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NATO/CCMS Pilot Study

Clean Products and Processes
(Phase I)

Report Number 242

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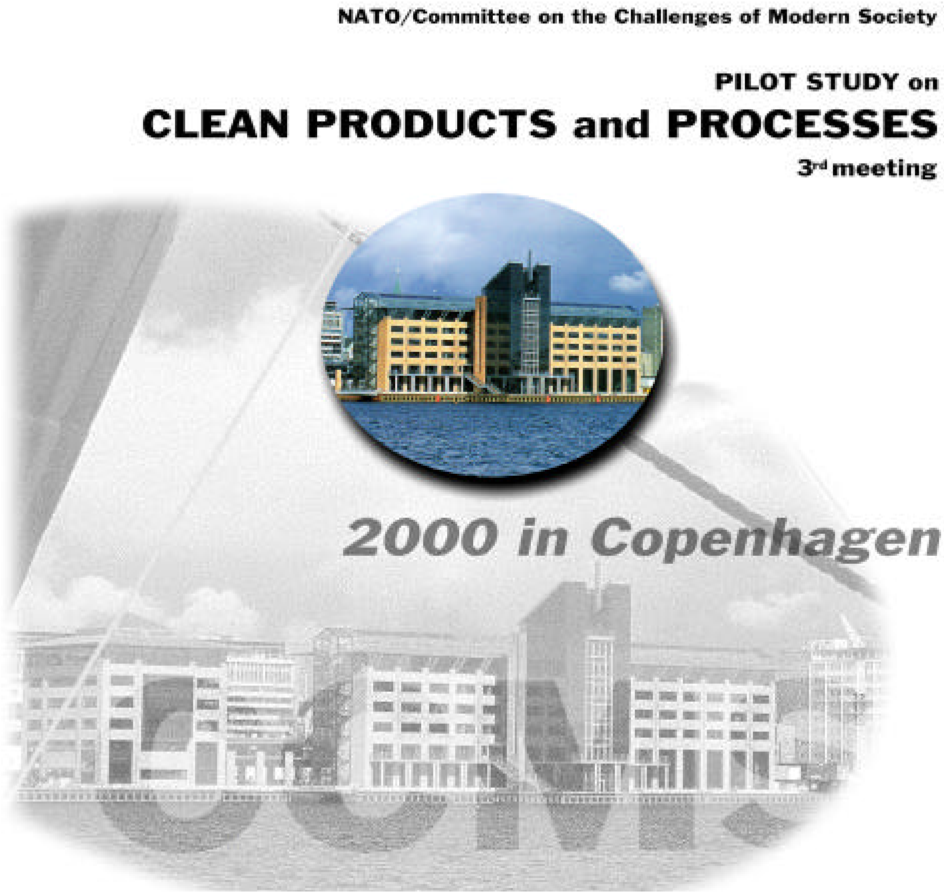
NOTICE

This report was prepared under the auspices of the North Atlantic Treaty Organization's Committee on the Challenges of Modern Society (NATO/CCMS) as a service to the technical community by the United States Environmental Protection Agency (U.S. EPA). This report was produced as a result of a cooperative agreement with U.S. EPA's National Risk Management Research Laboratory, under the direction of E. Timothy Oppelt, and the Technical University of Denmark (DTU). This report was produced by Henrik Wenzel, Christine Molin, Michael Hauschild and Hans Henrik Knudsen of DTU. Mention of trade names or specific applications does not imply endorsement or acceptance by U.S. EPA or DTU.



The Association of Danish Engineers Conference Center at the Copenhagen harbor front was the venue for the 2000 meeting

PREFACE

The Committee on the Challenges to Modern Society (CCMS) was established by the Council of the North Atlantic Treaty Organization (NATO) in 1969. The mission of CCMS is to develop meaningful programs to share information among countries on important environmental and societal issues that complement other international efforts and to provide leadership in solving specific problems facing modern society. A fundamental role for CCMS is the transfer of technological and scientific solutions among nations facing similar environmental challenges.

The goal of reaching sustainable development, where human activities, including industrial manufacturing and commercial services, exist in harmony with the natural environment, including conservation of resources and energy, is an increasingly important aspiration for the nations of the world. With increasing populations demanding improved standards of living comes increasing industrialization and production. Also, with an expanding global marketplace and the explosion of information technology, social pressures on industries to become “greener” are increasing. The challenge to nations and industries is the achievement of sustainability while successfully competing in a global marketplace. We established this CCMS pilot study on Clean Products and Processes to create an international forum for open discussion on applying cleaner industrial processes and producing cleaner products around the globe. By discussing, debating, and sharing current trends, developments, and expertise in use of cleaner technologies and production of cleaner products, we hope that this pilot study will simulate productive interactions among international experts, with the end result being effective technology transfer.

The third meeting of the pilot study was held in Copenhagen, Denmark on May 7-12, 2000. This meeting maintained the momentum generated during the of the first two years of the pilot study, focusing on progress made on several pilot projects being implemented by participating nations and continuing to build a program of collaborative endeavors. This meeting featured a special topical seminar titled, Product Oriented Environmental Measures, which focused participants’ attention on advances in product design and use. The meeting featured several guest lectures on significant developments in government programs, academic research and industrial applications. This report presents the ideas and views shared by the delegates and invited participants at the Copenhagen meeting.

As we move ahead into the third year of this pilot study, we want to thank Associate Professor Henrik Wenzel, Technical University of Denmark, Institute for Product Development, for his gracious hospitality and hosting the third meeting of the pilot study. We also want to thank Christine Molin for her tireless efforts in planning and coordinating the Copenhagen meeting. We now look forward to continuing to build strong, cooperative relationships with our fellow delegates as we plan the fourth meeting of the pilot study to be held in Oviedo, Spain, in May 2001.

Subhas K. Sikdar, Pilot Study Director
Daniel J. Murray, Jr., Pilot Study Co-Director

Preface, Introduction and Opening of the Meeting

Introduction

Already at the first pilot study meeting in Cincinnati in 1998, we discussed the possibility of hosting one of the meetings in Denmark. The new Danish initiative on a product oriented environmental initiative had been presented, and the idea was to take the opportunity to go into more detail with product oriented measures at a later meeting hosted in Denmark. Denmark and the rest of the Nordic and Northern European countries are known to be drivers in product oriented environmental work, and by locating a meeting here, it would be possible to invite a number of companies, academia and authorities and to learn from their experience in the field. A special topic day addressing product-oriented measures was envisioned.

One year later, at the meeting in Belfast, it was decided to locate the year 2000 meeting in Copenhagen. Key persons from companies, academia and authorities all accepted invitations to present their product oriented work and all contributed to making the special topic day what it was intended to be – an introduction to state-of-the-art within product oriented work in the Nordic region. We are very grateful for their contribution and their willingness to share their experience with us. Another Danish focus area is renewable energy, especially wind- and bio-mass technology. We took the opportunity to present advances in both areas at the field trip to the Technical University of Denmark. As a special event, cleaner transportation was investigated, going back to the Viking Age and experiencing their means of transportation on land and over sea

The network between delegates, and the benefit of the pilot study is steadily growing. So is the volume of the annual meeting report. We have tried to keep this report focused, structured and easily accessible. The purpose of the report is to hold on to the information presented at the meeting and to serve as a catalyst of the ever increasing exchange of information and strengthening of the network.

The country delegates have supported the reporting very much by providing well-structured presentations, good abstracts and copies of slides and overheads or full papers. This has much facilitated the compilation of the material and creation of the report. The report comprises, thus, both elaborated abstracts, summaries of presentations and full papers.

We wish you pleasure with the reading.

On behalf of the organisers
Henrik Wenzel
Associate Professor
Meeting host

OPENING OF MEETING

The pre-meeting opening session was held in the Danish Design Center in the heart of Copenhagen. Surrounded by an exhibition of Danish and International designed furniture, the NATO/CCMS pilot study director Subhas Sikdar, co-director Dan Murray and the Copenhagen meeting host, associate professor Henrik Wenzel, bid all the delegates and guests welcome and conveyed their expectations for the meeting to be held the four following days at the conference center of Danish engineers on the Copenhagen harbour front.

Get-together at the Danish Design Center in Copenhagen

Welcome by pilot study director, co-director and Danish host

Following the welcome, the delegates and guest were able to visit the exhibition TASTE in the adjoining showroom. The TASTE exhibition was organised for the Design Center by one of the world's most foremost commentators on design, style and culture Stephen Bayley, educated at Manchester University and Liverpool School of Architecture.

INTRODUCTION TO CITY HALL VISIT AND PRESENTATION

During the first day morning session, the meeting adjourned for a few hours to attend a reception at the Copenhagen Town Hall. The reception was hosted by one of the seven the Mayors of Copenhagen, Mayor of the Environment Bo Asmus Keldgaard,

Reception at Copenhagen City Hall - the Mayor of the Environment welcoming the NATO/CCMS Pilot Study participants

A SUMMARY OF THE PRESENTATION GIVEN BY MAYOR OF THE ENVIRONMENT BO ASMUS KJELDGAARD,

Authorities like the Municipality of Copenhagen has an obligation to work for a more sustainable public procurement in order to encourage the creation of cleaner products in our supply lines.

Copenhagen has a lot of experience in the environmental field. The city is international renown for its waste management, where an excellent partnership between citizens, companies and authorities has created a comprehensive system.

Although Copenhagen has achieved a lot in the environmental field, there is still a long way before the city achieves its goal of becoming a Sustainable City. Growing traffic makes it difficult to meet the targets in the CO2 reduction plan, and the soil of the city is in places widely polluted by diffuse soil pollution. However, these are not facts, which are disguised. Hard work is done to overcome the problems, and the first precondition for handling environmental problems is to recognize them. RETURN TO CONTENTS PAGE

CONTENT

INTRODUCTION TO TOUR DE TABLE PRESENTATIONS

Each country delegate presents an abstract or paper on cleaner products and processes by own choice. The trade and sector specific areas on which the CCMS meeting series focus are textile industry, organic chemical industry, the energy sector, paper and pulp industry. The focus areas for products and services are: transport, electronics, electro mechanical products, buildings, packing and energy supply. However, other pollution areas may also be addressed.

The following Tour de Table presentations are given in the chronological sequences in which they were scheduled for presentation.

SPAIN

MEMBRANE AND MEMBRANE-BASED HYBRID PROCESSES IN CLEANER PRODUCTION

Prof. José Coca
Spanish delegate

Pulp and paper effluent treatment by membrane processes

The actual concern about water pollution from industry has moved most of the countries to increase restrictions over effluent disposal. Pulp and paper industry is particularly affected because of its water requirements.

Effluent treatment and reuse is starting to be considered among the main goals for most industries. The minimization of waste water discharge reduces the environmental impact and increases savings in raw materials and chemicals. Many waste streams can be individually treated, and water reused in the process depending on quality and volume needs.

ECF bleaching effluents treatment

Bleaching stages in the pulp and paper industry are responsible for more than 50% of water pollution. Waste waters have a heavy load in terms of colour and chemical oxygen demand (COD). Classical waste treatments reduce BOD and COD, but they usually lack of colour reduction.

In this study different commercial tubular ultrafiltration and nanofiltration membranes are compared in the treatment of several effluents from the bleaching plant of kraft pulp. The research has been focused on determining the feasibility of the process in order to utilize it in industrial scale.

Water quality has been evaluated in terms of colour, COD, lignins, ionic content and carbohydrate content. Permeate flux and flux reduction due to both fouling and concentration polarization have been studied as functions of the process variables: temperature, pressure and flow rate.

Results show that nanofiltration is a reliable technique for the treatment of the bleaching effluents and their reuse in the bleach plant.

TCF bleaching effluents treatment

The use of membranes in Pulp and Paper industry has already proven to be effective for the treatment of bleaching effluents and different processes. The membranes have been used mainly to the removal of organic matter of relatively high molecular weight (10000 down to 4000 dalton). The use of nanofiltration would allow the removal of low molecular weight matter (around 500 dalton) as well as di- and tri-valent ions. In the present case, transition metals such as iron and manganese have been removed not in the ionic form in solution, but as a chelate formed with an acetic acid-based chelation agent. This work shows that nanofiltration membranes can be very useful in the reduction of waste discharges and the reuse of process water inside a pulp mill. Membranes showed chemical and thermal stability at the process conditions providing a very good selectivity and, thus, yielding good quality water.

Kraft black liquor fractionation

The most common use of Kraft black liquors is as an energy source, being burnt after a concentration, in order to produce steam and recover chemicals which are recycled to the process.

