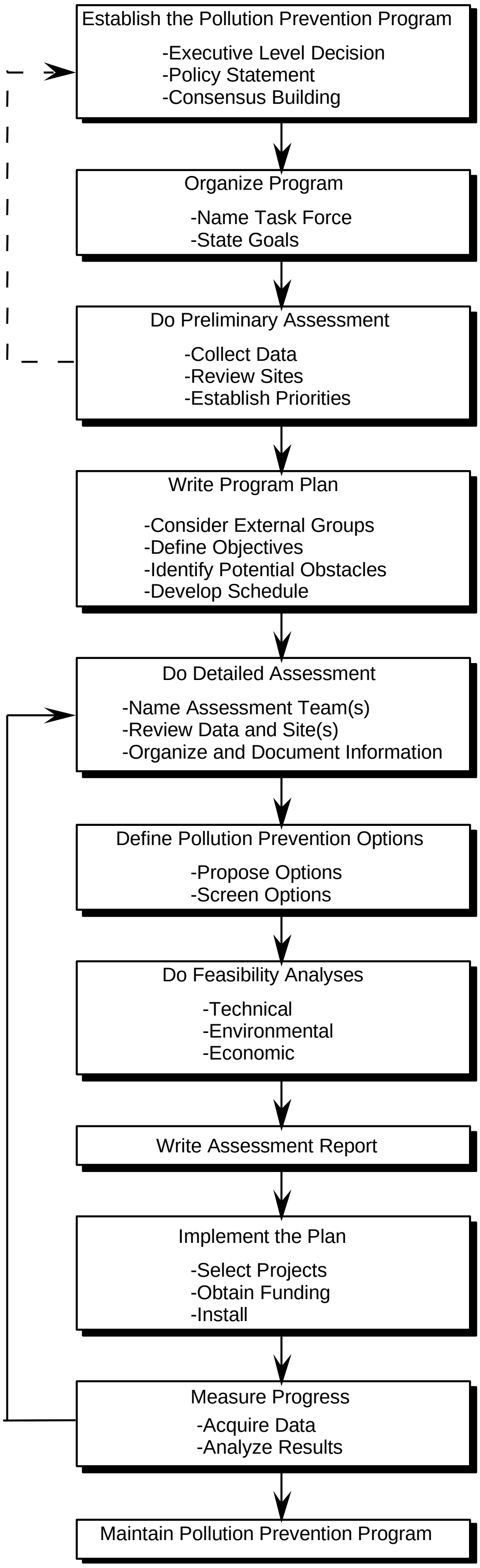

Figure 6.2. Facility Pollution Prevention Program.
Phases in the revised US EPA manual (EPA 1992 p. 13)

Norwegian experiences

The methods applied in Norway are presented in this chapter. The experiences from utilising these methods in Norwegian industry are described and discussed in Chapter 9 and 10.

Other CP-related tools

Life Cycle Analyses.

Referring to Lindfors et al (1995), the Life Cycle Assessments (LCA) process is understood as:

> *"A process to evaluate the environmental burdens associated with a product system or activity, by identifying and quantitatively or qualitatively describing the energy and materials used, and wastes related to the environment, and to assess the impact of those energy and materials uses and releases to the environment. The assessment includes the entire life cycle of the product or activity, encompassing extracting and processing raw materials; manufacturing; distribution; use; reuse; maintenance; recycling and final disposal; and all transportation involved. LCA addresses environmental impact of the system under study in areas of ecological systems, human health and resource depletion. It does not address economical or social effects*".

Examples on the main environmental impacts a practical LCA study typically focuses on:

- global warming
- acidification
- ozone depletion
- eutrophication
- hazardous waste

For more detailed description of the LCA method and its applications the reader is referred to literature by Lindfors et al (1995) and Hanssen (1995).

Environmental Management

Regulations and standards for environmental management (EMS)

A British standard for environmental management (BS 7750) existed since 1993 (BS 1993), and was the forerunner to the EU standard on Environmental Management and Audit scheme (EMAS) (European Commission 1993, 1998). EMAS should replace the BS 1993 and this standard will not be dealt with in this thesis. EMAS is designed for the European Community. In order to address international conditions, the ISO 14001 (ISO 1996) on environmental management was developed. There were 46 Norwegian companies certified in accordance with the ISO 14001 standard and 44 registered in accordance with EMAS, by November 1998. There are no current regulations or standards for Energy Management.

What is EMAS

EMAS is a regulation for the voluntary participation of industrial corporations in an environmental management and environmental audit scheme in the EU. It was introduced into Norwegian legislation on April 10, 1995, and is now an appendix to "The Norwegian Pollution Control Act".

The revised EMAS (EEC 1998) is made up of 18 articles and 7 annexes. A brief explanation of the most important articles and annexes pertaining to Energy Management follows:

Article 1: General on environmental management, the environmental audit scheme and objectives of these.

Article 2: Definitions of terms and expressions used in the regulations.

Article 3: Procedure for fulfilling the certification requirements for an EMAS review.

Article 4: Audit and validation.

Article 5-18: Formal matters not relevant for organisations implementing EMAS (accreditation and supervision of environmental verifiers, competent bodies, registration, logo, promotion and information.

Annex I: Environmental management systems requirements and issues to be addressed by organisations implementing EMAS.

Annex II: Requirements concerning internal environmental auditing.

Annex III: Environmental Statement.

Annex V: Accreditation, supervision and function of the environmental verifiers.

Annex VI: Environmental aspects (about an organisations consideration on all environmental aspects of its activities).

Annex VII: Initial Environmental Review.

To Whom Does EMAS Apply

EMAS is open to any organisation dedicated to improving its overall environmental performance. Examples are: industrial operations; commercial firms; service industries and local and state government administrations.

What are the intentions behind EMAS

The intention is primarily to prevent, or reduce, pollution, or unnecessary use of energy and material resources by addressing the process sources causing the problems. “Purification Plant Solutions" designed to separate pollutants into several fractions seldom solve the problem and should be replaced by approaches which reduce pollutants at their sources. This can be achieved through product change, the use of cleaner technologies, or “smarter” processing solutions, or through better, more integrated and proactive management.

Industry itself is held responsible for the effects of its activities and products on the environment. It should therefore, for its own benefit, work systematically towards the improvement of its processes, products and services. Developing and implementing an environmental policy, environmental objectives and environmental programmes, as part of an integrated system for environmental management, can achieve this. The environmental policy (in addition to being in accordance with all relevant regulatory environmental stipulations) should include a commitment to continuous improvement in environmental performance.

In order to achieve EMAS-registration, the company should publish and distribute periodic environmental statements. These statements should contain information for the public on the actual environmental performance of their company. The environmental policy should be reported, as well as the environmental programme, environmental objectives and environmental management system. Employees are to be made aware of their own role with regard to preventive environmental measures, and to be given the necessary training.

Article 1 in EMAS outlines the objectives and includes the following:

> *"...The objective of EMAS shall be to promote continual improvements of environmental performance of organisations… "*

What this implies is that environmental issues cannot be solved through a single all-out effort, but rather must be solved through a systematic and ongoing strategy.

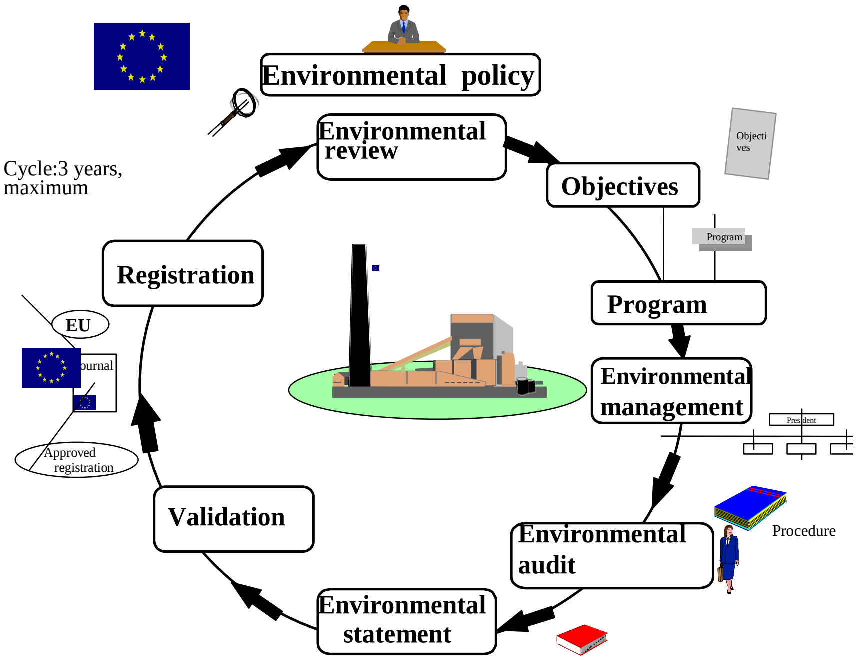

Figure 6.3 The Main Elements in EMAS (from NHO 1996)

The main elements of EMAS

For an industrial site to be registered as part of the EMAS scheme, the enterprise must:

- approve an environmental policy for the company;
- carry out an environmental review;
- lay down objectives for lasting improvements in environmental performance;
- introduce an environmental programme for the industrial site;
- establish an environmental management system;
- implement, or have implemented, environmental audits;
- publish a separate environmental statement.

The phases in a systematic EMAS process, and how these are connected, are shown in Figure 6.3. All of these phases are also relevant to Energy Management, with the exception of the registration procedure. There is no reason why Energy Management and environmental management cannot function well together, although the enterprise is not EMAS-registered. However, a non-registered company loses a marketing benefit and access to an external control system, which can contribute to keeping the system dynamic and up to date.

ISO 14001

ISO 14001: "Environmental management system", (ISO 1996). The ISO home page[42] describes the standard as given in footnote[43].

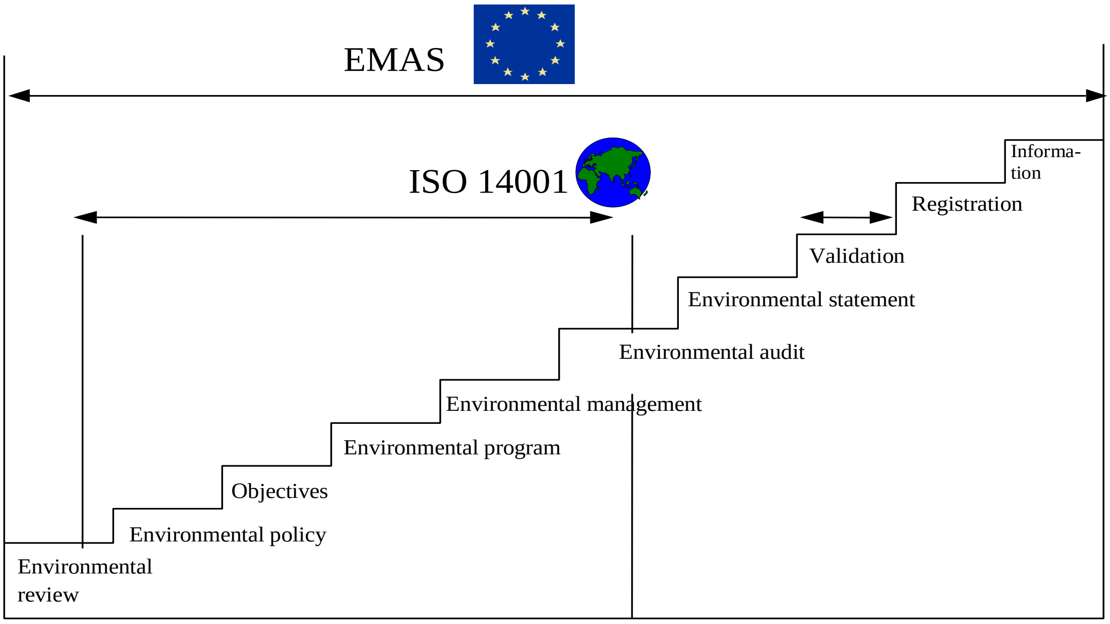

Figure 6.4 The figure illustrates the connection between ISO 14001 and EMAS. The content of EMAS is the same as in ISO 14001 plus the environmental statement and information.

[42] http://www.iso.ch/9000e/14kbusy.htm
[43] ISO 14000 and environmental management systems for busy managers

The ISO 14000 family addresses various aspects of environmental management. The very first two standards, ISO 14004 and ISO 14001 – published respectively in September and October 1996 – deal with environmental management systems (EMS).

What is an ISO 14000 EMS?
An environmental management system based on the ISO 14000 standards is a management tool enabling an organisation of any size or type to control the impact of its activities, products or services on the environment. An environmental management system makes possible a structured approach to setting environmental objectives and targets, to achieving these and to demonstrating that they have been achieved.

How does it work?
The standards do not specify levels of environmental performance – so how, you ask yourself, can they improve things? Well, if they specified levels of environmental performance they would obviously have to be specific to your business activity – and that's not the intention. In addition to ISO 14000, ISO also has a wide portfolio of standards that are specific to, for example, air, water, or soil pollution.

ISO 14000 was developed with another aim: that of providing a framework for an overall, strategic approach to your organisation's environmental policy, plans and actions. The underlying philosophy is that the requirements of an effective EMS are the same, whatever your business.

What's in the EMS standards?
ISO 14004 provides guidelines on the elements of an environmental management system and its implementation, and discusses principal issues involved.

ISO 14001 specifies the requirements for such an environmental management system. Fulfilling these requirements demands evidence that can be audited to demonstrate that the environmental management system is operating effectively in conformance with the standard.

What if my business implemented an ISO 14000 EMS?
ISO 14001 is a tool that can be used for internal purposes: to provide assurance to management that you are in control of your processes and activities having an impact on the environment. Employees, in turn, may be happier if assured that they are working for an environmentally responsible organisation.
ISO 14001 can also be used for external purposes: to provide assurance to interested parties – stakeholders – such as customers, the community and regulatory agencies.

ISO 14001 and EMAS

Figure 6.4 shows a comparative analysis between ISO 14001 and EMAS. The content of EMAS is the same as in ISO 14001 plus the environmental statement and information. The certification system differs since ISO 14001 is an international standard, while EMAS is a regulation. When EMAS has been introduced in the company, ISO 14001 certification can be realised through small initiatives. A "certification" within the ISO 14001 system comes instead of EMAS "approval".

Table 6.1 The ISO 14000 family of standards, ongoing work and other ISO 14000 publications [44]. ISO web page: (http://www.iso.ch/9000e/iso14000.pdf).

Designation	Publication	Title
ISO 14001: 1996	1996	Environmental management systems – Specification with guidance for use
ISO 14004: 1996	1996	Environmental management systems – General guidelines on principles, systems and supporting techniques
ISO 14010: 1996	1996	Guidelines for environmental auditing – General principles
ISO 14011: 1996	1996	Guidelines for environmental auditing – Audit procedures – Auditing of environmental management systems
ISO 14012: 1996	1996	Guidelines for environmental auditing – Qualification criteria for environmental auditors
ISO/ WD 14015	To be determined	Environmental assessment of sites and entities
ISO 14020: 1998	1998	Environmental labels and declarations – General principles
ISO/ DIS 14021	1999	Environmental labels and declarations – Self-declared environmental claims
ISO/ FDIS 14024	1998	Environmental labels and declarations – Type I environmental labelling – Principles and procedures
ISO/ WD/ TR 14025	To be determined	Environmental labels and declarations – Type III environmental declarations – Guiding principles and procedures
ISO/ DIS 14031	1999	Environmental management – Environmental performance evaluation – Guidelines
ISO/ TR 14032	1999	Environmental management – Environmental performance evaluation – Case studies illustrating the use of ISO 14031
ISO 14040: 1997	1997	Environmental management – Life cycle assessment – Principles and framework
ISO 14041: 1998	1998	Environmental management – Life cycle assessment – Goal and scope definition and inventory analysis
ISO/ CD 14042	1999	Environmental management – Life cycle assessment – Life cycle Impact assessment
ISO/ DIS 14043	1999	Environmental management – Life cycle assessment – Life cycle Interpretation
ISO/ TR 14048	1999	Environmental management – Life cycle assessment –Life cycle assessment data documentation format
ISO/ TR 14049	1999	Environmental management – Life cycle assessment –Examples for the application of ISO 14041
ISO 14050: 1998	1998	Environmental management – Vocabulary
ISO/ TR 14061	1998	Information to assist forestry organisations in the use of the Environmental Management Systems and standards ISO 14001 and ISO 14004
ISO Guide 64: 1997	1997	Guide for the inclusion of environmental aspects in product standards

[44] NOTE: CD = Committee Draft; DIS = Draft International Standard; FDIS = Final Draft International Standard; TR = Technical Report.

Continuous improvement is an important issue within corporations, emphasised both in EMAS and ISO 14001.

International Standards

Referring to an ISO web page, (http://www.iso.ch/9000e/isoanden.htm) the environmental management system standard, ISO 14001, is key to the ISO 14000 series. However, the series includes many other standards that allow an organisation to evaluate how its activities, products and services interact with the environment and how improvements can be achieved. Since the environmental management standard, ISO 14001, was published in September 1996, a number of other standards in the ISO 14000 series have also been published. Looking to the future, more standards are being developed (see Table 6.1). These include environmental labels and declarations, life cycle assessment and integrated environmental audit on quality and EMS. The ISO 14000 family of standards, ongoing work and other ISO 14000 publications are listed in Table 6.1, as per spring 1999.

Process tip one
Make it a point to talk to the operators on the floor as much as possible. They often have suggestions - and a lot of good ideas.

Process tip two
Keep it simple! Try to work within the system. The easier you make things, the more likely your are to get participation and input.

Process tip three
Keep communications flowing! It is critical that team members communicate with management, and with their external partners.

Process tip four
Involve the people who know the system best.

Process tip five
Pollution prevention usually is best from an environmental and business perspective. Evaluate pollution prevention options thoroughly before considering treatment technologies.

Process tip six
You know your business best. Do not hesitate to make intelligent choices on the basis of less-than-perfect information.

Process tip seven
There is no universal metric. Develop several metrics that provide necessary information and clearly convey results to different audiences.

Process tip eight
Risk-taking is okay! The goal is not to find a perfect solution based on irrefutable data. Instead, make environmental improvements based on best available information

Process tip nine
The end of the project is the beginning of a new project. Success in one project doesn't mean the QEM process is over. It means starting a new project or improving upon the one just completed

Figure 6.4. Process tips for use in implementing the CP and Environmental management. (PCEQ 1993, p 17-37)

Integrated Management System

A Total Quality and Environmental Management system

The US-President's Commission on Environmental Quality (PCEQ) (PCEQ 1993), developed a system for integration of Total Quality and tools to prevent pollution. The method describes eight steps to obtain an integrated system. The steps are referred in Figure 6.4. In Figure 6.5 process tips for use in implementing the method, are included.

An R&D project in the Nordic Countries worked on this task (Amundsen 1995b). In this project, a method called "*It is about management*" was tested and improved in twenty-five Nordic Companies (Alstrup 1995).

The step to:
Total Quality and Environmental Management System (TQEM)

The way to walk to the goal: a total quality and environmental management system, could be described as the following eight steps.

Step 1
Management Commitment
- empower employees
- allocate resources
- involve stakeholders

Step 2
Quality Action Team
- cross-functional
- existing processes
- two-way communication

Step 3
Training
- timely
- practical

Step 4
Determine Environmental Impact
- collect data
- identify data gapes
- consider measures

Step 5
Select Improvement Projects
- develop criteria
- establish baseline
- collect additional data

Step 6
Implement Improvement Projects
- inform employees
- empower Quality Action Teams (QAT)

Step 7
Measure the Results
- develop metrics
- adjust as necessary

Step 8
Standardise the Improvements
- integrate improvements
- communicate with stakeholders
- recognise performance

Figure 6.5. Eight steps to obtain the PCEQ method. (From PCEQ 1993 p.17)

Relevant points for this study

Cleaner Production

The essential activities in a CP Programme, after finishing the CP-assessment, are the process that is supposed to take the production and products all the way towards CP, cleaner products, and cleaner services. The CP methods (Figures 6.1 and 6.2) describes a feedback loop to secure these continuous improvement activities. After implementing the options with the highest priority, the company is supposed to go back to the assessment phase and consider new options for implementation. The purpose of this important part of the method is to ensuring the continuous improvement process of CP; always working towards improvements and implementing new options. Figure 4.4 and 4.5 illustrates single- and double-loop learning; it is emphasised that double-loop learning is obtained when corrective action results in fundamental change in the companies' theory-in-use. Fundamental change in environmentally related policy and objectives occurs as a result of new approaches. Comparing this with the CP method described in Figure 6.1, single-loop learning can be recognised. The policy, objectives and organisation are not supposed to be revised in the described CP-method. The feedback loop in the CP methodology does not include evaluation or changes in policy or targets. No double-loop learning is present. In the revised US EPA method (EPA 1992) it is somewhat different. The additional upper loop added here, might take care of the double-loop learning. This method however, was never introduced in Norway on a big scale.

The theoretical conclusion here will be: the CP method introduced in Norway can be improved by addition of a double-loop learning system.

This important analysis demonstrates a bottleneck in the CP-method. The revised EPA-method attempts to remedy this obstacle, recommending a written Pollution Prevention Program as a first step. However, a better way is to categorise the method of CP Assessments as a tool to be used over a limited time period. To obtain continuous efforts on CP, a management and system-based method has to be used.

Referring to Chapter 4 on organisational learning, both top down and bottom up approaches should be utilised in implementing CP and Environmental Management in industry.

The organisation of CP Projects must involve top, middle and lower management, as well as employees from throughout the organisation. People directly connected with production: production leaders, technically responsible persons, maintenance persons and operators in the production process should be involved. The time available for learning activities and changes is often very limited. Changes usually cause stress, whatever the type of change. However, the company's success in the market is necessary for people in the organisation to have a job and an income in the future. Changes that will improve the company's position in the market are, despite a higher level of stress, of interest for people in organisations. The situation after the change is implemented may also mean better working conditions, e.g. automatic machinery is doing the hard work, or quality is improved so that production is stabilised. The CP method emphasises both approaches in a proper way.

Environmental management systems (EMS)

EMS and double-loop learning

Comparing the single- and double-loop learning as shown in Figure 4.4 and 4.5, to the EMAS method described in Figure 6.3, single-loop learning can be recognised. Evaluation and revision of the environmental policy is not implemented in the EMAS circle. Setting new objectives will be an activity at the start of each three-year cycle. The environmental policy however, is outside the cycle and will not necessarily be revised as a continuous activity. A conclusion is that implementing a system for revising the policy as a continuous activity at each new revolution of the cycle, will be necessary in order to obtain continuous organisational learning. This also applies to ISO 14001, which is similar in this matter.

How do EMAS and ISO 14001 differ?

EMAS and ISO 14001 are different, even though they are built on similar methodology. Referring to Figure 6.4, three important differences distinguish EMAS and ISO14001: 1) EMAS requires a deeper initial review, 2) EMAS require an environmental statement. This statement should be written in a way that is easily understandable for the public. 3) EMAS requires active information to be given to stakeholders.

The initial review gives conditions for development of improvement options in an increased way compared to the ISO requirements. In EMAS, the environmental policy involves both compliance with regulatory requirements regarding the environment, and commitments to reasonable and continuous improvements in environmental performance. This is done with the objective of reducing environmental impacts to levels not exceeding figures corresponding to an economically viable application of best available technology (BAT). BS and ISO have no such requirements.

EMAS requires the publication of an environmental statement. Article 5 has a detailed description of the statement required. An environmental statement must follow after the initial environmental review and the completion of each subsequent audit, or audit-cycle, for every site participating in the scheme. It has to be designed for the public and written in a concise, comprehensible form. BS and ISO have no requirement for publishing an environmental statement. The public and customers are given the opportunity to respond to the work for environmental improvements through the EMAS statement, which may turn out to important in securing a continuous process.

The Audit Cycle is limited to three years in EMAS, while ISO recommends a "suitable" period without specifying the number of years. This difference may also turn out to be important in securing a continuous process inside the company.

In environmental management systems, continuous improvement throughout the entire system is considered to be a most important matter. The Audit Cycles are supposed to be restricted to a limited time scale. EMAS requested three years as a maximum (differs from plant to plant). This restricted cycle may turn out to be a very important criterion in achieving success in attaining improvements on the long road to clean production.

EMAS, however, is not a standard, but a regulation. For this reason it is not possible to obtain EMAS certification in Norway[45]. EMAS has its own system, which each year publishes information on those companies registered in the Community.

CP can not be obtained through one or two single projects. It has to be developed through a long-term strategic program for CP and cleaner products. Establishing a continuous process is necessary. The cycle requested in environmental management systems is an important procedure in order to secure continuous improvement. Other important procedures are used to systematise intermittent applications of different CP tools inside the EMS-system. What kind of tools to use, and when to use them, must be determined by the different branches and factories. Life cycle analysis should be considered.

Integrated EMS systems

To a large extent, the environment has become as prominent as it has because of the ever-broadening spectrum of stakeholders and expectations to which business must relate. It is no longer just the financial experts and shareholders who make demands at the annual meeting, or call up the chief executive officer, or the investor relations director with importunate questions. There are now environmental groups, employees, neighbourhood and community organisations, unions, banks, and insurers, pension fund managers and consumers demanding information and action. They all have power in their own way. They can all influence how successful a company will be. To be competitive a company must listen, understand and perform to expectations.

We can identify at least five clusters of expectations.

- *Economic*: A business cannot survive if it is not financially viable. Management must include in the decision-making mix not only knowledge of costs and projected revenues, but also an awareness of risk and liabilities.
- *Quality:* Customer and client expectations are increasing. Market access and competitiveness more and more mean providing assurance of quality.
- *Occupational health and safety*: Unions, employees and government regulators want assurance that the workplace is safe and presents no risks to health.
- *Environment:* An ever-broadening range of constituencies are keeping an eye on environmental performance and seeking corporate commitment to improve.
- *Social responsibility*: Management is increasingly being faced with issues and pressures related to social responsibility and equity.

Standing back and looking at this line-up, it is easy to see that much co-ordination is required. Although, these demands represent different areas of concern, they can be addressed in a similar way. The organisation identifies the issues and expectations, establishes policies and objectives to meet them. They manage their implementation, and monitor, document and provide verifiable assurance of commitment, performance and improvement.

An integrated TQEM system might be designed as shown in Figure 6.9. (Amundsen 1995b)

Some industry managers have experienced the quality system as a bureaucratic system. The top-down strategy further described in Chapter 4, which the system is built upon, does not call upon creativity and innovation. The bottom-up strategy, on the other hand, might not have the overview required to consider all the environmental aspects. The daily work is done according to procedures and does not promote innovations, or improvements. Modifications and improvements are not easy to realise in such a system. The reality is that these systems become bureaucratic sets of procedures and instructions, requiring either a decision-making system, resisting innovative improvements, or a paper system stored in archives at the factory, but not actively used. Quality consultants have developed a new concept called Total

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[45] In some countries (e.g. in the Netherlands), enterprises get an EMAS certificate. This is however not connected to the certification system of the International Standard Organisation.

Quality System (TQS) (Wright and Kenney 1994). Within this TQS concept, the quality system is not supposed to live its own life, but instead function as an integrated part of the management system.

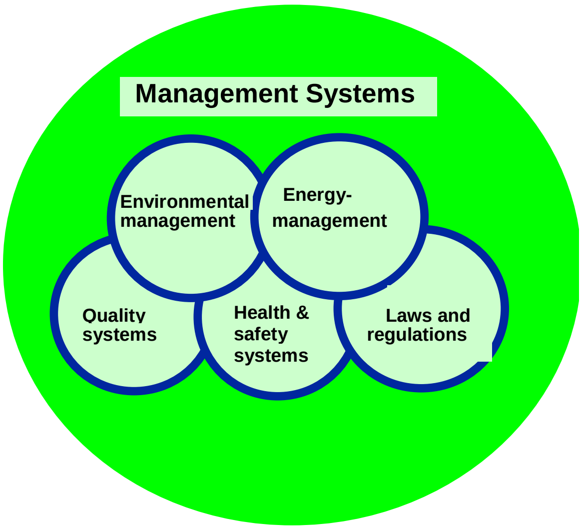


Figure 6.9. The figure illustrates integration of elements in a Total Quality and Environmental Management System in a company.

There are many lessons to learn from the work on quality systems, experiences that could be transferred from quality systems to EMS. To establish a continuous improvement process, it is necessary to obtain full integration of policy, objectives, targets and responsibility into the entire management system.

How do we develop the best features from Quality systems into an environmental management system?

The answer may be an integrated system based upon know-how from health and safety, total quality systems and environmental management systems. It is important and beneficial to develop one system instead of having three parallel systems. The experiences so far on integrated systems have not been evaluated. Some current research and development (R&D) projects in industry, which integrate Total Quality and Environmental Management systems (TQEM), might provide an answer.

Organisational Learning and Cleaner Production

In organisational learning on CP activities for example Energy Management, both top down and bottom up approaches will improve the project results due to this authors experience. To exemplify; the organisation of an Energy Management development project should involve top, middle and lower management, as well as employees from throughout the organisation. People directly connected with production: production leaders, technically responsible persons, maintenance persons and operators in the production process should be involved. The time available for learning activities and changes is often very limited. Changes usually cause stress, whatever the type of change. However, the company's success in the market is necessary for people in the organisation to have a job and an income in the future. Changes that will improve the company's position in the market are, despite a higher level of stress, of interest for people in organisations. The situation after the change is implemented, may also mean better working conditions, e.g. automatic machinery is doing the hard work, or quality is improved so that production is improved in a way that the workers' health and safety is also improved.

Continuous improvement is a key factor in corporate environmental performance. Optimising human learning in organisations in training programs may mean that humans in organisations improve. Emphasising double-loop learning could mean future potential benefits obtained in the organisation.

1. identify the need for CP;
2. secure (or re-secure) top leader commitment, secure an environment for system thinking in organisational learning by involving a supervisor with proper skills, setting up training programmes and frequent internal meetings;
3. establish (or revise if it is established) the environmental policy; consider external stakeholders as well as internal factors;
4. organise (or re-organise):
    a. Identify a person responsible for enforcing the programme within the organisation;
    b. ensure a high level of communication, involve all levels in the organisation;
    c. establish teams and provide opportunities for team learning;
    d. follow a guide or a method which include a double-loop learning and use both top down and bottom-up strategies, to help keep focus on what needs to be done and avoid frustration and effort put into discussions about how to perform the task;
    e. create space for employees to be owners of their suggested improvement options. (Let employees keep their "babies").

Figure 6.10. The steps to secure an environment of continuous learning connected to implementation or an ongoing CP Programme in companies.

In addition to the recommended CP method shown in Figure 6.2, this author emphasis that environmental issues are multidisciplinary and need to be listed separately:

1. Emphasis on environmental care, future enthusiasm and necessity of worker's contributions for improvements.
2. Need for external or internal advisors, or supervisors for CP tools and systems, should be considered if the company have no such available competence or capacity within the organisation.

3. Patience; step by step expectation, referring to Huisingh (1990) *"Cleaner Production is a journey, not a destination".*

Continuous learning in an organisation is more complex than pulling a lever, or commanding that "this and that should be done". To build an environment of continuous learning, it is necessary to take certain steps. From experiences in companies (from which the empirical data in this study are extracted), the author would like to suggest the steps shown in Figure 6.10. In addition to the recommended CP method shown in Figure 6.2 (EPA 1992), these steps are suitable in the implementation of CP in an organisation. If a CP programme is already implemented it is recommended to use steps 2-4 in Figure 6.10 in an evaluation of the implemented programme.

Combining CP and EMS

The EMS system is developed from quality standards, while CP has roots in the understanding of the need for pollution prevention options. For this reason, CP is option-oriented, while EMS is management oriented. The EMS system builds an organisation suitable to perform continuous improvement activities.

The methodologies could be combined to secure both implemented options and continuous improvement activities. A proposed CP-assessment and EMS method is shown in Figure 6.11.

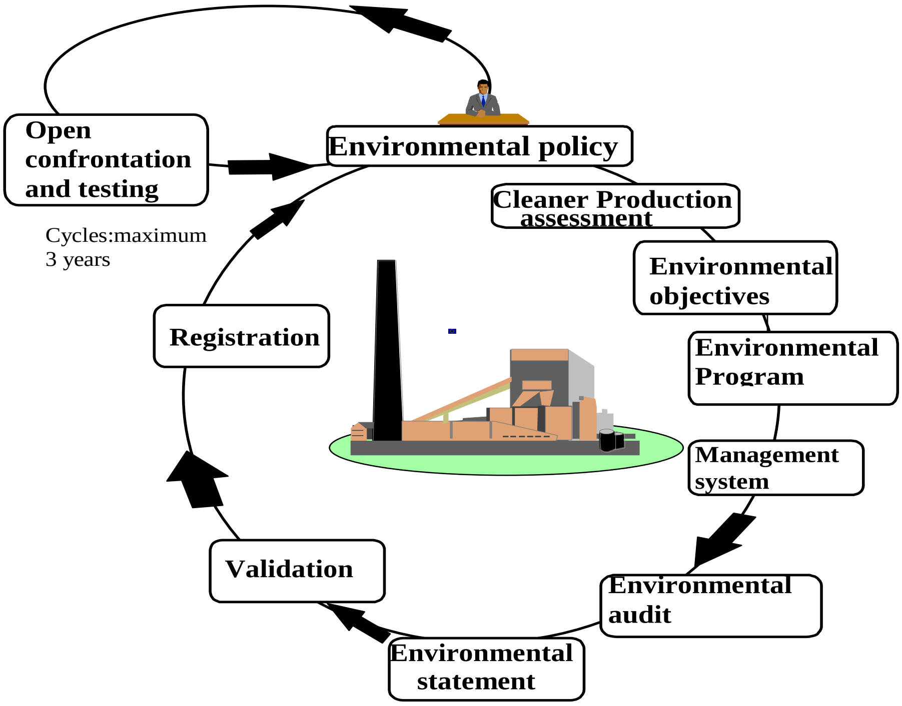


Figure 6.11. The Figure illustrates an improved and combined CP/EMS method. A CP assessment is utilised in the Environmental Review and an extra cycle connected to the Environmental Policy illustrates that new insight by open confrontation and testing should be developed. External factors should be considered in the revision of the policy.