An alternative process for overflows and spillages could be the recovery of lignin and its use, or the use of some of the fractions, in the manufacture of more valuable compounds, such as adhesives, polymeric materials as polyurethanes or as fillers in composite materials. It has been shown that the molar mass (MM) distribution is the key parameter, which determines the potential use of those lignin fractions. Low MM lignin fractions could be incorporated in phenol-formaldehyde type resins, while high MM fractions are preferred for substitution of polyols in polyurethane manufacture.

Membrane processes are effective in the separation of both fractions and also allow recovering the salts, that in turn could be recycled to the pulping process.

Experiments were carried out in a tubular membrane module, using ultrafiltration membranes with nominal MWCO ranging from 4 to 100 kDa. Diafiltration experiments have been also carried out to enrich the retentate in the high MM fraction.

Removal of waste emulsified cutting oils from effluents in the metalworking industry

Oil refining and metal-finishing industries, such as rolling mills and mechanical workshops, produce large quantities of oily wastewaters that need to be treated before their disposal, because of their detrimental effects on aquatic life and their interference with conventional wastewater treatment processes. Water-based lubricants and cutting oils have gained an increasing acceptance in the metalworking industry, replacing some petroleum-based products because of their more efficient performance and less severe environmental problems. These fluids, containing mainly emulsified oil and surfactants, become less effective after use because of their thermal degradation and contamination by substances in suspension, and therefore they must be replaced periodically.

The aim of this work is the design and construction of a modular pilot plant for the treatment of different water-based coolants and oily wastewaters generated in metalworking processes and steel cold rolling operations. Different treatments are considered depending on the nature of the oily waste emulsion, such as coagulation/flocculation, centrifugation, membrane processes (micro and ultrafiltration) and sorption processes. The main advantage of this pilot plant is its versatility, allowing the combination of the aforementioned treatments, being a feasible waste management alternative from an economic point of view. This might lead to a better control of this kind of wastes and a better reuse of water, in the case of large industrial plants, with the resulting environmental and economic improvements.

Membrane-based hybrid processes

Membrane contactors

Membrane contactors represent a new way to carry out separation processes like gas adsorption and solvent extraction. They are commonly hollow fibre modules used as substitutes for packed towers. Extraction with hollow fibre modules are fast due to the large interfacial area per volume. The interface is stabilised at the membrane pores, avoiding emulsification. Dispersion-free solvent extraction has been recently studied and proved to have several advantages over conventional extractors: high surface area per volume, no need for density difference between phases to achieve phase separation, no limitations of loading or flooding, ability to handle particulate and systems that emulsify readily, no need of agitation or moving parts, and ability to provide several extraction stages in a single equipment. The main disadvantage is the slower mass transfer rate, due to the resistance to mass transfer in the pores of the membrane, which is minimised by using microporous membranes where the solute diffuses easily through the pores.

The work examined the influence of the hydrodynamics of both organic and aqueous phases on the overall mass transfer coefficient of the extraction of organic acids and phenol from an aqueous solution. A continuos extraction-stripping process has also been tested with satisfactory results.

Lactic acid derivatives

About 25% of the national production of cheese is located in the region of Asturias. This implies the production of more than 400000 t/year of whey, 87% of it coming from only seven companies.

The management of such big amounts of cheese whey is a serious problem for the dairy industry. Proteins are usually recovered by ultrafiltration, but treating the permeate as a waste before dumping represents a considerable cost. Therefore, other alternatives such as production of chemicals may be justified.

This work focuses on the valorisation of whey permeate by means of the production of lactic acid and several valuable derivatives. It includes improvement of the continuous production of lactic acid by lactose hydrolysis prior to fermentation, recovery of lactic acid from the fermentation broth by membrane extraction (pertraction) and obtaining lactic acid esters by hybrid processes involving reaction and separation.

GREECE

STATUS OF IPPC AND LCA IN GREECE
Georg Gallios
Greek delegate

Greece as a member of EU should comply with the 96/61/EU directive concerning Integrated Pollution Prevention and Control (IPPC). Actions that have been planned in order to help industries undertake the necessary actions will be presented in the meeting. The attitude of the industries towards the use of tools like LCA will be discussed. A brief description of LCA studies completed so far will also be presented. Finally, a current research project for the development of an electrochemical procedure for the removal of biologically non-degradable azodyes from the effluents of industrial processes will be described.

UNITED KINGDOM

UK SUPPORT FOR CLEAN PRODUCTS AND PROCESSES
Prof. Jim Swindal
United Kingdom delegate

It continues to be a central plank of UK Government policy to encourage and support clean and sustainable production and clean up of contaminated land.

There are a number of available initiatives including the Environmental Technology Best Practice Programme; Bio-Wise, a new programme to encourage the applications of biotechnology in industry with an emphasis on bioremediation; CLAIRE a public private partnership for the remediation of contaminated land in a sustainable way, ENTRUST an organisation to distribute revenue from landfill tax, Business in the Community which encourages companies to be more proactive in their interaction with their communities. Each region has local initiatives such as the Northern Ireland IRTU waste exchange, technical clubs, financial assistance for environmental audits and funding for environmental research, the Belfast City Council sponsored SME environmental starter pack etc.

There can be no doubt that the UK takes its responsibilities with respect to clean production very seriously as a member of the European Union and also as a responsible member of the World community. The UK record on the implementation of European environmental legislation is among the best of any member state.

DENMARK

THE ROLE AND GOALS OF THE DANISH TEXTILE STAKEHOLDER PANEL WITHIN THE PRODUCT ORIENTED ENVIRONMENTAL INITIATIVE.

Henrik Wenzel
Danish delegate

As one out of three industries in Denmark, textile industry was chosen as pilot industry for testing the feasibility of the product oriented environmental initiative. A key element was to establish a panel of essential stakeholders in the market for textile products, and have this panel itself draft a strategy for the product oriented environmental measures in the industry.

The textile panel has now, early 2000, evaluated its first year of action. In Autumn 1999, the two main activities were partly to get the industry's designers, manufacturers, ands retailers to buy the idea of developing and marketing environmentally friendly products, partly to establish a knowledge centre on environmentally friendly textiles. The initiative has been received positively by these stakeholders. The panel sees it as its most important task for the coming year to get a higher volume of environmentally friendly products with the EU Eco-label (the "flower") on the market and to motivate the purchasers and the consumers to buy these products.

The Danish tour-de-table presentations of 1998 dealt with the product oriented initiative in general. In 1999, the measures in textile industry in general were presented, and this year, it is chosen to go in depth with the role, goals and actions of the textile stakeholder panel.

POLAND

SELECTED ACTIVITIES ON CLEAN PRODUCTS AND PROCESSES IN POLAND

Andrzej Doniec
Polish delegate

An understanding of the necessity of production process improvement is growing higher in Poland. Over 200 Polish enterprises have obtained a Cleaner Production Certificate, which endorses their environmental performance. To recognize the potential for a broader implementation of the cleaner production concept, research has been done which also shows incentives and barriers to cleaner production. Almost a 100% of responding companies are interested in implementing of a waste minimization program, which is close to the number who claimed to be familiarize with the cleaner production idea. As part of the continuing effort to spread the idea, a waste minimization program for military equipment repairing enterprises has been designed and a demonstration program in one of the unit has started.
In a separate, more general approach, a list of cleaner production options for the food processing industry has been developed. The first step was done to describe waste streams currently generated by dairy sector. Some environmental and effectiveness indicators differ slightly from those of highly developed countries.

CZECK REPUBLIC

CZECH NATIONAL CLEANER PRODUCTION PROGRAM (NCPP)

Dagmar Sucharovova
Czech Republic delegate

By signing the Declaration in 1999, the Czech Republic endorsed the global program of cleaner production. Government Resolution No. 165 of February 9, 2000 created the framework for meeting this commitment.

The purpose of the National Cleaner Production Program (NCPP) of the Czech Republic is to change the approach of enterprises, the state administration and the public to the choice of measures providing for protection of the environment in industrial and other activities, including the provision of services. The program is based on the conviction that the generation of waste and pollution must be limited in the process of the activity through the implementation of changes in the technology and procedures employed. The change in the approach simultaneously

- enables limitation of construction of end technology to an essential minimum,
- ensures a higher level of utilization of input materials and energy (and consequently a decrease in demand for material resources and energy),
- optimizes expenditures for investments and for management of waste and pollution (and consequently reinforces innovative trends and the competitiveness of the product on domestic and foreign markets).

NCPP should create conditions for the implementation of voluntary activities of enterprises and organizations in the area of preventative environmental protection. The Program is based on analysis of projects and programs of cleaner production; if a business entity or other organization voluntarily implements its own program of cleaner production and the results of this program are reflected in its plans and practice, the requirements on protection of the environment, following from the Laws, can be fulfilled in an economically effective manner and can exceed the framework of these Laws. Simultaneously, the resources employed are saved and thus the effectiveness of the processes is increased.

Implementation of NCPP offers

- an improvement in the environment as a whole and introduction of an integrated approach to environmental protection as required by the IPPC Directive (Council Directive 96/61/EEC)
- an increase in competitiveness in innovation processes and a decrease in economic losses
- increased qualification of workers and the creation of new working opportunities in the area of management systems, monitoring of material, energy and financial flow in processes and in regions and also in the area of development, implementation and maintenance of cleaner production measures
- the creation of preconditions for integration of economic, social and environmental aspects of development in the individual regions and sectors.

In the Czech Republic, there is sufficient professional capacity required for commencement of implementation of NCPP, especially in the framework of the Czech Cleaner Production Centre

(CPC) and its regional centers, training cleaner production centers at universities, enterprises and cities, which introduce cleaner production programs, and the Association of cleaner production managers or professionals, who have been trained in this area as consultants and instructors. However, it will be necessary to train further professionals for every-day application of the principles of cleaner production at all levels.

Aims and Targets of the National Cleaner Production Program
The target of NCPP is to utilize information and create conditions for voluntary application of cleaner production projects (as instruments in the prevention approach) in the framework of programs announced by the individual sectors. The creation of NCPP thus reacts to the fact that

- it is necessary to ensure systematic assistance from the state in the area of protection of the environment, which will be based on preventative measures
- the increasing demands on protection of the environment as a whole require new approaches: these approaches are economically effective if they are integrated into production processes and products (they thus improve the environment and simultaneously increase the competitiveness of enterprises)
- these new approaches are complex and must be the result of close cooperation amongst the individual special-interest groups.

Thus, in the long term, NCPP will support the new trend in the "product/service - user needs" relationship, which is characterized by an increase in the importance of provision of services at the expense of the importance of the product itself. This change will be dependent on user requirements. The proposed increase in the effectiveness of the system of satisfying needs will not mean that the needs of human beings will be satisfied less, but that they will be satisfied with new quality.

The short-term target of NCPP consists in decreasing the environmental impacts of processes, products and services, with a simultaneous increase in the competitiveness of the economy. Every sector will set its own specific targets.

SLOVAC REPUBLIC

CLEAN PRODUCTS AND PROCESSES, SLOVAC REPUBLIC

Lubomir Kusnir
Slovac Republic delegate

It follows from todays economy status that following the 10 years of transformation Slovak industry and the whole economy face the need for sweeping and deep-seated restructuring. Slovakia s specific is the fact that industrial policy has to be implemented in the situation where much of the economy has to be subject to restructuring.

Under this situation, also the application of sectoral programs will be considered to help the industries that need to undergo restructuring (e.g. mechanical engineering, mining, metallurgy, textile industry, woodworking). If such an instrument is used, it will be done so in strict compliance with the EU rules on granting state aid and competition protection rules.

Companies in the Slovak republic are under the increasing competitive pressure of free-market economy, while facing the shortage of available funds and tougher environmental legislation. Companies have to operate under unstable tax and business regulations, compete for qualified working power with foreign firms, satisfy increasing compulsory fees and deliveries, manage inherited environmental problems, and incorporate new social issues.

The Slovak Cleaner Production Center had been established, aiming not only to assist in solving environmental problem for these companies, but also to achieve a change of values and priorities in relation to environment protection. As a tool to systematic approach, management and improvement, the Slovak Cleaner Production Center (SCPC) effectively uses standards for management systems –QMS according ISO 9002 and EMS according ISO 14001. Through its activities, the SCPC mainly supports project implementation mainly in small and medium-size enterprises and prefers complex solutions on regional basis.

MOLDOVA

ENERGY SUPPLY, -COMSUMPTION AND -SAVING POTENTIALS

Sergiu Galitchi
Moldovan delegate

SUMMARY

Moldova, like other countries in transition is facing many challenges. Moldova is located between the Ukraine and Rumania, and has approx. 5 mio inhabitants. The main sources of income are agriculture, product processing, electronic manufacturing, machine building, building material (cement) production.

An UNEP supported assessment was made concerning the different branches contribution to climate change. Fossil fuels account for approx. 75% of CO2 emissions. Combustion of fossil fuels and biomass account for approx. 65-75% anthropogenic emissions of NO2. However, production facilities are only working at approx. 40% of the full capacity

Energy supply is a major problem in Moldova. Energy is needed both for production and to improve quality of life and is essential for economical development. Moldova is dependent on electricity from the Russian Federation. Alternative energy source are interesting, i.e. solar power (Moldova has 310 days per year with sunshine), and biogas.

Energy efficiency regulation must be dynamic to evolve the technology. Savings in energy can be obtained by substituting old equipment with less energy consuming equipment. A project has been planned on substituting old pumps in municipal plants with Grundfos pumps using 30% less electricity. The pay-time for such a venture is approx. 6 months, but there has been bureaucratic hold ups. There are also large saving potentials in house hold electric appliances. Overall, energy saving potentials are very large and in many circumstances cost-effective.

The end user will see his energy bill decrease and at the same time his comfort will enhance. Energy efficiency regulation will also reduce emissions, the utility companies will easier meet he energy demand and it will delay new investments on the supply side.

ISRAEL

STANDARDIZATION AS INCENTIVE - WATER SUBSIDIARIES – HAZARDOUS WASTE

Chaim Forgacs
Israeli delegate

SUMMARY

Standardization
One of the most important single issues for large companies in Israel is to obtain the ISO 14000 certification. Very large part of the Israeli production goes to export and it becomes increasing important that exporting companies have ISO9000 and ISO 14000 certification. ISO standards might be a more effective driving force in clean products and clean processes than any governmental regulation.

Water shortage
Israel has implemented large-scale seawater desalination. There is an ongoing discussion between the Treasury and Department of Agriculture and the Water Commission concerning water shortage. The Treasury argues that there is no problem with water shortage in Israel, the problem is that water is subsidized for agricultural production, and agricultural goods are exported. If the subsidies are cut, it will put a stop to the water shortage.
However, stop of subsidies will end agriculture in Israel as know today, and it will reduce the green zones of the country, which already is under pressure due to massive constructions activities in the middle part of the country. Ways must be found to maintain agriculture in these parts of the country. Minor solutions have recently been implemented in few places e.g. small electrodialysis plants for selective removal of nitrate from municipal wells.

Hazardous waste
Waste collection stations are being set up, and waste collected all over the country is transported by train to national plants for treatment.

EDUCATION IN ENVIRONMETAL ENGINEERING AT BEN-GURION UNIVERSITY, ISRAEL

SUMMARY

The goal of the M.Sc. program in the Environmental Engineering Unit is to educate professionals to cope with environmental problems within
- enforcement – governmental, municipalities
- Obeying regulations – industrial entities etc.
- Offering special environmental services

Enrolment in the courses was in 1997≈ 50, in 1998 ≈ 25 and in 1999 ≈ 25. The unit has 5 Ph.D. students. Core courses are

1. Introduction to environmental engineering
2. Environmental chemistry
3. Environmental biology
4. Waste water control
5. Air pollution control
6. Solid waste and hazardous materials
7. Environmental laws and regulations
8. Environmental Engineering laboratory
9. Seminars with guest lectures from industry and government

Below a partial list of elective courses:

1. Environmental analytical chemistry
2. Advanced waste water control
3. Advanced air pollution control
4. Environmental management
5. ISO 14000 workshops
6. Membrane processes
7. Chemical plant design with environmental considerations
8. Green chemicals
9. Toxicology
10. Renewable energy sources
11. Environmental acoustics
12. Mathematical modelling

ITALY

RESEARCH FOR CLEAN PRODUCTIONS IN PROGRESS

E. Drioli
Italian delegate

Significant efforts are devoted to environmental control in various industrial production lines. The tentative to introduce innovative technologies along the production line in Italy and not only at the end of the pipe is becoming more traditional than in the past. National research projects under the leadership of industrial groups are in progress in the agrofood industry, in the textile industry, in the chemical industry, where the environmental aspects are very well present in each research projects.
Educational programs are carried out in parallel to each one of these projects. The sponsorship is mainly from the Ministry of University and Research.

The IRMERC - CNR is active in some of the activities with the specific objective of evaluating the possibility of membrane engineering in the razionalization of industrial production.

TURKEY

REPORT ON THE STATUS OF CLEANER PRODUCTS AND PROCESSES IN TURKEY

Akin Geveci
Turkish delegate

Turkey does not yet have an organization to promote the Cleaner Production. This is because the Turkish Legislation still foresees the end-of-pipe treatment not the pollution prevention.
This situation will change with the establishment of National Cleaner Production Centre in the very near future.

With the directive issued by The Science and Technology Supreme Committee in its meeting in June 2, 1998 a Working Group was formed to advise the national policy to promote environmental friendly technologies and environmental management systems. As a result of two years working of the group the establishment of NCPC was decided to be within TUBITAK-MRC.

The responsibilities of NCPC will be as;
-Advise the authorities on the C.P Policies and Strategies,
-Conduct and/or assign R&D on C.P. And whenever possible manage technology transfer,
-Test, analysis and certification (ISO 9000 and 14001),
-Technical and managerial consultancy,
-To establish C.P information centre,
-C.P training.
The industries which will be dealt with are textile, leather tanning, food, metal working, paper and chemical.

PORTUGAL

THE PORTUGUESE TEXTILE INDUSTRY – CLEAN TECHNOLOGY AND WASTE MANAGEMENT

Susete Martins Dias
Portuguese delegate

The Portuguese textile industry comprises about 17 000 companies operating in different sub-sectors from cotton, wool and synthetic fibres to cloth manufacturing, woollen and home textiles. Although the Representatives of the Textile Associations only refer 5196 companies with 250 000 employees.

The Portuguese textile industry represents 22% of Portuguese manufacturing industry, accounting for 20-25% of annual exports, which amounts to 50 million EURO.
Most of the companies are located in the North of Portugal, in the Ave river basin, namely in Famalicão, Santo Tirso and Guimarães. The competitiveness of these companies is threatened by the textile market liberalisation in 2005. Efforts to overcome this problem focus on process

technology innovation, accomplished by a rationalisation of the implemented capacity, marketing and human resources.

The textile industry technology innovation is being supported by The Technological Centre for the Textile and Garment Industries of Portugal (CITEVE), The National Institute for Engineering and Industry Technology (INETI), Minho and Beira Interior Universities and Instituto Superior Técnico in Lisbon, on issues like clean technology, process integration and environmental management. Several projects aimed at innovation in the textile industry were undertaken under the SIMIT programme (Incentive System for the Textile Industry Modernisation), since 1995, co-financed by the EC. An Integrated Decontamination System for River Ave region was developed which includes the wastewater treatment of more than 250 textile companies by the Public Administration.

BULGARIA

CLEAN ENVIRONMENT AND IT'S SUSTAINABLE DEVELOPMENT. WATER RESOURCES IN BULGARIA

Stefka Tepavitcharova
Bulgarian delegate

During the last years Bulgarian national policy in the field of ecology aims at: (i) preservation of the environmental status of the unpolluted and with kept natural resources areas; (ii) improvement of the quality of environment in polluted areas with disrupted natural balance.

The water resources are main part of the national nature wealth and their conservation is of extreme significance. A draft law on water has been elaborated. There are a number of national and international projects which purpose is to improve the status of water resources in Bulgaria. The investments in construction and reconstruction of wastewater purification stations and in technological renovation of production processes are defined as priority. The quality of the Bulgarian water resources (surface, ground as well as Black sea coastal water) is characterized for 3 years period using physicochemical and biological monitoring data. The result is water resources status improvement in Bulgaria in the last years.

UKRAINE

CLEANER PRODUCTION STRATEGY AND TACTICS, DEFINITION TOOLS AND METHODS BASED ON SYSTEMATIC APPROACH TO SUSTAINABLE PRODUCT DEVELOPMENT FOR SYSTEMATIC REDUCTION OF ENVIRONMENTAL LOADS (ECOLOGIZING OR "ECOLOGIZATION")

William Zadorsky.
Ukrainian delegate

This presentation is continue of 1999 year presentation "A Ukrainian's Version of a systems Approach to Sustainable Development in Environmentally Damaged Areas: Cleaner Production

and Industrial Symbiosis as Major Ways to Pollution Prevention". NATO/CCMS Pilot Study "Clean Products and Processes (Phase 1)" 1999 Annual Report, Number 238, pages 45-48.

Introduction

Cleaner Production is conceptual and procedural approach to production, demanding that all phases of a product or process life cycle be addressed with the objective of preventing or minimizing short- and long-term risks to the humans and the environment. Cleaner Production utilizes improvements in product design, raw materials production, selection and their efficient use, as well as production and assembly of final products, consumer use of the products, waste and disposal recycling, transportation of raw materials and products, and energy savings. Specifically, adoption of Cleaner Production principles offers industry opportunities to promote operating efficiency while improving environmental performance. Source waste reduction eliminates costly post-production effluent control or bolt-on treatment. This conserves raw materials and energy, eliminates usage of toxic materials and reduces quantity and toxicity of all emissions and wastes in a closed-cycle process. For products, Cleaner Production spans the entire process life cycle from raw material procurement to disposal of byproducts of industrial material processing. Cleaner Production is achieved by applying know-how, by improving technology and changing attitudes. Cleaner Production is generally cost effective due to potential improvements of both process efficiency and improved product quality. These economic advantages of CP are especially evident when compared with other environmental protection strategies, for example such as end-of-pipe waste water treatment, waste processing, and exhaust gas treatment. Apart from cleaner production in industry, it is possible also to survey opportunities and constraints for cleaner energy conversion and improved energy utilization.

Part 1. Cleaner production strategy and TACTICS based on systematic approach to sustainable product development

Main principles of the cleaner production concept are as follows:

- All ecological problems should be solved in cooperation with a unified comprehensive planning.
- Ecologizing economy supposes modernization of objects, which are real or potential pollutants of environment.
- The prosperity of ecologizing implies existence of professionals skilled in the theory and practice of ecologizing, cleaner production and ecological management.
- The creation of civilized ecological market is a necessary prerequisite for ecologizing of economy and sustainable development of the country.

As known, the cleaner production concept as and sustainable development concept includes three aspects: ecological, economic and social. Underestimating any one of these components will bias the whole equation and infringe strategy of sustainable development. Indeed, reassessment of an economic force having underestimed ecological and social implications, results in infringement of stability of development, for it is impossible to ensure improvement of conditions of life of the next generation if the improvement of economy will not be accompanied by reduction of technogenic loads per capita, and mastering social problems of a community. Therefore, only mutually balanced simultaneous comprehensive tackling of the three tasks (economical growth with simultaneous improvement of ecological conditions and decision of social problems) will allow to realize progressive CP strategy.

The system analysis shows strong interaction and feedback among the mentioned three factors of CP strategy. In this regard, the strongest parameters determining stability of development are just those that render influence on at least two out of the three factors of Cleaner Production concept.
The increase of manufacture cleanliness renders influence on the economic and ecological characteristics of system, and, consequently, can be regarded as one of the basic Cleaner Production factors.

The set of engineering techniques and methods for Cleaner Production seems somewhat limited and lacking diversity. The reason may be in unwillingness to disclose know-how by some practitioners, or simply absence of new approaches. Anyway, a simple analysis shows that our western partners can offer only Cleaner Production tools and methods as follows: recycling, use of biotechnology, separative reactions, systemic approach, and industrial symbiosis. That is about all. Yet, effective methods to increase product cleanliness is something much bigger. For example, we are using the following Cleaner Production tools and methods:

- Recirculating flow of the least hazardous agent taken in excess over its stoichiometric value;
- Controlled heterogenization of the contacting phases for softer conditions and improved selectivity;
- Separative reactions: removal of reaction products at the moment of their formation;
- Synthesis and separation in an aerosol to increase intraparticle pressure and reaction rate;
- Self-excited oscillation of reacting phase flows at frequencies and amplitudes matching those at the rate-limiting tiers of the system;
- Flexible synthesis systems and adaptive equipment to embody them;
- Process engineering for high throughput to cut processing time and reduce byproducts and wastes, and industrial symbiosis as a basis for management of secondary materials and energy.