The environmental policy is implemented in the main cycle, differently to the EMAS method suggested in the applied EMS method utilised in Norway. The Norwegian method is recommended by the Norwegian Confederation of Norwegian Business and Industry (NHO 1995 and Viddal et al. 1997). This author strongly recommends frequent revisions of environmental policy to facilitate double-loop learning. Double-loop learning is important in order to obtain organisational learning as outlined in Chapter 4 in this thesis. The revision of the environmental policy should be dependent on two factors:

1. Internal, in company, factors.
2. External factors, from outside the company.

An extra cycle connected to the Environmental Policy illustrates that external factors should be systematically considered in the revision of the policy. The activities in this revision consist of consideration of:

- new and forthcoming laws;
- new market demands;
- competitors' behaviour
- new, or forthcoming national and international environmental obligations (The Kyoto-protocol, The Rio declaration etc.)

Activities to be performed in the policy-revision cycle should be:

1. New insight by open confrontation and testing of the old policy. To obtain double loop learning, applied concepts like Eco-efficiency, Factor 10, Zero-outlet, Sustainable Development or Industrial Ecology should be considered.
2. Environmental compliance assessment (the company's situation compared to future laws and regulations etc.).
3. A study of changes in relevant external driving forces for the company (market demand for expanded producer responsibility etc.).
4. Ranking of environmental performance parameters relevant for the company (the company should make up their mind about the importance of parameters like CO_2, NO_x, BOD, etc.).
5. A cost benefit analysis. This analysis should consider the different costs connected to the different environmental options for the company.

Reports from the new insight gained by open confrontation and testing should be used as a strategic tool for the board of the company.

A CP would normally be suitable for use as a method to perform an environmental review. The recommended CP method in combination with

EMAS is shown in Figure 6.1 (EPA 1988). This method is sufficient in combination with EMAS, since the EMS in the rest of the circle secures continuous activity.

In order to keep up the improvement process (ensuring that the implementation becomes a continuous activity, not a project with a limited destination) the steps shown in Figure 6.11 are recommended.

When organising and performing the EMS, the fifth discipline, or system thinking (Senge 1990), should be emphasised as outlined in Chapter 4.

Conclusions

In the 1990' time period of environmental strategies, EMS could be seen as a further development of the CP methods. However the methodologies have different roots in their development phase. CP is option-oriented, while EMS is management oriented. The EMS system builds an organisation suitable to perform continuous improvement activities.

The methodologies could be combined to help to ensure both implemented options and continuous improvement activities. According to Figure 6.1 (EPA 1988) it would normally be suitable to utilise a CP assessment as a method for performing an environmental review. This would please the company because the results from this activity identify profitable options that give benefits to the environment. A proposed CP/EMS method, developed in this thesis, is shown in Figure 6.11. This method emphasises double-loop learning to secure organisational learning and optimum continuous activity. To apply this, a systematic and reliable revision of the environmental policy is required, as a strategic future tool to secure emphasis on the right environmental issues.

The organisational learning's fifth discipline, system thinking outlined in Chapter 4 (Senge 1990), should be implemented in the environmental and management training programmes in order to obtain maximum organisational learning. The theoretical conclusion on the CP method introduced in Norway is that this should be improved by a double-loop learning system, if this method is to secure continuous organisational learning.

In choosing EMAS or ISO 14001, EMAS should be preferred from an environmental improvement point of view. However, market demands may decide, EMAS is not well known outside Europe. ISO 14001 is a proper way to start. Life Cycle analyses should be utilised within an EMS system.

Benefits can be gained by integrating the EMS as shown in Figure 6.9.

This chapter has analysed the CP and EMS methodology with a theoretical approach. Results from testing in industry will be presented in part B of this thesis. Energy Management was not addressed in this chapter, but is the main issue in Chapter 7.

Chapter 7 Energy Management

Summary

Energy Management is not a goal by itself, but it helps the company to secure its' energy supply in terms of quantity, quality, emissions and operating expenses. It is a tool for obtaining continuous improvements with regard to energy efficiency and choice of energy sources. Energy Management does not differ significantly from other management systems. In many cases Energy Management can therefore, be successfully integrated into the company's existing management routines and administrative systems.

The emphasis in this chapter is on the overall approach that can be taken for Energy Management, rather than the particular techniques employed.

Chapters 4 and 5 state theoretical frames related to Energy Management. Chapter 6 on CP and EMS discuss how Energy Management can be integrated to EMS. EPIs connected to Energy Management are discussed in Chapter 8. Examples on utilising Energy Management are described in the empirical part of this thesis, Chapter 11.

Introduction

From the perspective of thermodynamics and the biogeochemical cycles in nature, as presented in Chapter 3, energy management should theoretically be an integral part of environmental management. Industry managers however, seldom have this perspective. An energy skilled employee is required to take responsibility for energy consumption and energy management needs. Energy management has historical roots in industry, so has environmental management. However, energy and environment often have separate management departments. This author focuses on how these departments can profit from co-operation. Energy management from the perspective of integration into environmental management is emphasised in this chapter.

Thinking strategically means being alert to all of the influences on a company's operation, such as the market, competitors and suppliers, as well as environmental concerns from competitors, stockholders, consumers and from the government. Management can then assess the impact that any changes are likely to have, and look for the best opportunities for the business as a whole. Developing a corporate strategy from this is an exercise in integrating the various management functions so that they are all working towards the same goals.

Energy Management should be an integral part of this, linked to an organisation's corporate objectives rather than an end in itself. Energy efficiency management is most relevant in industries in which the energy costs comprise a large share of overall costs. Table 7.1 shows examples of typical figures.

Table 7.1 Energy Cost in Relation to Overall Costs in some chosen industry branches (IEEN 1997b, p 33).

Industry	Estimated potential [46]Energy Savings in relation to total energy consumption (%)	Energy Cost in relation to overall operational costs (%)
Bakeries	15	2-5
Meat Processing Industry	25	3-9
Dairy Industry	15	4
Timber and Saw mill Industry	10	4
Laundries and dry-cleaners	25	9
Grain-drying Industry	5	10
Foundry Industry	5	10
Pulp and paper Industry	10	13
Fish Meal Industry	20	25

What is Energy Management?

The objective of Energy Management is:

> *"A tool which results in continuous improvements in energy use efficiency and choice of energy sources." (Amundsen et.al. 1998a)*

Energy Management has, like other management systems, a system oriented approach - a procedure, or routine that will help the company reduce its energy use. The results of this system should be implemented improvement options, which improve energy efficiency in all corporate activities. The thermodynamics and ecological dynamics in nature, related to Energy Management, are discussed in Chapter 3 and should be taken into account when performing Energy Management. Organisational learning aspects (described in Chapter 4) and utilisation of supervisors (described in Chapter 5) should be taken into account in the design of the Energy Management in order to obtain continuous improvement activity in the company.

Referring to Caffall, important elements in Energy Management (Caffall 1995 p.14) are:

[46] Energy saving potential includes options with less than four years of payback on the investments. In longer payback periods, the potential increases.

- *Obtaining senior management support for a programme to save energy;*
- *Commencing with an energy audit to find where energy can be saved;*
- *Monitoring energy usage (indexed to production) to report that savings are being made and maintained;*
- *Recognising that management is just as important as technology;*
- *Ensuring that a plan containing a number of energy saving projects exists and that the projects are co-ordinated together, rather than being implemented in an ad hoc or piecemeal way.*

Caffall (1995) emphasises that these points are crucial. Many industrial companies have attempted to do something about reducing their energy use, but with limited success. This has been because after the initial enthusiasm to make savings, the project was not continued. Campaigns to encourage employees to save energy at work are especially prone to fading away. Early gains are lost as people fall back into previous wasteful habits. Disappointing results often follow projects being launched in isolation; e.g. a one-off training programme for a small group of workers, or a monitoring system that only the energy manager uses.

For an energy saving initiative to be really effective, and to continue to be so, it must be part of a coherent set of projects that are linked together. For example, the output from a monitoring system should be reported to all managers on a regular basis, allowing the savings from a particular project to be seen and thus maintained. Any subsequent training can then take place in an atmosphere of energy awareness, with a means of measuring progress already in place.

Energy and environment

Concern for the environment has a growing interest in the marketplace and gets higher corporate priority. Environmental legislation is shifting the responsibility for what used to be seen as society’s problems, towards the resource-using companies. Growing environmental awareness amongst consumers has created a demand for “green” products. These trends are forcing industrial companies to publicly do something about the environmental effects of their operations. Companies are publishing environmental policies and creating senior posts to administer them.

The links between energy consumption and choice of energy source on the one hand, and emissions to the environment on the other, are outlined in Chapter 4. The volume of energy consumption and burning of fossil fuel are key words.

Approaches to Energy Management

The ABC's of Energy Management

What is particularly important in the introduction of Energy Management will vary according to the starting point of the industry branch and company. Some companies have emphasised energy conservation and through this, they already have substantial experience, expertise and greater involvement in energy efficiency. In designing Energy Management programmes it is important to consider Heap's theories (see Figure 4.3, Heap 1998) on organisational learning:

1. *Know-how*
2. *Involvement*
3. *Action*

The manager of a small fish processing company in *Engelsviken* puts his involvement like this:

> *"We used to pay the electricity bill as a necessary evil. Now we look forward to receiving it, because it is exciting to see how small it is."*

But what are the main elements of Energy Management? The components are (Amundsen et al 1998a):

1. *Energy Policy*
2. *Energy Analysis*
3. *Energy Objectives*
4. *Energy Programme*
5. *Energy Management & Training*
6. *Energy Audit*
7. *Annual Report*

Referring to Caffall (1995, p. 15-25), strategic approaches to Energy Management are becoming widely applied in the Netherlands. This is a result of agreements made between industry and the Dutch government as part of its National Environmental Plan. To achieve the target of a 19% improvement in efficiency by the year 2000, 17 industrial sectors have so far signed long-term voluntary agreements to reduce their energy consumption. The measurement and awareness of energy consumption is then encouraged within each sector.

The Dutch approach has four stages (Caffal 1995 p.15):

1. *"Preliminary: securing management commitment and motivation;*
2. *Analysis: performing an energy audit;*
3. *Planning: development of an energy plan;*
4. *Realisation: implementing projects and installing Energy Management."*

An important tool used during the first three stages is the energy potential scan (EPS) pioneered by the company Philips as part of its response to the Dutch initiative. The EPS produces a list of energy saving possibilities, which then form the basis of the Energy Management programme implemented in stage four (Caffal 1995, p 15). The key aspects of the EPS are to:

- *Obtain the commitment of management;*
- *Obtain insight;*
- *Judge energy efficiency;*
- *Prepare decision-making.*

At the outset, senior management needs to be convinced of the value of Energy Management. Once there is commitment from the top, staff can be made available to form an energy action team. This should comprise staff from different areas of the company who will carry out the EPS. The strengths of EPS are thus the commitment of management, the involvement of employees, and the use of the employees' knowledge. These are important strengths, which can flow through the entire Energy Management programme.

Referring to Caffall (1995 p 16), the UK Government has, since 1991, invited companies to "Make a Corporate Commitment" to Energy Management. The chairman or chief executive of each company taking part publicly signs a declaration, which commits the company to the actions, detailed below. Most of the elements of a strategic approach to Energy Management discussed so far are present in this list. A three-page "chairman's check list" explains the key questions that the company needs to consider. This is supported by a five-page "executive action plan", which helps the senior manager responsible for Energy Management (nominated by the chairman).

The Corporate Commitment requires the company to:

- *Publish a corporate energy policy.*
- *Establish an Energy Management responsibility structure.*
- *Monitor and evaluate performance levels.*
- *Set performance improvement targets.*
- *Increase awareness of energy efficiency among employees.*
- *Hold regular reviews.*

- *Report performance improvements of employees and shareholders.*

A survey conducted in 1994 (Caffall 1995, p. 16), found significant differences between companies that had signed the commitment, and those that had not. For example, 86% of signatory companies had made someone responsible for monitoring energy use, compared to 61% of non-signatories. Sixty-three % of signatories had set targets for energy efficiency, while only 40% of non-signatories had done so. Most importantly, 85% of companies that had made the commitment were planning to implement energy efficiency projects in the coming year; the corresponding proportion of uncommitted companies was 52%.

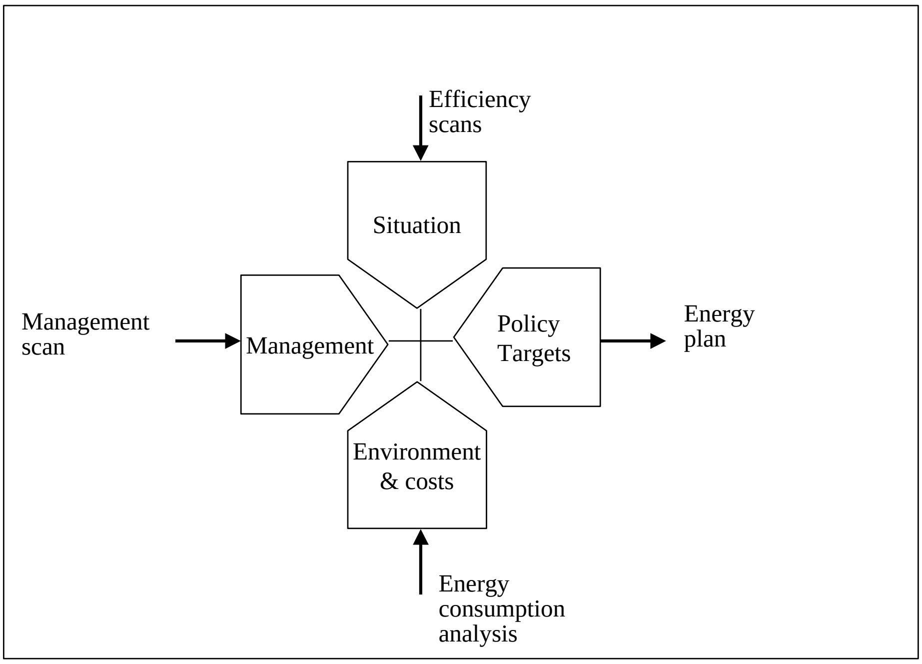


Figure 7.1 The EPS model (Caffall 1995, p.17)

Tools in Energy Management

Energy assessment

When commencing a structured approach to Energy Management, the first step is to understand the present situation within the company concerned (Amundsen et al 1998a). The Dutch EPS method provides a good example of ways to do this, having recognised that energy saving requires more than technology alone. Company policy and the quality of Energy Management are important too, if savings are to be realised and then maintained. According to Caffall (1995 p. 17), the EPS was based upon the "administrative cloverleaf" model that has been successfully used worldwide to improve the quality of management.

Within the EPS model, four elements interact:

- *Environment and costs* - how much energy is used? What are the effects on the environment and associated costs? Energy consumption analysis should give the answers.
- *Situation* - how efficiently do the company's production processes, buildings and facilities use energy? Efficiency scans should give the answers.
- *Management* - how is Energy Management organised? What information is available? The management scan gives this.
- *Policy* - how much energy is to be saved? How can this target be reached? What resources are needed for this? Energy saving programme should give the answers.

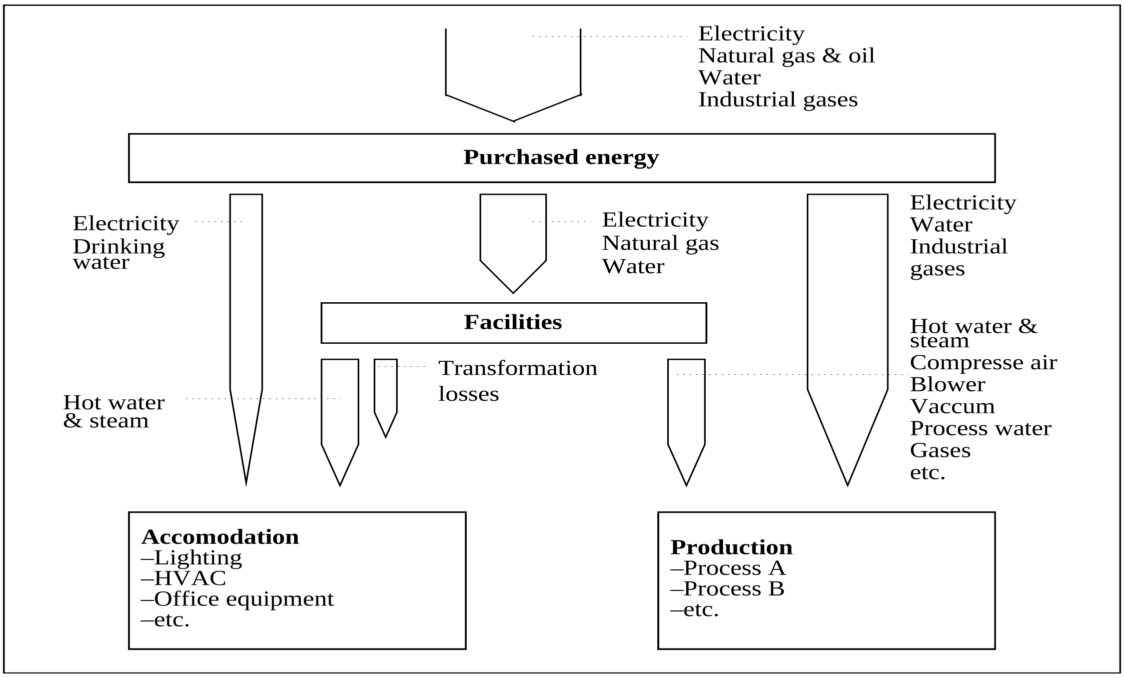


Figure 7.2 Analysing the energy flows (from Caffall 1995, p 18 and Saur & Amundsen 1994b)

Energy consumption

All the information about the site is gathered. By understanding the energy use of each process, energy flows around the site can be determined. A diagram showing how much each energy type is used directly can be developed (including any conversion into other forms of energy, such as compressed air or steam). Figure 7.2 shows an example of this.

The results of this analysis highlight which parts of the processes should be the subject of energy efficiency scan.

Energy efficiency scans

These form the heart of the EPS method and determine what savings are possible. The scans follow a basic input-output model for each process. Theoretical data for efficiency of the machinery, energy conversion possibilities and the nature of the raw material is gathered. It may be necessary to break an activity down into a number of processes in order to perform the scan. The objective is to see if the energy inputs and outputs can be optimised. The design criteria referred to in Chapter 3 (about maximising renewable energy sources and optimising the exergy level), have to be det-

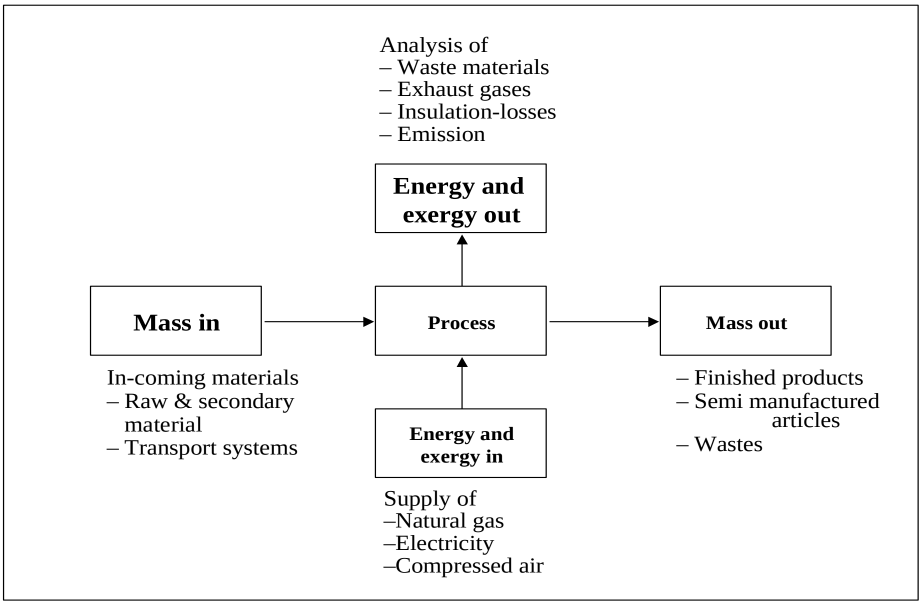


Figure 7.3 Scanning energy and mass flows for each process (Derived from Caffall 1995 p.19 and Amundsen 1993 p 98).

ermined. In addition to analysing the existing process, the scan can show if using a redesigned or alternative process could save more energy. For tools to be utilised in this scan, the author refers to Chapter 3 and suggests principles like Exergetic Life Cycle Assessment (Cornelissen 1997), Sankey diagrams (illustrated in Figure 3.3, Equipartition of Driving Forces (Sauar et al. 1996) and Pinch Technology (APEC 1999) should be utilised. Steps 1 and 2 within the EPS model represent the more technical processes of auditing current energy use and identifying areas where efficiency can be improved. The other two elements from the model in Figure 7.1 cover a less tangible aspect, i.e. the management of the organisation.

Energy and Environmental Accounting

The format of an energy and environmental accounting system is crucial to an environmental review. All significant consumption of energy/raw materials/water and additives are to be recorded and quantified. The results from an environmental accounting system are shown in Figure 7.4.

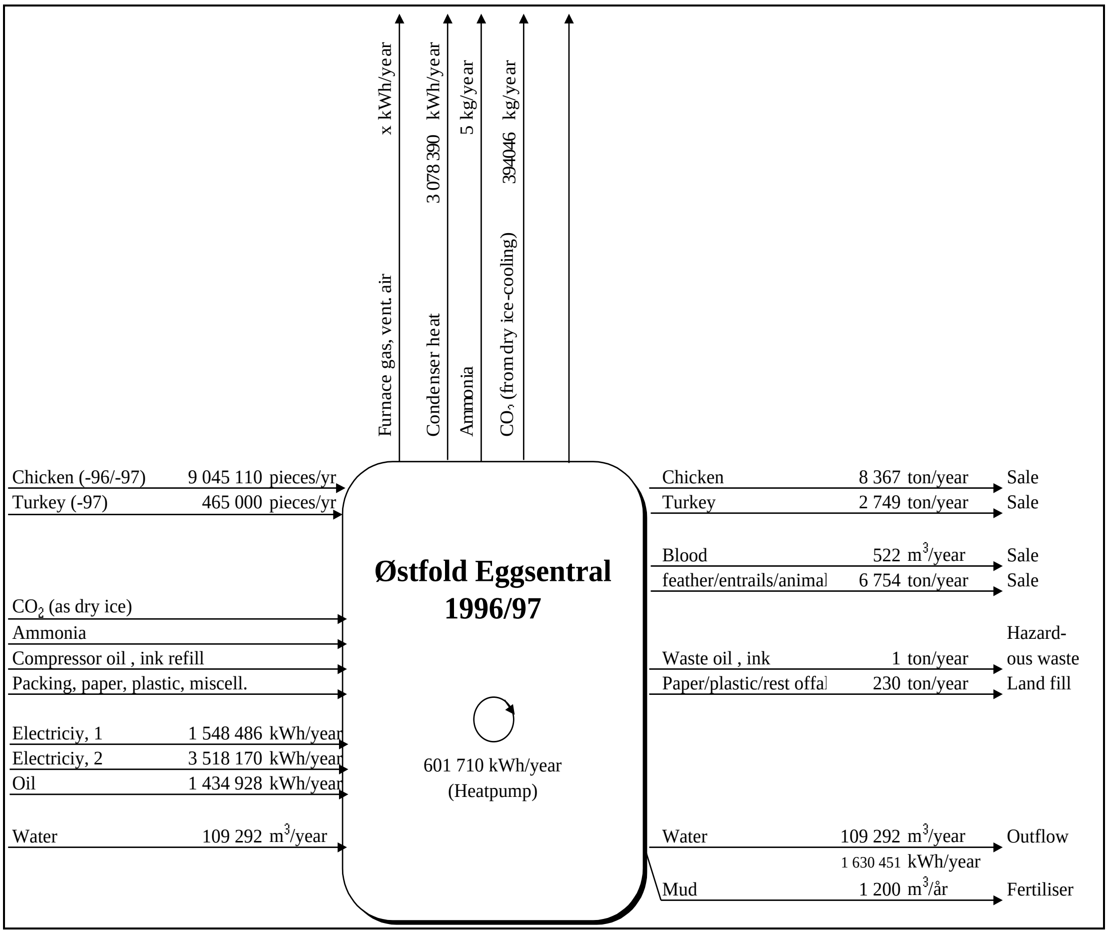


Figure 7.4 This figure illustrates a figurative result from an environmental accounting system; mass- and energy balance for the company Østfold Eggsentral in Norway (Saur and Amundsen 1994b and Saur 1997)

During the work on environmental accounts, this question often arises: How detailed should the accounting be? When answering this question, one should remember that large, expensive and hazardous flows or masses should be accounted for while some of the lesser flows may not be so important, at least for the final assessment phase.

A computer based environmental accounting system for the company "Food Industry Ltd." is shown in Figure 7.5. This is suitable for the setting up of the primary data in an environmental accounting system.

On the basis of the figures from the environmental accounts, the company should be able to quantify its material flow, its energy consumption in various manufacturing processes, as well as its air, water and solid waste streams.

This account will be an important starting point for the company, when it subsequently moves on to developing and implementing specific energy efficiency improvement measures.

Energy and Environmental Analysis

In an energy and environmental analysis, the objective is to identify possible improvement measures, calculate the effects on the environment and the energy saving potential, calculate potential, profitability and evaluate how the measures can contribute to fulfilling the approved objectives.

Environmental account 1998
Food Industry Ltd.

Key-figures (EPIs).
6 m3/tons final product
1719 kWh/tons final product

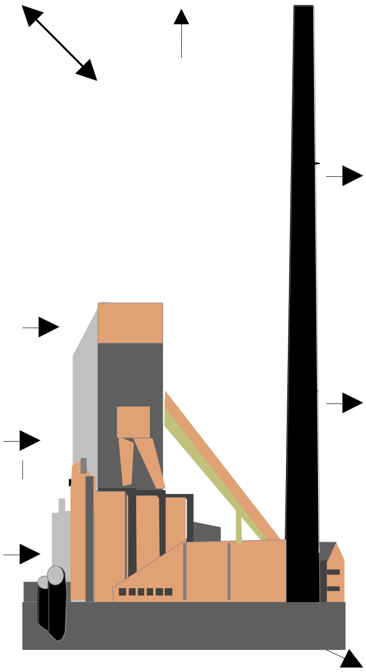
Target
5 m3 water/tons final product
1000 kWh/tons final product

Emissions to air	**kg/yr**	**Energy, kWh**
SO2	100	
NOx	100	
CO2	1 000	
Odours from oven	some	
Heat from cooling plant		significant
Heat from freezing plant		significant

Raw material	**tons/yr**
R 1	140
R 2	160
R 3	240
R 4	430
R 5	40
R 6	33
R 7	350
R 8	1
R 9	4
R 10	6
R 11	2
Miscellaneous	2
Total Raw material	**1 408**

Water	
Water cons.(m3/yr	6 162
Water (kEUR/yr)	1000

Energy	**per year**
Max power ouput (KW)	332
Tot. energy cons.(MWh)	1 788
Tot.energy cons.(kEUR)	236
Price pr kWh (EUR)	0,13



Products	**tons/year**
Dough/Forcemeat	60
Sausages	223
Cold cuts	165
Meat balls	108
Kebab, raw	140
Mild cured/smoked	59
Miscellaneous	17
Total Products	**1 040**

Waste	tons/ year	**Costs k EUR**
Waste to landfill	31	15
Waste to recycling	34	0
Hazardous waste	20	40
Foodstuff 1	12	0
Foodstuff 2	0	0
Total Waste	**97**	**65**

Effluents to water	**m³/yr**	**Costs k EUR**	Heat kWh>10C
Process water	4 030	101	9 403
Washing	2 132	53	136 803
Sanitary water	50	1	0
Cooling water	0	0	0
Sludge	100	3	233
Total water	6 312	**158**	146 440

Figure 7.5. Environmental Accounting System for "Food Industry Ltd." The figure shows the result page from a worksheet-software designed for this purpose. (Amundsen et al 1998a)

If the company does not possess the necessary expertise to carry out this work, it can be expedient to acquire assistance from external sources for the areas in question.

Detailed mass and energy balances can be used as the basis for brain storming sessions on improvement measures. An important task for the project manager during this phase is to arrange the brainstorming sessions and record proposals. The proposals are then subjected to technical, financial and environmental analysis. A list of the measures arranged by priority is developed. Often, the most important criteria will be economic profitability, and the measures are then ranked by priority in three groups; see Table 7.2.

Table 7.2 Technical and economic proposals for prioritised energy saving measures. (Amundsen 1993 p.112)

Priority	**Pay-Back Time** (year=X)	**Implementation**
A	X<1	Immediate implementation
B	$1 \leq X \geq 5$	Put into the environmental programme
C	X>5	Wait until a later date

Profitability with Energy Management

A number of improvement options can be found, so that it proves to be a profitable investment to introduce energy and environmental management simultaneously. In energy intensive industries, such as the food industry, metal industry and laundries experience has shown that large savings can be realised as presented in Table 7.1

Energy Management performance

This involves examining the quality of the current Energy Management effort. Tasks, responsibilities and co-ordination are analysed. Of particular importance is the amount of energy usage information available to management. The efficiency scans will generate a large number of energy saving options but how many of these will be implemented, depends strongly on the organisational conditions within the factory. The evaluation should not just discover the current state of Energy Management in the company, but also suggest ways in which it can be improved in terms of organisation, metering, monitoring, information and technology. To quantify the management aspects of energy usage is more difficult than the audit work just described. One possible method described by Caffall (1995, p.20), is an analysis framework like that used for the 1983 barrier survey in the UK to assess the quality of Energy Management in a company. The framework considered four aspects of Energy Management: energy policy, Energy Management structure, energy reporting system and investment status. A score between 0 and 4 was made for each aspect. For example, a reporting system of quarterly energy costs would score 0, while full sub-metering giving energy units per unit of product was assigned a 4. Some aspects of this work were published by Amundsen et al. (1998b).

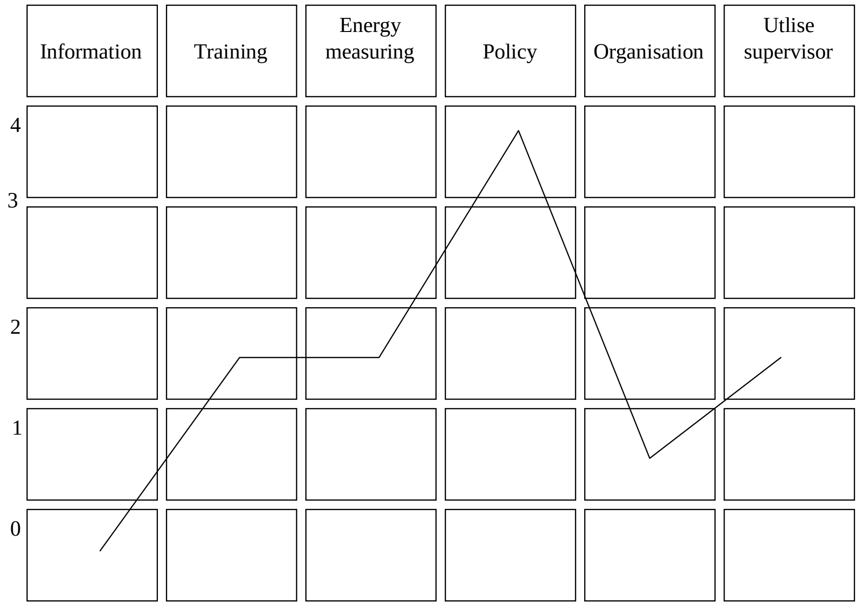


Figure 7.6 A typical performance assessment for Energy Management utilised in the Norwegian Industrial Energy Efficiency Network (Seyffarth and Skaugen 1998)

Cheriton Technology Management (Caffall 1995, p 20) proposed scoring the levels of development of Energy Management as a first step in the energy audit. The scoring categories are policy; organisation; monitoring and investment. In addition, it also scores for targets, purchasing and budgets. For example under budgets, putting energy costs within overhead would score 0, whereas 4 would apply where each department has its own energy budget and can invest in minor capital projects. Rather than looking to improve the total score, Cheriton suggests that it is more useful to make sure that the level of development of each category in roughly in step, with no more than two levels of difference between categories.

As well as showing the current status of a company's Energy Management effort, these scoring approaches highlight where more attention is needed. Figure 7.6 illustrate this performance assessment. The objective should be a balance across the categories by bringing the level of the lowest scoring area up to that of the best. It can also be a valuable exercise to ask middle managers to assess the scores from their point of view. Often this can highlight problems of which senior management is unaware.

Such assessment techniques can also be utilised during implementation of the Energy Management strategy. It is valuable to check progress of the strategy towards its objectives to see if any adjustment is needed. Individual programmes within the strategy should also be reviewed regularly to check that they are cost-effective. Subjective techniques like those above should be augmented by objective benchmarking measures such as specific energy consumption.