Some of these methods are little known in the West. But they may be used for joint development of Cleaner Production concept in the Ukraine and other countries. New environmental and Cleaner Production challenges in transition economies must be included in Cleaner Production concept realization. For example, there are severe environmental effects of restructuring, military conversion, privatization and economic transition. In any case, transition economies have no mechanisms for stimulating Cleaner Production technologies. It is desirable to use the systems approach in Cleaner Production Concept Implementation (or Cleaner Production Strategy and Tactics) for transition economies.

At the same time it is necessary to help Cleaner Production movement meet its economic goals in transition economies which have development features as follows:

1. Methodology for application of CP philosophy to economic restructuring, military conversion, privatization and economic in transition at a national or regional level.
2. Practicable program for embodying CP concept under sweeping changes in the NIS and other transition economies. (May be it desirable to launch a Special Pilot Project on Systems Approach to CLEANER PRODUCTION Concept Implementation (or CP Strategy and Tactics) for Transition Economies. In any case, transition economies have no mechanisms for stimulating CP technologies).
3. CP oriented priority-based investment programs for attracting investors to NIS.

We have some specific problems in the transition economies that need to be solved. For sample, CP approaches are concerned not only with production but also with transportation. The traffic has dramatically increased in Ukraine due to market development and occurrence of a great many of trade intermediaries and small businesses. This resulted in aggravated negative influence of transportation on environment, making cleaner transport a matter of survival and urging immediate and competent decisions. The "free" market has displaced regular grades of petrol for cheaper ones containing aromatics, that is hazardous byproducts of coke industry. These include benzene, toluene, xylene and others and their combinations. Expert judgment is that these aromatics cannot be burned in an engine completely and are massively discharged to air with exhaust gas. No research into amounts of aromatics in exhaust has been conducted. The analyses of government bodies generally do not include these compounds. Meanwhile, the content of aromatics like benzene in a fuel is limited by standards of advanced countries.

Cleaner Production main goal and objectives are:

1. Systematization of cleaner production general theory, strategy and tactics, search of the tools and methods based on a systematic approach as a foundation of sustainable product development in Pridneprovie.
2. Searching and elaboration of the economic mechanisms stimulating transition to CP technologies in conditions of transition economy.
3. Organizing of international collaboration, association, coordination and information of organizations and individuals dealing with CP.

Besides we need the specific steps and tasks to be proposed

1. Terms and definitions, unification of the terminology of Clean(er) Production.
2. Writing and editing in Russian and English a handbook or practical manual of CP.
3. Organizing of an online CP Help and Consulting Service.
4. A compendium of the best CP practices at a pilot project of transportation environmental problem realization for a large industrial city (for example, Dnepropetrovsk).
5. Launch a CP technology incubator or greenhouse.

Then we can receive some concrete results (deliverables) and expected outcomes:

1. A pilot project for demonstration of transportation environmental problem solving for a large Industrial city (for example, Dnepropetrovsk).
2. Handbook or practical manual of CP practices tools and methods.
3. Review to identify economic mechanisms stimulating transition to CP technologies in conditions of transition economy.
4. Online CP Help and Consulting Service.
5. CP technology incubator or greenhouse.

Main directions of PCPC's activities now are:

- elaboration of strategy and tactics for cleaner production, waste management, pollution prevention;
- system ecologizing of acting manufactures;

- development and introduction of methods of adaptation and rehabilitation of the population in conditions of the increased technical loads;
- development and realization of the program of sustainable development of an industrial region;
- continuous ecological training and education, based on the concept of active constructive ecology;
- development of the information at cleaner production technology and equipment.
- to demonstrate the economic benefits of pollution prevention and recycling to industry business operations.

For the decision of problems of *information exchange* we are ready together with other organization realize the following programs:

- Creation of computer information base at ecological engineering and technologies of cleaner production;
- Issue a periodic regional ecological electronic newspaper, distributing ecological information and experience of use of cleaner production in a region and in the world (with use of networks);
- Realization of active contacts to world community on exchange by the ecological information;
- Retraining of the experts of acting manufactures on directions resource saving and ecological technologies .

It's necessary to give the main attention not so much to cleaning of gases and liquids as to many non-waste technologies for processing of raw materials including but not limited to concurrent reaction-dividing processes, new effective methods of recycling using capillary and porous impregnation of waste materials, electric aerosol technology, and flexible chemical engineering.

And at last an important advantage in solving ecological problems is interdisciplinary approach via experience of various experts from different organizations with the purpose of the best decision making regarding specific problems.

Part 2. Cleaner production definition tools and methods based on systematic approach FOR systematic reduction of environmental loads (ECOLOGIZING OR "ecologization")

There is methodology and algorithm for systematic reduction of environmental loads (ecologizing or "ecologization"), based on the system analysis. This has allowed to formulate main strategic principles and define a tactical receiving to their realization.
Finally, this concept is not connected to fight with damage wastes pollution, but to deliver a process so that they were formed in the minimum amount (waste minimization).

The main strategic principles of proposed methodology:

1. The System approach prescribed in the base of proposed strategy for systematic reduction of environmental loads. It expects that previously, than problems on methods of industrial waste conversion or utilization choose will be solve, it is necessary to consider questions for systematic reduction of environmental loads at the tier of strictly production. It's very

important to realize economic justified variants of removal or essential waste reducing by selectivity of main process raising at the lowest hierarchical object tiers.
The System approach is shown in the next table:

1	TIER OF HIERARCHY	Frequency order	Dimension order, m	CLEANER PRODUCTION TOOLS AND METHODS
1	Manufacturing	0.001-0.01 s^{-1}	10^2	Industrial Symbiosis, Waste Management.
2	Plant item	0.1-1 s^{-1}	1	Pollution Prevention, Recirculating, Local neutralization of emissions
3	Installation	0.1-1 s^{-1}	1	Flexibility and adaptability of technology and equipment
4	Apparatus or machine	$1\text{-}10^4\ s^{-1}$	1	Recirculating flow of the least hazardous agent, Isolation (close-looping in structure) of flows of substance and energy
5	Contact device	$1\text{-}10^4\ s^{-1}$	$10^{-3}...10^{-6}$	Synthesis and separation in an aerosol, Controlled heterogenization of the contacting phases
6	Molecular level	$10^5...10^8\ s^{-1}$	$10^{-9}...10^{-12}$	Minimization of time of processing, Surplus less toxic reagent, Oscillation of reacting phase flows, Separative reactions organizing

There should be a match between a tier in a hierarchy and the methodology of characterization, assessment or influence used at this tier.

1. We will have an maximum of cleaner production effect if to move on tiers in rising mode (from the lower tier to upper-level of system. In the event of above hierarchies of system levels it is necessary to move toward from 8 tier to 1 one.
2. At the choice of methods of influence to the system on limiting tier, it is necessary to follow a principle of correspondence, i.e. ensure a correspondence their parameters to the scale of limiting tier (for instance, it is necessary to select methods of influence, corresponding defining dimension order -frequency features on limiting tier).
3. One of the the most efficient cleaner production principles is integrated approach to the solving of the problems of industrial installations pollution decreasing. It is not only by using of low-waste technologies, not only by using an equipment for the local cleaning of gases and liquids, but, first of all - a decision of a complex problem on making an ecological engineering as unites of technology and equipment. Thereby, principle of integrated approach in this interpretation implies a simultaneous decision on a matter of apparatuses and technological optimization of processes.
4. For clean production raising it is necessary to ensure sufficiently high its flexibility level. Under flexibility is implied quantitative factor, reflective possibility of a technology and equipment functioning in the broad range of changing of external and internal parameters of installation with given values of level of forming the by-products. So, it’s possible to act upon the object, changing its flexibility.

5. It's possible to influence on the object to its intensify, using principle "repetitions in use resources and energies"
6. Maximum selectivity of syntheses and division principle is one of the most efficient one under the deep conversion of initial materials .

Algorithm for systematic reduction of environmental loads with some explanatory basing on stated above reasons is resulted below.

1. *DECOMPOSITION*. The analysis of the initial information including inspection of industrial manufacture, with the purpose of its decomposition on typical levels of hierarchy (for example, manufacture – plant item - installation –apparatus or machine - contact device - molecular level).

The system analysis recognizes that any system, including nature-technical, consists from taking place in hierarchical dependence under and upper-level subsystems. And the problem of maintenance of required ecological parameters at each hierarchical level carries individual character, while for realization of a general purposes - for systematic reduction of environmental loads of all system- it is necessary to establish the basic determining components of system, their external and internal connections, laws of functioning of system and connection of individual ecological parameters of a subsystem with a general integrated parameter of all system.

2. *IDENTIFICATION* of an initial level. Revealing of the bottom level of hierarchy limiting from the point of view of pollution to an environment.

3. *SELECTIVITY INCREASE*. Increase of selectivity of actually technological stages of processing at a limiting level of hierarchy.

For a choice of methods of influence it is expedient to use a database on tactical ecologizing receptions. Some of its principles have a common for technique character (repeated using, waste recycling and resource saving).Besides this database has also specific receptions for processing industries, in particular, for chemical, metallurgical, food branches of industry.

Except for ecologizing principles, the most common receptions for their realization, in particular, with reference to processing branches of manufacture are given in a database. Among them it is necessary to differentiate two closely connected among themselves groups of methods: regime-technological and apparatus – constructive ones. Alongside with traditional for any area of engineering methods (isolation of structure and multifunctionality of the equipment, intensification) the features of processing branches predetermine use of some special ecologizing methods.

Among them:
- Minimization of time of processing and surplus less toxic reagent, resulting all to increase of selectivity and reduction of formation of by-products,
- Synthesis and separation in an aerosol to increase intraparticle pressure and reaction rate,
- Self-excited oscillation of reacting phase flows at frequencies and amplitudes matching those at the rate-limiting tiers of the system,

- Recirculating flow of the least hazardous agent taken in excess over its stoichiometric value,
- Isolation (close-looping in structure) of flows of substance and energy by recirculating, resulting to "idealization" of modes of synthesis and significant reduction of speed of by-processes,
- Separative reactions organizing (synthesis and dividing processes organizing in the same palace and in the same time), allowing to reduce formation of by-products by removal of a target product from a reactionary zone at the moment of its formation,
- Controlled heterogenization of the contacting phases for softer conditions and improved selectivity,
- Flexibility and adaptability of technology and equipment allowing to ensure reliable work of technical system by "internal" reserves (flexibility) of installation using, that reduces an opportunity of harmful substances pollutions or reception of a sub-standard product.

If the expert is not satisfied with the result of work at this level, he has to rise to the next more high tier and to continue work.

Transition on next higher tier.
In connection with change of determining amplitudes and the frequencies at this tier, are used other cleaner production tools and methods.
First of all it’s Pollution Prevention and Recirculating. Modern ecologizing provides not neutralization of emissions "in general" in mixed polluting liquid or gas flows, but the local neutralization of emissions first whenever possible by each component, and secondly, as is possible closer to a source of their formation. This approach is alternative in relation to the principle, accepted in FSU (of creation of global clearing structures for neutralization or recycling at once of all scale of harmful emissions). So, the local for each component clearing as much as possible approached to sources of emissions, as has shown world experience, has appeared much more effectivecleaner production direction.

Transition on next higher tier.
Only after end of an actually manufactures CP stage it is necessary to begin the decision of questions of complex processing and recycling of sub-standard products and waste of manufacture. Here main methods are Industrial branch and interbranch Symbiosis and Waste Management.

The market economy requires thus, that the waste producer has ensured their transformation in secondary technogenous raw material. At the modern approach of installation of clearing or the recyclings should be a component of industrial object included in the basic technological line.

The following stage of the work is the realization of the technical and economic analysis of the chosen CP directions and methods with drawing up of accounts which are taking into account not only an expenses on CP and its results in sphere of manufacture, but also payments for resources, payments for above permitted standard emissions and other ecology-economic parameters.
The purpose of these accounts to determine priorities in the field of the investments in CP at all stages of life cycle of object and at all hierarchical tiers of object.
Only after that the experts make the choice of the ecology-economically justified CP variant .