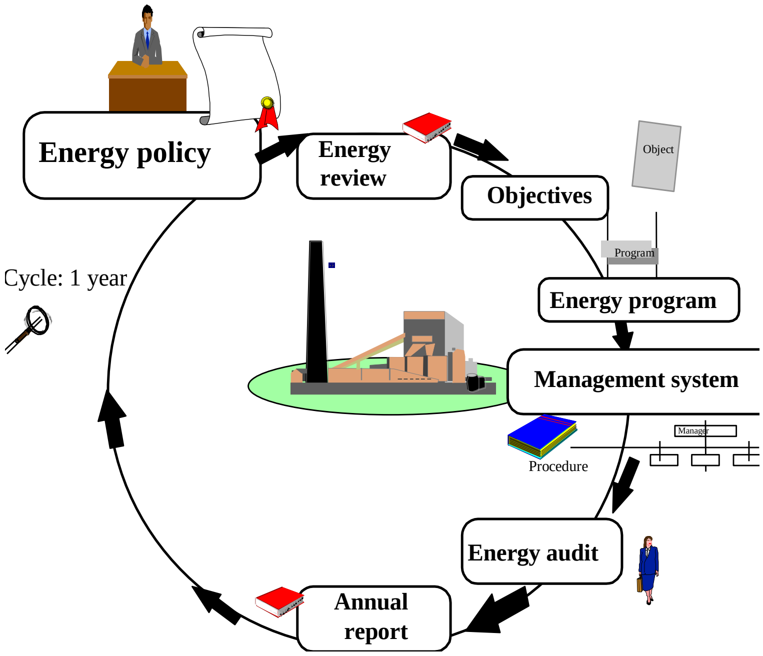


Figure 7.7. The Main Components of Energy Management (Amundsen et al 1998a)

Relevant Points for this Study

The author chose to study joint management of Environment and Energy. Relevant aspects connected to this issue are presented here.

Energy Management and organisational learning.

The aim of Energy Management is ongoing efficiency improvements, which ensure that the components of the Energy Management system do not become static. Like other energy analysis methods, the Dutch EPS method referred to in this chapter, does not stress the importance of repeating the process. Continuous improvement activities do not occur. With respect to this issue, the UK Government "Make a Corporate Commitment" to energy is to be recommended. This author recommends placing activities in a time cycle, as EMAS places its components in a time cycle.

Studying Energy Management with the organisational learning approach (outlined in Chapter 4) and supervisor approach (outlined in Chapter 5), at least three issues should be emphasised:

1. *double-loop learning;*

2. *top down and bottom up strategies;*

empower a supervisor in the implementation of Energy Management.

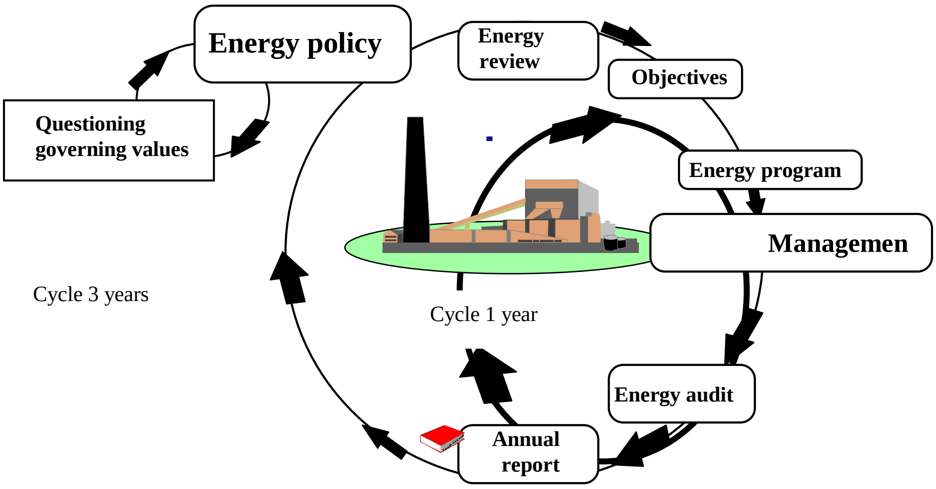


Figure 7.8. The Main Components of Energy Management applied to EMAS. A double-loop (the big circle) cycle has a three-year cycle to follow EMAS requirements and a single-loop (the small circle) cycle to allow creation of yearly improvement programs. An extra cycle connected to the Environmental Policy illustrates that new insight by open confrontation and testing should be developed. (Developed in this thesis.)

Commenting on the third point, the supervisor could be either external, or internal. If an internal person is available this is probably the most sustainable choice. He or she should have proper skills relevant to the actual situation of the company. Important work for the supervisor will be to build an Energy Management organisation on a) involvement b) know-how and c) action. The supervisor should design the Energy Management system to secure double-loop learning. The double-loop learning presented in Figure 4.5, can be applied to Energy Management as shown in Figure 7.7. The cycle is designed in this way so that the organisation revises the policy and objectives frequently. In this way, double-loop learning will be obtained (Argyris and Schön 1996, p 20-25).

Both the top down and bottom up strategy should be emphasised in Energy Management. The top down strategy means to secure top leader commitment. The bottom up strategy means involving and organising all levels in the organisation in energy efficiency.

The aim of Energy Management is ongoing efficiency improvements, which ensure that the components of the Energy Management system do not become static. In order to avoid this, they can be placed in a time cycle, as EMAS places its components in a time cycle.

EMS and Energy Management

Energy Management and EMAS – advantages and disadvantages.

Integration of Environmental Management Systems with other management systems like health and safety is discussed in Chapter 6. In this section, integration of energy and environmental management systems is focused. Companies that want to introduce EMAS have a lot to gain by focusing on energy and environment simultaneously, creating an integrated energy and environmental management system.

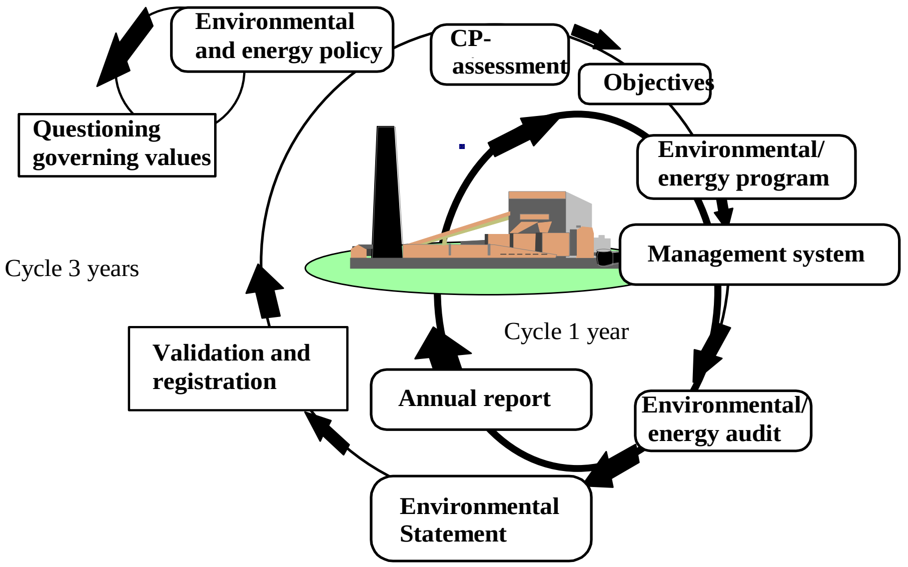


Figure 7.9 The Main Components of successful integration of Energy Management, EMS and Cleaner Production assessments. A double-loop (the big circle) learning cycle has a three-year cycle to follow EMAS requirements and a single-loop (the small circle) learning cycle to encourage creation of yearly improvement programs. An extra cycle connected to the Environmental and Energy Policy illustrates that new insight by open confrontation and testing should be developed. (Developed in this thesis.)

The following are some of the ***advantages*** of integrating Energy Management and environmental management:

- avoid parallel management systems for environment and energy;
- less paper work;
- easier maintenance;
- greater economic savings and greater environmental performance improvements.

The following are some of the ***disadvantages***:

- large overly complex system that is not suited to the organisation and the current responsibilities;

- advisors do not have expertise on both energy and the environment, but use of two different advisors can be expensive.

Referring to Amundsen et al (1998a), the individual elements of Energy Management can be compared with the elements in EMAS, as shown in Table 7.3. The table shows equalities in both systems, with the exception of the validation and registration steps. The equalities shows how the management systems fit together and can easily be jointly integrated.

In Figure 7.8, the main components of Energy Management are applied to the requirements of EMAS. A double-loop (the big circle) cycle has a three-year cycle to follow EMAS requirements and a single-loop (the small circle) cycle is designed to allow creation of yearly improvement programs.

When concluding, Energy Management and EMAS can be integrated, this also applies to ISO 140001 (ISO 1996). Figure 6.4 shows the equalities and differences in EMAS and ISO 14001. It shows that the most important difference is in reporting. The main components are the same. For this reason we can conclude: Energy Management can be integrated into EMS.

Conclusions

- Referring to the single-loop and double-loop organisational learning aspect, as shown in Figure 4.4 and 4.5, and comparing those to the EMAS circle developed in Figure 6.11, an applied Energy Management circle can be designed as shown in Figure 7.7.
- Both top down and bottom up approaches should be utilised when performing Energy Management.
- A supervisor with proper skills and competence should be active when implementing the Energy Management system. The supervisor should secure involvement, know-how and action from the employee. He or she should also secure the design and approaches for implementation.
- Measuring the performance of the Energy Management system is important.
- Energy Management can be developed to a double-loop learning system as shown in Figure 7.8.
- Energy management can be integrated within environmental management as a double-loop learning system, as shown in Figure 7.9.

Table 7.3 Energy Management in comparison with the EMAS requirements

Energy Management	EMAS requirements	Suitable for integration
Energy Policy Use the company's strategy, combine this with energy and think long term. Create an energy policy. Policy should be approved by the board.	**Environmental Policy** Specific requirements, among other: 1. compliance to law; 2. continuous improvement activities.	Yes
Energy audit 1. Create detailed mass and energy balances to determine the savings potentials. 2. Through voluntary brainstorming, an energy-efficiency option list is identified. Detailing basis for resolution. 3. Estimate of savings potential 4. Create improvement options	**Environmental Review** Specific energy relevant requirements: 1. Evaluation of environmental consequences of energy use; 2. Energy Management, efficiency and choice of energy source..	Yes
Energy Objectives Set up detailed objectives which are: 1. realisable within the scope of available resources; 2. comprehensible(to those involved); 3. describing deadlines.	**Environmental Objectives** Set up detailed objectives which are: 1. realisable within the scope of available resources; 2. comprehensible (to those involved); 3. describing deadlines.	Yes
Energy Programme Identify concrete improvement measures.	**Environmental Programme** Set up one list with concrete improvement measures.	Yes
Energy Management: Make instructions for: Who is responsible for what when (e.g.): Who reads the meters? Who works out the key energy figures? **Training** Carry out training programmes at all levels of the company.	**Environmental Management System;** Create and implement procedures for: Who does what when, who is responsible for what and by which authority? **Training** Analyse needs and carry out training either internally or externally.	Yes
Energy Audit 1. Test established standards against what has taken place. 2. Write a review report.	**Environmental Audit** 1. Test established objectives against what has taken place. 2. Publish an environmental statement.	Yes
Annual energy report Reporting on organisational responsibility, energy consumption and performance is recommended. Reporting is not mandatory.	**Environmental statement** Report on Environmental Impact, environmental systems and environmental programs should be included. Active information to internal and external stakeholders is required	Yes
Continuous Improvements Revise the policy and re-start from the top of the column. Adjust this according to the company's EMAS cycle.	**Continuous Improvements** Re-start from the top of the column. Use the company's new strategy, the environmental statement and revise the policy. Use maximum three-year cycles.	Yes
	Validation	No formal system for validation is available for Energy Management
	Registration	No formal system is available for registration of Energy Management.

Chapter 8 Environmental Performance

Today's corporate practice is often to measure environmentally related activities by calculating the payback on the investment[47] only. Using only payback is insufficient for calculations related to environmental issues. Hazel Henderson (Henderson 1995) makes a similar observation:

> "...*trying to run a complex society on a single indicator like the Gross National Product is literally like trying to fly a 747 with only one gauge on the instrument panel...imagine if your doctor, when giving you a check-up, did no more than check your blood pressure."*

Summary

In Chapter 3, "The theory of Thermodynamics and the Biogeochemical Cycles in the Ecosystem", this author emphasised two important design criteria for energy systems, in order to secure sustainable development. The first criterion is to utilise a large share of renewable energy sources and the other to use a minimum of exergy. In this chapter, it is suggested that these criteria should be applied as Environmental Performance Indicators (EPIs).

Referring to the chapter on organisational learning, to measure performance is necessary to obtain continuous organisational learning. The presented methods for EMS[48] and Energy Management[49] require continuous learning as one important condition for success. EPIs are useful to measure improvements whether dealing with CP or with energy efficiency improvement activities and programmes.

This chapter reviews planned EPIs related to energy from the perspective of sustainable development and eco-efficiency. At the beginning of this chapter, dealing with the ISO /DIS 14031 (ISO 1998), this new standard is evaluated. The OECD "Eco-efficiency concept" and two current projects are evaluated. The two current projects are: a UN [50] initiative on Indicators of Sustainable Development and a European Green Table[51] initiative called EPIs in industry.

Two energy related EPIs are emphasised as necessary to obtain sustainable development and eco-efficiency in the final part of the chapter.

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[47] It is not common to calculate Present Value (PV) in small and medium sised Nordic industry. This is despite PV is more reliable (according to many economists) when decisions are to be taken relying on calculated figures. PV calculates future economic savings in a better way. Environmental benefits are not taken into account in these calculations.

[48] Information about Environmental Management Systems (EMS) is presented in Chapter 6.

[49] Energy Managementis presented in Chapter 7.

[50] UN – United Nations

[51] European Green Table (EGT) is an independent foundation established from Norwegian Industry leaders in 1989. Companies and Government Bodies from Europe participate in the foundation. The purpose is to support and strengthen the role of market mechanisms in the ongoing process to SD.

Environmental Performance Evaluation, ISO 14031

Environmental Performance Evaluation and Indicators, definitions

According to the ISO/DIS 14031 *"Environmental management- Environmental Performance Evaluation (EPE) – Guideline"* (ISO 1998), EPE is an ongoing internal management process and tool that uses environmental indicators to compare an organisation's past and present environmental performance with its environmental performance criteria. An organisation should base its planning of EPE and a selection of environmental indicators on:

- the significant environmental aspects over which it has control and it can be expected to have an influence;
- the environmental performance criteria;
- information about the local, regional/national or global environmental conditions;
- an understanding of the views of its multiple stakeholders;
- information needed to meet legal and other requirements.

The ISO-document suggests that environmental indicators describing the environmental performance of companies may be classified into the following three areas:

- the management area;
- the operational area;
- the condition of the environment (also referred to as Environmental Condition Indicators (ECIs) - should address local, regional and global issues.

The management and operational areas are intended to encompass the activities, products and services of the organisation, and the environmental area to consider the condition of the environment

ISO 14031 and energy related EPIs

In paragraph A.4.2.1 *"Examples of operational performance indicators"* in ISO/DIS 14031, energy is one group of the examples. Here are the stated examples:

"*Energy*

If management's interest is environmental performance related to the total energy or the types of energy used by, or the energy efficiency of, the organization's operations, possible OPIs[52] *may include:*

- *quantity of energy used per year or per unit of product;*
- *quantity of energy used per unite of service or per customer;*
- *quantity of each type of energy used;*

[52] OPI = operational performance indicators (ISO 1998).

- *quantity of energy generated with by-products or process streams;*
- *quantity of energy units saved due to energy conservation programmes."*

Indicators of sustainable development are not emphasised in ISO/DIS 14031.However the standard does not forbid the development and utilisation of such indicators.

Indicators of Sustainable Development

In the years after the Rio Conference, the United Nations Commission on Sustainable Development (CSD) developed numerous initiatives to promote sustainable development. These led to the adoption in April 1995 of a working programme on the Indicators of Sustainable Development. Since then, the group of experts from different organisations involved in drawing up these indicators has produced the list presented by the CSD[53] in the "Blue Book"[54]

The European Commission (1997) states the methodological idea in the choice of indicators in this project, see footnote[55].

This study pursues the objective of the United Nations of creating a number of international indicators of sustainable development. It is also the intention to comment on these indicators and to adjust them, taking into account both the situations of individual countries and regional interests.

The result from the study European Commission, (1997) is a list of indicators given in Table 8.1.

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[53] CSD = Committee of Sustainable Development, UN.

[54] The "Blue Book", published by CSD in August 1996, defines the framework and methodology of more than 130 indicators of sustainable development.

[55] Methodological ideas (Guinomet,1997)

The "blue book" presents the methodologies of the sustainable development indicators, which were established by the expert groups convened by the Commission on Sustainable Development (CSD). These methodologies are addressed to all the Member States of the United Nations taking part in the "test phase" which will allow the establishment of a number of common indicators for the year 2000. This phase is intended to adjust the currently proposed definitions and to measure the level of convergence of the various international situations towards sustainable development. Certain Member States of the European Union are already involved in this "test phase"; this involves Belgium, Germany, Finland and the Netherlands. Eurostat's contribution is not part of this "test phase" although it is made in parallel to it. Indeed, the aim in view in this study is to show that, for some if the indicators of the "blue book", of the European data are easily accessible and can be used, in a first reflection phase, by the Member States of the EU. Although, the submitted data are not exhaustive, they make it possible to take stock of the information quickly available and to note the existing major differences between European methodologies and those proposed by the United Nations.

The data submitted in this book come from various databases such as:

- New Cronos: public database making it possible to obtain statistical time series in the principal spheres of activity;
- Envstat: internal production database of the environment unit of Eurostat;
- the common questionnaire Eurostat/OECD which enables both institutions to use common methodologies and surveys.

However numerous problems were raised at the time of the drafting of this study. Indeed, the definitions proposed by the UN, sometimes broad, give several possibilities of interpretation.

It is the case in the economic part of Chapter 33 of the Agenda 21, which covers the financial resources and mechanisms and it is then difficult to present the indicator briefly. The same is true with regard to the definitions of the indicators of the social field presented in Chapter 36 of the Agenda 21, covering the promotion of education, of the training and public awareness raising. It is not possible to provide the statistics required to calculate this indicators because of the various situations met within the Member State of the EU. In addition, not all the indicators are available, either because their methodology is not defined, or because the data are not yet collected."

Table 8.1. A list of sustainable indicators from the European Commission (1997).

CHAPTERS OF AGENDA 21	DRIVING FORCE INDICATORS	STATE INDICATORS	RESPONSE INDICATORS
CATEGORY: ENVIRONMENTAL			
Chapter 18: Protection of the quality and supply of freshwater resources	– Annual withdrawals of ground and surface water – Domestic consumption of water per capita	– Groundwater reserves – Concentration of faecal coliform in freshwater – Biochemical oxygen demand in water bodies	– Waste-water treatment coverage – Density of hydro-logical networks
Chapter 17: Protection of the oceans, all kinds of seas and coastal areas	– Population growth in coastal areas – Discharges of oil into coastal waters – Releases of nitrogen and phosphorus to coastal waters	– Maximum sustained yield for fisheries – Algae index	
Chapter 10: Integrated approach to the planning and management of land resources	– Land use change	– Changes in land condition	– Decentralised local-level natural resource management
Chapter 12: Managing fragile ecosystems; combating desertification and drought	– Population living below poverty line in dryland areas	– National monthly rainfall index – Satellite derived vegetation index – Land affected by desertification	
Chapter 13: Managing fragile ecosystems: sustainable mountain development	– Population change in mountain areas	– Sustainable use of natural resources in mountain areas – Welfare of mountain populations	
Chapter 14: Promoting sustainable agriculture and rural development	–Use of agriculture pesticides - Use of fertilisers - Irrigation percent of arable land and water logging - Energy use in agriculture	– Arable land per capita – Area affected by salinization	– Agriculture education

Table 8.1 continued...

CHAPTERS OF AGENDA 21	DRIVING FORCE INDICATORS	STATE INDICATORS	RESPONSE INDICATORS
Chapter 11: Combating deforestation	– Wood harvesting intensity	– Forest area change	– Managed forest - Protected forest in percent of total
Chapter 15: Conservation of biological diversity		Threatened species as a percent of total native species	Protected area as of total area
Chapter 16 Environmentally sound management of biotechnology	–	–	R & D expenditure for biotechnology Existence of native biosafety regular guidelines
Chapter 9: Protection of the atmosphere	– Emissions of greenhouse gasses – Emissions of sulphur oxides – Emissions of nitrogen oxides – Consumption of ozone depleting substances	– Ambient concentration of pollutants in urban areas	Expenditure on an abatement
Chapter 21: Environmentally sound management of solid wastes	Generation of industrial and municipal solid waste		Expenditure on management – Waste recycling – Municipal waste

Eco-efficiency, the concept of the OECD-ministers

WBCSD[56] and OECD[57] have initiated an Eco-efficiency concept. The definition is (BCSD 1993):

> *"Eco–efficiency is reached by delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's carrying capacity."*

WBCSD has this definition:

Eco efficiency = Value added/environmental impact

Referring to Brattebø and Røine (1998), the eco effectiveness could be defined as:

Eco effectiveness = Eco efficiency x Total volume of activity.

OECD Environment Ministers observed that a strategy to improve "eco-efficiency" might enable industry, governments and households to separate pollutant release and resource use from economic activity. They encouraged the OECD to assess the potential of eco-efficiency in the light of studies

[56] WBCSD: World Business Council for Sustainable Development

suggesting that factor-of-ten efficiency improvements are both necessary and possible in the next thirty years.

In the following, an abstract of their recently published preliminary document is given.

Definition

Eco-efficiency expresses

the efficiency with which ecological resources are used to meet human needs.

It can be considered as a ratio of an output divided by an input: the "output" being the value of products and services produced by a firm, a sector, or the economy as a whole, and the "input" being the sum of environmental pressures generated by the firm, sector or economy.

Measuring eco-efficiency depends on identifying indicators of both input and output.

Strategies to improve eco-efficiency

The World Business Council for Sustainable Development (WBCSD 1997) has pioneered a business strategy to improve eco-efficiency that involves:

a) Developing indicators and goals.
b) Working towards the goals through a process of innovation in technology, modes of organisation and ways of thinking.
c) Monitoring the indicators and modifying the strategy if necessary.

Approaches based on indicators, targets, innovation and monitoring have considerable potential, but different meanings for different actors. Governments, community organisations and households have adopted such strategies.

Business goals, indicators and targets

WBCSD explains eco-efficiency goals at the firm level by referring to the definition (given on the previous page). This statement includes broad social objectives and environmental constraints. Such goals require government involvement, and also depend on businesses entering into partnerships with their customers and suppliers.

Criteria for eco-efficiency

Seven criteria for eco-efficiency have been embodied in a variety of qualitative indicators developed by firms.

WBCSD criteria (OECD 1998) for eco-efficiency:

1. ***minimise the material intensity of goods and services;***
2. ***minimise the energy intensity of goods and services;***

[57] OECD: The Organization for Economic Co-operation and Development

3. ***minimise toxic dispersion;***
4. ***enhance material recyclability;***
5. ***maximise the use of renewable resources;***
6. ***extend product durability;***
7. ***increase the service intensity of goods and services.***

Potential to improve eco-efficiency

The OECD has studied numerous initiatives to improve eco-efficiency at the firm or community level. Under current market conditions and environmental policy, manufacturers have found profitable ways to reduce their use of materials, energy and water per unit of production by 10-40%. Firms have also demonstrated technologies that cut the use or emission of toxic substances by 90% or more, although these technologies are not always put into practice.

A few firms have taken initiatives to reduce environmental impacts during and after the use of products, for example by recovering used equipment and re-using durable components. Initiatives that address impacts over the full life cycle offer the greatest potential for reducing pollution and resource use economy-wide

The OECD ministers emphasise that a major task for governments is to enhance the consistency of efforts at the firm and household level. They say that establishing a policy framework that reduces the gap between private and social aims can do this. "*Economic incentives to reduce pollution would improve the profitability of savings in energy and materials. Meanwhile, the technical potential for reducing toxic emissions is only likely to be achieved through government incentives and regulations*." Initiatives to reduce environmental pressure throughout the product life cycle most commonly occur where governments have introduced the concept of *"extended producer responsibility*".

Economy-wide indicators and targets

The "Factor 10 Club" (OECD 1998) argues that the intensity of material and energy use in the economy should be reduced by a factor of ten in industrialised countries over the next 30-50 years, in order to halve global CO_2 emissions while allowing for continuing economic growth.

National and local sustainable development goals and indicators are needed to address environmental challenges that vary among countries and locations. Eco-efficiency targets can <u>supplement</u> such goals, but they also need to be tailored to reflect sectoral trends and specific environmental challenges. OECD governments are increasingly working with stakeholders to develop quantitative benchmarks and goals for sustainable development. Stakeholder involvement can help corporate leaders to choose among complex and conflicting priorities, and also eases the subsequent introduction of policies to achieve the targets

Recent trends in pollution release and resource use, economy-wide

Many indicators of economic and quality-of-life "output" have improved in the last ten years in OECD countries. As Figure 8.1 shows, some indicators of eco-efficiency "input", such as emissions of regulated pollutants, have improved too. However, many indicators have worsened, including CO_2 emissions, waste generation, and water consumption.

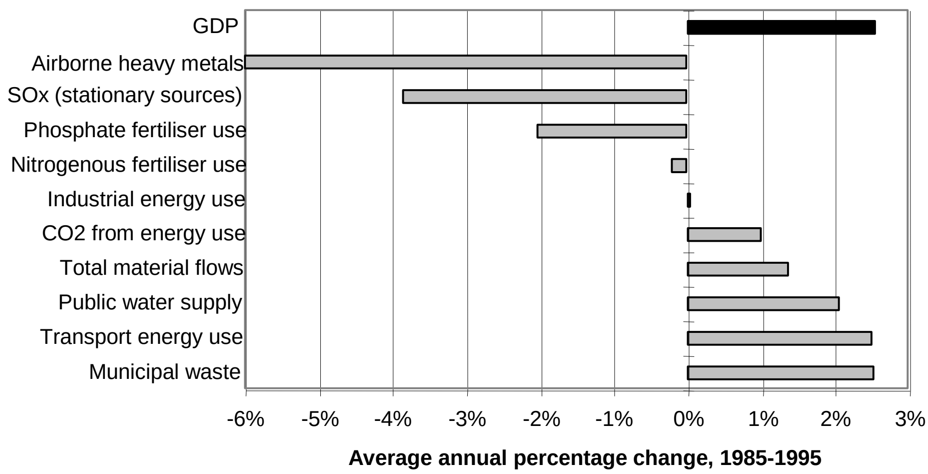


Figure 8.1 OECD trends in GDP and a range of eco-efficiency "input" indicators[58] (Source: OECD 1996)

Potential for improving eco-efficiency throughout the economy

High input prices and strong competitive pressures can contribute to rapid productivity increases. OECD economies have achieved average labour productivity increases of 2-3% per year over several decades, increasing incomes ten-fold while halving working hours.

Eco-efficiency improvements alone do not necessarily reduce environmental pressure. In the case of air travel, traffic grew by nearly 8% per year between 1974 and 1988, so that energy use increased by nearly 4% per year

Next steps

As one of four next steps, the OECD ministers emphasise

[58] Figures relate to all OECD Member countries except: airborne heavy metals and total material flows, which are for Germany, Japan and United States only; public water supply is for Canada, France, Germany, Japan, United Kingdom and United States only, 1985-1990. Sources: OECD Statistics, World Resources Institute

"identification or development of transparent, comprehensive indicators of eco-efficiency as part of a broader set of sustainable development indicators" to support the development of policies to improve eco-efficiency

Sustainable indicators presented on the WEB

Hart (1996) published a web page on sustainable indicators. Table 8.2 shows a copy of this web page, illustrating traditional vs. sustainable indicators in the category of environmental indicators. Social and economic indicators are also referred to on the same web site. Studying the indicators relating to renewables, the following indicator is suggested: "Ratio of renewable energy used to non-renewable energy used". Searching in the database for Exergy, Anergy or Energy Quality gave no hits, which is not surprising to this author. Quality of energy described by exergy and anergy is not something that is common know-how. The author emphasises the need for introduction of energy quality as an important indicator of SD.

Environmental Performance Indicators in Industry

Principles for selection and implementation of EPIs were investigated in a European Green Table initiative called "EPIs in Industry". The author and my colleague Elin Økstad, stated the following in a report (Økstad 1997):

> *When applying LCA for decision making purposes and goal setting purposes as in the Green Table project, the global perspective of such methods is important to include, since the pollution knows no borders, since products are distributed on an international market, and since benchmarking between companies may be carried out across country borders. The LCA valuation methods may be seen as input to company internal prioritizing already carried out by the companies on the basis of local regulations and general knowledge.*

Table 8.2 Traditional vs. Sustainable Indicators. Environmental indicators (Maureen Hart 1996)

	-	
Traditional Indicators	**Sustainable Indicators**	**Emphasis of sustainable indicators**
Ambient levels of pollution in air and water, generally measured in parts per million of specific pollutants	- Biodiversity. - Number of individuals of key species, such as salmon in a stream or birds in a given area	Ability of the ecosystem to process and assimilate pollutants
Tons of solid waste produced	Amount of material recycled per person as a ratio of total solid waste generated	Cyclical use of resources
Per capita energy use	- Ratio of renewable energy used to non-renewable energy used - Total amount of energy used from all sources	- Use of renewable energy - Conservation

The Green Table report (Økstad 1997) states that most indicators were developed to express the identified significant environmental aspects related to production processes on an operational level. Only a few companies were able to develop indicators of strategic importance, such as indicators expressing development of products, or technology. Most companies have thus a potential for future introduction of such indicators. The life cycle approach is a valuable tool for identifying the companies' significant environmental aspects.

Principles for Selection of EPIs

Referring to Økstad, the environmental impact assessment should identify the significant environmental aspects from products and processes. A life cycle approach should be applied for this assessment.

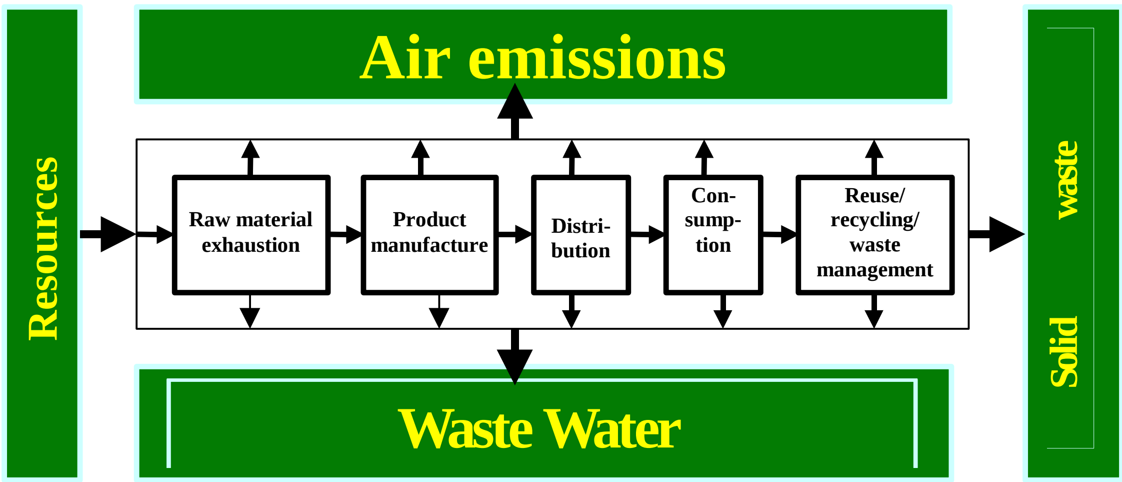


Figure 8.2 Life Cycle of products. Life cycle model of material flow in a product system with waste generation at the production and user phases. Material flows between product system units in kg material (Lindfors et al 1995).

The Life Cycle Approach: the selection of EPIs should be, when relevant, based on an understanding of the main potential impacts on the environment related to the total life cycle of product systems. Such knowledge is regarded as important when identifying improvement strategies and activities. The given companies should therefore take into consideration all processes, raw materials composition, energy, distribution systems and specification for application/utilisation/waste handling of the products in the entire life cycle as illustrated in Figure 8.2. EPIs should monitor and report on those parts of the product systems that cause the most significant environmental impacts.

To describe the potential environmental impacts, the Green Table project used the system of environmental impact categories described by the LCA Nordic project (Lindfors et al 1995). These impact categories describe the main impacts on environment and health:

1. impacts on resources (non-renewable energy and materials, water and land);

2. impacts on health (toxicological, non-toxicological, work environment);
3. impacts on environment (Global warming, acidification, euthrophication, photo-oxidant formation, ecotoxicological impacts, and biological diversity).

Table 8.3: Areas of main concern. These impacts should be related to the company's internal sources (products and processes). (Økstad 1997)

Company	Life cycle phases giving main impacts	Main potential Impacts on Environment	Significant environmental aspects identified in the environmental assessment
Dyno Stjørdal	• Raw materials	• Resource depletion • Global Warming	• Consumption of plastic material (fossil raw material, non recyclable resource) • Energy consumption (manufacture) • Waste generation (manufacture)
Electrolux AB	• Use of products	• Resources (energy, water) • Global warming • Local impacts	• Production site measures • Product performance incl. recycling
Jotun AS	• Use of products	• Photo-oxidant formation • Human health (secondary effect)	• Emission of VOC • Waste generation (raw materials and use of product)
Stabburet Råbekken	• Raw materials • Manufacture	• Euthrophication • Global warming	• Nitrogen and phosphorous to water (raw materials) • Fossil energy (all phases of product life)
Norpapp Industri	• Raw materials • Transport	• Global warming • Acidification • Eutrophication	• Management of forests • Production of fluting and liner • Transport of raw material and products • Quality of fluting and liner
MoDo Paper	• Raw materials • Manufacture	• Resources • Eutrophication • Global warming • Acidification	• Forestry • Energy • Air emissions from site • COD in water
Saga Petroleum	• Manufacture incl. engineering	• Eco-toxicity • Acidification • Global warming	• Emissions to air • Discharges to sea • Waste generation • Accidental Release/Oil spills • Disposal of platform installations
Brattvåg Skipsverft AS	• Raw materials (steel) • manufacture (Use not assessed)	• Local impacts • Resources (steel)	• Dust and noise from sand blasting and painting • Aesthetics • Usage of steel (resources and waste)
Kværner Florø AS	• Manufacture	• Resources (steel) • Local impacts	• Waste handling (steel, sand, paint, packaging) • Energy consumption
Norcem Brevik	• Manufacture	• Resources • Global warming • Acidification • Ecotoxic comp. • Local/work env.	• Air emissions • Energy consumption • Accidents • Aesthetics • Noise
SSAB Oxeløsund	• Manufacture • Raw materials	• Climate change • Euthrophication • Resource depletion	• Energy, CO_2 (steel plant) • tot-N, energy/CO_2, Solid waste (pellets/alloy)
Elkem Fiskaa	• Manufacture • Raw materials	• Global warming • Acidification • Resources	• Production site measures - air emission - energy consumption

The environmental impact assessment should be used as a basis for identifying the significant environmental aspects associated with the company's processes and products. Table 8.3 gives an overview of the results of the environmental impact assessments done by the case companies. The table identifies the part of the product life cycle where the significant environmental impacts occur, the corresponding potential impacts on the environment and the identified significant aspects for development of EPIs.

EPIs from the Green Table project

Important findings in the European Green Table EPI project, are:

- benchmarking is tested, but needs further development. "Indicators should be investigated concerning their statistical properties before being applied for benchmarking purposes".
- EPIs focus on the product lifecycle. An Electrolux product, a dishwashing machine for instance, is found to use most energy during the consumer use phase. Design for the environment seems important here, to help reduce energy usage in all phases of the product's life cycle.

Relevant Points for This Study

Indicators of sustainable development are not emphasised in the ISO/DIS 14031. However, the standard does not forbid the development and utilisation of such indicators.

The EU sustainable indicator project gives no operational indicators for industry. It does, however, provide useful indicators on a social level. The green table project focuses on EPIs in the product life cycle. However, indicators related to quality of energy, in line with the carbon cycle and the thermodynamics described in Chapter 3, are missing.

The OECD eco-efficiency report (OECD 1998) evaluates experience with approaches based on indicators, targets, innovation and monitoring to improve eco-efficiency in firms, local governments and communities. It also considers the role of national governments, both in encouraging local initiatives and in developing their own strategies to improve eco-efficiency economy-wide.

Many firms have developed targets for reducing their intensity of material use, energy consumption and toxic emissions per product unit. They monitor progress towards these targets and release the results in their annual environmental reports[59] (Orkla 1997). Few have developed quantitative indicators, or targets, for concepts that reduce impacts throughout the entire life cycle and all of their products.

A few firms have taken the initiative to reduce environmental impacts during and after the use of products. An example of this is the recovery of used equipment and re-use of durable components. Initiatives that address impacts over the full life cycle offer the greatest potential for reducing pollution and resource use, economy-wide.

The OECD ministers state that a major task for governments is to enhance the consistency of efforts at a business and household level. They need to establish a policy framework that reduces the gap between private and social aims.

> "*Economic incentives to reduce pollution would improve the profitability of savings in energy and materials. Meanwhile, the technical potential for reducing toxic emissions is only likely to be achieved through government incentives and regulations*."

Initiatives to reduce environmental pressure throughout the product life cycle most commonly occur where governments have introduced the concept of "extended producer responsibility".

The "Factor 10 Club" (OECD 1998) argues that

> *"the intensity of material and energy use in the economy should be reduced by a factor of ten in industrialised countries over the next 30-50 years, in order to halve global CO_2 emissions while allowing for continuing economic growth."*

Referring to Chapter 3 in this thesis, two energy related design criteria are emphasised. The eco-efficiency criteria from the OECD report do cover the criteria on renewable energy sources, but not the energy quality (the anergy/exergy share).

Added EPIs

From the European Commission' suggested Sustainable Development indicators, there is a need for added operational indicators which can be used to guide industry to sustainable development, or eco-efficiency.

The eco–efficiency report (OECD 1998) suggests criteria on renewable energy, but not on energy quality (exergy/anergy share). Few have developed

[59] Orkla is Norway's' second biggest company. Orkla include a statement about a "life cycle approach", in their environmental policy. A result of this is the calculated improvements to one of their products: 25% energy savings can be achieved for the consumers of household washing powder because the new powder can be used at a lower temperature. (Environmental report 1996 or 1997).

quantitative indicators, or targets, for concepts such as reducing impacts over the life cycle.

The European Green Table project concludes its report as follows:

- *Most indicators were developed to express the identified significant environmental aspects related to production processes on an operational level.*
- *Only a few companies were able to develop indicators of strategic importance, such as indicators expressing development of products or technology. Most companies have thus a potential for future introduction of such indicators.*
- *Those companies subject to market pressure regarding environmental performance of products have reached the most advanced level of EPI development.*

The Green Table project report also states:

"The life cycle approach has been a valuable tool for identifying the companies' significant environmental aspects."

Table 8.4 evaluates the chosen reports, or initiatives outlined in this chapter, on proposed energy related EPIs in the context of eco-efficiency and sustainable development.

Table 8.4 This table presents results of an evaluation of some reports, or initiatives on proposed energy related EPIs in the context of eco-efficiency and sustainable development.

Type of indicator suggested **Report/initiative:**	**LCA initiatives**	**Renewable energy**	**Energy Quality Share of exergy content**	**"Usual" EPIs, for example: Energy consumption per produced unit ,etc.**
ISO/DIS 14031	x	x		x
European Commission' Sustainable Development indicators	x	x		x
The OECD eco – efficiency	x	x		x
The Green Table project	x			x
The author's proposal	x	x	x	x

It can be seen in Table 8.4 that exergy/anergy share indicators are not included in other studies but are recommended by this author as a useful additional element. This fact brings us to this conclusion:

STATE of THE ART for EPIs outlined in this chapter and the design criteria on the carbon cycle and the thermodynamics described and discussed in Chapter 3:

two additional energy performance indicators should be emphasised:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency*[60]*).*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the exergy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency61).*

Conclusions

The reviewed projects in this chapter show that few EPIs related to energy and eco-efficiency, or sustainable development, are recommended. However:

- Many firms have developed targets and EPIs for reducing their intensity of material use and energy consumption;
- Renewable energy is included in the OECD eco-efficiency criteria;
- The life cycle perspective is recommended by the European Green Table.

To meet the challenge from the OECD ministers on identification and development of transparent, comprehensive indicators of eco-efficiency (as part of a broader set of sustainable development indicators) this author presents the following two, energy related, eco-efficiency indicators:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency.*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the energy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency*.

[60] According to this (OECD 1998) criterion 100% renewable energy is preferred. At 100% renewable energy the indicator will be 100, at 0%, the indicator is 0.

[61] High indicator will be 100% and occur for example when a room is heated by electricity. Low indicator will be near 0% and occur when low temperature energy source is utilised. Low indicator is preferred for eco-efficiency.

The theoretical part of this thesis ends here and the empirical section, part B follows. In this part, referring to the chosen research model (Figure 2.7), images from case studies are developed in order to study joint management of energy and environment.

PART B EMPIRICAL EVIDENCE

The theoretical part of this thesis was presented in part A, and the empirical part, B, begins here. The chosen research model is presented in Chapter 2, Figure 2.7. In Part B, the empirical data are presented and images are constructed in order to study joint management of energy and environment.

Chapter 9 Focus on Energy Conservation in Cleaner Production Programs.

Abstract

This chapter has a macro approach, evaluating the results of Norwegian governmental energy and environment programs. However, the results obtained are also connected to the micro-level (evaluating results on the factory level). Value added is know-how to:

- demonstrate for industry leaders that energy options within cleaner production programs have a high profit rate;
- jointly manage energy and environment in order to obtain a high profit rate and benefits to the environment;
- predict the best way for Norway to design future environmental and energy programs for industry.

This chapter presents the results from a quantitative analysis of economic and environmental benefits achieved through 67 assessments in selected industrial sectors. The main objectives of the study were to determine to what extent energy conservation is the source of economic and environmental improvements, and how the use of financial support and technical expertise influenced the results. The results show that:

- Cleaner Production Assessments create profitability and environmental benefits.
- Additional grants to emphasise energy conservation in the assessments generate additional corporate profits and benefits to the environment.
- The potential for energy conservation in various industry sectors was realised, resulting in large economic profits for the participating industries. This potential was realised in various ways. To use consultants in a proper way is very important in order to gain the results desired with a minimum of investment.

- Neither Cleaner Production Assessments nor Energy Audits create corporate conditions that lead to continuous improvement activities in energy conservation and waste reduction in companies.

By utilising the potential for corporate energy saving, an important contribution to fulfilling the Norwegian obligations within the Kyoto protocol can be achieved. This could be realised with large economic profits for industry and savings in raw materials, waste treatment, and emissions to the environment. Properly designed governmental programs, based on double-loop learning, are necessary as catalysts to enhance and to sustain the continuous improvement activities in companies.

Introduction

An important contribution to fulfilling the Kyoto protocol could be gained by focusing on energy conservation and cleaner production in all industry sectors. However, the way this should be performed in industry is extremely important to gain the desired results rapidly and efficiently. Based on an empirical study of 67 companies this challenge is discussed.

The Norwegian authorities have initiated support for CP assessments as a tool in the pollution prevention strategy in industry. Due to limited integration of energy conservation in these assessments, the energy authorities initiated a programme, which gave additional financial support to energy audits when carrying out CP assessments.
This chapter is developed from Amundsen (1993a) and Møller and Amundsen (1995)[62].

Norwegian financial support activities

Cleaner Production Demonstration Programmes

In 1990 the Norwegian State Pollution Control Authority (SFT) initiated the Cleaner Technology Programme (Abrahamsen 1993) for large manufacturing companies (in Norway: companies with more than 100 employees). The programme included both technology demonstration projects and CP assessments according to the adapted and translated U.S. EPA Manual (EPA 1988) (Amundsen and Vold 1991b). This programme is called the SFT programme. The main objective was to contribute to reaching the national environmental goals regarding pollution reduction.

[62] In the paper of Møller and Amundsen (1995), this author very strongly contributed to the conceptual development and data collection. The reporting in this thesis is this authors' contribution on conceptualisation and data collection.

In 1991 the Ministry of Industry and Energy initiated a similar programme; the National Environmental Technology Programme (the TI programme). The main objective of this programme was to provide assistance to small and medium-sized enterprises (SME) performing CP assessments. Special emphasis was given to both economic aspects and to integrating the assessment method into legislation concerning health, safety and environment (HSE). Also in 1992 a "Danish version" of the U.S. EPA Manual was translated and adapted for Norwegian SME's (TI 1992).

Both programmes offered grants in the form of "free" consulting assistance of approx. 70-150 hours depending on the company size. There was, however, a condition that the companies paid for a corresponding number of hours in addition to their own efforts. During the period 1991-1994 the total programme costs were about 2,75 millions ECU, including grants and information campaigns. At the end of 1994, the results were reported from approx. 200 participating companies. Three kinds of reports were produced concerning the results of each assessment:

1. An Internal Report, not available outside the company;
2. A Public Summary Report with a format similar to the (ICPIC) database in UNEP (UNEP 1991)(Møller and Amundsen 1995b).
3. A one-page Fact Sheet.

The documents in categories 2 and 3 are available from a national internet database (free of charge) operated by Oestfold Research Foundation (Amundsen and Koren 1998, http://www.sto.no/rp_internett/index_en.html). Two hundred and fifty Norwegian case studies were available by May 1998.

Integrated Energy Conservation- and Cleaner Production- Programme

To improve the focus on energy as a cost effective approach to CP, in 1992 the Norwegian Authority for Water Resources and Energy Administration (NVE) initiated an additional demonstration programme for Integrated Energy and Cleaner Production Assessments (the NVE programme). This was financed by the Norwegian Ministry of Industry and Energy and managed by the Norwegian Institute for Energy Technology (IFE).

The main purpose was to ensure that energy conservation was given special attention when carrying out CP assessments and to develop a standard methodology for such integration. Special attention was to be given to energy conservation in the detailed Assessment Phase and Feasibility Analyses (according to the Facility Pollution Prevention Guide, EPA 1992).

The NVE programme financed an energy conservation expert to support the advisor(s) financed by the SFT and TI programmes. Initially the TI

Handbook was revised to include energy conservation as an integrated topic. In the period 1992-1994 the programme financed 34 projects, each with additional energy consulting assistance of 100-150 hours, depending on the size of the company. The government invested approx. 0,75 million ECU in this programme. The reporting from the NVE programme was similar to that from the SFT and TI programmes.

Research questions related to the programmes

The objectives of this are to use quantitative analysis to determine (R2):

- What is the relative importance of energy savings on economic and environmental results?
- What is the effect of external financial support for energy audits on implementation of energy efficiency improvements?
- To what extent does project manning influence the results of and the integration of, energy conservation into corporate environmental management activities?

In the CP assessments financed by the three demonstration programmes. And (R3):

- does performance of cleaner production assessments stimulate corporate management to continue on the journey of environmental improvements?

Methodology

Data from the case studies in the three programs were categorised and entered into a database. The data included *calculated* results from the proposed options. When performing the assessments, data corresponding to the different problems and solutions were gathered. This was done using both measurements and estimates. Other relevant surveys from other authors should also be identified and utilised, if available.

Information sources

Results were extracted from the public summary reports and fact sheets. Of the total of about 200 reported CP assessments, the study was limited to include 67 assessments in a similar number of factories. Twenty-six of these had received additional financial support to focus specifically on energy conservation.

The assessments studied were chosen on the basis of the following criteria:

1. link between energy use and environmental issues, i.e. large water consumption, big discharge to the environment;
2. energy costs were a significant part of the total annual costs for the companies.

The following business sectors fulfilled these criteria[63]

[63] The figures behind each industry sector indicate: the total number of projects/number of projects with additional support from NVE programme

- Pulp and paper (11/4);
- Fish oils and fish meal (7/3);
- Laundry and dry cleaning (12/8);
- Food processing (37/11);

The following industrial sectors did not fulfil these criteria:

- Diaries;
- Slaughtering, preparing and preserving of meat;
- Canning, preserving and processing of fish;
- Soft drinks and carbonated water;
- Others.

General Project Data

The following data were registered for each project:

1. Financing programme;
2. Financial support (grant sum in ECU; 1 ECU = 8 NOK);
3. Competence of advisor(s) manning the project.

Pollution Reduction Data

The following pollution reduction data were registered for each project:

1. Reductions in air emissions: CO_2, SO_2, NO_x, CFC, VOC (tons/year).
2. Reductions in emissions to water: Phosphorus, Nitrogen, organic waste and toxic materials (tons/year).
3. Reductions in solid and hazardous solid waste (tons/year).

Table 9.1 Energy savings and corresponding reduction in emissions to air. (Source: Møller and Amundsen 1995b)

Sector	Installed el.-capacity (% of thermal[a])	Oil type	CO_2 tons/ MWh	SO_2 kg/ MWh	NO_x kg/ MWh
Pulp and paper	80	6 LS[b]	0.14	0.74	0.22
Fish oils and fish meal	0	6 LS	0.23	1.24	0.37
Diary	80	2	0.14	0.14	0.13
Meat slaughtering and processing	80	2	0.14	0.14	0.13
Fish processing	20	2	0.21	0.21	0.20
Other food and beverages	50	2	0.17	0.17	0.16
Laundry and dry cleaning	30	2	0.19	0.19	0.18

a) Actual use of electricity versus oil depends on current energy prices. Fifty percent of installed power capacity is an accepted mean value for the electricity consumption share over time for Norwegian conditions.
b) Low content of sulphur

Energy Reduction Data

Energy consumption in Norwegian industry consists of about 50% hydropower generated electricity. This electricity is also used for heating industrial premises. Reductions in CO_2, SO_2 and NO_x were derived from the project's annual energy savings based on individual sector conversion coefficients. These depend on the ratio of hydro-based energy in percentage of fossil-based energy, oil type, and substitution possibilities between oil and electricity for thermal purposes. Emission factors for burning fossil fuel come from Lindfors et al. (1995).

Improvement option data

The following result parameters were registered for each recommended improvement option:

1. Investment (ECU);
2. Total annual cost savings (ECU/yr.);
3. Annual energy savings (MWh/yr.);
4. Annual water use reductions (m^3/yr.);
5. Categories of investment:
    a. Good housekeeping option: zero, or very low cost and very profitable investments less than 1.250 ECU and payback period less than 0,3 year;
    b. Investment option: requires a significant investment;
6. Category of cleaner production:
    a. Source reduction option;
    b. Recycling, treatment or disposal option.
7. Category of profitability:
    a. Profitable option;
    b. Not profitable option (payback period longer than 6 years).
8. Category of result (an option may get a score for results in more than one category):
    a. Energy option;
    b. Environment option: waste or pollution reduction;
    c. Health or safety improvement option;
    d. Production option: increase in production capacity or improved product quality.
9. Status (category) of technology:
    a. Available;
    b. Unknown.

Calculated indicators

Combining various result parameters can develop numerous indicators. The list below shows the main categories of indicators calculated:

1. Number of options in the project (in sample); e.g. total and for different categories
2. Share of total options in different option categories
3. Economy; e.g. investment, annual cost savings, payback, investment per grant sum received by that company, annual savings per grant sum received by that company.

4. Energy; e.g. annual energy savings, annual energy savings per annual cost savings, annual energy savings per grant sum received by that company, reduction of emissions
5. Environment; e.g. reductions in air and water emissions and solid waste.

Table 9.2 Main results from all assessments. Average values per assessment for all sectors and for each sector

Number of projects in the category	67	11	7	37	12
	Average for all sectors	Pulp & paper	Fish oils & fish meal	Food processing	Laundry & Dry clean.
Economy					
Grant sum (1000 ECU/company)	10.3	16.5	11.8	8,7	8,7
Investments (1000 ECU/company)	358	480	1,369	147	309
Cost savings (1000 ECU /year /company) (1)	157	402	475	56	58
Pay-back period (year)	2,3	1,2	2,9	2,6	5,3
Options which require investments of total number of options (%) (2)	60	61	74	51	92
Profitable options of total (%) (3)	87	88	85	88	82
Energy:					
Energy savings (MWh/year/company)	4,310	14,550	13,910	627	680
Savings related to energy per grant sum (kWh/ECU)	418	885	1,182	72	78
Savings related to energy as a percentage of total cost savings (%)	69	90	73	28	29
Number of energy options of total (%)	45	55	69	30	70
Environment					
Water use reductions (m^3/year)	57,100	293,827	2,282	12,730	8,883
Reductions in CO_2 (tons/year)	750	2,037	3,199	105	129
Reductions in SO_2 (tons/year)	3.7	10.8	17.3	0.1	0.1
Reductions in NO_x (tons/year)	1.1	3.2	5.2	0.1	0.1
Reductions in organic effluent (tons/year)	354	1,800	6	105	0
Reductions in solid waste (tons/year)	35	1	7.5	48	41
Reductions in hazardous waste (tons/year)	0.04	0	0	0.1	0
Environment related options of total number of options (%)	51	49	32	58	46

(1) Based on an average energy price of 25 ECU/MWh for all branches. (2) Options with a payback of more than 0.3 year and with investments more than 1250 ECU. (3) Payback of less than 6 years

Selection variables

The following variables were used to establish samples of assessments:

1. Industry sector (NACE code[64])

   Calculations were made for a variety of sectors. Special attention was made to the pulp & paper and fish oils & fishmeal sectors due their energy intensive production.

2. Project manning

   Three categories of advisor competence were defined:

   - Energy Conservation: special competence in energy conservation in certain sectors;

[64] NACE code is an international standard deciding figures for each industry sector.

- Pollution and Environment: special competence in pollution and environmental issues;
- Project Management: special competence in human co-operation in running projects.

3. Financing programme

Special attention was given to the investigation of the effect of additional financial support from the NVE programme.

Results

The figures concerning economic, energy saving and environmental results, from the 67 CP assessments included in the study, are shown in *Table 9.2*. The table displays the results as average values per assessment, for all sectors for each sector.

To evaluate the effect of governmental financial support for energy conservation, the assessments were divided into two sub-categories: with and without governmental support from the NVE programme. Note that the NVE programme only financed CP assessments in addition to either SFT, or the TI programme. To eliminate the dominance of energy intensive sectors, the assessments were first divided into two sub-categories: energy-intensive and non energy-intensive sectors. The energy-intensive group consists of the pulp & paper and fish oils & fishmeal sectors. *Table 9.3* shows average values per assessment, with and without additional support to energy audits, for energy-intensive and non energy-intensive sectors.

Project manning

Two categories of assessments were defined: assessments with and without energy conservation experts connected to the projects, either as the main or co-advisor. *Table 9.4* shows the results given as average values per assessment. To exclude the effect of governmental financial support on results, assessments that received such support were not included here. In addition, energy intensive sectors were excluded. These restrictions limited the number of suitable assessments. They were insufficient for studying the three advisor categories separately. Thus, only two combinations of manning are considered:

1. Projects *with* an energy advisor
2. Projects *without an* energy advisor; i.e. with a Cleaner Production & environmental advisor or a Project management advisor.

Table 9.3. Results as average values per assessment, with and without governmental support for audits within energy. Energy-intensive sectors and non energy-intensive sectors

	Energy-intensive sectors		Non energy-intensive sectors	
	With additional support for energy audits	Without additional support for energy audits	With additional support for energy audits	Without additional support for energy audits
Number of projects in this category	7	11	19	30
Economy:				
Average grant sum (1000 ECU/company)	24.6	8.3	13.0	6.0
Average investments (1000 ECU/company)	1,160	613	301	114
Average annual cost savings /company (1000 ECU/yr.)	779	209	66	51
Average pay-back period (year)	1,5	2,9	4,6	2,3
Average number of investment options of total number of options(%)	87	71	72	49
Energy:				
Average energy savings (MWh/year/company)	30,716	3.855	1.004	409
Average savings related to energy as a percentage of total cost savings (%)(a)	95	46	38	20
Average savings related to energy per grant sum (kWh/ECU)	1,246	467	77	69
Average number of energy options in (%) of the total options	78	38	57	26
Environment:				
Average number of environmental options in (%) of the total options	25	64	61	52
Health & safety options in (%) of the total options	4	2	18	25

[a] Based on an average energy price 25 ECU/MWh for all sectors

Discussions

Three evaluations of the three Norwegian governmental programs have been conducted, one by the State Pollution Control Authorities (Abrahamsen 1995), one by Sæter and Amundsen (1996) and one by Aasen and Onsager (1995). Abrahamsen describes the programmes as successful and reports economic benefits for the companies of 1.4 mill ECU per year as a result of preventive options. For the 103 companies involved in the programmes, the following improvements have been made:

1. Average pollution reduction/year/company
   VOC: 641 tons
   Hazardous Waste: 478 tons
   Waste from Production Process: 5000 tons
2. Total annual reduction in energy usage: 17.5 GWh
3. Reduction of water usage: 10 - 50%.

This study is comprised of a relatively small number of assessments, which limits the ability for the author to draw firm conclusions when studying certain effects at the sector level. Observed trends are used in these discussions.

Relative importance of energy savings for economic and environmental results

The indicator "Average savings related to energy as a percentage of total cost savings", illustrates the relative importance of energy savings in the economic results. In *Table 9.2* the percentage values for this indicator are shown for different industry sectors. The average value for all 67 assessments is 69 %, which is a considerable share. The range is wide, for the food-processing sector, it is as low as 28 % and as high as 90 % in the energy intensive pulp and paper sector. These results indicate that energy conservation should be emphasised at a higher level in industry. This is most important in the energy-intensive sectors.

The reductions in emissions of CO_2, SO_2 and NO_x are related to energy savings. Any general correlation between energy savings and reductions in water consumption could (surprisingly for the author) not be identified.

Effect of governmental financial support on energy audits

Twenty-six of the assessments were designed to emphasise both cleaner production and energy efficiency. They received support from two programmes. It was impossible to relate the different results to a corresponding programme. Hence, direct measurements of the effect of an additional energy advisor cannot be made. Indirectly, we have an indication by comparing two types of assessment: assessments with additional support for energy audits ("energy support") and those without.

Table 9.3 shows the results from these samples for two categories: energy-intensive and non energy-intensive sectors. Assessments with energy support on average received more than twice the grant sum than assessments without. As far as the energy savings level and relative energy savings (per grant sum) are concerned, the expected correlation between additional energy support and results seems to exist. Although there are minor divergences for some sectors, one may conclude that assessments with energy advisors' support identify more energy savings than assessments without. A most important result of this is the corresponding increase in reductions in CO_2, SO_2 and NO_x emissions.

The results show significant differences between the energy-intensive group (pulp & paper, fish oils & fishmeal) and the other group. Values for the energy savings for these two groups are 1246 and 77 kWh/ECU, respectively, for assessments with energy advisor support. Without energy advisor support, the energy savings were 467 and 69 kWh/ECU, respectively. These differences correspond to differences in the share of the total options that are energy options and to differences in the share of cost savings that are attributed to energy savings.

It was not possible to draw conclusions regarding additional energy advisor support with respect to economic results at company level. This was mainly due to some “diverging” results between the energy-intensive and non energy-intensive group for assessments with and without energy advisor support. This might be explained by the fact that the programmes initially had the character of pilot-programmes. A cost/benefit approach of grants is not reasonable when allocating financial support. Sufficient attention has not been paid to the companies’ size, complexity, and potential for improvements in energy usage and pollution prevention. Hence, various degrees of financial mismatching may have occurred in particular sectors. This gave results other than those found in a situation with careful allocation of resources.

The use of additional energy advisor support revealed that there is significant potential for energy conservation in many sectors. CP assessments are suitable tools when certain considerations are taken into account. The concern that energy conservation was initially not given enough attention in CP assessments is supported by these results. One reason for the low priority of energy conservation in the majority of the CP studies, is probably the very high proportion of clean and cheap hydro-electrical energy in Norway.

Influence of project manning

With the purpose of studying the possible consequences of varying types of competence among the project advisors with regard to significant differences in the results, two combinations of project options were studied:

1. Projects where staff obtained grants from both a CP assessment programme and from the energy conservation programme. This means that each factory project got support from a consultant with special competence on energy conservation.
2. Projects staffed with consultants with competence in management related processes. These projects had no grant from the energy conservation programme and no advisor with special energy competence.

Table 9.4 displays results focusing on economic and energy matters. This table shows that the energy options in total for the two groups are 66 % and 29% respectively. A higher score on energy options in the group that received additional energy conservation advice was expected, but it might be surprising that the differences are so big. The explanation for the higher investment level in the projects that received additional grants for energy audits can be found in the limited number of options with small, or no investment and large profit potentials. "The low hanging fruits"[65] might already have been picked before the CP assessments were done, through the companies' own efforts on process improvements.

Table 9.4. Results as average values per project for selections with and without additional support on energy conservation from the NVE programme.

Category	**With support for Cleaner Production assessment and Energy Auditing**	**With support for Cleaner Production assessment, but no support for Energy Auditing**
Number of projects in the category	26	41
Economy:		
Average grant sum (1000 ECU)	16.1	6.6
Average corporate investments (1000 ECU)	530	250
Average annual cost savings per grant sum (1)	16.0	14.1
Average payback period (year)	2.1	2.7
Average profitable options related to total number of options (%) (2)	85	88
Energy:		
Average energy savings (MWh/year)	9,003	1,334
Average savings related to energy as a percentage of total cost savings (%)(1)	87	36
Average number of energy options in each company in percent of the total options (%)	66	29
Environment:		
Average number of environmental options in each company in (%) of the total options	55	49
Health & safety options in (%) of the total options	17	32
Source-reduction options as a percentage of the total (%)	63	78

(1) Based on an average energy price 25 ECU/MWh for all sectors
(2) Payback of less than 6 years

Assessments that received additional support for energy conservation received, on average, more than twice the grant sum compared to projects that did not receive additional support. Regarding the savings per grant, the additional support was reasonably cost - effective compared to projects without additional energy competence. By focusing on environmental improvements, it was found that CO_2, NO_x and SO_2 savings for the projects staffed with energy competence have a higher score. These findings were a direct result of the reduction in oil consumption.

Note that both categories have identified health and safety options. Referring to the discussion on integration of management systems in Chapter 10, these findings indicate that both energy audits and CP assessments generate options related to occupational health and safety.

[65] The term "the low hanging fruits" means options with small or no investment and payback times of less than one year.

Cleaner Production Assessments - do they lead to continuous improvement efforts?

The data indicates that cleaner production assessments give relatively profitable environmental improvements, when the improvements identified are implemented. According to Aasen and Onsager (1995), 60% of the participating companies have implemented more than half of the identified options. From Tables 9.1 and 9.2 and references concerning Norwegian (Amundsen and Koren 1998) & international experiences (UNEP 1991) (Huisingh 1985) (Van Berkel 1996), Norwegian experiences are in line with results from international CP assessments. The results show:

1. Sound economic benefits come from implementing the improvement options identified.
2. Significant reductions of emissions and effluents are achieved.
3. Occupational health and safety options are generated in both cleaner production assessments and energy audits.

With regard to the (R3) question: *"Does performance of cleaner production assessments stimulate corporate management to continue on the journey of environmental improvements?"* the picture changes somewhat. The method for CP assessments includes a feedback loop. After implementing the prevention options with the highest priority, the company is supposed to go back to the assessment phase and consider new options for implementation. The purpose of this part of the method is to help ensure the continuous improvement process in CP (to continue to work on improvements and implementation of new options).

In a survey conducted by Aasen and Onsager (1995) 80% of the companies that received support from the programs, stated that they (to some degree) had started a more continuous improvement process. What this improvement process consisted of was not stated. It seems that the survey reveals positive attitudes towards continuous improvement, but no systematic efforts were documented. Another evaluation of 25 of the participating companies, Sæter and Amundsen (1996), conducted through interviews with the consultants working as advisors in the companies, indicates that only one third of the companies work on continuous environmental improvement. These findings provide evidence that the CP assessments and energy audits are mainly short-term projects or activities. They are therefore, not part of a larger, continuous improvement process among the companies. However, during the projects, the attitudes towards a continuous process become more positive. Referring to the methodological criticism of the Cleaner Production Method in Chapter 6; the lack of continuous activity is not surprising. The method, as it has been utilised in Norway, is based on single-loop learning (Argyris and

Schön 1996, Morgan 1997, p 87). An improved method, integrating CP assessments, Environmental Management Systems and Energy Management, which includes double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87), is suggested in Chapter 7 (Figure 7.9). This issue should be highlighted in future governmental programmes.

Conclusions

Energy savings may contribute considerably to both economic and environmental results when cleaner production assessments are carried out. In energy-intensive sectors, when special attention is given to energy conservation, energy cost savings can exceed 90% of the total savings. This special attention is in the form of financial support, and skilled advisors providing technical support.

The reductions of CO_2, SO_2 and NO_x are directly related to the corresponding energy savings. This may be the most important matter when considering integrated energy conservation and CP assessments as tools for pollution prevention.

Two factors will substantially improve the economic results of assessments. The first factor is careful allocation of financial support, according to the company's complexity and potential for energy efficiency improvement. The second factor is to use advisors with appropriate skills. Good housekeeping options are often identified during the preliminary assessment phase. As the number of these options is limited, it is necessary to do a deeper examination to achieve further results. Many of these options are of a complex nature and will require a deeper analysis in the detailed assessment phase. Hence, specialists may be needed. Norwegian energy consultants' competence and training in specific industry sectors means that they are well qualified to be involved in CP assessments. The results clearly indicate that energy competence has a significant influence on energy savings, economic results and environmental benefits.

The energy savings are an example of what can be achieved when sufficient effort is provided to certain areas. It can, however, be of major importance for cost efficiency that resources (man-hours and competence) are matched to the typical complexity and improvement potential in the various sectors. When initially performing a CP assessment every resource, including energy, should be emphasised. Progressing into the detailed assessment phase, priorities are identified in accordance with targets set for specific areas. The key word is *integration*. This aspect should also be reflected in national and international programmes.

Two reasons for the limited integration of energy conservation in Norwegian CP programmes may be:

1) National environmental ministries and pollution control authorities supported the historical development and adaptation of the CP concept;
2) The low price of clean, hydropower-based electricity in Norway reduced the economic and environmental incentives for energy conservation. It was therefore, a low priority.

This study is based on 67 case studies. The results from this study combined with references to other surveys show that 1) CP assessments create profitability and environmental benefits. 2) Additional grants to emphasise energy conservation in the assessments generate additional profits and benefits for the environment. 3) The potential for energy conservation in various industry sectors could be realised, resulting in big economic profit for industry. This potential could, however, be realised in various ways. To use consultants in a proper way is very important in order to gain the desired results with a minimum of investment. However, consultants or supervisors may be helpful for short periods. To obtain continuous improvements, there might be a need for organisational changes, empowered persons to take responsibility for environmental issues, training programs etc. 4) Neither CP assessments nor Energy Audits, secures continuous improvement activities on energy conservation and waste reduction in companies.