For processing industries the especially important parameter of a CP degree is achieved and achievable results of performance of manufacture, as the increase of waste quantity promotes increase of expenses both on manufacturing, and on increase of total emissions of harmful substances in an environment.

$$Ji = \frac{P_{1i} - P_{2i}}{P_{maxi} - P_{2i}},$$

where P_{1i}, P_{2i}, P_{maxi} - accordingly, final, initial and maximal size of the factor determining calculated parameter.
The size $Đ_i$ can be as a uniform parameter quantitatively describing this or that property of system (for example, degree of dust-cleaning, factor of extraction etc.), and complex integrated parameter which is taking into account at once e of the some basic characteristics of object. Use or additive CP parameters in the latter case is expedient:

$$P_i = \overset{n}{\underset{j=1}{S}} K_j P_{ij} ,$$

where K_j - the importance of a j-parameter (is estimated by experts and changes within the limits of 0 + 1), or multiplicate CP factor:

$$J = \overset{ê}{\underset{i=1}{Ï}} J_{i},$$

Having the quantitative characteristics of an ecological level of production, it is possible to compare the various technical decisions, to choose optimum and even to project new systems with the beforehand given level of influence on an environment. It will promote transition from “about-cleaner production” conversations to creation of actually cleaner installations, manufactures and enterprises.

UKRAINIAN COOPERATION PROPROSAL

Following the Ukrainian tour-de-table presentation, the Ukrainian delegate introduced the following cooperation proposal to the NATO/CCMS meeting for further consideration:

Proposals about cooperation

1. We would like to be included in a list of NATO/CCMS Project participants with one of the themes:

- Systematization of cleaner production general theory, strategy and tactics, search of the tools and methods based on a systematic approach as a foundation of sustainable product development.

(Terms and definitions, unification of the terminology of Clean(er) Production. Writing and editing in Russian and English a handbook or practical manual of CP, elaboration of strategy and tactics for cleaner production, waste management, pollution prevention; system ecologizing of acting manufactures; development and introduction of methods of adaptation and rehabilitation of the population in conditions of the increased technical loads; development and realization of the program of sustainable development of an industrial region; continuous ecological training and education, based on the concept of active constructive ecology; development of the information at cleaner production technology and equipment, demonstration the economic benefits of pollution prevention and recycling to industry business operations).

- Searching and elaboration of the economic mechanisms stimulating transition to CP technologies in conditions of transition economy.
- Organizing of international collaboration, association, coordination and information of organizations and individuals dealing with CP with use of modern information technologies (Russian – English CP Information – Consulting Net, organizing of an online CP Help and Consulting Service, Virtual INTERNET CP Exhibition – Market of CP Technology, CP Digest English - Russian version of "Constructive Ecology and Business Journal", Creation of computer information base at ecological engineering and technologies of cleaner production;).
- Launching a CP technology incubator or greenhouse.
- Retraining of the experts of acting manufactures on directions energy -resource saving and CP technologies (solving ecological problems on the base of interdisciplinary approach via experience of various experts from different organizations with the purpose of the best decision making regarding specific problems).

2. We are ready to organize one of the next NATO ARWs (jointly with one of the NATO member country):

- Methodology for application of CP philosophy to economic restructuring, military conversion, privatization and economic in transition at a national or regional level.

(Practicable program for embodying CP concept under sweeping changes in the NIS and other transition economies. May be it desirable to launch a Special Pilot Project on Systems Approach to CLEANER PRODUCTION Concept Implementation (or CP Strategy and Tactics) for Transition Economies. In any case, transition economies have no mechanisms for stimulating CP technologies. CP oriented priority-based investment programs for attracting investors to NIS).

- Problems of Cleaner urban transportation. A compendium of the best CP practices at a pilot project of transportation environmental problem realization for a large industrial city .

(We have some specific problems in the transition economies that need to be solved. One of them, CP approaches are concerned not only with production but also with transportation. The traffic has dramatically increased in Ukraine due to market development and occurrence of a great many of trade intermediaries and small businesses. This resulted in aggravated negative influence of transportation on environment, making cleaner transport a matter of survival and urging immediate and competent decisions. The "free" market has displaced regular grades of petrol for cheaper ones containing aromatics, that is hazardous byproducts of coke industry. These include benzene, toluene, xylene and others and their combinations. Expert judgment is that these aromatics cannot be burned in an engine completely and are massively discharged to air with exhaust gas. No research into amounts of aromatics in exhaust has been conducted. The analyses of government bodies generally do not include these compounds. Meanwhile, the content of aromatics like benzene in a fuel is limited by standards of advanced countries).

- CP and energy – resources saving at the military technique and rocket plants (on the base of NASA (USA) and NSA (Ukraine).

ROMANIA

ONE MORE STEP TO POLLUTION PREVENTION

Viorel Hârceag
Romanian delegate

Sustainable development requires real economic growth because only such growth can create the capacity to solve environmental problems. Steel is essential for economic development. It is the most important construction and engineering material available to modern society. The demand for steel grows at a high rate in developing countries. Each activity in the cycle of steel has a different perspective on its relationship with the complete system.

The natural and longest established closed cycle of steel explains the interest of steel in using life cycle assessment techniques as a valuable environmental management tool. Life cycle involves the evaluation of the impact of a steel-using product over its complete life cycle from raw material assembly through to steel production, the manufacture of the steel-using product, the working life of that product, the end of life disposal and the recycling of the steel it contains. The concept of life cycle assessment (lca) is to evaluate the environmental effects associated with any given activity from the initial gathering of raw material from the earth until the point at which all residuals are returned to the earth. Lca is a technical tool to identify and evaluate opportunities to reduce the environmental effects associated with a specific product, production process, package, or activity. Implementation of opportunities pointed out in the third stage of lca can be made using pollution prevention techniques.

In NATO/CCMS meeting held in 1999 in Belfast, I described LCA study in metallurgical field, in a sintering plant. It was conducted using US EPA methodology (LCA, how to do it, UNEP – Industry and Environment, ISBN 92-807-1546-1).

In the current paper is presented next step, LCA in iron production in blast furnace, conducted in the same manner. Iron production occurs in a blast furnace and involves the conversion of iron ores into molten iron by reduction with coke and separating undesirable components such as phosphorus, sulfur, and manganese through the addition of limestone.

The blast furnace is a counter-current reactor, loaded or charged from the top with layers of feed and coke, the molten iron and slag being drawn off from below. Hot air is injected in the opposite direction from the bottom of the furnace. Residual materials (waste) such as oily metal chips and oily rolling scale can be introduced after sintering. The principal emissions, residues and waste materials are:

- top gas, with the following potentially environmentally relevant components: CO, CO_2, SO_2, NO_x, H_2S, HCN, CH_4, As, Cd, Hg, Pb, Ti, Zn
- top gas dust (dry) from the gas cleaning plant with high iron contents (35 - 50%)

- slag with the following major components : SiO_2, Al_2O_3, CaO, MgO
- sludge from the waste gas cleaning system
- wastewater from the waste gas cleaning system, with the pollutants: cyanides, phenols, ammonia

The waste gases from the blast furnace are pre-treated in mass force separators (dust catchers or cyclones) and, in a second stage, finally cleaned with a high-pressure scrubber or wet electrostatic precipitators. Clean gas dust concentrations from 1 to 10 mg/m^3 are achieved. Other dust emissions in the blast furnace area, particular from the burdening process, pig iron desulphurisation and the casting house must also be identified and cleaned.

The top gas contains between 10 and 30, though possibly as much as 60 g/m^3 dust with 35 to 50% iron, i.e. 30 to 80 kg/t iron, in older plants 50 to 130 kg/t pig iron. The dust is separated in the dry state in mostly multistage separators, from where it goes to the sintering plant and from there back to the blast furnace. In view of the zinc and lead content and other factors, the top gas scrubbing water sludge must be disposed of by dumping, unless there is a special hydro-cyclone separation system. With higher concentrations, it should be transferred to a non-ferrous metal works. Recycling in this way would leave the blast furnace process practically free of residues. Dumping involves the risk of leaching and hence penetration of the soil and groundwater by compounds of zinc, lead and other heavy metals. The dump must be permanently and verifiably sealed and the seepage water must be collected and chemically processed. The special requirements imposed on such a dump must be laid down in the project planning stage. The top gas can be used as a fuel for heating purposes within the works, in view of its high carbon monoxide content due to the reducing atmosphere in the blast furnace, though this will inevitably result in the formation of carbon dioxide, with its climatic implications. Excessive levels of sulphur dioxide and nitrous oxide gases can be reduced by flue gas desulphurisation and denitrification.

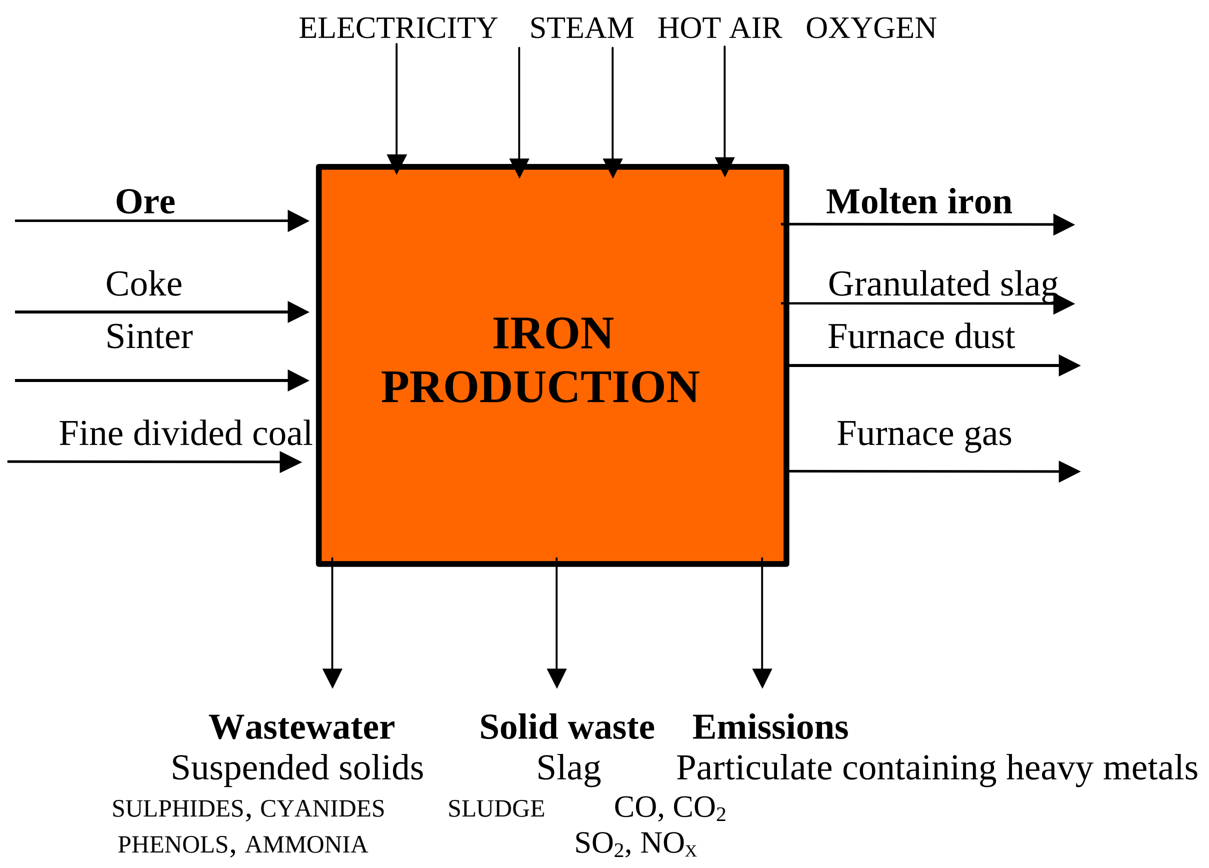
Slag produced by the blast furnace process accounts for roughly 50% of the overall waste materials from iron and steel production. This slag is mostly used in road building. Part of the molten slag is granulated by quenching in water. This so-called slag sand is also used in road building. Part is used to produce iron slag portland cement and blast furnace cement. Slag heaps sometimes produce seepage water with high levels of dissolved sulphides and strong alkaline reaction, posing a hazard for the groundwater. Slag heaps must be sealed and any seepage water must be treated.

Wastewater is generated by top gas scrubbing and simultaneous wet de-dusting. The wastewater is normally clarified in settling tanks and, where necessary, gravel bed filters and recirculated. The wastewater contains suspended matter (dust) and sulphides, cyanides, phenols, ammonia and other substances in dissolved form. The last three substances must be removed from the wastewater using appropriate physical and chemical treatment processes.

Carbon monoxide concentrations in the workplace pose a particular problem. Where top gas pipes are not perfectly leak proof there is a danger of poisoning with possible fatal consequences for workers present at the furnace throat. Close attention must also be paid to co concentrations by carrying out measurements and ensuring that protective breathing equipment is worn during repair and maintenance work on shut-down blast furnaces or gas cleaning systems.