Recommendations

An improved method, integrating CP assessments, Environmental Management Systems and Energy Management, which includes double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87), is suggested. Utilisation of this improved method is supposed to provide industry with short-term profitable options and help to ensure continuous activities on environmental performance. The method, based on double-loop learning and shown in Figure 7.9, facilitate identification of long-term profitable options.

This improved method, should be highlighted in future governmental programmes.

The potential for corporate energy savings can make an important contribution to fulfilling the Norwegian obligations within the Kyoto protocol. This could be realised with big economic profits for industry and savings in raw materials, waste treatment, and emissions to the environment. Properly designed governmental programs, based on double-loop learning, are necessary as catalysts to foster and continue to support continuous improvement activities in companies.

Chapter 10 Implementation of Cleaner Production and Environmental Management. Experiences and results from Nordic food-processing companies

Summary

This chapter summarises the experiences from the NordFood project, Cleaner Production (CP). Two groups of methods in the context of CP have been tested in 22 Nordic factories in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97.

In the first phase of the project, a CP assessment was performed in the factories[66]. The CPA step resulted in a number of implemented options, which required an investment of 43 mill. NOK, had an average payback period of 1.7 years and resulted in significant reduction in pollution to the environment. The yearly savings made by the 22 companies are 25 mill. NOK.
The CPA method has been analysed to see if it produces continuous pollution prevention activities in the factories, and the results show that the performed assessments have been ad hoc activities. The companies which participated in this first phase of the project, but not in the follow up second phase, turned out to have a lack of continuous improvement activities on CP initiatives, compared to the companies which also implemented an EMS.

In the second phase of the project, the principles of Environmental Management System (EMS) were introduced in the factories. A handbook on integrated EMS and Quality Systems was prepared to ease the implementation. Twelve companies have implemented an EMS system and four have gained a certificate corresponding to EMAS or ISO 14001/BS 7750. Four companies have integrated existing quality systems with the EMS resulting in a Total Quality and Environmental Management System (TQEM). The results from this phase of the project show well-organised continuous improvement activities in the factories. These activities resulted in additionally implemented options with short payback periods and reduced impacts to the environment. The reduced impacts are mainly reduced outlet of organic

[66] The participating companies and research institutions in the project were:

- Norway:	Troll Salmon AS, Christian Halvorsen Bakeri og Kond., Østfold Eggsentral, GildeFellesslakteriet, Grimstad Konservesfabrik AS, Oestfold Research Foundation (STØ), MATFORSK
- Iceland:	Faxamjöl hf, Krossanes hf, Utgerdarfelag Akureyringa hf, Sildarvinnslan hf, Vinnslustödin hf, Milk Distribution Centre, Kjotumbodi hf.(Godi), Technological Institute of Iceland, The Icelandic Fisheries Laboratories,
- Sweden:	Procordia Food AB, Abba AB, Nordreco AB, Van der Bergh Foods, Frigoscandia AB, The Swedish Institute for Food and Biotechnology (SIK)
- Denmark:	Taabel Fiskeeksport AS, TICAN, Mejeriselskabet Vesthimmerland, Aalborg University.

materials and less greenhouse-gases. The companies with an EMS system have better conditions in order to meet the increasing demands for ECO-friendly products and CP from customers and other stakeholders.

Finally, this chapter discusses if the methods of CPA and/or EMS will fulfil the next century's expectations for sustainable production and products. Results from CPA and EMS are discussed in consideration with what Nordic politicians have approved as political goals connected to Agenda 21 and the Kyoto protocol for the next century. The conclusion is that CPA and EMS are useful but not sufficient methods for industry to meet the politically approved expectations in the next century. Future challenges are additional methods like Life Cycle Assessment, the OECD eco-efficiency concept and co-operation with the stakeholders of the factories including the local community in the context of Industrial Ecology.

In order to meet future customer and market expectations on ECO-products and production, the Nordic food-processing industry have to take up the challenge and make environmental improvements in the whole product chain.

Introduction

The objective in the project was to implement CP in the food processing industry on a permanent basis in order to improve the resource efficiency in the Nordic food-industry and through this also to improve their competitiveness in the market. There were 22 participating food companies: 5 from Norway, 8 from Iceland, 6 from Sweden and 3 from Denmark.

The average number of employees in the participating companies; 69 in Norway, 168 in Iceland, 751 in Sweden and 255 in Denmark.

With the purpose of integrating CP activities in the factories as an ongoing continuous activity, a CP assessment and the application of the new standards for Environmental Management Systems (EMS) were introduced in the participating companies. Attention was focused on how the EMS standards "ECO-Management and Audit scheme (EMAS)" and "ISO 14001, Environmental Management System" could be integrated in already established management systems in the factories.

Typical results and the situation after the CPA and/or the EMS were performed, is summarised in this paper. Research questions were highlighted and experiences from the 22 participating companies are summarised and discussed.

This chapter is based upon Amundsen (1993b), Amundsen (1996c), Amundsen et al (1997), Amundsen (1998c), Amundsen et al (1998f) and further reflections and experiences during the project[67].

Objectives of the project

The main objectives of this project were to test methods and systems in the context of ***Cleaner Production (CP)*** in the Nordic food-processing industry. ***Cleaner Production assessment (CPA)*** and ***Environmental Management System (EMS) should*** be introduced in 22 companies.

The aims of the project were to:

- introduce CP in the participating 22 Nordic companies;
- implement CP options in the participating companies ;
- introduce EMS in the participating companies and consider how EMS could be integrated in other management systems;
- study experiences from the companies that chose to implement EMS.

Research questions

Detailed research questions were developed and grouped into three categories, which correspond to the historical stages of the development of tools and systems in the context of CP. Some of the research questions are:

GROUP A *CP assessments*

- What are the driving forces in companies and what is the need for external assistance to make them become effective in fostering continuous improvements?
- Do companies focus on short-term profitable options, or also on long-term options?
- Have profitable options been identified and evaluated?
- Have the improvement options been implemented?
- Are there specific types of CP options, which provide big savings?
- Is making a contribution to “sustainable development” important for companies?

GROUP B *Environmental Management System (EMS)*

- What is the driving force for implementing an EMS, and what are the obstacles for the implementation of such systems?

[67] In the project described in Amundsen (1993b), Amundsen (1996c), Amundsen et al (1997), Amundsen (1998c), and Amundsen et al (1998f), this author designed the research, developed the concept of the paper and reports, designed the data collection for all countries and gathered the data from the Norwegian companies.

- Is EMS necessary and sufficient to gain continuous environmental improvement activities?
- Are corporate activities better organised and more effective if they are implemented within companies with an EMS, compared to those that do not have EMS systems?
- Is employee involvement stronger in companies with an EMS, than in companies without one?

GROUP C *Future needs*

- Are CP assessments and EMS necessary, but insufficient to catalyse implementation of sustainable production in participating companies? Has the introduction of CP, CP assessments and EMS led to product improvements? Do the companies use Life Cycle Analysis (LCA) to improve their products?
- Do the companies use EPIs to measure their improvements?
- To what extent do CP assessments, EMS and Energy Management help companies to achieve a more consistent contribution to eco-efficiency?

Methods

PROJECT TASK 1: Introduction of Cleaner Production

"Waste Minimization Opportunity Assessments" from the US-Environmental Protection Agency (EPA) in 1988 (EPA 1988), was the first complete description of a method to perform a CP assessment. This method has been translated to many languages and adopted in specific branch-manuals. Based on country-specific experience, the method was rewritten into country-specific versions. Amundsen and Vold (1991b) are an example of a Norwegian version of this manual. This method was the basis for the introduction of CP in most of the participating companies. In Sweden a benchmarking method was used.

CP options was developed in this phase and the companies were supposed to implement interesting options.

PROJECT TASK 2: Integrated Environmental Management systems

Environmental Management Systems (EMS) were introduced in the companies. At present, three EMS standards are in common use in the Nordic countries:

1. BS 7750 = British Standard for Environmental system (BS 1993)
2. ECO-Management and Audit scheme (EMAS)= EC Council Regulation (EEC 1993 and EEC 1998)

3. ISO 14001 = International Standard for Environmental Management System. (ISO 1996)

These publications were the conceptual basis for the introduction of the system into the participating companies. Since the project ended, BS 7750 was replaced by EMAS. Guidelines like (Euro Info 1995), (Poulsen et al 1995), (Pai 1996), (Remmen[68] et al 1994) were used in the implementation phase.

EMS was considered to be integrated into other already existing management systems in the participating companies. In the project the Danish participants developed a guideline for help in the implementation phase of the EMS system (Alstrup 1995).

Table 10.1 Cleaner Production improvement options for the company Grimstad Konservesfabrik in Norway. (Saur and Amundsen 1994a)

	Savings					
Option	Energy	Water	Money	In-vest-ment	Pay-back	Environmental benefits
	MWh/y	m^3/y	kNOK/ year	kNOK	year	
Reuse of cooling water		2,115	12.3	50	4.1	Reduced consumption of water
Automatic sorting replaced by eye-sorting of raw materials (1)			1,000	1,200	1.2	Decreased use of raw-materials
Modification of auto boiler	31	1,750	19	50	2.7	Reduced energy and water consumption
Reclamation of condenser water from boiler(1)	62	390	19,1	50	3	Reduced energy consumption.
Regulation of water supply		470	2.7	0	0	Reduced water consumption
Information/training of operators	108	2,720	46	0	0	Reduced energy and water Reduced organic release
Energy Management system	216	5,440	91	25	0.3	Saving energy and water
Concentration of waste organic materials from waste water			10.3	100	9.7	Use as food for pigs. Less transport. Reduced organic release: 1,000 tons/year
Separation of water and organic materials			?	?		By-product from waste, less release of organic wastes
Total	417	12,880	1200	1475	1.2	

(1) For all the production lines at the factory

QUANTIFYING RESULTS

Project experiences were collected by observations and reporting during the project. Final results and experiences in the companies were followed up by using a questionnaire in the final phase of the project. The questionnaire and the detailed results are shown in Appendix 1 of this thesis. The most interesting questions and results will be given in the following text.

Results

On the microscale

One CP case study illustrates the typical options and reporting of options in the participating companies:

Grimstad Konservesfabrik AS, Norway preserves fruit and vegetables, it has 60 employees, and a turn over of 10 mill. $ per year.

The stages in the production consist of washing, thermal processing, pickling and packaging of the preserved fruits and vegetables.

The results from Phase 1 of the project are shown in Table 10.1. The table contains a list of options with an average payback of 1.2 years and the resulting benefits to the environment.

Table 10.2. Results from all companies. Investments, savings and payback periods of the Cleaner Production options in the twenty-two participating companies Figures from 1996.

Country:	**Investments NOK**	**Savings NOK/year**	**Payback (Year)**
Iceland	1,222,000	5,496,500	0.2
Norway	3,488,275	3,313,160	1.1
Sweden	28,750,000	11,500,000	2.5
Denmark	10,000,000	5,000,000	2
Total	43,460,275	2,530,9660	1.7 (average)

Results on macroscale

The results from the projects in all the factories, are profitable options with a short payback time[69]. Table 10.2 shows a total investment of 43 mill NOK, a yearly saving of 25 mill NOK and an average payback time of 1.7 years. The CP-options also provide good benefits for the environment. Water and energy are the two most important resources, which have large and profitable potential savings in the participating companies. The figures are per year in 1996, some of the options were implemented in 1994 and 1995. The companies keep up their saving potential on the tracking date in October 1997. No information was available to indicate that the savings will not continue in the coming years.

Environmental Performance Indicators (EPI)

In the project, efforts were made to stimulate the companies to use environmental performance indicators (EPI) systematically to measure improvements. The answers from the questionnaire show that 80% of the

[68] Arne Remmen from Aalborg University, was the Danish projectleader in the research team in the project.
[69] Short payback for companies, means less than three years according to this authors experience.

companies, which implemented an EMS, use EPIs systematically, while only 10 % of the companies without EMS use EPIs systematically.

Specific energy consumption differs between the different participating companies and it is not easy to compare because of the differences in production.

As one example, efforts have been made by the Swedish to develop EPIs for benchmarking the project development from year to year. Energy consumption in terms of kWh/kg processed product is one important EPI which has been tracked. Water usage per kg processed product, was the other typical EPI. Those EPIs have been used for benchmarking the results from the efforts to decrease the input of raw materials per production unit.

The specific energy consumption in the participating Swedish companies shows a variation between 0.39 to 2.28 kWh/kg product. Decreased energy consumption from year 1 (1994) to year 2 (1995) has been (Olsson[70] 1996) was found to be;

Factory A	12 %
Factory B	6.2 %
Factory C	20 %
Average value:	11 %

Table 10.3 Grouping of all options in all the 22 Nordic companies. The table shows the percentage of each group of the implemented options.

Type of option	% of implemented options in each category
Resource efficiency improvements (energy, water etc.) with little or **no investment**	91
Resource efficiency improvements (energy, water etc.) which **required investment**	77
Changed **raw material**(s) usage	14
New **processing equipment incorporated**	50
Changed to **new production process**	36

The water consumption in the participating Swedish companies was studied in the same way. It decreased an average of 8,4% and provided economic savings of one mill SEK in one year.

Improvements in production

Results from the questionnaire regarding improvement options are given in Table 10.3 and show that the group of "Resource efficiency improvements (energy, water etc.) with little or no investment" is the biggest group. Ninety-

[70] Pär Olsson from the Swedish Institute for Food and Biotechnology, was the Swedish projectleader in the research team in the project.

one percent of the participating companies have implemented options in this category.

Integration of EMS in the companies

In ***Denmark,*** environmental management systems have been established and implemented in three participating companies. All three companies have a certified quality management system (ISO 9002) and two of the companies have a certified quality management system (BS 5750). The third company has chosen to adopt environmental management in practice, without integrating it into the quality management system. In ***Norway***, three companies have integrated the EMS into the quality and Energy Management system. One company has chosen to keep the EMS system as a separate system in the implementation phase, but has plans for integration at a later stage. All companies have future plans for integration with the occupational health and safety system at a later stage. In ***Sweden*** one company has integrated the EMS with the quality system. In ***Iceland*** no EMS system was implemented in the participating companies.

The performance in the companies that have a fully integrated EMS system has been compared with companies that do not have integrated EMS. This was done to find out if integration was successful. All companies fully support their own choice.

Driving forces for implementation of CP and EMS

What are the most important driving forces for implementing CP and EMS? Results from the questionnaire show that the most important factors for the companies that have implemented EMS are "Meet future expectations from the market" (54%) and “Economic savings" (48%). Table 10.4 presents these results in detail. The "Level of importance" indicated in percentage, is a measure of how many of the companies selected the different driving forces as the most important driving forces for them. They marked the three most important categories and for this reason, the sum is near 300%.

The driving forces for performing a CP assessment, shows a focus on the same driving forces as for implementation of EMS. The group of factories involved is larger since more companies performed a CP assessment. Eighty-one percent emphasise future market expectations and 83 % emphasise economic savings.

The companies could still mark the three most important categories, thus the sum is near 300%. Table 10.6 presents the results. Contribution to sustainable development seems to be of small importance to these factory managers, only 17 % identified this category as a driving force.

Table 10.4 What are the most important driving forces for implementation of EMS in your company? The table presents the answers to this question from 22 Nordic food-processing companies.

Type of driving force	Level of importance %
Governmental requirements	38
Meet future expectations from the market	54
Market demand	38
Useful tool to develop the organisation	25
Useful tool to secure employee involvement	23
Economic savings	48
Contribution to sustainable development	29
Other, please indicate;	29

Eco efficient companies

Experimental Data

An eco-efficiency test was performed on the participating companies. The OECD eco-efficiency criteria outlined in chapter 8 (OECD 1998) were used (criteria 1-7 in Table 10.5). Two criteria on utilising low temperature energy sources were added to build upon a design criterion suggested by the author in Chapter 3. This criterion is about the maximum utilisation of low temperature energy sources. The extent and validation necessary to reach eco-efficiency described in the data from the 22 companies were evaluated against each criterion. The results are presented in Table 10.5.

Table 10.5. The table presents an eco efficiency test of the 22 participating companies. The test shows significant compliance to some criteria, and insufficient compliance to other criteria.

Criterion	Number of the participating companies fulfilling the criterion after performing a CP assessment. No EMS is present. Total number of companies: 22	Number of the participating companies fulfilling the criterion after performing a CP assessment and EMS. Total number of companies: 8
1 Minimise the material intensity of goods and services	22	8
2. Minimise the energy intensity of goods and services;	22	8
3. Minimise toxic dispersion	22	8
4. Enhance material recyclability	1	1
5. Maximise the use of renewable resources	0	0
6 Extend product durability: utilising LCA.	2	0
7. Increase the service intensity of goods and services	0	0
8. Utilising profitable low temperature energy sources	0	4[71]
9. Utilising low temperature energy-sources, beyond what gives profit[72]	0	0

[71] All companies that utilise profitable low temperature energy sources have implemented Energy Management.
[72] The term "Utilising low temperature energy-sources, beyond what gives short term profit" is described in detail with respect to the technical part of the statement, in Chapter 3, where a design-criterion on utilising a minimum of exergy is presented. "Beyond what gives short term profit", means payback longer than 5 years.

Discussion

CP – phase of the project

Twenty-two factories are a small group of factories to generalise the results for the entire food industry. However, CP-assessments have been performed also in other projects outside the NordFood R&D program. Taking those projects into account (Huisingh 1985, ICPIC-UNEP 1998, Amundsen 1993, Amundsen and Koren 1998), it is reasonable to conclude as follows:

1. The results from a CP-assessment always identify many economically profitable ways for making environmental performance improvements.
2. A relatively high percentage of short-term options are implemented.
3. The CP-options also provide good benefits for the environment.

Table 10.6 What are the most important driving forces for implementation of CP assessments in your company? The table presents the answers to this question from 22 Nordic food-processing companies.

Type of driving force	Level of importance %
Governmental requirements	23
Meet future expectations from the market	81
Market demand	14
Useful tool to develop the organisation	32
Useful tool to secure employees involvement	14
Economic savings	83
Contribution to sustainable development	17
Other, please indicate:	15

Continuous improvement activities

The participants in the project were asked if the CP assessment led to a high level of continuous improvement activity on CP. A majority of the company's managers had the opinion that the CP assessment was useful and led to activities on CP, but not on a continuous basis as required in an environmental management system, such as EMAS or ISO 14001.

Aasen and Onsager (1995) did a study of 216 enterprises, which had performed a CP assessment. Referring to Table 10.7, the companies were asked to what degree has the CP assessment stimulated more continuous improvements and permanent efforts at the establishment. One hundred and thirty-eight companies, representing 64.5 % of the companies, answered to some extent. A minority of the Norwegian companies, 16.8% answered to a large degree.

Another experience, however, from CP-assessments is that the continuous, systematic, step by step, improvements, do not always occur. The questionnaires and observations of the company leaders during the project period give some reasons for this. Comparing the companies that have implemented an EMS, to companies which do not have an EMS, certain significant differences were observed. In the companies without an EMS it was found:

Table 10.7 Did CP assessments in 216 Norwegian enterprises stimulate them to continue to make environmental performance improvements? (Aasen and Onsager 1995)

More continuous and permanent environment related work -	Distribution	
	No	%
To a large degree	36	16.8
To some degree	138	64.5
To a small degree	40	18.7
Total	214	100

- environmental issues are "nobody's" responsibility;
- there is a lack of an environmental program;
- less specified responsibilities are given to employees concerning environmental matters;
- less tracking of environmental performance indicators occurs;
- there is a lower frequency of discussion of environmental issues in the company’s leader-group.

In the companies with an EMS it was found:

- continuous activity towards improved environmental performance was present two years after the EMS implementation.

To utilise consultants in a proper way is very important in order to gain the desired results with a minimum of investment. However, consultants or supervisors may be helpful for only a short period of time. Double-loop learning (Argyris and Schön 1996), as outlined in chapters 4 and 5, will facilitate continuous improvements. A need for organisational changes, an empowered person to take responsibility for environmental issues, training programs etc, should be considered.

Conclusions on continuous improvement activities:

CP assessments do not create continuous improvement activities related to environmental performance. Organisational changes facilitate double-loop learning were not present. In the companies with an EMS system, continuous improvement activities on environmental performance were present two years after the EMS implementation.

Environmental performance, driving forces in the companies

The research question to be answered in this paragraph is: *"What are the driving forces in the company when it comes to compliance with environmental issues?"*

The findings in the NordFood-project

Referring to the company's leaders reasons for performing CPA/EMS, which also include implementing of options in the company, Tables 10.4 and 10.6 presents the results: *"future expectation on environmental issues in the market"* is the most important reason besides *"economic profit". "Contribution to sustainable development"* (which from the company point has the same meaning as "eco-efficiency"), is not a strong driving force. Low emphasis is put on sustainable development or long term options.

Even though there are no governmental requirements to implement EMS or to perform CP, about 10% of the companies give this as a reason.

How can we understand the decision-making process in the companies? Are energy efficiency improvements emphasised in the decision-making? To answer these questions, data from the project this author were involved in was compared with the results from the NordFood project.

International Environmental Business Barometer (EBB)

Referring to Ytterhus (Belz et al 1997p 55), he included fourteen possible stake-holders in a questionnaire to several hundred company leaders and asked:

"Assess the actual influence on the company from the following stakeholders when considering/deciding to undertake an environmental initiative."

The respondents were given five possible answers: none, little, some, considerable and strong influence. The results are shown in Figure 10.1.The most important stakeholders were owners, national regulators, customers, employees/labour unions, international regulators and the press/media. In the previous survey of this barometer, environmental regulators have always been at the top of the ranking (Belz et al 1997 p. 55). Public and political stakeholders still have some influence, but market stakeholders have become more important when compared to our last national survey (Belz et al. 1997p 55).

Discussion of driving forces.

Looking to the future, referring to the Eco Efficiency Concept (OECD 1998), Agenda 21 UNCED 1992) and the World Commission Report (WCED 1992) and the participating Nordic Governmental policies connected to the national follow-up on these documents (Lafferty 1997, Report No. 29, 1997-98 and Report No. 13, 1992-93), Eco Efficiency and Sustainable Development (SD) have been acknowledged by politicians as important challenges for the future. The main findings from the NordFood project regarding driving forces are short-term profit and future expectations from the market. The companies do not stress compliance to SD or eco-efficiency as an important driving force.

Ytterhus (Belz et al.1997) found that consumer organisations rate 2.7 in a scale from 0-4, where zero is no influence. He also concludes that environmental regulators, which had a big influence in earlier years, now have lower importance. Market demand is an increasing factor, Ytterhus concluded.

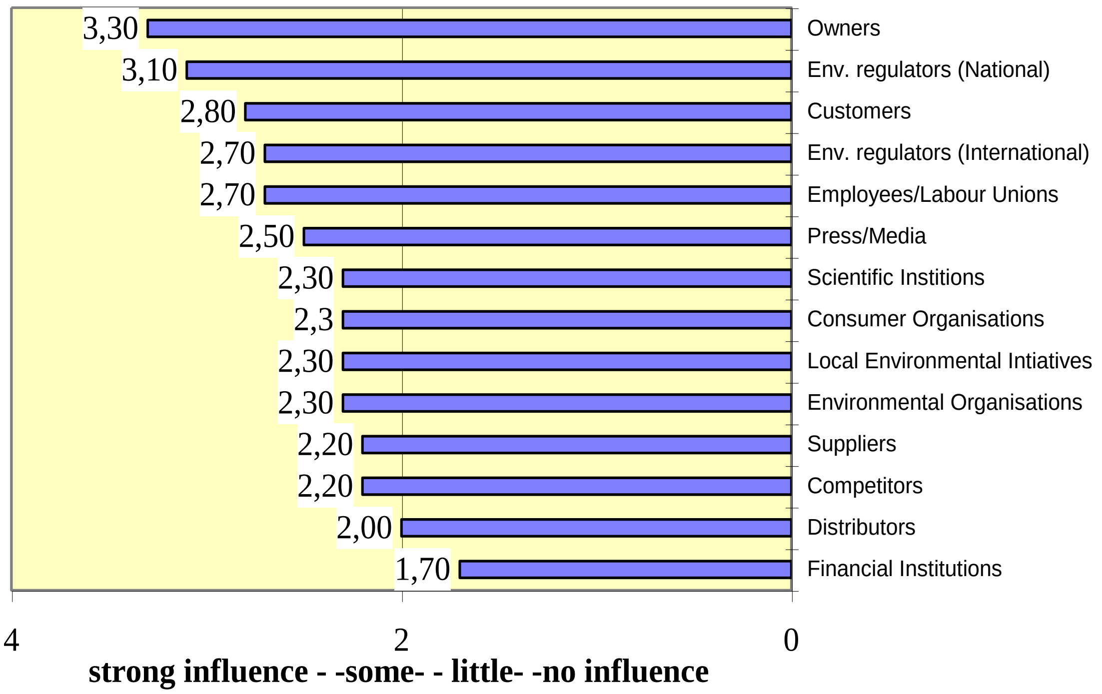


Figure 10.1: The figure shows the influence on the company from different stakeholders when considering/deciding to undertake an environmental initiative (Belz et al 1997, p. 54). The x-axis indicates the level of influence from no, at 0, to strong, 4. The Y-axis indicates the different categories of stakeholders.

Conclusions on driving forces

Short-term profit and future expectations from the market are the company's main driving forces to act on environmental issues. Eco efficiency and SD were low on the motivation scale. To overcome the challenges decided by the politicians, four options exist:

1. increase the market demand for environmental sound products;
2. increase the profit for the companies by "carrots" from the government;

3. eco-efficient production and products are forced on the companies by law;
4. EMAS and ISO 14001 should have requirements for emphasis upon compliance to eco-efficiency and SD.

Integration of CP and EMS to other management systems

Integration of CP assessments and EMS

In the environmental review required for EMAS a CP assessment was performed in the participating companies. When asked, the supervisors and the employees participating in the project agreed on a successful integration. They reported that:

1. The mass and energy balance in the CPA gave a deep insight into the environmental challenges connected to each company.
2. The CPA considers more options than the case where this method is not used.
3. The integration took more time and resources than the "easiest" way. ISO 14001 is one example of an "EMS-light".

Management systems

The EMAS, or the ISO 14000 series on EMS standards, shares common management principles with the ISO 9000 series of Quality system standards. While quality management systems deal with customer needs, environmental management systems, like EMAS and ISO 14001, address the needs of a broad range of interested parties including the evolving needs of society for environmental protection. Additional to EMS and quality, the following management systems all (to a greater or lesser extent) deal with environment, health and safety:

- Occupational Health & Safety systems are mandated by law for all Nordic Companies;
- Internal Control systems are mandated by law for all Norwegian Companies;
- Internal Control System for the food Industry. This system has specific requirements for hygiene in the food industry, and is mandated by law;
- Energy Management systems;

- Factory specific management systems, some small and medium sized enterprises have developed a factory specific management system[73].

The reasons for integration of an EMS into the Health and Safety system are:

A. This system deals with environmental protection;

B. The system is mandatory.

The reason for lack of integration is that different departments in the company are involved, so that complicated large organisational changes are required.

Continuous environmental improvement activities in the factory

In a paper by Jørgensen and Remmen (1995) the following question was posed:

"Is implementation of an environmental management system an appropriate tool to create a dynamic process in the company in order to make continuous environmental improvements?"

To answer this question, the following criteria could be appropriate:

1. concrete environmental improvements must go hand in hand with the implementation of the environmental management system;
2. environmental management can be a means to ensure continuous improvements;
3. employee participation must anchor environmental management in all parts of the organisation;
4. environmental management must be integrated with other management systems and areas of responsibility;
5. life cycle approaches must increasingly be the foundation for environmental efforts.

Experiences from the cases show that the three first criteria have been fulfilled in all companies with an EMS. In one of the factories, nine environmental groups took part in anchoring the environmental work in the organisation. In Denmark, two of the three firms constructed an integrated quality and environmental management system. This system includes hygiene and, to some extent, occupational health and safety.

In three of the four Norwegian companies, the EMS is integrated into the quality system. In all four companies Energy Management is integrated with EMS. One company decided to integrate EMS with the management system for occupational health, safety and the workers environment. In this company,

[73] This system is sometimes unofficially called "The managers pocket system" because it is not very well documented and often known only by the manager, who keeps the system in his (seldom her) pocket.

the integrated management system is as presented in Figure 10.2, even though they do not call it a “*Sustainable Development System”.*

Concluding; integration of management systems

When choosing whether to create a separate, parallel EMS system to other management systems, or to integrate the EMS system in already existing management systems, most companies have decided to integrate the EMS system into already existing management systems. Figure 10.2 illustrates the integration of elements in a sustainable management system in a company. However, the strategy differs somewhat. Some companies select a fully integrated *“sustainable development management system”* in the long term, but keep the EMS as an individual system in the implementation phase and for the first three years. In this way the information about the EMS will be available for employees. According to some managers, it is easier to distinguish the differences in the different management systems with separate systems. Energy Management has been found to be easy to integrate with the EMS system in all Norwegian companies. The number of companies is too small to rate any level of success with respect to integration of management systems. This could be an issue for future research. However, the data indicate that no better performance is measured in the companies with an integrated system than in the companies that have separate systems.

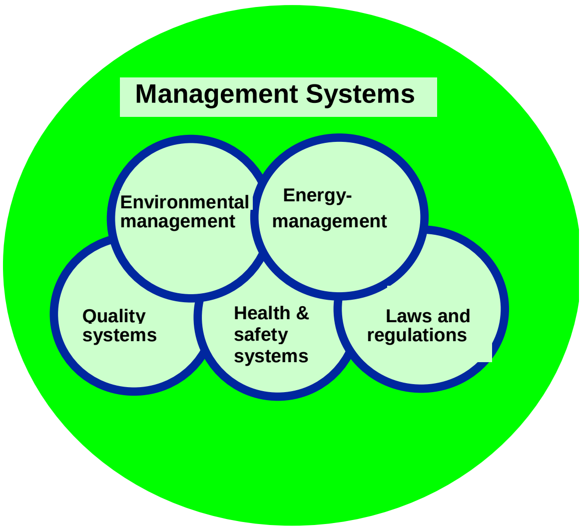


Figure 10.2. The figure illustrates integration of elements in a sustainable management system in a company. (Derived from Amundsen 1996b)

Discussing eco-efficiency and the 22 participating companies.

All companies demonstrate compliance to the first three criteria regarding minimising the material intensity of goods and services, energy and toxic dispersion. The driving forces have been profit and improved market value for the companies' products. The 4th criterion, "enhanced material recyclability", is complied with if the law requires it, or if it is profitable. The 5th criterion regarding renewable resources is utilised in the companies only if it is profitable. Regarding the 6th criterion, only two of the participating companies have performed a Life Cycle Analysis (LCA) which was used as the basis for the evaluation on "Extend product durability". Neither the CPA nor EMS systems require a LCA. In order to meet future customer's expectations on ECO-products and production, the Nordic food-processing industry has to take up the challenge and make environmental improvements in the whole product chain utilising LCA.

Compliance to the 7th criterion: "increase the service intensity of goods and services" and the 9th criterion on utilising low temperature energy-sources, beyond what gives profit, are not emphasised in the companies. Compliance with the 8th criterion on utilising profitable, low temperature, energy-sources is achieved if the company has implemented Energy Management.

Concluding remarks to the discussion on eco-efficiency.

The conclusion is that the methods of CPA and/or EMS alone will not fulfil the next century's expectations for sustainable production and products. CPA and EMS are useful, but not sufficient methods for industry to meet the politically approved (OECD 1998) expectations in the next century. One possibility is to force the companies to compliance with eco-efficiency by law. Another option is to strengthen the requirements in EMAS and ISO14001 for compliance with eco-efficiency expectations. The government can play an important role in information and "carrot" activities, which can facilitate corporate behavioural changes (OECD 1998). Future challenges are to utilise methods and systems, like Energy Management, Life Cycle Assessment and co-operation with the stakeholders in the factories (including the local community) in the context of Industrial Ecology.

The most important conclusion is that 1) the companies implement short term profitable options, but 2) do not emphasise long term investments in improved eco-efficiency.

Design criteria and performance indicators developed in Part A of this Thesis.

In Chapter 3 of this thesis two important design criteria for optimum utilisation of renewable energy sources and minimisation of exergy consumption are developed. To measure a company's performance utilising the design criteria from Chapter 3, two additional energy performance indicators are emphasised in Chapter 8. These design criteria and performance indicators were discussed with the participating companies. The company leadership showed little interest in adopting the criteria and performance indicators. Utilisation of the design criteria and the performance indicators was tested in the companies. The results are shown in Table 10.5, criteria 5, 8 and 9. Comparing the companies which had performed a CP assessment to those also had implemented EMS, a significant part of the companies with an EMS system (category 8, 50%), showed compliance to the design criterion on minimising exergy consumption by utilisation of profitable low temperature energy sources. None of the companies had targets or performance indicators that complied with the above mentioned design criteria (categories 5 and 9).

By the end of the work on this thesis, the author has developed improved insight and understanding on how to incorporate the above mentioned design criteria and performance indicators into corporate management systems. In similar future projects, the author will emphasise these design criteria and performance indicators as centrally important parts of the project. This can be facilitated by utilisation of a double-loop joint management system for energy and environment, as presented in Chapter 7 (Figure 7.9).