Noise in blast furnace plants comes mainly from the combustion air fans and the charging process; also there is the noise generated upon changeover from blast to heating operation. Suitable abatement measures include silencers, enclosure of the furnace throat or encapsulation of all valves and shields. The noise level from the blast furnace plant is in the range of 110 to 125 db(a); the level of background noise in the immediate vicinity may be 75 to 80 db(a). Possible noise reduction measures should be selected as early as the blast furnace planning phase. Their effect can be determined by advance calculation, taking care to ascertain the significance of the emission sources (plant sections and operating processes). One should preferably begin by damping or eliminating occurrences and noise sources which arise only periodically.

Emissions produced by the iron and steel industry requires particularly extensive measures and systems for air protection. Above all, dusts containing substances hazardous to health and the environment, such as lead, cadmium, mercury, arsenic and thallium, must be cleaned by high-performance separation systems. Nowadays, not only the primary emission sources, such as sintering plants, but also secondary sources such as blast furnace casting bays can be intercepted and dedusted. In the case of gaseous emissions, attention must be paid primarily to reducing carbon monoxide and sulphur dioxide, as well as nitrous oxides and fluorine compounds.



Iron fabrication flow chart

The execution of inventory stage results in a set of data sheets and growing insight into the availability of information. So, in the following tables is shown the environmental data sheets that includes raw materials, energy inputs and air pollutants outputs of the process fabrication for one ton of iron.

Environmental data sheet
PROCESS: Iron fabrication

Furnace no.2

	Kg/tone	Quantity (tones)	Notice
Product – Molten iron	1,000	404,000	
Co-products – Furnace gas (Nm^3)	2,189	884,356	recycled
Furnace dust	10	4,040	recycled
Fine treatment sludge	5	2,020	recycled
Granulated slag	151	61,004	recycled
Wastes – Dumped slag	280	113,120	At the dump
Wreckage	5	2,020	At the dump
Metallic wastes	10	4,040	recycled
Technological losses	92.2	37,245	Difference

Furnace no.3

	Kg/tone	Quantity (tones)	Notice
Product – Molten iron	1,000	454,482	
Co-products – Furnace gas (Nm^3)	2,074	942,595	recycled
Furnace dust	10	4,545	recycled
Fine treatment sludge	5	2,272	recycled
Granulated slag	148	67,263	recycled
Wastes – Dumped slag	275	124,982	At the dump
Wreckage	5	2,272	At the dump
Metallic wastes	10	4,545	recycled
Technological losses	107.3	48,766	Difference

Furnace no.4

	Kg/tone	Quantity (tones)	Notice
Product – Molten iron	1,000	547,551	
Co-products – Furnace gas (Nm^3)	2,070	1,133,431	recycled
Furnace dust	10	5,475	recycled
Fine treatment sludge	5	2,738	recycled
Granulated slag	144	78,848	recycled
Wastes – Dumped slag	267	146,196	At the dump
Wreckage	5	2,738	At the dump
Metallic wastes	10	5,475	recycled
Technological losses	112.6	61,654	Difference

Furnace no. 5

	Kg/tone	Quantity (tones)	Notice
Product – Molten iron	1,000	1,025,220	
Co-products – Furnace gas (Nm^3)	2,104	2,157,062	recycled
Furnace dust	10	10,252	recycled
Fine treatment sludge	5	5,126	recycled
Granulated slag	150	153,782	recycled
Wastes – Dumped slag	240	246,052	At the dump
Wreckage	5	5,126	At the dump
Metallic wastes	10	10,252	recycled
Technological losses	91.4	93,705	Difference

Furnaces 2 – 5

	Kg/tone	Quantity (tones)	Notice
Product – Molten iron	1,000	2,431,253	
Co-products – Furnace gas (Nm^3)	2,130	5,178,569	recycled
Furnace dust	10	24,312	recycled
Fine treatment sludge	5	12,156	recycled
Granulated slag	151	367,119	recycled
SLAG FOR BRICKS	-	1,082	used
Wastes – Dumped slag	259	629,694	At the dump
Wreckage	5	12,156	At the dump
Metallic wastes	10	24,312	recycled
Technological losses	97.5	237,047	Difference

Each input component of iron fabrication coming with its own energy and raw materials consumption and its own pollutant emissions, data which are similarly centralized in environmental data sheets (not presented in this paper) for the main following components processes: iron ores preparation, coke production, sinter production and electricity production. All data from the environmental data sheets were centralized in the inventory table.

Iron production
Plant: Furnace no. 5
Year: 1999 April - May

Energy resources (GJ)			**Product and Co-products**		
Electricity	5,465,250	KW	Molten iron	156,150	t
Coke	66,364	T	Granulated slag	21,861	t
Fine divided coal	19,519	T	Furnace gas	327,915x10^3	Nm^3
			Furnace dust	2,342	t
			Air emissions		

Raw material resources			Particulate (Partic.)	30	t
Sinter	234,225	T	CO	3,771,023	Nm^3
Pelettes	17,177	T	CO_2	3,934,980	Nm^3
Ore	18,738	T			
			Waste water		
			Suspended solids (SS)	0.008	t
Hot air	$202,995x10^3$	Nm^3			
Steam	2,030	T	**Solid wastes**		
Oxygen	48,406,500	Nm^3	Fine treatment sludge	1,093	t
			Dumped slag	40,599	t
			Wreckage	781	t

The contribution of each main process was adjusted, using a ***contribution factor***, which represents the relative contribution of that process to the fabrication of one ton of iron.

Inventory table for 1 ton of iron

Energy resources (GJ)			**Product and Co-products**		
Electricity	35	kW	Molten iron	1,000	kg
Coke	425	kg	Granulated slag	140	kg
Fine divided coal	125	kg	Furnace gas	2,100	Nm^3
			Furnace dust	15	kg
			Air emissions		
Raw material resources			Particulate (Partic.)	0.2	kg
Sinter	1,500	kg	CO	24.15	Nm^3
Pelettes	110	kg	CO_2	25.20	Nm^3
Ore	120	kg			
			Waste water		
			Suspended solids (SS)	0.051	g
Hot air	13	kg			
Steam	1,300	Nm^3	**Solid wastes**		
Oxygen	310	Nm^3	Fine treatment sludge	7.00	kg
			Dumped slag	260	kg
			Wreckage	5.00	kg

Inventory analysis results are the base of ***impact assessment***. This stage of LCA consist in: *classification* – specifies which environmental problems are to be included in the analysis of iron fabrication, *characterization* – quantifies the environmental impacts, and *valuation* of classification and characterization results.

Raw materials consumption and pollutant releases for iron fabrication, according with the inventory table, can produce following environmental problems: Global warming (GW), Photochemical oxidant creation (PO), Human toxicity (HT), Eco-toxicity (E), Abiotic depletion (AD), Energy depletion (ED), Acidification potential (AP), Nitrification potential (NP), Ozone depletion (OD). To estimate the environmental impact of iron fabrication, for each environmental problem presented, has used an *equivalency factor*, measured as follows:

- GW = measured relative to the effect of 1 kg CO_2;
- PO = measured relative to the effect of 1 kg ethylene;
- HT = measured as the human body weight that toxicologically acceptable limit by 1 kg of the substance;
- E = volume of water that would be polluted to a critical level by 1 kg of substance;
- AD = measured relative to global supplies;
- ED = measured as MJ/kg or MJ/m^3;
- AP = measured relative to the effect of 1 kg SO_2;
- NP = measured relative to the effect of 1 kg phosphate;
- OD = measured relative to the effect of 1 kg CFC.

The values of each impact parameters in the inventory table were multiplied by the values of equivalency factor correspondents. The results are presented in table below; note that one parameter may score under several environmental problems simultaneous. The final result consists in a score for each environmental problem analyzed, which can give an image of possible impact produced by iron fabrication.

Classification and characterization for 1 ton sinter fabrication

	Raw materials Kg	*Ener-gy* GJ	**Air emissions** kg						**Wastewater** kg		
			Partic.	CO_2	CO	NOx	SOx	COV	CCO	SS	
Inventory Analysis	3,600.50	14.74	70.91	402.55	24.82	3.33	6.59	1.94	0.44	0.89	
Equivalence factors											
GW(kg/kg)	-	-	-	1	-	-	-	-	-		
PO (kg/kg)	-	-	-	-	-	-	-	0.38	-	-	
HT (kg/kg)	-	-	4.75	-	0.01	0.78	1.2	-	-	0.02	
E (kg/kg)	-	-	3,500	-	-	-	-	-	-	-	
AD (-/kg)	$1x10^{-12}$	-	-	-	-	-	-	-	-	-	
ED (GJ)	-	1	-	-	-	-	-	-	-	-	
AP (kg/kg)	-	-	-	-	-	0.7	1	-	-	-	
NP (kg/kg)	-	-	-	-	-	0.13	-	-	0.02	0.33	
OD (kg/kg)	-	-	-	-	-	-	-	-	-	-	
Multiplied characterization results											**TOTAL**
GW(kg/kg)				402.55							402.55
PO (kg/kg)								0.74			0.74
HT (kg/kg)			336.8		0.25	2.60	7.91			0.018	347.58
E (kg/kg)			248,185								248,185
AD (-/kg)	$3.6 \cdot 10^{-9}$										$3.6x10^{-9}$
ED (GJ)		14.74									14.74
AP (kg/kg)						2.33	6.59				8.92
NP (kg/kg)						0.43			0.009	0.30	0.74
OD (kg/kg)	-	-	-	-	-	-	-	-	-	-	-

Classification and characterization provides an environmental profile of a product, which consists in a set of scores on environmental problems in absolute figures. So, for iron fabrication, the greatest problems are lied by the ecotoxicity (E), due to the presence of heavy metals in the particulate emissions. Particulate are also responsible for human toxicity (HT), which obtained a high score, like the environmental problems lied by the global warming (GW), due to the great CO_2 quantity from pollutant emissions. A smaller score was obtained by energy depletion (ED), because of energetic consumption and acidification potential (AP), caused by SOx and NOx emissions from gases released in the sintering and iron production process. Very small scores have presented by photochemical oxidant creation (PO) and nitrification potential (NP), abiotic depletion (AD).

The results of the inventory analysis and impact assessment conduced to study the effects on the environment produced by processes components of iron fabrication system (iron ores preparation, coke production, electricity production and sintering), in the frame of ***improvement analysis***. We can remark that:

- the greatest particulate quantity arises from iron ores preparation process;
- the greatest quantity of pollutant gases arises from sintering and coke production;
- the greatest consumption of energy is achieved in the sintering and iron production;
- the greatest quantities of waste water arises from coke production;
- the greatest quantities of solid wastes arises from iron production process.

The finding of this interpretation may take the form of conclusions and recommendations to decision-makers, grouped in:

- actions to reduce electricity;
- actions to minimize pollutant emissions.

It is necessary to take the following measures:

☺ ***Efficiency increasing as a result of sintering installation improvement*** **by:**

- advanced control of burning front
  - best distribution of coke granulation in sintering bed;
  - best gases permeability through sintering bed as a result of good preparation of raw materials;
  - reduction of false air exhausting;
  - modernization of ignition system with the purpose of fast start burning at high temperatures (lead to a decreasing of coke-oven gas consumption).
- increasing of heat use efficiency
  - reusing of gas heat for preheating of combustion air (this is lead to an increasing of flame temperature) and raw materials;
  - reusing the heat of sinter cooling air for preheating of combustion air and raw material – when cooling air have low temperature – or for steam production – when cooling air have high temperature;
  - reduction of heat losses as a result of decreasing of sinter returned material;
  - recirculation of sintering gases.

☺ Diminution of energy spending and of wastewater and gases emissions, by fractional replacing of coke with fine divided coal (up to 200 kg / tone of iron produced).

- ☺ ***Reduction of dust emissions*** can be done first of all by best handling operations of raw materials. So, reusing of fine blast furnace dust and fine sintering dust must be forbidden without a previous pelletising.
  Taking in consideration the big quantity of dust, which is in preparation shops, must be installed, where there are not, a hood, or resizing the exhaust system.
  Because the dust is in a great quantity in the zones where air, respective the cool air have high temperature, an efficient method to reduce the level of dust emissions is recovery of heat eliminated with cooling air.
- ☺ ***Reduction of SOx emissions*** to stack can be realized by using raw materials and fuels with low level of sulphur (when that is possible).
- ☺ ***Reduction of NOx emissions*** in combustion gases is possible by diminishing the volume of false air exhausted and by improving the burning.

Few months after the end of this assessment, some people have cleaned an annex facility of examined furnace no. 4. They do not respected technological prescriptions and an explosion took place killing 2 people and hurting other 8. Conducted LCA do not contain any data about this possible accident.

In the impact assessment stage of LCA we have used US EPA criteria to estimate the environmental impact of iron fabrication. The accident occurrence impels me to make the proposal to supplement the above mentioned criteria with one more item, related to industrial accident potential (AP). It have to be multiplied with a statistic (probabilistic) coefficient, and can be measured in kg TNT in case of explosion potential or in terms of toxicity if the potential accident can release toxic substances:

AP x k (occurrence probability) = measured relative to the effect of 1 kg TNT

USA

SUSTAINABLE DEVELOPMENT – NEW CHALLENGES TO ENVIRONMENTAL R&D

Subhas K. Sikdar
Pilot study director and US delegate

Several significant events in the past year presented newer challenges to environmental R&D in the US EPA. The National Risk Management Research Laboratory has begun asking questions on sustainable development that require answers from science, technology, and economic perspectives. There are two focus areas for these queries. First, we want to develop a scientific framework for sustainability, which can perhaps be defined and measured. Second, we would attempt to identify a small set of robust criteria for describing place-based sustainability, be it a watershed or an urban setting. Emission of mercury from coal-fired power plants has surfaced as a big issue recently. Elemental Hg escapes through electrostatic precipitators and ends up in soil and water bodies. Mercury in fish poses danger to consumers. A cleaner power plant would have to remove the mercury from the flue gas itself, perhaps by adsorption on finely divided, high surface area, sorbents. Methyl t-butyl ether (MTBE) used in gasoline for octane boosting and for reducing tropospheric ozone in urban areas, has come under stiff consumer resistance. The State of California has declared a phased withdrawal of MTBE from the market, with the Federal Government following suit. Banning does solve the longer-term problem, but the urgent concern is to remove it from drinking water sources, perhaps at the point of use in the water works. Technologies in the latter two areas are critical needs. RETURN TO CONTENTS PAGE

INTRODUCTION TO PILOT PROJECTS UPDATES

The following pilot projects vere presented in Belfast 1999 and scheduled for updating in Copenhagen 2000:

1. Danish Products Oriented Environmental Measures in the textile industry
   Denmark
2. Pollution Prevention Tools
   USA
3. Energy efficiency in Moldova
   Moldova
4. Water Conservation and Recycling in Semiconductor Industry: Control of Organic Contaminaiton and Biofouling in Ultra Pure Water systems
   USA and United Kingdom
5. Clean Processes in the Turkish Textile Industry
   Turkey
6. Cleaner Production through the Use of Intelligent Systems in the Pulp and Paper industry
   Canada
7. Clean Products and Processes in the Textile Industry
   USA
8. Cleaner Energy Production With Combined Cycle Systems
   Turkey

In the following abstracts and/or papers present the status and progress of the pilot projects, presented in the chronological sequence in which they were scheduled for presentation for the Copenhagen meeting (not all pilot project managers were present in Copenhagen).

POLLUTION PREVENTION TOOLS

Subhas K. Sikdar
USA

Last year we discussed the utility of several design tools that were in development at the National Risk Management Research Laboratory. PARIS II, a solvent design software, has been completed and transferred to TDS, Inc. (New York City) for marketing. Beta testing has just started with 50 companies participating. PARIS II program designs, in the computer, solvent mixtures with reduced environmental impact (such as toxicity and other measures) that match the property profile of the solvent mixture being used currently. Further information on PARIS II is available in chapter on Computer Tool Café. Waste Reduction (WAR) algorithm was developed for flow sheet-based cleaner process design. The measure used to express a degree of "cleanliness" is potential environmental impact (PEI), which is a user-chosen composite of a set of chemical and non-chemical impacts, such as human toxicity, eco-toxicity, ozone depletion, global warming, etc. WAR has been incorporated in the latest version of the commercial process simulator Chemcad (Houston, TX). A more advanced product has been recently completed. This is an integrated design tool that combines WAR with Aspen Plus and the commercially available costing package Icarus. The EPA Office of Enforcement and Compliance is planning to use this tool in helping industry to reduce waste generation and emissions. With this integrated tool, a complete analysis (including production, cost, and environmental) of a process facility can now be done. For more information, please enquire at cabezas.heriberto@epa.gov and young.douglas@epa.gov.

DETECTION AND CONTROL OF MICROBIOCONTAMINATION IN ULTRAPURE WATER PROCESSES

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Bacterial contamination of water is a common problem that threatens many of its industrial uses; particularly in the microelectronics industry where ultrapure water is utilized in the rinsing stage of microchp manufacture. Although ultrapure water is an environment almost completely depleted of nutrients, a group of microorganisms, termed oligotrophs, can adapt to these stringent conditions. The objective of this project is to detect and control the bacterial contamination in an ultra-pure water (UPW) system. The project is carried out in collaboration with laboratories in the University of Arizona, New York State University at Buffalo and the New Jersey Institute of Technology (NJIT). The project is coordinated By Professor John O'Hanlon at the University of Arizona Centre for Microcontamination Control (CMC) and much of the work is based around their substantial "state-of the-art" microprocessor research and pilot production facility and its ultrapure water (UPW) system. Described here will be the role of the QUESTOR Centre group in identifying contaminant microorganisms by using sophisticated microbiological analysis and in the development of microbiological expertise for the other laboratories. Initially this has involved characterisation of microbial contaminants in the CMC UPW system then validation of detection systems developed at Buffalo and control systems developed at NJIT.

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REVIEW OF PROGRAMS IN CLEANER PRODUCTION (POLLUTION PREVENTION)

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Introduction

Cleaner production and pollution prevention are relatively new concepts in the environmental field, but are now advancing within NATO and other European countries. Defining cleaner production is often best done with the use of a hierarchy, Figure 1. Technologies, operational procedures, and management techniques that are nearer the top of the hierarchy are referred to as cleaner production. However these approaches also generally meet two other criteria,

1) technologically feasible
2) cost-effective

This double hurdle has focused pollution prevention to a series of case studies or projects that have evolved rapidly and innovatively. One of the largest collection (about 13,000) of these case studies can be accessed at http://www.P2PAYS.org. With this conceptual definition of cleaner production there are several terms that identify closely related activities:

In order to better understand the contribution that pollution prevention has made, a study was made of the development of this field among the members of a NATO/CCMS project (Sikdar, 1998). The author wishes to acknowledge that this study would not have been possible without the exceptional assistance of all the individual members of this project.

Methodology

The NATO/CCMS project represented initially about 18 countries. This has expanded to 23 and these countries serve as the database for this study. Review of the data tables of this paper indicates the participating countries. Each country representative participated in defining the parameters used to characterize cleaner production overall and within the textile industrial sector. This definition lead to a standardized set of questions from which the answers could be analyzed to present a picture of the evolution and the partial nature of cleaner technology. The selection of textiles coincided with a related emphasis of other studies in the NATO/CCMS project.

* (Acknowledgement of NATO/CCMS Fellowship support. Conclusions are those of the author and do not necessarily represent views of the CCMS or of NATO member countries)

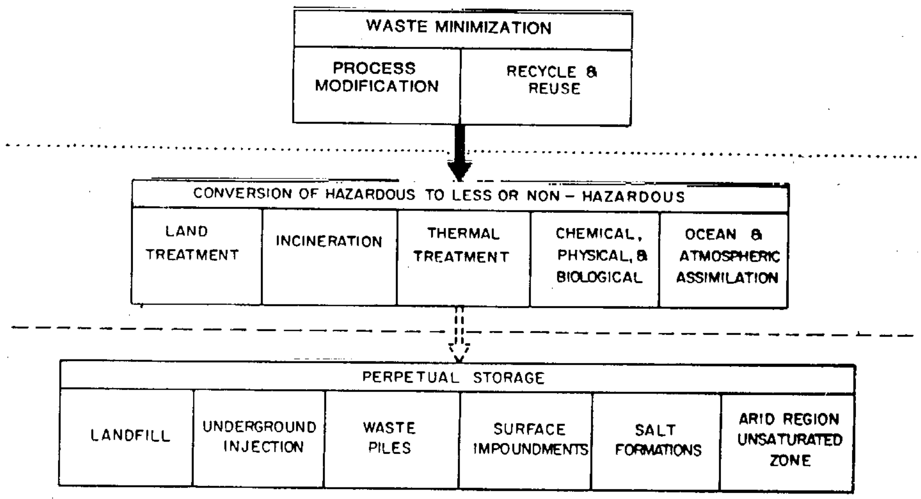

Figure 1 Relationship of alternate waste reduction concepts to overall hierarchy of hazardous waste management

Results

The development of a pollution prevention program within a State (as illustrated by the U.S), a region (as illustrated by the Dnieper River/Black Sea Project for the Ukraine), or a whole country generally occurs with several initial events or activities. These include

- Concept Conference
- Legislation
- Education and training of industrial or consulting personnel
- Demonstration of clean technology in industry

For each country, the approximate date and activities initiating their clean production program are given in Table 1. Using five year time periods, the initiation of cleaner production is illustrated in Figure 2 and 3. There were a smaller number of countries in the first decade and now a much greater penetration in 1990 - 2000. In Figure 2, the time to organize and complete the initial pollution prevention activities appears to be 3 - 5 years. Such information can help countries to realistically judge the time a resource requirements for a cleaner production program.

Resources are required to successfully introduce the concepts and benefits of cleaner production; and then, to have these adopted more widely by industry. A number of organizations (government and non-government) have been committed to stimulate pollution prevention in various countries. These resources seem to have been successful. A listing of such early financial and technical support for cleaner production is given in Table 2. An number of countries and the U.N. are repeatedly recognized as having provided resources to begin the shift toward cleaner production approaches in the environment.

As pollution prevention evolves within a country, various industrial sectors appear more active in adopting and implementing cleaner production. This also changes with time. The survey identified the three industrial sectors with significant pollution prevention activity in 1999, Table 3. Across all participating countries, the frequency of current planning and/or use of cleaner production, by sector, are given in Figure 3. A wide variety of industrial types are presented. The most common are chemicals, metal finishing/electroplating, and textile manufacturing, as these represent both large numbers of facilities and areas with extensive pollution prevention case studies to gain credible ideas. The industrial progress, Figure 3, is often the result of cleaner production advocacy, which has made resources available, increased the awareness, and encouraged technical innovation. Which groups are currently the more prominent advocates of cleaner production was surveyed, Table 4. Again ;a great deal of diversity is found, but universities and government organizations appear to be the most active advocates during the latest years.

Table 1. Early Events in the Creation of Cleaner Production Programs

Country	Approximate Beginning Year for Cleaner Production Programs	Conference on Concept of Cleaner Production	Legislation	Education/Training	Industrial Demonstrations
Bulgaria	1995	Not Major Mechanism	National Plan for Healthy nation and Sustainable Development (1995) National Plan for Ecological Activities (1998) Municipal Action Plan (1999)	University Staff Training and student Ecology Courses (1999)	NATO for Peace/ Bulgarian Academy of Science Regional Project on Black Sea (1999) EU Fifth Framework Projects (1999)
Czech Republic	1992	Not Major Mechanism	Government Resolution on Cleaner Production (2000, proposed)	Czech-Norwegian Training Program (1992)	1992
Denmark	1976 – 1979	Not Major Mechanism	Statutory Order for Recycling and Minimization of Wastes (1984) Danish Government Plan (1988) Environmental Protection Act No. 358 (1991)	Common Nordic Project	Nordtextil VA (1976-79)
Country	Approximate	Conference on	Legislation	Education/Training	Industrial

	Beginning Year for Cleaner Production Programs	Concept of Cleaner Production			Demonstrations
Hungary	1997	Not Major Mechanism	Not Major Mechanism	1998	1998
Israel	1998 – 1999	Not Major Mechanism	Not Major Mechanism	Not Major Mechanism	ISO 14000 (1998 - 1999)
Italy	1987 – 1988	Not Major Mechanism	Interministerial Committee for Industrial Planning (1990)	Not Major Mechanism	National Research Council and National Association of chemical Industries (1992)
Japan	1999	Not Major Mechanism	Not Major Mechanism	Not Major Mechanism	Not Major Mechanism
Lithuania	1993	Waste Minimization Opportunity audits in Lithuanian Industry (1993)	Lithuanian Laws on Waste Management (1997) National Program for Cleaner Production and Environmental Industry Development (1998)	Pilot Project (Lund University, Danish Environmental Management Center, and Kaunas University of Technology (1993) Norwegian-Lithuanian Cleaner Production Training Program (1995)	Pilot project (1993) Waste Minimization in Chemical Industry, world Environment Center (1993) Implementation of Cleaner Production in Lithuanian Tanneries (1996)