Overall Conclusions

The main conclusions are:

1. CP assessments within the participating companies facilitate the identification and implementation of CP options, which reduce costs for the company and provide benefits for the environment;
2. The companies implement the CP options depending on the profit potential. The profit potential should be equal to or better than a three-year payback;
3. Water and energy are the two raw materials having the biggest potential savings in most food-companies;
4. The method of CP does not necessarily lead to continuous improvement activities on CP in companies. Additional methods like an environmental management system, or organisational changes are required to facilitate double-loop learning and secure CP as a continuous improvement activity;
5. There is a limited focus on long-term options and this does not depend on whether the EMS is implemented;

6. The companies, which have integrated the EMS and other management systems like Quality-, Energy- and Health & safety-systems have good experiences with respect to the integration;
7. The companies that had performed a CP assessment and/or implemented an Environmental Management System, do not completely fulfil the eco-efficiency criteria. CP and EMS are necessary, but not sufficient methods to move the food industry towards sustainable production and producing sustainable products.

Recommendations

To overcome the Eco-efficiency challenges, the following recommendations are made as help to ensure improvements:

A. to facilitate utilisation of design criteria and performance indicators on maximum utilisation of renewable energy sources and minimising exergy consumption, a double-loop joint management system for energy and environment as presented in chapter 7 (Figure 7.9) should be implemented in the companies;
B. increase the market demand for environmentally sound products;
C. increase the profit and motivation for the companies by "carrots"[74] from the government;
D. eco-efficient production and products should be forced on the companies by law;
E. EMAS and ISO 14001 should require compliance with the Eco-efficiency criteria;
F. CP assessments should be utilised in the environmental review phase of EMAS;
G. utilisation of Life Cycle Assessment (LCA) is a future challenge for companies. These will help to put focus on the most important environmental burdens in the product chain;
H. utilisation of Industrial Ecology and co-operation with the factories' stakeholders (including the local community) are future challenges in order to secure co-operation among companies within a limited geographical area. Such co-operation can give new opportunities for co-operation on transport, renewable energy production and utilising of low temperature energy sources;

I. utilisation of waste heat in the production process (beyond what gives short-term profit) should be emphasised in companies. Referring to the company leaders description of to-days practice, only options with less than three years of payback are implemented. The payback period has to be extended to 5-10 years.

The author suggests further research to identify limits and governmental measures necessary in order for all companies to implement option in order to achieve consistent contributions to Eco-efficiency.

[74] "Carrots", means support from the government, typically 1) training programs, seminars etc. 2) governmental programs which use external advisors to help industry to identify potential improvements or 3) financial support in order to encourage the company to implement potential improvements.

Chapter 11 Joint management of energy and environment

Summary

According to the Kyoto Protocol, Norwegian emissions of greenhouse gases must be reduced by about six per cent from the 1996 level by 2012. The Government intends to give greater priority to energy efficiency measures, renewable energy sources and the use of heat pumps.

The programme and scheme studied here are the Norwegian Energy Efficiency Network (IEEN) and the Eco-Management and Audit Scheme (EMAS). This chapter describes experiences from the implementation of Energy Management in Norwegian industry. It also discusses the possibilities of integrating this methodology with EMAS. Better integration of existing energy and environmental schemes represents a CO_2 reduction potential that may be realised at short-term net cost savings.

This chapter argues for joint management of energy and environment.

Introduction

The follow-up of the Kyoto protocol, outlined in Chapter 1 in this thesis, calls for energy conservation programmes to be implemented in Norway.

Parallel to the Kyoto related activities, Norwegian companies are developing an environmental management system according to the European Community's regulation (EMAS 1993). By the spring of 1998, 40 Norwegian companies were registered as using EMAS (NHO 1998).

The EMAS and Kyoto related activities, as well as the call for integration and multi-disciplinary co-operation between environmental and energy authorities, are the greatest challenges for business.

This chapter discusses these challenges. It also suggests, and argues for, an emphasis on Energy Management within an environmental management system e.g. EMAS.

The chapter is built from Amundsen, Helgerud and Mydske (1998b)[75], Amundsen (1998d) and Amundsen, Mydske and Seyffarth (1998a)[76]. Where referred to, also other sources are consulted.

[75] In the paper of Amundsen, Helgerud and Mydske (1998b), this author very strongly contributed to the conceptual development and data collection. The reporting in this thesis is this authors' contribution on conceptualisation and data collection.

[76] In the report of Amundsen, Mydske and Seyffarth (1998a), this author did the entire conceptual development and data collection. In the reporting in this thesis some of the data is completed by 1999 figures.

Research questions

In order to develop scientifically, constructive solutions, four research questions (R1-4) were developed. The research questions are discussed and answered in the concluding section of this paper/report:

- Are benchmarking with EPIs and co-operation through networking among companies, effective ways to organise industry in order to obtain decreased energy consumption per unit of production?
- Is Energy Management emphasised to a high level in the Environmental Statements in the Norwegian EMAS registered companies per spring 1998?
- What are the similarities and differences in Energy Management and Environmental Management systems (EMS)?
- Is integration of Energy Management in EMS-systems (e.g. EMAS and ISO 14001) efficient in obtaining results for energy conservation measures and also securing continuous improvements?

Methodology

To answer the research questions, the following sources were consulted:

1. Energy data were extracted from a database of the 540 member companies in the Norwegian Industrial Energy Efficiency Network (IEEN) (IEEN 1998);
2. Environmental Statements were obtained from the Norwegian EMAS-register (Brønnøysund register 1998), interviews were conducted to verify data extracted from the reports;
3. A supplementary survey was conducted among 76 IEEN-companies using a questionnaire (Seyffarth and Skaugen 1998)
4. Documentation from the development and testing of an integrated methodology for emphasising Energy Management in EMAS (Amundsen et.al. 1998a) in ten case studies.

Tables and data from the data-sources were compiled in order to answer the research questions. The different surveys and initiatives are described, and discussed in the perspective of the research questions in the following text.

Surveys and Initiatives

A. The Industrial energy efficiency network

Background

The Industrial Energy Efficiency Network (IEEN) is a governmental, industry-guided, energy efficiency programme[77]. IEEN was established on the initiative of the authorities in 1989, to stimulate energy efficiency measures in industry. By 1997 the IEEN included 540 member companies from 13 energy intensive industry sectors (IEEN 1996 and IEEN 1997). The membership in the IEEN is voluntary and free of charge for companies. The author is connected to the IEEN partly as a research scientist and partly as a consultant for companies.

The Network's Analyses Support Scheme

Energy Management is not a goal by itself, but it helps the company to secure its' energy supply in terms of quantity, quality and price. It is a tool for obtaining continuous improvements with regard to energy efficiency and choice of energy sources. As presented in Figure 4.2, pre-conditions for change and innovation are applied know-how, involvement and action. (Ken Heap 1998). Energy Management does not differ significantly from other management systems. In many cases Energy Management can, therefore, be successfully integrated into the company's existing management routines and administrative systems as argued in the paragraph *"Integrated management systems"* in Chapter 6. The IEEN can be a catalyst in this process.

More than 140 companies within the IEEN (IEEN 1997) have benefited from the Network's Analyses Support Scheme to establish Energy Management systems, or carry to out energy audits. The Scheme has two main phases. In the first phase the expression Dynamic Competence has been introduced to the participating companies in the IEEN. This reflects the objectives of the scheme, namely to stimulate industry to optimise their actions and activities related to energy efficiency. Achieving Dynamic Competence is based on three conditions, namely Motivation, Knowledge and Obligations. These three conditions subsequently depend on a number of sub-conditions, which should be in place to obtain this stimulating effect. This model (illustrated in Figure 11.1) is a hybrid developed on the basis of British Telecom's Energy

[77] The Norwegian Water Resources and Energy Administration (NVE), is responsible for co-ordinating the energy efficiency activities outlined by The Ministry of Petroleum and Energy. NVE has assigned the Institute for Energy Technology (IFE) to be the operating agent for the industry sector. IFE is responsible for carrying out measures to stimulate industry into more efficient and environmentally friendly energy consumption. The IEEN has an Advisory Board with representatives from the participating industrial sectors.

Management programme (Cook and Nicholson 1996) and experience from implementing Energy Management in the IEEN member companies (IEEN 1997, Seyffarth and Skaugen 1998).

Introducing Energy Management based on the model in Figure 11.1, supports the idea of using the Industrial Energy Efficiency Network, with all its elements of Motivation, Knowledge and Obligation, as a basis for the scheme. The applied Motivation, Knowledge and Obligation for a network member are explained in the next paragraph.

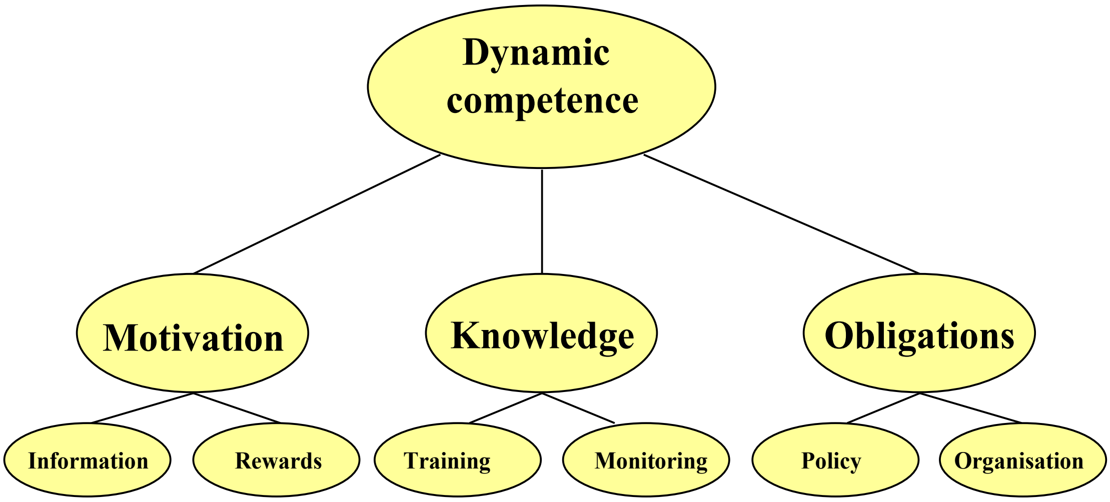


Figure 11.1 Dynamic Competence consists of different parts. The presented model is utilised from the energy efficiency network (IEEN) (IEEN 1996).

Membership benefits

Stronger focus on environmental and energy efficient production will require further efforts to reduce energy consumption in industry. Industry can use the IEEN to increase competitiveness as a result of lower energy costs and a higher environmental profile. Dynamic Competence is considered to be a prerequisite for successful implementation of Energy Management. The IEEN has designed its membership benefits according to this. Today, a member of the Network will benefit from the following advantages:

Motivation

- Information, news and results from energy efficiency projects in Norway and abroad;
- Possibility to benchmark the company's energy consumption against other companies within the same sector.

Knowledge

- Seminars, training courses and site-visits for professional and technological updating and exchange of experiences;
- Investment support for energy monitoring equipment;

➢ Through the Network's "Analyses Support Scheme" the companies can acquire technical and economic support to initiate Energy Management schemes.

Obligations

➢ The companies are obliged to submit annual energy- and production data to the Network Secretariat. They must also establish some kind of energy monitoring system to be included in their general management system.

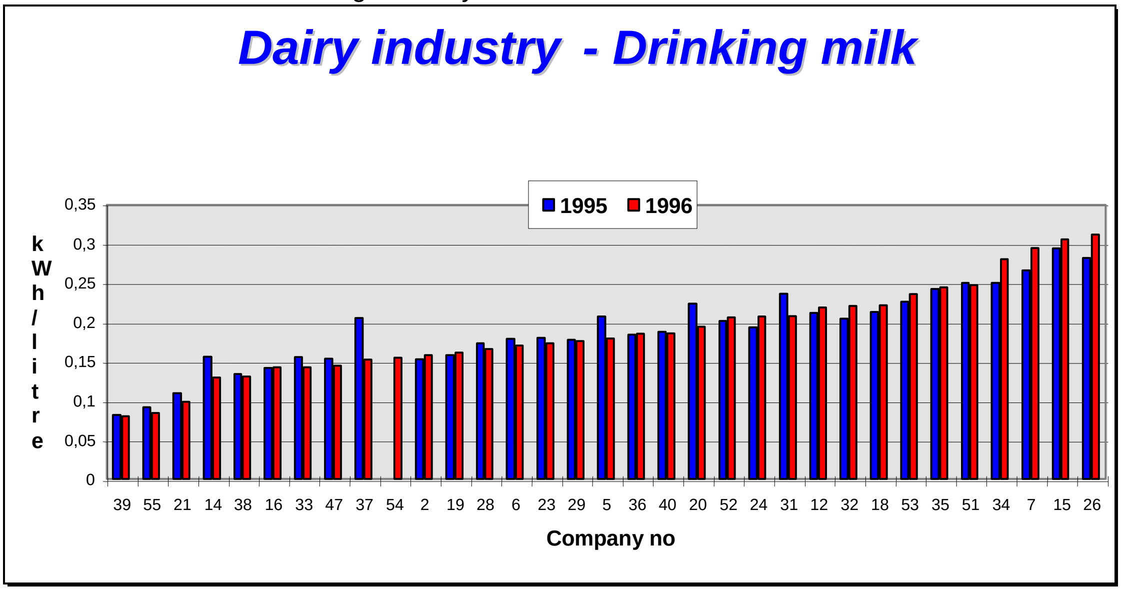


Figure 11.2 Specific energy consumption for drinking milk producers in the dairy industry measured in kWh/litre drinking milk. (IEEN 1996)

Benchmarking - energy efficiency potential

To illustrate the energy efficiency potential in Norwegian industry, it is interesting to examine the significant differences in specific energy consumption within a sector where the production processes are comparable. Specific energy consumption means total energy consumption measured for instance in kWh, divided with total production, measured for instance in tons. The Figure 11.2 shows the dairy industry while Figure 11.3, shows the meat processing industry represented in the IEEN (IEEN 1996). The figure shows that the companies are "secret" by only being represented as a number, not by name. Only the companies know their own numbers. This gives the companies the possibility to contribute to benchmarking data on specific energy consumption among competitors, but keeps their identity as a secret.

Reduction in specific energy consumption

The collected and compiled energy- and production data from the 540 IEEN member companies forms a good basis for monitoring the development of specific energy consumption in Norwegian industry. Furthermore, it is a tool for evaluating the energy efficiency potential corresponding to new technology developments, new governmental measures etc.

From 1995 to 1997, the 540 IEEN member companies have achieved significant energy efficiency improvements. Based on the 1998 production level, the IEEN member companies reduced their energy consumption by 290 GWh. This gave a corresponding cost saving of 58 million NOK during this period (energy price 0,02 ECU/kWh). Figure 11.4 shows the change in specific energy consumption in percentage from 1995 to 1997 for 12 of the 13 sectors represented.

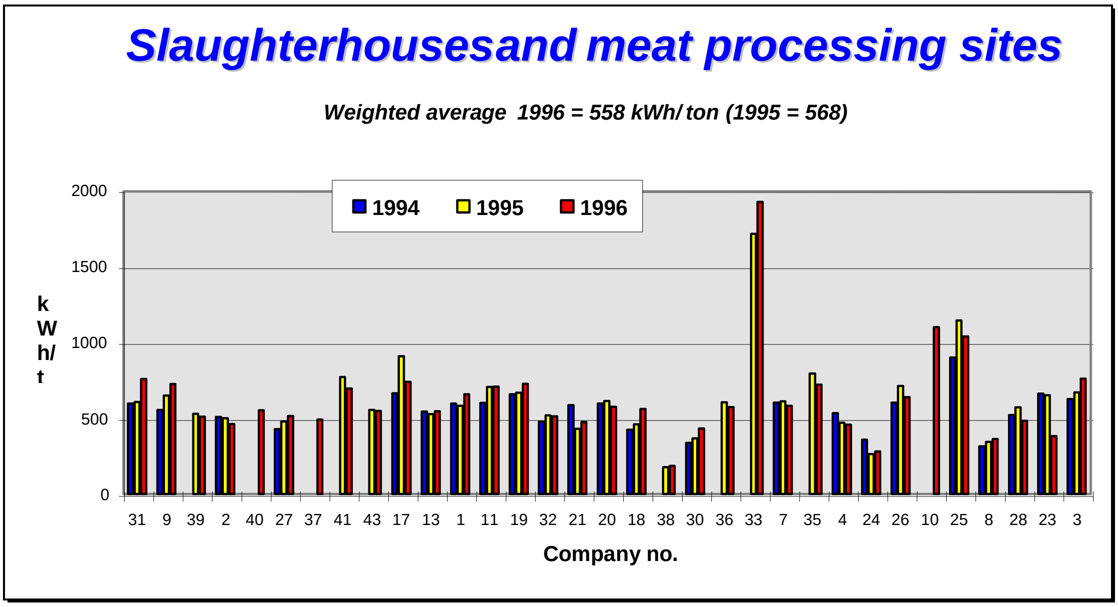


Figure 11.3. Specific energy consumption for companies in the meat processing industry measured in kWh/ton processed product. (IEEN 1996)

Discussion

The Industrial energy efficiency network

Studying Figures 11.4 and 11.5, it can be observed that 25% of the companies increased their specific energy consumption in the studied period. This study has no answer to this, but a possibility like lack in proper management or changed production to more energy intensive products could be the answers. Figure 11.4 however shows that the specific energy consumption decreased by 6 to 2.5 % within the Bakery and Meat Industries.

In order to benchmark a company’s energy consumption against other companies within the same sub-sector, the Norwegian Institute for Marketing and Media (MMI 1998) carried out the survey “Use of, and behaviour issues related to the IEEN Annual Report.” This was carried out in IEEN member companies. The survey confirms the benefit the companies gained in this benchmarking activity.

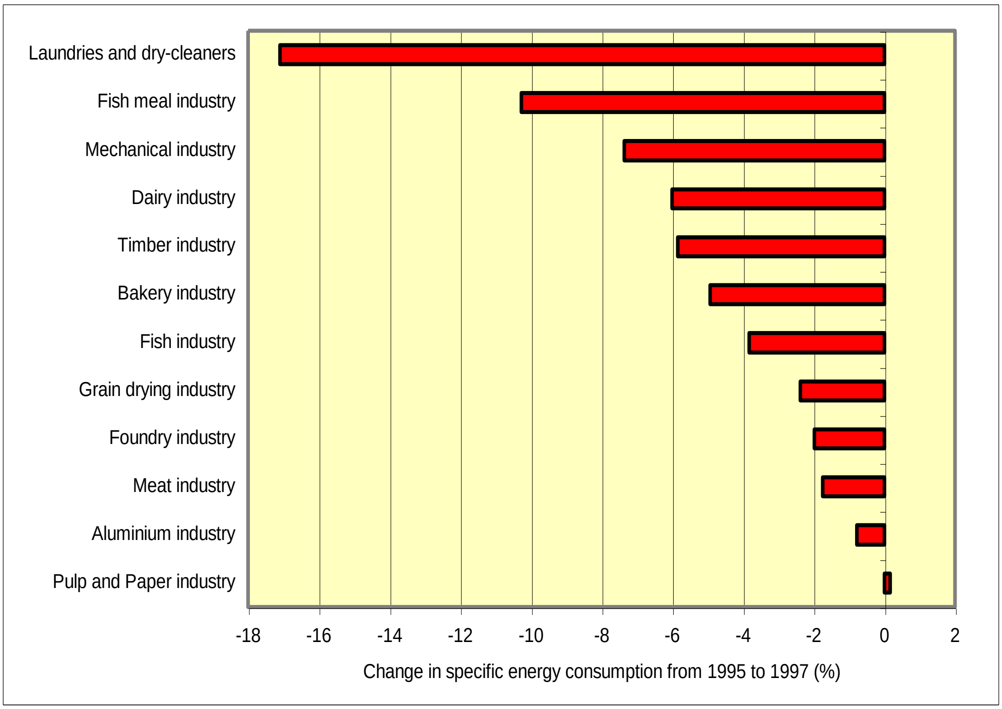


Figure 11.4 Change in specific energy consumption (measured in kWh per production unit), average for the IEEN companies from 1995 to 1997 (IEEN 1997)

Seyffarth and Skaugen (1998) carried out an evaluation of the Network Analyses Support Scheme in 140 companies. The objective was to evaluate the scheme with regard to the following:

- What initiated the companies' interest in Energy Management?
- How is the Analyses Support Scheme received among the companies?
- What are the actual results obtained, and are they sufficiently documented?
- Has the quality and the ability of the consultants been satisfactory for the purpose?

Without going into many specific details from the evaluation, 80% of the companies confirmed that the participation in the Analyses Support Scheme had a positive influence on the leaders' and employees' engagement with regard to energy efficiency.

Furthermore, the evaluation confirms the important role played by the consultants, not only in terms of promoting the scheme among the companies. Consultants were regarded as even more important for the long-term organisational approach of introducing Energy Management. Some consultants still have a prevailing technical approach to the companies, starting the Energy Management process by directly suggesting technical

energy efficiency measures. This approach does not secure the objective of continuous improvements in the company's performance, since the necessary follow-up procedures will not necessarily be incorporated into the organisation. On the other hand, the majority of the 50 consultants presently associated with, and trained by, the Analyses Support Scheme, have become more process oriented. This means that the consultants now put more emphasis on anchoring Energy Management into the existing organisational structures, before moving on to the more technical phases.
After the completion of the first phase of the Analyses Support Scheme, the companies were asked to evaluate to what extent they have improved their abilities and performance. Referring to Cliffal (1995) and the description on evaluating Energy Management in Chapter 7, the criteria they were asked to evaluate include:

- Information;
- Training;
- Energy Monitoring Systems;
- Policy;
- Organisation.

Figure 11.6 shows the results from this evaluation (Seyffarth and Skaugen 1998). The figure confirms that the companies consider participation in the Network's Analyses Support Scheme to be important with regard to their own performance. The companies were first asked to rate their own performance on a scale 0-3 before joining the Scheme. Subsequently the same self-performance evaluation was done after having worked through the phase 1 of the Scheme. As Figure 11.6 illustrates, the average rating increased considerably for all of the criteria.

Environmental driving forces

<u>Emphasis on environment in companies' annual reports.</u>

All Norwegian companies must provide annual reports to the Brønnøysund register. These reports must contain an economic audit, a description of the company's activities and also environmental impacts. To study the emphasis on environment and energy, Ytterhus evaluated 613 Norwegian environmental reports in a survey called *"The Norwegian Business Environmental Barometer"* (BEB) (Belz and Strannegård 1997). A survey was carried out by means of a standardised questionnaire. The Norwegian sample consisted of 613 manufacturing companies selected randomly from manufacturing companies with 10 or more employees. The survey was carried out from August until October 1996 and the response rate was 30%.

Eighty-six Norwegian companies produce food and beverage products. The area of action was tracked. The companies were asked what elements were implemented to some or to a large extent in the companies' annual report. The results are shown in Figure 11.5.

When the BEB report (Ytterhus in Belz and Strannegård 1997) comparing the Norwegian results with results from manufacturing companies in Sweden and Belgium, it was found that there were many similarities. However, there were some exceptions regarding environmental information in annual reports. According to Ytterhus, 60 % of the Norwegian companies give such information, compared to 10% in Sweden and 40% in Belgium.

Examining recent laws and regulations, we find that the Norwegian Companies Act § 11 - 12 and the Stock Exchange Regulations, 1994, push Norwegian companies to make such disclosures. In addition, the Confederation of Norwegian Business and Industry (NHO) has been very active in pushing its members to publish environmental information, although few companies publish a separate environmental report (19%).

A ranking indicates that 65% of firms manufacturing chemicals and chemical products have implemented environmental systems. It should be underlined that the environmental system the companies have been asked about, typically are company specific systems and not Environmental Management Systems (EMS) in compliance with EMAS or ISO 14001. Sixty-one percent of the food products and beverages manufacturing industries have implemented environmental systems (Ytterhus in Belz and Strannegård 1997). Of the SMEs[78], 39% have started the implementation of environmental management systems. According to Millar and Ytterhus, the main factors which slow down a wider adoption of environmental initiatives are: financial costs, management efforts and lack of perceived environmental impact (Millar 1995) and (Ytterhus in Belz and Strannegård 1997 p 64). Implementing environmental management systems may depend on the company's economic resources; i.e. large companies have an advantage when starting environmental actions. With respect to environmental impact, Ytterhus (Ytterhus in Belz and Strannegård 1997, p 68) conclude: *"Managers perceive their company's environmental impact to be very low along their ecological product life cycle".* Since 40% in the sample are very small companies (i.e. the number of employees is between 10 and 19), this is not surprising according to Ytterhus. Ytterhus (Belz and Strannegård 1997, p 68) conclude like this:

[78] SME's : small and medium sized enterprises or firms with less than 100 employees

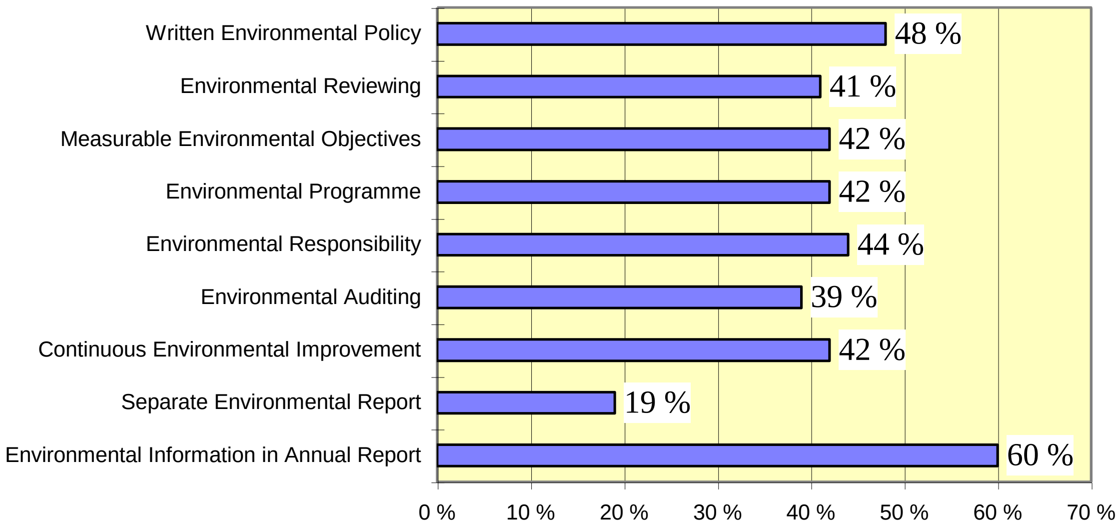


Figure 11.5: Implemented elements in the annual report in 613 Norwegian companies. (From Belz and Strannegård 1997 p 60)

"From the business barometer, there are clear indications that more than 60% of the companies have performed improvement options related to energy.

As we can see from the survey, none of these have emphasised energy in their policies.

Very few companies have implemented an EMS system, but many, especially Norwegian, have environmental information in their yearly reports".

Referring to the research question in this chapter about emphasis on Energy Management, the BEB verify the absence of emphasis upon Energy Management in the company environmental reports, though 60% have performed options related to energy. Environmental matters, especially environmental information, are present in 60% of the companies' reports. This author's conclusion is that governmental and/or Confederation of Industry initiatives for joint management of energy and environment have the potential to stimulate the companies to increase the emphasis on energy in Norwegian Industry. Such initiatives might push industry into decreasing energy consumption.

Conclusion

"Are benchmarking with EPIs and co-operation through networking among companies effective ways to organise industry in order to obtain decreased energy consumption per unit of production?"

To summarise the discussion regarding the network approach, three major observations are important:

1. The variations in specific energy consumption among comparable production sites and products are significant.
2. If all the companies within a sector could improve their specific energy consumption to match the best performing site, the realised energy efficiency potential in the sector would be significant.

More than 60% of the IEEN member companies benefited from participating in the Network's activities with regard to improving their energy efficiency performance.

The research of Ytterhus on the Business Environmental Barometer, outlined in the discussion of this Chapter, proves that Energy Management is not emphasised in industry. Considering this and the conclusions in this paragraph and the three observations listed above, the answer to the research question above should be yes.

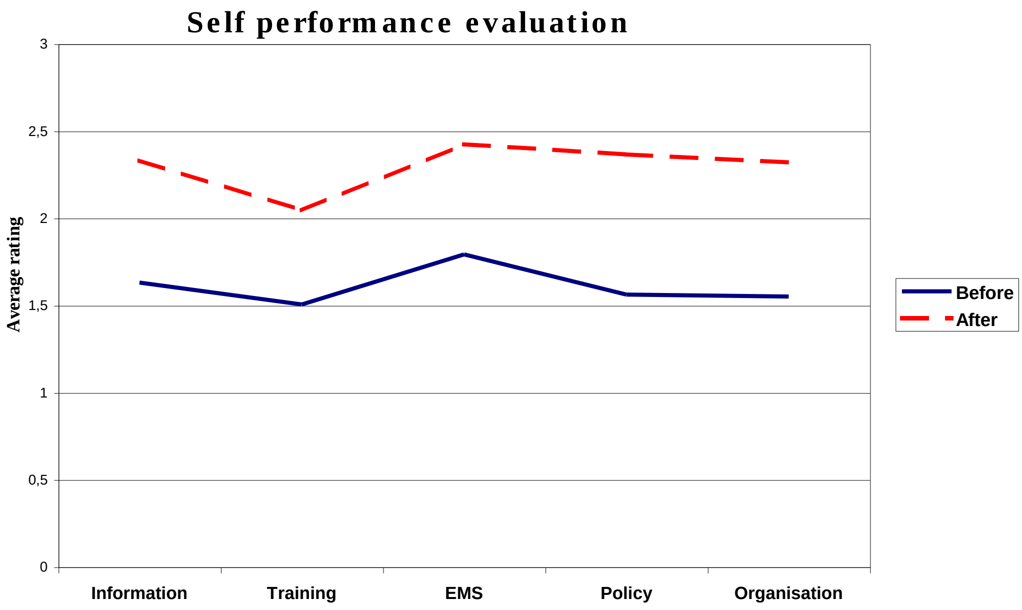


Figure 11.6. Improvement in Dynamic Competence after implementing Energy Management in 114 network members. (Seyffarth and Skaugen 1998 p.5-9 and Caffal 1995 p.21)

B. Environmental Statements in Norwegian Companies

Research question

The research questions to be focused on in this section is related to the following statement:

"EMS implementation in food processing Industry - contribute significant to energy performance"

The research questions are:

- Is Energy Management emphasised in the Environmental Statements of the Norwegian EMAS registered companies (all branches) (spring 1998)?
- Is Energy Management focused upon in EMS implementation in the food-processing industry in Norway?
- Is energy mentioned in the annual, environmental reports?
- Are energy related EPIs reported in EMAS reports in energy intensive food-processing industry?

Is energy emphasised in EMAS?

According to the EMAS Regulation (EMAS 1993), energy is meant to be handled as an environmental factor equal to the others, i.e. effluents to water, emissions to air, waste etc. However, in all of its 21 Articles and the 5 Annexes, the EMAS-Regulation text mentions energy explicitly only four times. Companies, therefore, get limited help in interpreting the EMAS Regulations with regard to energy.

Table 11.1. Energy Cost in Relation to Overall Costs in some industry sectors (derived from IEEN 1997 and Amundsen 1998).

Industry	Estimated potential [79] Energy Savings in relation to total energy consumption (%)	Energy Cost in relation to overall costs (%)
Bakeries	15	2-5
Meat Processing Industry	25	3-9
Dairy Industry	15	4
Timber and Saw mill Industry	10	4
Laundries and dry-cleaners	25	9
Grain-drying Industry	5	10
Foundry Industry	5	10
Pulp and paper Industry	10	13
Fish Meal Industry	20	25

Is energy emphasised in EMAS reports?

To study if energy is emphasised, thirteen EMAS registered environmental reports were chosen from a total of 41 (Brønnøysund Register 1998). The criteria for being chosen were high-energy costs in relation to overall costs. (Referring to Table 11.1). Data on energy related issues were compiled and compared. Table 11.2 shows some results from the survey. Thirty eight percent mention energy in their policy, 61% have quantified energy-related data in their objectives and improvement programmes, while 46% have energy explicitly mentioned in their management system. This study is

[79] Energy saving potential includes options with less than four years of payback on the investments. In longer payback periods, the potential increases.

supported by the study ”EMAS - an energy efficiency measure?” by (Mydske et.al 1998). This study discusses the weighting given to energy as an environmental factor in EMAS registrations in Norway. The objective was to see whether or not there is potential for putting more emphasis on the energy elements in EMAS. This emphasis thus contributes to realising an incremental energy efficiency improvement potential as a consequence of EMAS.

Table 11.2 Quantitative information collected from 13 EMAS-registered companies

		EMAS-regulation, article 5		
Company	**Sector**	**3e) Energy in Policy**	**3e) Energy in objectives, and programmes**	**3e) Energy in management system**
Elopak	Packaging industry	No	Yes, quantified	No
Maarud	Food industry	No	No	No
Kloralkaliefabr. (Borregaard)	Chemical industry	No	Yes, quantified	No
Isola	Construction industry	No	No	No
Peterson	Pulp and paper industry	Yes	No	Yes
Norske Skog Van Severen	Timber and sawmill industry	No	Yes, quantified	Yes
ADAS as	Mechanical industry	No	No	No
Norske Skog Saugbrugs	Pulp and paper industry	Yes	Yes, quantified	Yes
OSO Hotwater	Mechanical industry	No	Yes, quantified	No
Hydro Aluminium Karmøy	Metallurgic industry	Yes	Yes, quantified	Yes
HÅG	Furniture industry	No	No	No
Gilde Fellesslakteriet	Meat processing industry	Yes	Yes, quantified	Yes
Østfold Eggsentral	Meat processing industry	Yes	Yes, quantified	Yes
All	all	38%	61 %	46%

The study of Mydske et al (1997) is based on a survey of 13 companies that had recently completed their EMAS-registration (Mydske et al 1998). It is interesting to note that companies from the highly energy intensive industries such as metal, pulp and paper and the chemical industry, have put high emphasis on energy in their EMAS-process. This is not very surprising since their economic incentives for energy efficiency are clear. The two meat processing sites (Gilde Fellesslakteriet and Østfold Eggsentral) seem to be on the same level as the before mentioned energy intensive industries. This can be explained by the fact that these two companies were used as pilot-sites in a project to develop and test an integrated methodology for emphasising Energy Management in EMAS (Amundsen et al. 1998a). Table 11.2 also indicates that there is potential for putting more emphasis on the energy element in EMAS. The greatest potential seems to be within less energy intensive SMEs.

Discussion

Discussing the statement for this paragraph:

> *"EMS implementation in food processing Industry - contribute significantly to energy efficiency performance",*

relevant conclusions on the research questions are:

- From the business barometer, there are clear indications that more than 60% of the companies have performed improvement options related to energy. As we can see from the survey, none of these have emphasised energy in their policies. (Ytterhus 1997);
- It is a potential for putting more emphasis on the energy element in EMAS. (Mydske et al. 1998);
- Two of the three EMAS registered food-processing companies in Norway have also implemented Energy Management. The empirical material is inadequate to conclude on the emphasis related to Energy Management in the food-processing industry in Norway;
- Energy is mentioned in the EMAS report;
- Energy related EPIs is not reported in the EMAS statements except for the two companies, which have implemented an Energy Management system. One company represents the energy intensive food-processing industry, which do not report EPIs.

In Chapter 3 of this thesis two important design criteria on maximum utilisation of renewable energy sources and minimising exergy consumption are developed. To measure a company's performance utilising the design criteria from Chapter 3, two additional energy performance indicator are emphasised in Chapter 8. It was not possible to rate the companies against these criteria or EPIs from the existing empirical evidence.

Conclusion

The statement:

> *"EMS implementation in food processing Industry - contribute significantly to energy efficiency performance"*

is not possible to evaluate from the studied material. Further studies will be necessary.

C. Implemented Energy Management, case studies

Joint management of energy and environment in companies.

Ten energy intensive, Norwegian food-processing companies, which have implemented Energy Management, have been studied in order to gain experience on integrated energy and environmental management. All companies are members of the IEEN network (IEEN 1997). There are differences in how the integration of the Energy Management system is performed. Table 11.3 provides information about the companies.

Table 11.3. Norwegian food processing companies which have Energy Management schemes. (Source: The author's minutes)

Company name	**Branch**	**The Energy Management system is integrated in**
Østfold Eggsentral	Poultry slaughterhouse	EMAS
Gilde Fellesslakteriet	Slaughterhouse	Quality system EMAS
Grimstad Konservesfabrikk	Preserving vegetables	Quality system Not certified ISO 14001
Kjøttcentralen, Oslo	Meat processing	Quality system Not certified ISO 14001
Telemark Vestfold Eggsentral, avd SEM	Poultry slaughterhouse	Quality system EMAS
PRIOR Midt –Norge	Poultry slaughterhouse	Quality system EMAS
Hærland Produkter	Meat processing	Quality system EMAS
Østlandsmeieriet Tolga	Diary	Quality system Not certified ISO 14001
Troll Salmon	Fish processing	None
Telemark Vestfold Eggsentral, avd Bø	Egg processing	Quality Not certified ISO 14001

This section of the report presents information from four companies in the Norwegian meat processing industry. All four have implemented Energy Management as an integral part of their EMAS registration process. The companies have worked on energy with different intensities and at different time-spans during their EMAS registration process. They have, therefore, achieved different results. The companies' ambitions and requirements differ according to the percentage of total costs that are directly attributable to energy.

Østfold Eggsentral, Rakkestad

The company is affiliated to the Norwegian egg producers' co-operative society "PRIOR" and is the largest Norwegian chicken and turkey slaughterhouse.

- Number of employees is 138, and the capital turnover for 1996 was 42.9 mill. ECU.
- Production volume in 1996: 8,367 tonnes of chicken and 2,449 tonnes of turkey
- Energy carriers are oil and electricity, 20.9 TJ/year in total. The company utilises a heat pump.
- The company was EMAS registered in January 1998. The Director of Quality Assurance is responsible for the company's environmental control and EMAS registration.

Environmental policy

Our aim:

Østfold Eggsentral shall continue its work towards good exploitation of all resources and through actively influencing the working environment and company culture take the steps necessary to ensure personal safety and minimise emissions to the environment.

Energy and water consumption shall be closely monitored, and reduced to a minimum.

Østfold Eggsentral will develop a conscious attitude with regard to purchasing, and furthermore influence all suppliers and contractors to supply environmentally friendly products. Where process equipment or methods are changed, environmental impacts will be evaluated.

Østfold Eggsentral will, to the largest possible extent, use environmentally friendly and recyclable packaging. Furthermore, we will work actively with reduction, recycling, reuse and transport of waste and pollutants.

Østfold Eggsentral will exceed government regulations regarding the environment, and thus undertake a full annual review of the company's significant environmental parameters

Østfold Eggsentral will collaborate actively with local authorities and the public.

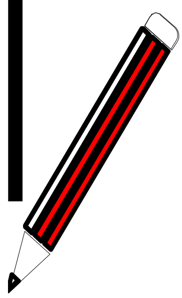


Figure 11.7 The energy and environmental policy for Østfold Eggsentral (Nilsen & Lyngstad 1999)

Energy and environmental policy

The annual report for 1996 introduced the companies' environmental policy and its consequences for the external surroundings. This represented a milestone because the external surroundings have never previously been in focus in the annual report, or at the annual meeting. The energy and environmental policy is shown in Figure 11.7.

Energy Management- routines

Energy Management was included as an internal quality system during the EMAS registration process, and is summarised in the following:

- *Systems for monitoring and targeting* were implemented. The company has implemented a monitoring system database, which logs water and energy consumption for each production department.
- *Calculation of Environmental Performance Indicators (EPIs).* The logged data are compared with the production parameters and EPIs are calculated for energy consumption and other relevant parameter.
- *Corrective action.* The management team frequently considers EPIs and consumption figures. Corrective measures are put into effect if any major discrepancies are detected.

EPIs are evaluated on a weekly basis. To ensure that this work proceeds properly, duties are clearly defined and assigned to designated personnel within the organisation. This assignment of responsibilities is clearly defined in documents within the quality assurance system.

Table 11.4. Percentage of total of monitored mass and energy flows at Østfold Eggsentral 1996. The remaining part is calculated. (Saur and Amundsen 1994b, Saur 1997)

Flow	Percentage Monitored
Water	90 %
Thermal energy	60 %
Electrical energy	50 %

Energy Management- projects

Energy Management is defined within the Environmental management system and is related to the initial environmental review and the environmental programme.

A technical environmental audit is scheduled as a project with involvement of external expertise every third year. The objectives of this project are to identify new improvement measures, determine new targets and to suggest actions that should be incorporated into the environmental programme. Through this work the company has to do the following:

1. *Perform an audit of mass and energy flows.* Every third year the company performs an audit of the most important mass and energy flows. This audit will help the company to identify key issues and assist it in setting the priorities for further action. The existing Mass and energy balance for "Østfold Eggsentral" is shown in Figure 11.8.

2. *A profitable energy conservation and environmental improvements list is produced.* The suggested actions will be evaluated and finally entered into the environmental programme.

Performance indicators

The monitoring percentage shown in Table 11.4, describes how much of the total consumption is measured, or studied in a proper way. A monitoring percent of 100 can be inappropriately expensive to obtain. Specific energy consumption (total energy consumption divided with total production) is an important indicator for a company with an energy intensive production process.

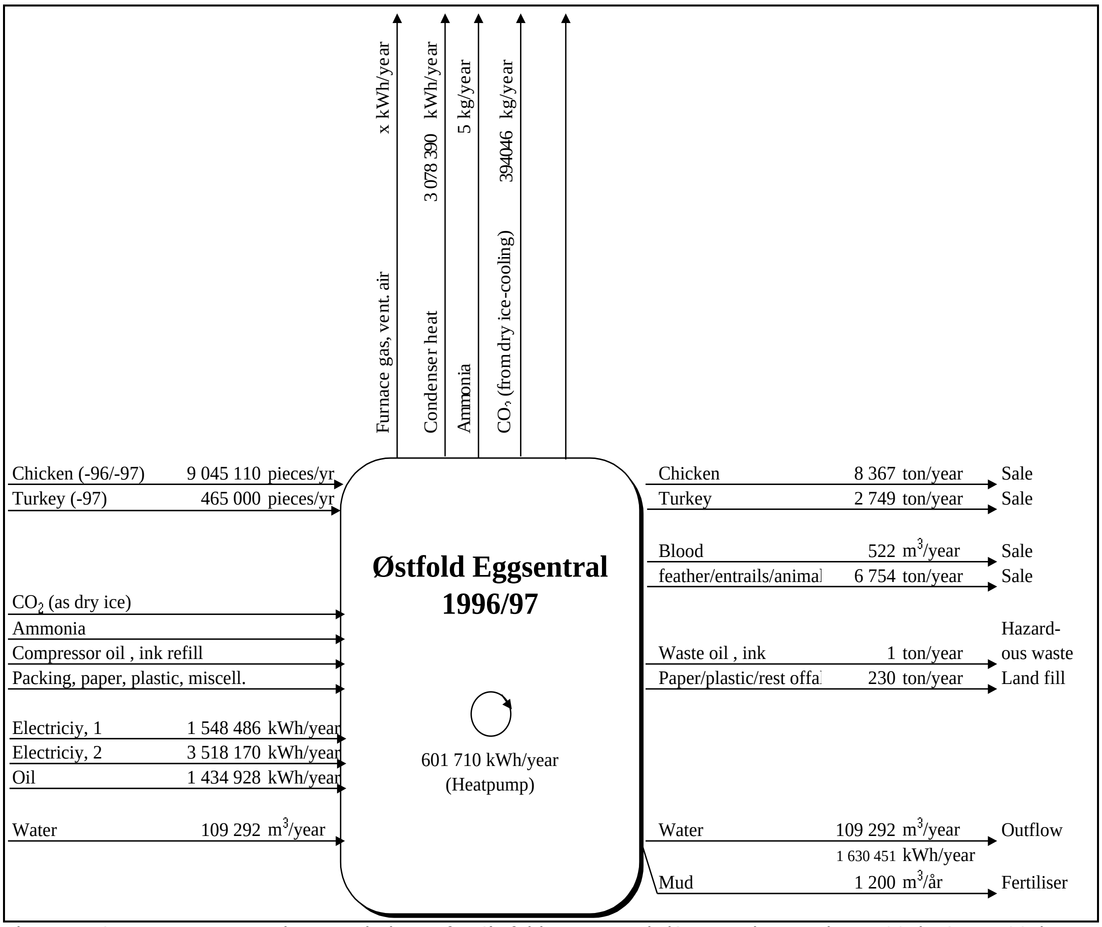


Figure 11.8 Mass and energy balance for Østfold Eggsentral. (Saur and Amundsen 1994b, Saur 1997)

The improvements, measured in the two energy related performance indicators (energy and water consumption), are shown in Figure 11.9 and Figure 11.10 (Nilsen & Lyngstad 1999). The figures show an immediate reduction in energy consumption from the year the Energy Management scheme was implemented. From 1996 to 1999, the company shows capability to continuous improvements. Figure 11.11 shows the targets Østfold Eggsentral has for its future energy and water savings.

Economic, environmental and energy savings:

Have the companies' efforts within energy and environmental savings been profitable? According to Nilsen & Lyngstad (1999), the following points answer this question:

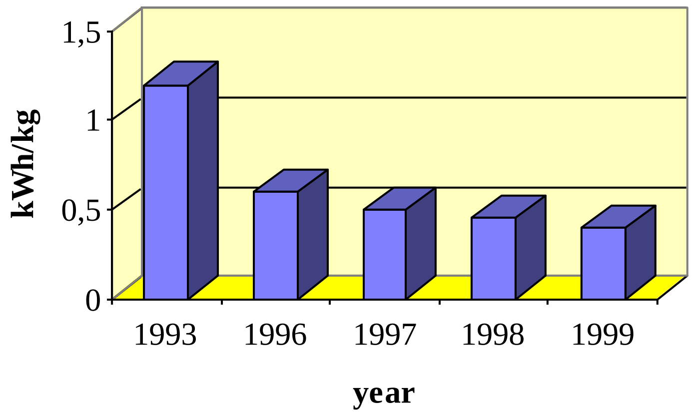


Figure 11.9 The figure shows improvements in specific energy consumption at Østfold Eggsentral, measured in kWh per kg production (Nilsen & Lyngstad 1999).

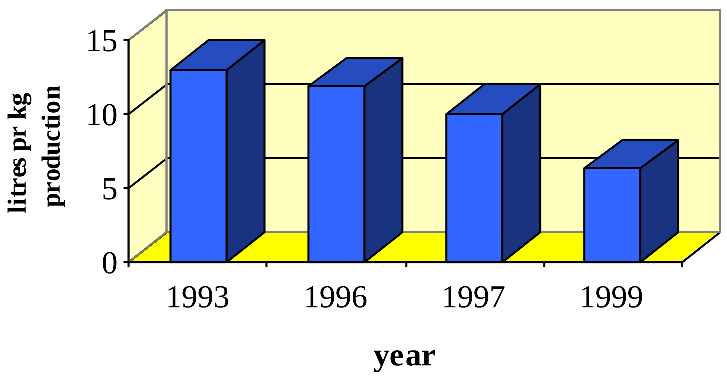


Figure 11.10 The figure shows improvements in water consumption at Østfold Eggsentral, measured in litres per kg production (Nilsen & Lyngstad 1999).

- The heat pump installation was paid off within 36 months and subsequent savings are about 200,000 NOK/year (energy price 0.3 NOK/kWh).
- The company reduced its specific energy consumption by 67%, from 1.2 to 0.4 kWh/kg processed product. Because of changes in production (less frozen product and less refinement in the production), the energy savings are difficult to estimate. However, if

today's production had followed the older routines, the reduction has been about 35%.

- The company reduced its specific water consumption from 13 to 6.3 l/kg finished product (53%) This represents savings of 1 mill. NOK each year.

For detailed information about the efforts within the company, the environmental statement should be consulted (Nilsen & Lyngstad 1999, Saur & Amundsen 1994b and Saur 1997).

Year	1997	1998	1999
Water consumption	10%	5%	5%
Energy consumption	5%	5%	5%

Figure 11.11 This figure shows future targets in Østfold Eggsentral for savings on water and energy consumption.

Gilde Fellesslakteriet, Sarpsborg

About the company

The company processes Norwegian meat products with the trademarks "Gilde" and "Goman". Norwegian farmers own the company and the number of employees is 350. The production process includes transportation of animals, slaughtering, refining, packaging, storage, transportation of products and sales. The turnover for 1996 was 0.2 billion ECU and 4600 tonnes of meat products were produced. The energy carriers are oil and electricity, 65.9 TJ/year in total. The company got its EMAS certificate in November 1997.

Energy and environmental policy:

The leaders of the slaughterer's co-operative society profiled the company as a "green company" and already in 1994 they announced that:

> *"Gilde Fellesslakteriet shall run the production without adverse effects, including the environment, people, animals and nature."*

This announcement represented a milestone since the leaders of the company had never focussed upon the external surroundings before.

Environmental control and Energy Management

Energy Management was incorporated as an internal quality system during the EMAS registration process; it is summarised in the following points (Møller and Amundsen 1997):

- *Systems for monitoring and targeting* were implemented. The company implemented a monitoring system database, which documents water and energy consumption for each production department.

- *Calculation of EPIs*. The logged data are compared with the production parameters and EPIs are calculated for energy consumption and other relevant parameters. Figure 11.12 illustrates the EPIs published in the environmental statement (Svendsen 1997)
- *Corrective efforts.* The management team frequently considers EPIs, key statistics and consumption figures. Corrective measures are put into effect if any major discrepancies are detected.

"Gilde Fellesslakteriet" repeat that energy and water consumption constitutes important environmental impacts in their environmental statement, Svendsen (1997).

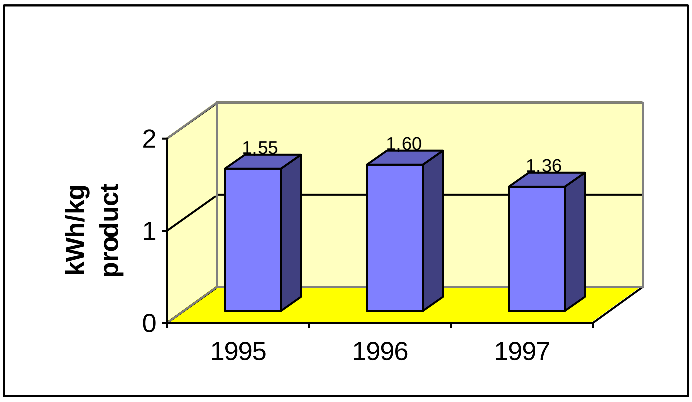


Figure 11.12 This figure illustrates the relationship between electricity consumption and sales volume at the Norwegian company Gilde Fellesslakteriet, Sarpsborg. (Svendsen 1997)

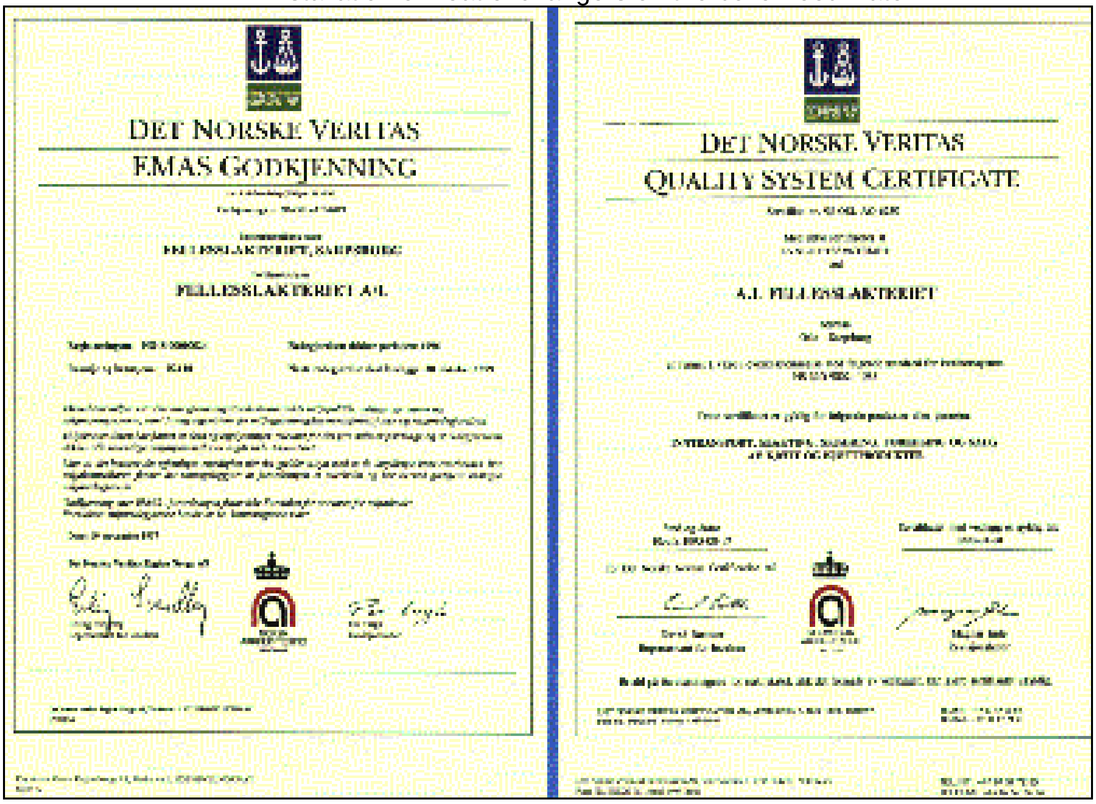
Introduction of Energy Management and EMAS registration occurred in 1996 and 1997. The company had, however, already started with an energy audit and a Cleaner Production (CP) assessment in 1993-94. The company's EMAS registration was accepted in November 1997, see Figure 11.13.

Results

The company has, through several energy efficiency improvement measures, obtained considerable operational savings every year. Measures that have been implemented are (Møller and Amundsen 1997):

- recovery and use of thermal energy from air compressors for heating water;
- use of compressed air from the compressors to run processing equipment;
- increased power efficiency in the direct-fired boilers because of calcium removal from the boiler feed water;

- energy saving light bulbs were installed;
- the control of the air compressors was optimised;
- installation of electricity and direct-fired oil boilers with high power efficiency;
- installation of heat exchangers on the boiler feed water.


DET NORSKE VERITAS
EMAS GODKJENNING
FELLESSLAKTERIET A/L

DET NORSKE VERITAS
QUALITY SYSTEM CERTIFICATE
A.L. FELLESSLAKTERIET

Figure 11.13 EMAS registration and quality certificate for “Gilde Fellesslakteriet” are shown side by side to illustrate that they are integrated in the company. The figure is copied from the company’s environmental statement. (Svendsen 1997)

Table 11.5 Water consumption at “Gilde Fellesslakteriet” (Svendsen 1997)

Key indicators (water)	1995	1996	1997
Production (ton/year)	11, 179	11, 407	11, 600
Water consumption (m^3/year)	163 ,000	133, 000	116, 000
Specific water consumption (l/kg final product)	14.5	11.7	10.0

“Gilde Fellesslakteriet” reduced its water consumption as presented in Table 11.5. Even though the production rate increased in the same period, the decrease of water consumption is considerable, from 14.5 to 10 litres of water per kg processed product. In economic terms, these results represent a saving of 0.7 mill. NOK per year.

Planned improvement measures:

- investigate possibilities for regaining condenser heat from refrigeration systems;

- investigate possibilities for utilising heat from the scorching oven for space heating.

Grimstad Konservesfabrik, Grimstad

"Grimstad Konservesfabrik" (GK) is owned by *Gartnerhallen* and has 40 employees. The capital turnover for 1996 was 8.5 mill. ECU. The company preserves fruit and vegetables. The energy carriers it uses are oil and electricity.

Table 11.6 Environmental Performance Indicators (EPIs) at GK for 1993-1998. (Amundsen 1998c)

Indicator (EPI) Year:	1993	1994	1995	1996	1997	1998
Water (l/kg final product)	25.0	20.9	21.8	18.0	17.4	14.1
Energy (kWh/ton final product)	-	-	4.2	3.8	3.5	3.2

External demand
GK shall be open to customers', local government's and society's demands within quality, health, environmental and safety questions. With the aid of GK's quality and environmental management system we shall secure continuous improvements to obtain top quality and environmentally friendly products.

Personnel
The employees shall have a good know-how and expertise about their functions and a spirit and enthusiasm that will secure the right procedures, quality and working environment.

Business
The company's system for supply of raw materials and purchasing of packaging and other input factors, shall secure that the products are in accordance with GK's environmental and quality requirements. Developments in the suppliers are important.

Technique
GK regards pollution as resources on the wrong path. Problems concerning pollution shall be solved by reduction at source, as for instance closing processing plants, recycling energy and re-use. We shall be on the cutting edge concerning demand and specifications and be in the lead on using environmentally friendly techniques. We shall use production methods and equipment, which utilise raw materials and energy resources effectively and with the right quality. We shall use products and packaging, which, from life cycle perspective, shall lead to good quality and keep pollution at a minimum. That means we must have a pro-active management concerning new production methods and the composition of manufactured products.

Environmental and quality system
GK's environmental and quality system shall be based on EMAS and ISO 9001.

Information
We shall aim at open contact with our employees, local government, mass media and with public authorities.

Figure 11.14 Integrated environmental and quality policy for the company Grimstad Konservesfabrik (Amundsen 1997).

Energy and environmental policy

The company has an environmental policy that is integrated with its quality policy. The quality policy is shown in Figure 11.14.

Energy Management

Energy Management was introduced and integrated in the quality system and EMS, it consists of the following:

- *Systems for monitoring and targeting were implemented.* The company has implemented a monitoring system database, which logs water and energy consumption for each production department.
- *Calculation of EPIs.* The logged data are compared with the production parameters and EPIs are calculated for energy consumption and other relevant parameters. Table 11.6 shows environmental indicators for GK.
- *Corrective efforts.* The management team frequently considers EPIs, key statistics and consumption figures. Corrective measures are put into effect if any major discrepancies are detected.

Table 11.7 List of improvement measures at the company Grimstad Konservesfabrik AS (Saur and Amundsen 1994a).

Option	**Priority**	**Savings**					**Environmental benefits**
		Energy	Water	Money	Invest-ment	Pay-back	
		MWh/ yr.	m^3/yr.	NOK/ yr. (1000)	NOK (1000)	yr.	
Re-use of cooling water	B		2,115	12.3	50	4.1	Reduced water consumption
Automatic sorting of raw materials (1)	B			1,000	1,200	1.2	Less raw material waste
Modification of auto-clave	B	31	1,750	19	50	2.7	Reduced energy and water consumption
Reuse of condensation water from boiler (1)	B	62	390	19.1	50	3	Reduced energy consumption
Regulation of water supply	A		470	2.7	0	-	Reduced water consumption
Training of operational staff	A	108	2,720	46	0	-	Saved energy and water. Reduced effluents of organic materials.
Energy Management	A	216	5 440	91	25	0.3	Saved energy and water
Concentrate of organic material from waste water.	C			1.3	100	9.7	Sold as pig fodder. Less transport, reduced BOD emissions: 1000 tonne/yr.
Separation of water and organic materials.				?	?	-	By-product made from former waste. Reduced organic material effluents.
Total		**417**	**12,880**	**1,200**	**1475**	**1.2**	

Results

Results from GK concerning energy and environmental improvements are shown in Table 11.7. The table shows that it is possible to save 1.2 mill. NOK. With an investment of 1.5 mill. NOK, Table 11.6 shows the longitudinal improvements. From the table a decreased energy consumption of 23.8% can be calculated from 1995-98. The decreased water consumption, which also means less organic effluents discharged into the river, is 43.6% from 1993 to 1998. (Saur & Amundsen 1994a and Amundsen 1997).

Kjøttcentralen, Oslo

About the company

The company Kjøttcentralen, is a small factory, which process meat from animals that have been slaughtered outside the company. The company's customers are commercial kitchens. The number of company employees is 20, and the capital turnover in 1996 was three mill. ECU. The energy source is hydroelectricity. The company is striving for EMAS registration by 2000.

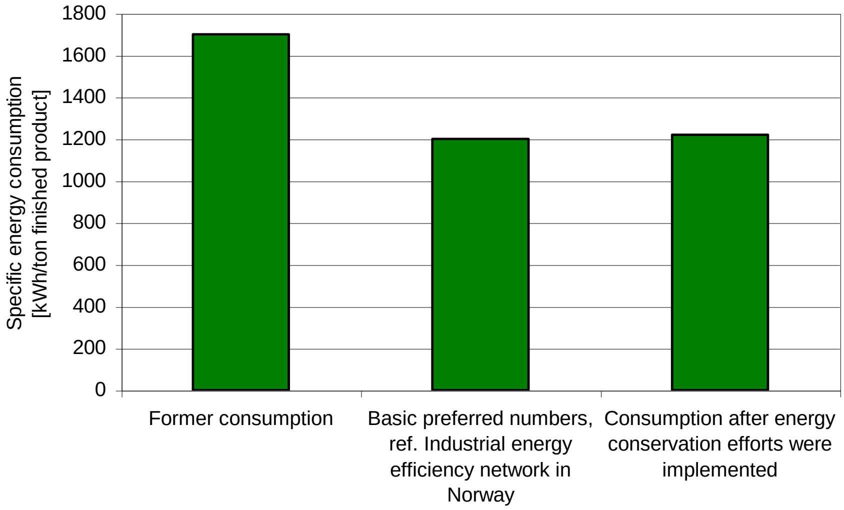


Figure 11.15 The potential for energy conservation for Kjøttcentralen (Amundsen 1998d)

Energy efficiency audit as a part of the environmental review

Since the company had relatively small environmental problems, it became natural to focus on energy conservation. An environmental account was established, the same as the model shown in Figures 7.4 and 7.5. For key energy figures, this is as shown in Figure 11.15. The potential, which appeared from this figure, motivated the company to focus on Energy Management.

Energy Management

Energy Management was introduced as an internal quality system during the EMAS registration process, and is summarised in the following:

- *Systems for monitoring and targeting* were implemented. The company implemented a monitoring system database, which documents water and energy consumption for each production department.

- *Calculation of EPIs.* The logged data are compared with the production parameters and EPIs are calculated for energy consumption and other relevant parameters.
- *Corrective efforts.* The management team frequently considers EPIs, key statistics and consumption figures. Corrective measures are put into effect if any major discrepancies are detected.

Table 11.8 A list of improvement options at Kjøttcentralen (Amundsen et al. 1998a)

Measure	Energy savings (kWh)	Savings (NOK/year)	Investments (NOK)
Energy monitoring systems	88,500	28,143	
Regulation of heater cable	10,000	3,180	6,500
Reduction of condenser pressure	25,000	7,950	4,000
Recycling of condenser heat	80,000	25,440	141,450
Adjustment of electricity preheating	140,000	44,520	
Recycling of condenser heat to heat administration area.	130,000	41,340	180,000
Optimising of air flow rate	11,200	3,562	7,000
Improved cooling of engine room			
Curtain cold store			
Regulation of the lighting			
Time regulation of air flow rate			
Measuring equipment for performance efficiency		38,112	13,000
SUM	**484,700**	**192,247**	**351,950**

What has been achieved?

In the preliminary phase of EMAS registration, the company discovered that they had both cooled and heated an area *at the same time*. The area had changed function from needing heating, to now requiring cooling. The heating in the ventilation system could only be turned off and, for prevention, the fuse removed.

The improvement measures shown in Table 11.8 show good profitability, with an average payback time of 1.8 years.

Discussion

The case studies show implemented energy efficiency options, which produce profit for the company and environmental benefits for the environment.

The statement:

> *"EMS implementation in the food processing Industry - contributes significantly to energy performance"*

is supported by the findings in the study of 10 food processing companies. However, an important condition with these 10 companies is that all of them have implemented an Energy Management system as well. The conclusion should be:

"Energy Management systems in the food processing Industry – contribute significantly to energy efficiency within participating companies".

Table 11.9. The table shows EPIs in active use in 10 Norwegian food-processing companies, which have performed Energy Management. (Amundsen 1998c)

Company name	**The Energy Management system is integrated in:**	**EPIs on** **-A: Outlet to air** **-B: organic effluent** **-C: disposed solid ……waste** **-D: waste for ……recycling**	**EPIs on** **-A: Energy consumption and/or** **-B: Water consumption**	**EPIs on** **-A: Renewable energy and/or** **-B: Energy quality (exergy)**
Østfold Eggsentral	EMAS	D	yes	no
Gilde Fellesslakteriet	Quality system EMAS	D	yes	no
Grimstad Konservesfabrikk	Quality system Not certified ISO 14001	no	yes	no
Kjøttcentralen, Oslo	Quality system Not certified ISO 14001	no	yes	no
Telemark Vestfold Eggsentral, SEM	Quality system EMAS	no	yes	no
PRIOR Midt – Norge	Quality system EMAS	A	yes	A
Hærland Produkter	Quality system EMAS	no	yes	no
Østlandsmeieriet Tolga	Quality system ISO 14001	no	yes	no
Troll Salmon	None	no	none	no
Telemark Vestfold Eggsentral, Bø	Quality. Not certified ISO 14001	no	yes	no

Utilising renewables and /or low temperature energy sources. Design criteria and performance indicators developed in Part A of this Thesis.

In order to study the implementation of the energy related criteria from:

1. this author's design criteria argued in Chapter 3 on optimum utilisation of renewable energy sources and minimising exergy consumption;
2. this author's environmental performance indicators related to the mentioned design criteria on maximum utilisation of renewable energy sources and minimising exergy consumption presented in Chapter 8;
3. the eco-efficiency concept (OECD 1998) presented in Chapter 8;

in-depth interviews with employees in the ten food-processing companies were performed (Amundsen 1998c).

The results are presented in Table 11.9. The employees and managers were asked if the company had plans for utilising renewable energy, or low temperature energy sources. This is, according to an interview of the top manager Vermund Lyngstad in Østfold Eggsentral, not the primary objective (Amundsen 1998c). The primary objectives are short-term profit and not environmental benefits. However, if short-term profit could be combined with environmental benefits, this would be preferred. The environmental director of another of the case study companies, Lisbeth Svendsen, supports these opinions (Amundsen 1998c). In depth interviews with personnel responsible for energy in the other eight factories, also support the statement of Lyngstad.

From experiences with CP assessments, indications shows that targeted guidance with regard to energy during the assessments increases the companies' willingness to invest in energy efficiency measures. This enables companies to realise a larger part of the economically viable energy efficiency potential. Assuming this is also valid for EMAS, there is potential for combining Energy Management and the environmental management system in EMAS.

In the end of the work on this thesis, the author has developed improved insight and understanding on how to emphasise the above mentioned design criteria and performance indicators into corporate management systems. In similar future projects, the author will emphasise these criteria and performance indicators as centrally important parts of the project. This can be facilitated by utilisation of a double-loop joint management system for energy and environment, as presented in Chapter 7 (Figure 7.9).

Conclusions

The conclusions from the study of the ten food processing companies are:

- Integration of Energy Management in EMS systems, like EMAS, is efficient in catalysing improvement in energy conservation measures and in securing continuous improvement activities;
- Organisational changes that facilitate double-loop learning in companies (outlined in Chapters 4 and 5) are demonstrated in the case studies. These facilitate continuous activities towards improved energy efficiency and eco-efficiency;
- The companies studied do not know the consequences and the costs and potential benefits of utilising low temperature energy sources;
- Managers of small and medium sized companies are not familiar with exergy and anergy;
- The need for exergy and anergy approaches, are not considered as design criteria related to energy;

- Managers of small and medium sized companies do not use EPIs on renewable energy sources or exergy/anergy;
- The studied companies do not consider the proportion of renewable energy when choosing their source of energy.

Overall Conclusions

Based on the existing data material compiled and discussed in the previous chapters, the network approach is an effective way of organising the implementation of Energy Management in industry. This approach contributes to the realisation of significant energy savings. Considering the documented similarities in the methodologies of both Energy Management and Environmental Management Systems, there is strong evidence that the network approach would be beneficial with regard to implementing Environmental Management Systems in industry. *Or for that matter, integrating the two into the same network.*

Data presented in this thesis indicate the potential benefits of putting more emphasis on the energy element in EMAS, mainly within less energy intensive SMEs. Doing so through existing network structures, would be a cost-effective way of achieving good results. The conclusions are:

- *Co-operation through networking among companies is an effective way to work among industries to help them achieve lower energy consumption per produced unit;*
- *Energy Management was not emphasised to a high level in the Environmental Statements in the Norwegian EMAS registered companies in spring 1998;*
- *The studied small and medium sized companies do not consider the share of renewable energy when choosing their source of energy*
- *The studied small and medium sized companies do not use EPIs on renewable energy sources or exergy consumption;*
- *There are big similarities in Energy Management and Environmental Management systems (EMS). The differences are mainly in the verification and registration systems;*
- *Integration of Energy Management in EMS-systems, like EMAS, seems to be efficient in obtaining improved energy efficiency and in helping to ensure that the company continues on the improvement journey.*

Recommendations

Recommendations from this author are:

- *Need for exergy and anergy should be considered as design criteria related to energy;*
- *The companies should get necessary "carrots"*[80] *to utilise low temperature energy sources;*
- *To utilise environmental performance indicators (EPIs) in order to facilitate maximum utilisation of renewable energy sources and minimising exergy consumption, a double-loop joint management system for energy and environment as presented in chapter 7 (Figure 7.9), should be implemented in the companies.*
- *Organisational changes that facilitate double-loop learning in companies (outlined in chapters 4 and 5) are demonstrated in the case studies. These facilitate continuous activity towards improved energy efficiency and eco-efficiency.*

[80] "Carrots", means support from the government, typically 1) training programs, seminars etc. 2) governmental programs which use external advisors to help industry to identify potential improvements or 3) financial support in order to encourage the company to implement potential improvements.

PART C RETRODUCTION, CONCLUSIONS AND RECOMMENDATIONS

Chapter 12 Retroduction

Summary

In this thesis, research questions connected to the hypotheses presented in the introduction have been investigated. Referring to the chosen research model (Figure 2.7, in Chapter 2 of this thesis), theory and analytic frames have been presented and discussed in part A of this thesis. The analytic frames considered were CP, EMS and Energy Management. Performance Evaluation was included as one analytic frame. In Chapter 8, indicators for sustainable development were investigated. Criteria for testing the hypotheses are presented in this part of the thesis. The Eco-efficiency concept (OECD 1998) was been underlined as the most concrete and applicable concept for corporate industrial development. The analytic frames were discussed and the improvements suggested.

In part B of the thesis, images have been constructed from the evidence, which consists of qualitative data from 112 industrial case studies and quantitative data from 820 companies.

In part C of the thesis, the retroduction is performed. The analytic frames from the theory and methodology presented are connected to the images from part B. Retroduction is used to test the hypotheses presented in Chapter 1.

Test of the hypotheses.

In this chapter, tests of the hypotheses stated in the introduction, is performed. The results are utilised to formulate advice for the future application of energy and environmental management.

Test of the H1 hypothesis.

The H1 hypothesis is:

> ***"Performing Cleaner Production assessments in Norwegian industries helps them to reduce their environmental burdens by making process and procedural improvements. Such process improvements have short payback periods."***

EVIDENCE 1

The results from 280 CP assessments in Norway, published by this author on the World Wide Web, show implemented improvement options in the companies (Amundsen and Koren 1998[81]). Aasen and Onsager (1995 p.18) performed a study in 216 of the 280 companies. They found that 88% of the 216 companies had implemented at least one of the identified improvement options.

These options reduced costs for the company with a short pay-back period and provided benefits for the environment. Other authors, dealing with companies in other countries, have had the same experience (Van Berkel 1996 and Huisingh 1985).

This evidence supports the H1 hypothesis.

EVIDENCE 2

Referring to Chapter 9, this study is based on Cleaner Production Assessments in 67 Norwegian companies. Energy conservation is emphasised in some of these companies. The results from this study are supported by a study performed by Sæter and Amundsen (1996). The studies show that performing Cleaner Production Assessments in Norwegian companies helps them to reduce their environmental burdens. Table 9.2 quantifies these reductions in environmental burdens. On average, each company had a yearly reduction of: 750 tonnes of CO_2, 3.7 tonnes of SO_2, 1.1 tonnes of NO_x, 354 tonnes of organic effluent, 35 tonnes of solid waste and 40 kg of hazardous waste. Such process improvements have an average pay-back period of 2.3 years.

This evidence supports the H1 hypothesis.

EVIDENCE 3

Chapter 10 summarises the experiences from the NordFood project, Cleaner Production. Two groups of methods for Cleaner Production have been tested in 22 Nordic factories in Denmark, Iceland, Norway and Sweden, over the duration of the project, 1994 -97. Conclusions that relate to the H1 hypothesis are:

- Implemented cleaner production options that produce profit for the company and provide environmental benefits.
- The companies implement the cleaner production options depending on the profit potential. The profit potential, according to the companies, should in general be equal to, or better than, three years payback time.

[81] http://www.sto.no/rp_internett/index_en.html

- The payback time varies from an average of 0.2 years in Iceland, to 2.5 years in Sweden. The average payback time for the implemented options (for all participating countries) is 1.7 years.

This evidence supports the H1 hypothesis.

CONCLUSION.

The three chosen pieces of evidence support the H1 hypothesis.

Test of the H2 hypothesis.

The H2 hypothesis is:

> ***"When a Cleaner Production Assessment is performed, the relative importance given to energy efficiency improvements in the company is dependent upon the skills and interests of the external advisor."***

EVIDENCE 1

The results from the study in 67 Norwegian companies, given in Chapter 9, indicate that the energy competence of the external adviser, has a significant influence on energy savings, economic results and environmental benefits within the companies that was evaluated.

The energy savings are an example of what can be achieved when sufficient effort is provided on certain areas. It can, however, be of major importance for cost efficiency that resources - man-hours and competence - are matched to the complexity and improvement potential in the various industrial sectors. The main conclusions from Chapter 9 are:

(i) that energy conservation may contribute significantly to economic efficiency improvements and environmental benefits;

(ii) that energy advisors positively influence the results with regard to energy savings and environmental improvements;

(iii) that energy should be emphasised in cleaner production assessments due to the significant potential for energy savings and related profitability and environmental benefits.

The result from a study of Norwegian companies (Sæter and Amundsen 1996) is that CP assessments depend on the consultant's competence. The results from the Norwegian program focusing on energy conservation, indicate that additional energy efficiency improvement activities are cost-effective, both for the government and for industry, and they provide added benefits for the environment.

The evidence supports the H2 hypothesis.

Test of the H3 hypothesis.

The H3 hypothesis is:

> ***"Performance of Cleaner Production Assessments is sufficient to create systematic, continuous improvements in companies"***

EVIDENCE 1

Referring to one of the conclusions in the study by Sæter and Amundsen (1996):

> *"Cleaner production assessments do not produce a continuous improvement process in most companies, but the attitudes towards such processes become more positive. The typical situation is that the cleaner production activity is a project limited to preparing a cleaner production assessment report and to implementing the most profitable prevention options."*

Sæter and Amundsen (1996) also state:

> *"These findings provide evidence that the cleaner production assessments are mainly a short term project or activity, and are not part of a larger, continuous improvement process among the companies, but that the attitudes towards a continuous process have become more positive."*

The evidence does not support the H3 hypothesis.

EVIDENCE 2

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic factories in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. Conclusions relating to the H3 hypothesis are:

> *"The method of cleaner production does not necessarily lead to continuous improvement activities on cleaner production in companies. Additional methods, like an environmental management system, are required to secure cleaner production as a continuous activity"*

According to the theory on double-loop learning (as outlined generally in Chapter 4 and applied to CP in Chapter 6) the CP methodology should be challenged. Policy formulation and revision are not utilised as a tool for continuous improvement activities. Interviews in the companies that had performed a CP assessment, but had no EMS system were performed two years after the end of the project. In general, the results showed that environmental policy formulation and follow up were not utilised in the companies participating in the project. No double-loop learning occurs.

This evidence does not support the H3 hypothesis.

CONCLUSION

The evidence does not support the H3 hypothesis.

Test of the H4 hypothesis.

The H4 hypothesis is:

"CP assessments, EMS and Energy Management helps companies to achieve a more consistent contribution to eco-efficiency"

EVIDENCE 1

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic factories in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. Referring to the eco-efficiency test of the companies in Chapter 10, relevant conclusions related to the H4 hypothesis are:

- CP assessments within the participating companies facilitate the identification and implementation of cleaner production options, which reduce costs for the company and provide benefits for the environment.
- Water and energy are the two raw materials having the biggest potential savings in most food-companies.
- There is a limited focus on long-term options and this does not depend on whether the EMS is implemented.
- The companies that had performed a Cleaner Production Assessment and/or implemented an Environmental Management System do not completely fulfil the eco-efficiency criteria. CP and EMS are necessary, but not sufficient methods to move the food industry towards sustainable production and producing sustainable products.

DISCUSSING THE EVIDENCE

The evidence supports the hypothesis with respect to the CP assessments and EMS part. Regarding Energy Management, the findings are that only the companies with an implemented Energy Management system utilise low temperature, energy sources that give short-term profits. When it comes to utilising low temperature energy sources, beyond what gives short-term profit[82], none of the companies have implemented such options. The OECD (1998 p.4) concept, does not require implementation of non profitable options, stating; *"Eco-efficiency is reached by the delivery of competitively-priced goods…"* The term *"competitively- priced goods"* allows the companies, as this author understands the term, not to implement options *"beyond what gives short term profit".* The conclusion regarding Energy Management is that the evidence supports the hypothesis.

To what extent does the implementation of CP assessments, EMS and Energy Management help companies to achieve a more consistent contribution to eco-efficiency? The formulation of the hypothesis is not suitable to test its limitations. If the following alternative hypothesis was stated;

> ***"CP assessments, EMS and Energy Management secure a consistent contribution to eco-efficiency in the companies",***

the hypothesis is not supported.

More detailed research should be done to identify the limits. The criteria for eco-efficiency are not specified and detailed. Further research should be done to examine the extent of these criteria.

CONCLUSION

The evidence supports the H4 hypothesis.

Test of the H5 hypothesis.

The H5 hypothesis is:

> ***" EMS implementation in the industry contributes significantly to improved energy efficiency"***

EVIDENCE 1

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic food-processing companies in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. The conclusions relating to the H5 hypothesis are that:

A. Energy efficiency options are identified at a significantly higher frequency in the companies which have an Energy Management system, compared to those companies which do not have such a system;

[82] Beyond what gives short-term profit means payback longer than 5 years.

B. There is a limited focus on long-term options and this does not depend on whether the EMS is implemented;
C. Utilising low temperature energy sources, beyond what gives short-term profit, are not emphasised in the companies.

The evidence provides no significant support for the hypothesis.

EVIDENCE 2

One of the findings of Chapter 11 is:

> *"Energy Management was not emphasised to a high level in the Environmental Statements in the Norwegian EMAS registered food-processing companies in spring 1998."*

This finding does not support the H5 hypothesis regarding the EMAS part of the registered companies. However, referring to the comparison of ISO 14001 and EMAS for Energy Management (Chapter 6, in the paragraph on EMS), no difference is found between ISO 14001 and EMAS regarding Energy Management. The conclusion from evidence 2 is that EMS systems built on EMAS or ISO 14001 do not contribute significantly to corporate improvements in energy efficiency. The H5 hypothesis is not supported.

CONCLUSION

Discussing this difference in the test results, the following points are addressed:

Evidence 1 is based on 22 Nordic companies. This is a limited number of companies. Evidence 2 includes 13 EMAS approved companies in Norway. The author recommends further research to study how different approaches to EMS implementation may have positive consequences on the results with respect to improved energy efficiency.

The author finds that the evidence does not support the H5 hypothesis.

Test of the H6 hypothesis.

The H6 hypothesis is:

> ***"Benchmarking energy related EPIs and co-operation, through networking among companies, helps companies reduce their energy consumption over a time span of three years"***

In the study of 540 companies, presented in Chapter 11 this conclusion was stated:

> *"Co-operation through networking among companies is a proper way to organise industry in order to obtain lower energy consumption per produced unit".*

CONCLUSION

The evidence supports the H6 hypothesis.

Test of the H7 hypothesis.

The H7 hypothesis is:

> ***"Energy Management in the food processing industry contributes significantly to improved energy efficiency."***

EVIDENCE 1

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project, CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic food-processing companies. The systems were tested in the companies in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. Five of these companies have implemented Energy Management. The conclusions relating to the H7 hypothesis are:

- Energy efficiency options, which produce profit for the company and environmental benefits, were implemented;
- The companies implement the cleaner production options depending on the profit potential. The profit potential should be equal to, or better than, three-year payback;
- Water and energy are the two raw materials having the biggest potential savings in most food-companies;
- The five companies with an Energy Management system had implemented profitable options in order to utilise low-temperature energy sources (see Table 10.5).

EVIDENCE 2

In Chapter 11, 540 companies with an Energy Management system are studied. In the food-processing industry a decreased specific energy consumption of 2 - 11 % (measured in kWh per production unit) was found in different food processing branches (meat industry: 2% and fishmeal industry: 11%). Figure 11.4 illustrates this. The conclusions from Chapter 11, regarding the in-depth study of 10 food processing companies (see the last part of Chapter 11), were:

- Energy efficiency options, which produce profit for the company and environmental benefits, were implemented.
- The criteria for implementation are mainly economic. The profit potential should be equal to, or better than, three years of payback.

- Water and energy are the two raw materials with the biggest potential savings in most food-companies.
- The companies are not familiar with exergy and anergy, they do not consider the proportion of exergy and anergy before choosing their source of energy. They do not know the procedures and the costs and benefits of utilising low temperature energy sources. The reason for this is that they do not believe it is profitable.

This evidence supports the H7 hypothesis.

CONCLUSION

The H7 hypothesis is stated to distinguish between the H7 and the H8 hypothesis regarding the extent of corporate eco-efficiency improvements accomplished. The companies have big potentials for energy efficiency improvements (for instance utilising low temperature energy sources). To some extent, the potential is realised. The hypothesis is supported.

Test of the H8 hypothesis.

The H8 hypothesis is:

> ***"Energy Management in the food processing industry contributes significantly to improving eco efficiency."***

EVIDENCE 1

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic food-processing companies. The systems were tested in the companies in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. The conclusions relating to the H8 hypothesis are that:

1. Water and energy are the two raw materials having the biggest potential savings in most food-companies.
2. There is a limited focus on long-term options and this does not depend on whether the EMS is implemented.
3. The companies that had performed a Cleaner Production Assessment and/or implemented an Environmental Management System do not completely fulfil the eco-efficiency criteria. CP and EMS are necessary, but not sufficient methods to move the food industry towards sustainable production and producing sustainable products.

These findings do not strongly support the H8 hypothesis.

EVIDENCE 2

The evidence used to test the H8 hypothesis is found in Chapter 11:

- Continuous activity is secured.
  Integration of Energy Management in EMS-systems, like EMAS, seems to be efficient in obtaining improved energy efficiency and in helping to ensure that the company continues on the improvement journey;
- Managers in small and medium sized companies are not familiar with exergy and anergy;
- The need for exergy and anergy is not considered as design criteria related to Energy Management;
- The companies studied do not know the techniques, the costs and the benefits of utilising low temperature energy-sources;
- Managers in mall and medium sized companies do not use EPIs on renewable energy sources;
- The studied companies do not consider the proportion of renewable energy before choosing the source of energy.

This evidence does not significantly support the H8 hypothesis.

CONCLUSION

The evidence does not support the H8 hypothesis.

Test of the H9 hypothesis.

The H9 hypothesis is:

> ***"Integration of Energy Management in EMS-systems (e.g. EMAS and ISO 14001) is efficient in facilitating the implementation of energy conservation measures and ensuring continuous improvements".***

EVIDENCE 1

Chapter 10 summarises the experiences from the NordFood project, *"Cleaner Production and Environmental Management".* In this project CP assessments and Environmental Management systems (EMS) have been tested in 22 Nordic food-processing companies. The systems were tested in the companies in Denmark, Iceland, Norway and Sweden over the duration of the project, 1994 -97. The conclusions relating to the H9 hypothesis are that:

A. Water and energy are the two raw materials having the biggest potential savings in most food-companies.
B. The companies that have integrated EMS and other management systems (like Quality, Energy and Health & Safety systems) have good experience with respect to integration.

C. CP assessments and Environmental Management Systems should be combined in a way that the CP assessment is utilised in the environmental review phase of EMAS.

This evidence does not provide a 'false' or 'true' to the hypothesis, however it does A) tell us there is a potential for savings; B) tell us it is possible to integrate EMS and Energy Management and C) recommend CP assessments as a part of EMS.

EVIDENCE 2

From Chapter 11, relevant conclusions for the H9 hypothesis are:

- Energy Management was not emphasised very frequently in the Environmental Statements of the Norwegian EMAS registered companies in spring 1998 assessment.
- There are big similarities in Energy Management and Environmental Management systems (EMS). The differences are mainly the verification and registration systems.
- Integration of Energy Management in EMS systems, like EMAS, seems to be efficient in obtaining improved energy efficiency and in helping to ensure that the company continues on the improvement journey. The integration should be performed as shown in Figure 7.9, and according to the guidelines in Appendix 2.

This evidence supports the H9 hypothesis.

CONCLUSION

The second set of evidence supports the H9 hypothesis.

Chapter 13 Conclusions and recommendations

In addition to the scientifically based conclusions in this thesis, the author presents recommendations based upon his 25 years of experience working with Energy Management, cleaner production and environmental management in industry, world-wide. A summary of the retroduction from Chapter 12, is presented here as conclusions and is written for new readers. Readers who have been trough Chapter 12, can proceed directly to the recommendation which is the second part this chapter.

Conclusions

The conclusions from the retroduction are summarised in the following. Readers who have read the retroduction in Chapter 12, can proceed direct to the Recommendation part of this chapter.

H1 ”Performing Cleaner Production assessments in Norwegian industries helps them to reduce their environmental burdens. Such process improvements have a short pay-back period”

Cleaner Production Assessments, in the way that they have been performed in 280 Norwegian companies, facilitate:

1. implemented waste reduction options with a payback of less than three years;
2. benefits to the environment.

H2 “When a Cleaner Production Assessment is performed, the relative importance given to energy efficiency improvements in the company is dependent upon the skills and interests of the external advisor.”

In a study of 67 Norwegian Companies, one of the conclusions is that energy advisors positively influence the results with regard to energy savings and environmental improvements.

H3 “Performance of Cleaner Production Assessments is not sufficient to create systematic, continuous improvements in companies

Based upon data from 67 Norwegian and 22 Nordic companies, one conclusion is that Cleaner Production Assessments, in the way they were performed, are not sufficient to create systematic, continuous environmental improvements in the participating companies.

H4 "CP assessments, EMS and Energy Management helps companies achieve more consistent improvements in eco-efficiency"

Cleaner Production Assessments within 22 Nordic food-processing companies, facilitate the identification and implementation of cleaner production options. These options reduce costs for the company and provide benefits for the environment. This evidence supports the H4 hypothesis. However, weaknesses were found, due to the lack of long-term thinking connected with initiatives to help stimulate companies to achieve a more consistent contribution to eco-efficiency improvements.

It was found that EPIs for exergy/anergy and renewable energy were not applied as strategic tools in the 22 companies. Studying the limitations to fulfilling the eco-efficiency concept in the 22 companies, the following conclusion was made:

> *"CP assessments, EMS and Energy Management as currently done within the subject companies was not sufficient to secure a consistent improvements in eco-efficiency".*

H5 " EMS implementation in industry contributes significantly to improved energy efficiency"

While studying 13 Norwegian EMAS registered companies, it was found that neither energy nor Energy Management was emphasised, to a high level, in the Environmental Statements in the food-processing Industry.

H6 "Benchmarking energy related EPIs and co-operation, through networking among companies, helps companies reduce their energy consumption over a time span of three years"

Benchmarking against energy related EPIs, connected to networking among 540 Norwegian companies, helps company leaders compare their performance with others in the same sector and thus helps them to be motivated to reduce their energy consumption.

H7 Energy Management in the food processing industry contributes significantly to improved energy efficiency

Energy Management, as shown in Figure 7.8, applied in the food processing industry, contributes significantly to improving energy efficiency.

H8 "Energy Management in the food processing industry contributes significantly to improving eco efficiency."

Energy Management in the food-processing industry contributes significantly to improving energy efficiency. However, because limited long-term thinking is created, only short-term profit is the driving force in companies. Low temperature energy sources have a large potential for corporate improvements in energy efficiency, but are not currently utilised as fully as could be done. A payback time of less than three years is a typical criterion for implementing improvement options. If the option also results in reduced emissions to the environment, this is considered by corporate leaders to be an extra benefit.

H9 “Integration of Energy Management in EMS-systems (e.g. EMAS and ISO 14001) is efficient in facilitating the implementation of energy conservation measures and ensuring continuous improvements”.

Case studies in 10 Norwegian food processing companies, where Energy Management was integrated in implementation of EMAS (as shown in Figure 7.9), were efficient in obtaining improved results in energy conservation measures and also in securing continuous efficiency improvement activities. Such integration can be facilitated according to the guidelines provided in Appendix 2.

Recommendations for companies, consultants, advisors, teachers:

Today's energy consumption by Norwegian industry is approximately 77 TWh per year (NOU 1998 p. 77). From experience, this author sees the possibility of saving 15 % of this energy. This can be achieved by improvement options using developed technology, which have a payback time of less than 5 years. This would mean an energy saving potential of 12 TWh. To put this in to perspective, two planned natural gas power stations in Norway (Kollsnes and Kårstø) yearly would produce 5,6 TWh with CO_2 emissions at 0.5 million tonnes. (NOU 1998, p. 269). To realise this energy saving potential, governmental programmes will be necessary. Some suitable governmental programmes are suggested in the following.

Recommendations for industry

The following advice is aimed at companies that will be in the front line of the eco-efficiency, paradigm shift and will be required to produce environmentally sound products.

Join a benchmarking, energy efficiency network.

Networking and benchmarking among companies helps motivate corporate leaders to reduce their energy consumption per unit of product.

What are the principle opportunities for the company (supporting initiatives, supervisors, network, web based learning. etc.)?

This thesis does not prioritise "best options" for this question. However, it can be stated that networking and benchmarking among companies leads to lower energy consumption, per unit of product over a time span of three years.

Being a member of the voluntary Norwegian Industrial Energy Efficiency Network (IEEN) provided benefits. These were:

- a lower energy consumption per unit of product was achieved over a time span of three years;
- benefits to the environment.

Joint management of energy and environment

An improved method, integrating CP assessments, Environmental Management Systems and Energy Management is suggested. Utilisation of this improved method is supposed to provide industry with short-term profitable options and help to ensure continuous activities on environmental performance. The method, shown in Figure 7.9, is based on double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87), which facilitates identification of long-term profitable options.

Corporate leaders wishing to comply with their responsibilities for energy efficiency and eco-efficiency, should consider renewable energy sources and a minimum of exergy consumption.

Which criteria and indicators should be considered when combining energy efficiency with eco-efficiency? An important issue for indicators is to distinguish between long-term and short-term objectives. The short-term criterion is typically profit. Long term indicators should consider physical laws (the first and second laws of thermodynamics and equilibrium in nature). Important design criteria in process modifications, or design, should include:

> *"Utilisation of the highest feasible proportion of renewable energy sources to fulfil the energy requirements"*

and

> *"Utilisation of the lowest feasible proportion of exergy consumption to fulfil the energy requirements"*

These criteria are not commonly used in industry today. They should be used in all societal sectors, including industry. Governmental programmes, information and taxes on energy are recommended measures to stimulate corporate leaders to implement the design criteria.

Utilise Environmental Performance Indicators connected to eco-efficiency improvements.

Two more EPIs should be used to help industry to evaluate their performance against eco-efficiency. The two EPIs are related to energy and eco-efficiency (or sustainable development). However:

- Many firms have developed targets and EPIs for reducing their intensity of material use and energy consumption.
- Renewable energy is included in the OECD eco-efficiency criteria.
- The European Green Table[83] recommends that a life cycle perspective should be used in helping companies make systematic improvements in SD.

The European Green Table[83] recommends that a life cycle perspective should be used in helping companies make systematic improvements in SD.

In order to meet the challenge from the OECD ministers on reducing environmental impacts from industry, eco-efficiency indicators need to be identified and developed. These indicators need to be transparent, comprehensive indicators of eco-efficiency. They are needed as part of a broader set of sustainable development indicators. The author recommends that industry calculates energy related, eco-efficiency indicators based on the following principles:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency.*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the energy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency.*

Recommendations for national governments

From the author's experience, governmental measures such as, taxes, technical and management training and information, financial support and "SD laws and regulations" will be required to stimulate industry to achieve eco-efficiency. This may be facilitated through governmental initiatives such as:

Future strategy for the government

To overcome the future Eco-efficiency challenges, the following recommendations are made as help to ensure improvements:

A. to facilitate utilisation of design criteria and performance indicators on maximum utilisation of renewable energy sources and minimising exergy consumption, a double-loop joint management system for energy and environment as presented in chapter 7 (Figure 7.9) should be implemented in the companies;
B. increase the market demand for environmentally sound products;
C. increase the profit and motivation for the companies by "carrots" from the government;
D. eco-efficient production and products should be forced on the companies by law;
E. EMAS and ISO 14001 should require compliance with the Eco-efficiency criteria;
F. CP assessments should be utilised in the environmental review phase of EMAS;

[83] European Green Table (EGT) is an independent foundation established by Norwegian Industry leaders in 1989. Companies and Government Bodies from Europe participate in the foundation. The purpose of the EGT is to support and strengthen the role of market mechanisms in the ongoing process towards SD.

G. utilisation of Life Cycle Assessment (LCA) is a future challenge for companies. These will help to put focus on the most important environmental burdens in the product chain;

H. utilisation of Industrial Ecology and co-operation with the factories' stakeholders (including the local community) are future challenges in order to secure co-operation among companies within a limited geographical area. Such co-operation can give new opportunities for co-operation on transport, renewable energy production and utilising of low temperature energy sources;

I. utilisation of waste heat in the production process (beyond what gives short-term profit) should be emphasised in companies. Referring to the company leaders description of to-days practice only options with less than three years of payback are implemented. The payback period has to be extended to 5-10 years.

Improve EMS, strengthen the requirements in EMAS and ISO 14001.

EMS implementations in industry should be improved by:

- organising the components systematically, as a double-loop learning system, as shown in Figure 7.9;
- improving policy instruments in order to verify internal and external factors;
- utilising CP assessments as one component within EMAS;

Requirements should be made to utilise the improved policy instruments, set scope for all the work to be done and secure implementation as follows:

- Short-term improvements: so that energy efficiency is dramatically improved;
- Long-term improvements: comprehensive options to realise improved eco-efficiency (OECD 1998) in all corporate activities.

The following should be required as verification in an improved EMS:

- yearly reporting of energy and materials efficiency;
- yearly reporting of toxic use reduction and improvement in workers health and safety.

The reporting should include proper EPIs to show compliance to the Rio Declaration, the Kyoto protocol and the OECD, eco-efficiency concept.

Recommend proper EPIs for industry

In order to meet the challenge from the OECD ministers (OECD 1998) on reducing environmental impacts from industry, eco-efficiency indicators need to be identified and developed. These indicators need to be transparent, comprehensive indicators of eco-efficiency improvements. They are needed as part of a broader set of sustainable development indicators. The author presents the following energy-related, eco-efficiency principles to be used in calculating EPIs:

1. *In a life cycle perspective, the share of renewable energy sources required to fulfil the company's energy requirements should be maximised. A high indicator is preferred for improved eco-efficiency.*
2. *In a life cycle perspective, the share of exergy consumption required to fulfil the energy requirements, should be minimised. A low indicator is preferred for improved eco-efficiency.*

From the author's experience, stimulating measures from the government, such as taxes, will be required for industry to take these new criteria into account in all of their corporate activities.

National Program on Joint Management of Energy and Environment

A program to encourage co-operations to make improvements in energy efficiency and in other environmental aspects

With the goal of overcoming limitations to environmentally friendly production and products, the government should start a National Program on Joint Management of Energy and Environment. An objective for this network should be to increase eco-efficiency in industry. The network program should provide industry with information, supervision and financial support on how to implement eco-efficient improvement options. A voluntary network of companies should be established within the program. The network should have the resources to:

- provide information about the network;
- provide relevant technical and non-technical information on eco-efficiency and SD;
- provide help to establish and utilise relevant EPIs for each company;
- provide help to identify profitable environmental improvement options;
- provide financial assistance for implementing the improvement options, by necessary "carrots"84 to utilise low temperature energy sources;
- perform benchmarking for different industry branches on EPIs relevant for eco-efficiency and SD;
- make the results of the comparative benchmarking work available in usable form to help industries help themselves to make ongoing improvements;

[84] "Carrots", means support from the government, typically 1) training programs, seminars etc. 2) governmental programs which use external advisors to help industry to identify potential improvements or 3) financial support in order to encourage the company to implement potential improvements.

so that industry can benefit from participation.

An improved method, integrating CP assessments, Environmental Management Systems and Energy Management is suggested. Utilisation of this improved method is supposed to provide industry with short-term profitable options and help to ensure continuous activities on environmental performance. The method, shown in Figure 7.9, is based on double-loop learning (Argyris and Schön 1996, Morgan 1997, p 87) and secures also identification of long-term profitable options.

This improved method, should be highlighted in future governmental programmes.

The potential for corporate energy savings can make an important contribution to fulfilling the Norwegian obligations within the Kyoto protocol. This could be realised with big economic profits for industry and savings in raw materials, waste treatment, and emissions to the environment. Properly designed governmental programs, based on double-loop learning, are necessary as catalysts to foster and continue to support continuous improvement activities in companies.

The program should provide practical guidelines on joint management of environment and energy to facilitate the implementation in industry. If companies follow this, it will help them on their journey towards eco-efficiency. A proposal for guidelines on the integrated management of energy as part of its implementation of EMAS, is presented in Appendix 2.

Database for case studies

The State Pollution Control Authority and Oestfold Research Foundation[85] have published a database of CP case studies (Amundsen and Koren 1998[86]). This database can be utilised from industry, consultants, government and universities as an idea generator in industry. This database could be expanded to also include eco-efficient improvement options, long term plans, policies etc. The purpose of this would be to inform industry about such possibilities and about enhanced profitability and improvements in eco-efficiency. The State Pollution Control Authority is hereby challenged by the author to initiate this type of program.

Future research

Referring to the above-suggested future governmental strategy, the author suggests further research. This research should identify limits and

[85] The author is employed in this research foundation.
[86] http://www.sto.no/rp_internett/index_en.html

governmental measures necessary in order for all companies to implement option in order to achieve consistent contributions to Eco-efficiency.

Recommendations for local governments

From the author's experience, stimulating measures by local government (such as prices for local goods and provision of information) will be required to help catalyse industry to achieve eco-efficiency. This can be performed through measures such as:

Pricing waste for disposal

Prices charged by local government for goods and services such as water and waste disposal, should be dear enough to encourage industry to utilise integrated, waste minimisation approaches and reduce its consumption of water and energy. The higher the prices charged, the higher the number of profitable improvement options that the companies will find and utilise.

Environmental Performance Indicators (EPIs)

Municipalities can stimulate industry to produce and to apply EPIs for, for instance, energy, exergy, renewables, freshwater, wastewater and solid waste management, providing industry with easy to understand, monthly and yearly information integrated in their utility bills. This information should contain figures on how much of the municipality's goods each particular customer has purchased in the last time period. These figures should also be compared to figures from earlier periods. Industry can use those figures for EPIs on, for instance, waste disposal per unit of product produced, or waste recycled per unit of product produced. These EPIs will help industry measure their own progress.

Sustainable energy production and consumption programme.

Local energy supply companies should, in co-operation with environmental authorities, develop plans for sustainable energy production and consumption. Renewable energy sources and the utilisation of low temperature energy sources, should be identified, prioritised and implemented.

AGENDA 21 programmes

Local governments should design and implement their AGENDA 21 programmes in co-operation with industry, trade associations, chambers of commerce, academic institutions and NGO's. These programmes should foster eco-efficiency in all corporate implementation plans and should be incorporated with regional programmes for industrial ecology and regional infrastructure programmes to foster and support regional improvements in eco-efficiency.

Technical and non-technical assistance programmes

Local governments should set up technical and non-technical assistance programmes to support companies in continuing their improvement efforts towards Sustainable Production.

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APPENDICES

Contents

Appendix 1 Questionnaire and results from 22 Nordic companies

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Appendix 2 Guideline: Joint Management of Energy and Environment in Industry

Vrak denne siden