Country	Approximate Beginning Year for Cleaner Production Programs	Conference on Concept of Cleaner Production	Legislation	Education/Training	Industrial Demonstrations
Poland	1991	Not Major Mechanism	Act on Protection and Management of the Environment & Polish Movement for Cleaner Production (1997)	Norwegian-Poland Cleaner Production Program (1991)	1991
Portugal	1993	New Environmental Technologies and Business Strategies (1993)	Not Major Mechanism	ADAPT (1993)	First Portuguese Cleaner Production Program; Programe for Sustainable Production at Setubal (1994)
Romania	1995	Not Major Mechanism	Environmental Protection Law (1995) Sustainable Development in Romania (1999)	Not Major Mechanism	Not Major Mechanism
Slovak Republic	1994	Cleaner Production (1995)	Not Major Mechanism	1994	1994
Turkey	1996	Not Major Mechanism	National Environ-mental Action Plan; Mediterranean Plan UNEP 1997	1997 -1999	1997 - 1999

Country	Approximate Beginning Year for Cleaner Production Programs	Conference on Concept of Cleaner Production	Legislation	Education/Training	Industrial Demonstrations
Ukraine	1994	Industrial Environmental Problems and Technology in Dnieper River and Black Sea (1995)	Not Major Mechanism	Pridneprovie Cleaner Production Center Non-Profit/Non-Governmental (1994) Consultant Training (1995)	Projects in Transport, Agriculture, and Industrial Audits (1995)
United Kingdom	1990	Not Major Mechanism	Environmental Protection Act (1990) Environmental Technology Best Practice Program (1994)	Department of Trade and Industry (1993)	Aire and Calder Project (1992)
United States	1976 – 1979	Making Pollution Prevention Pay (1982)	Not Major Mechanism	North Carolina State Office of Science and Technology and North Carolina State University (1980)	3M Corporation 1976

Figure 2 Approximate Initiation Date for Textile Cleaner Production - NATO/CCMS Study Members

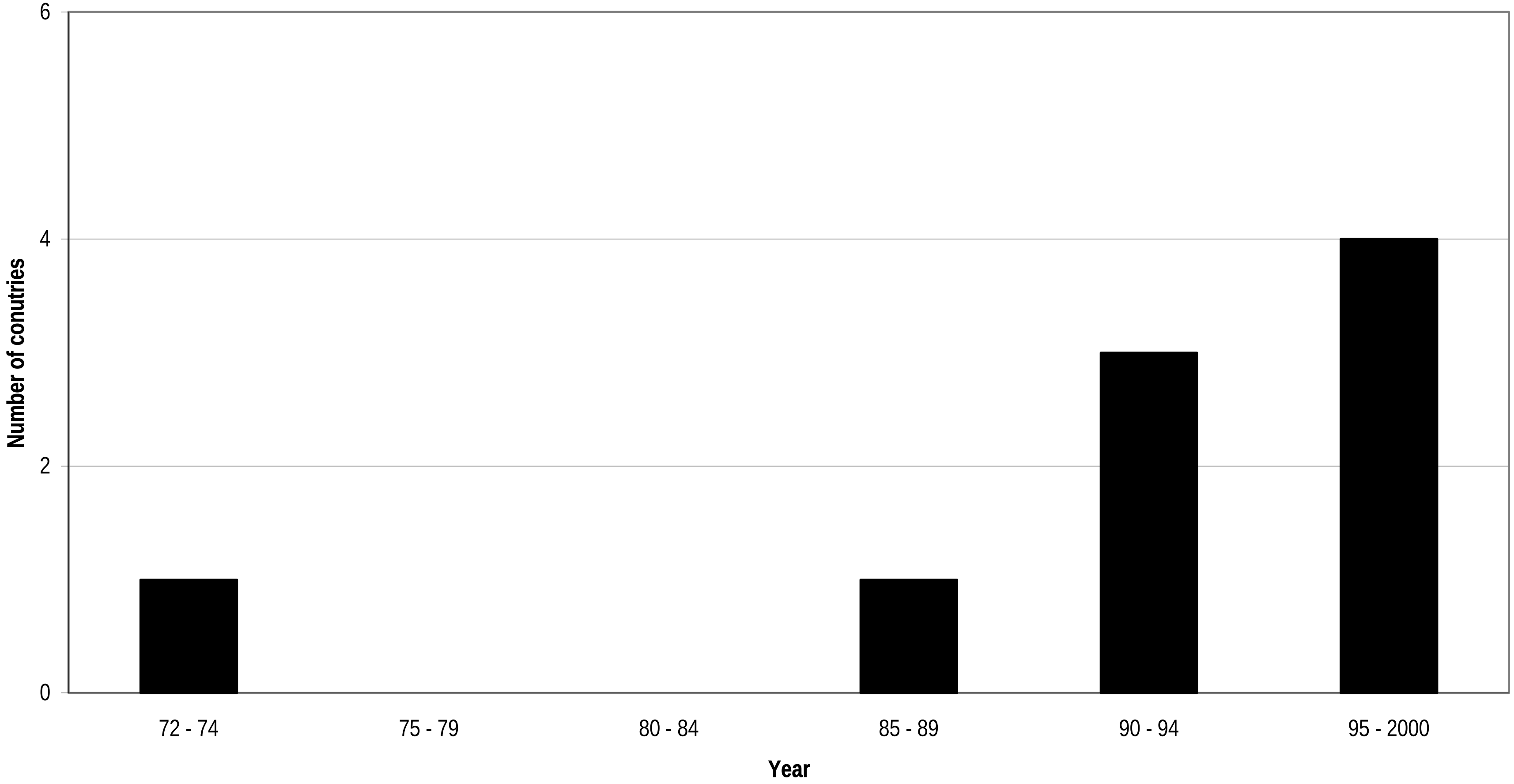

Figure 3 Historical Dynamics of Cleaner Production Efforts - NATO/CCMS Study Members

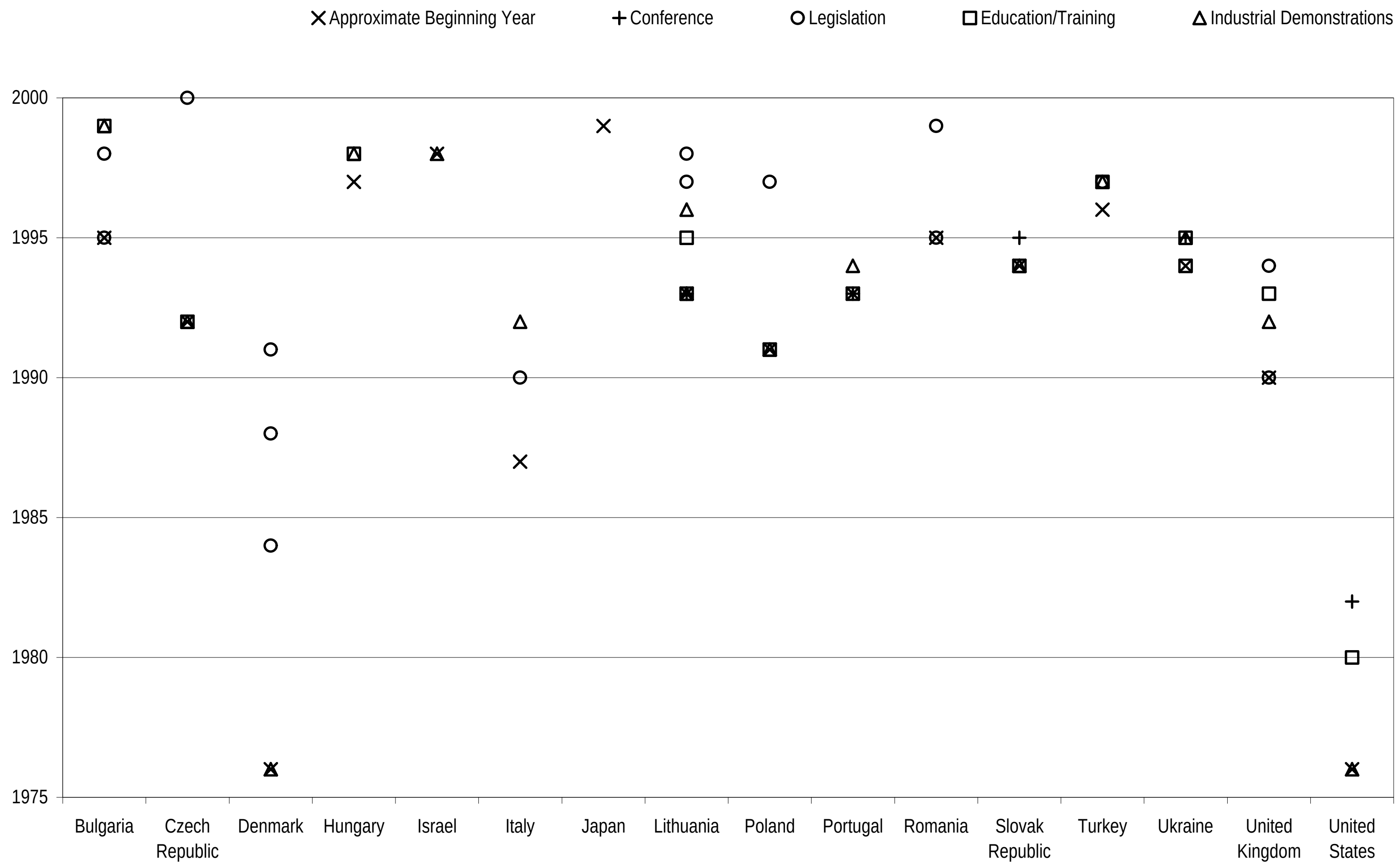

Table 2. Exchange Programs to Initiate Cleaner Production

Country	Early External Support for Cleaner Production
Bulgaria	NATO for Peace; Bulgarian Academy of Science Regional Project on Black Sea; EU Fifth Framework (1999)
Czech Republic	UNIDO/UNEP National Cleaner Production Center (1995)
Denmark	None
Hungary	UNIDO/UNEP (1997)
Israel	None
Italy	None
Japan	None
Lithuania	Sweden (1993); Danish Environmental Management Center (1993); World Environment Center (1993); Norway (1995); University of Amsterdam (1998)
Poland	Norway (1991); World Environment Center/USAID (1992)
Romania	None
Slovak Republic	USAID; UNEP; World Environment Center ; Norway: Austria: Holland (1994)
Turkey	World Bank (1997); Danish Technological Institute(1997)
Ukraine	None
United Kingdom	None
United States	None

Table 3. Industrial Sectors with Significant Current Activity (1999) in Cleaner Production

Country	Recent Sectors (3) That are Active in Cleaner Production		
Bulgaria	Chemical Industry	Ferrous/Non-Ferrous Industry	Small/Medium Firms
Czech Republic	Municipal Water and Sewer Services	Public Transport	Food and Agriculture
Denmark	Textiles	Metal Finishing and Electroplating	Graphics and Printing Industry
Hungary	Automobiles	Graphics and Printing Industry	Chemicals
Israel	Chemicals	Pharmaceuticals	
Italy	Textiles	Leather Industry	
Japan			
Lithuania	Textiles	Food Processing	Electronics
Poland	Public Services (Water, Rail,Power)	Food and Agriculture	Metal Finishing and Electroplating
Portugal	Metal Finishing and Electroplating	Chemicals	
Romania	Pulp & Paper	Textiles	
Slovak Republic	Public Sector	Chemical	Food and Agriculture
Turkey	Textiles	Metal Finishing and Electroplating	White goods Manufacture
Ukraine	None at this time		
United Kingdom	Chemicals	Graphics and Printing Industry	Metal Finishing and Electroplating
United States	Chemicals	Metal Finishing and Electroplating	

Table 4. Network of Current Advocates for Cleaner Production (1999)

Country	Current Leading Advocates (3) of Cleaner Production		
Bulgaria	Bulgarian Academy of Science	University of Chemical Technology and Metallurgy, Sofia	Technical University, Sofia
Czech Republic	Center for Cleaner Production UNIDO/UNEP	Municipal Officials	Several Universities
Denmark	Universities	Government Offices	NGO
Hungary	Universities	Consulting Firms	
Israel	Ben-Gurion University	Technion – Israel Institute of Technology	
Italy	Ministry of Industry	Association of Chemical Industries	Ministry of Environment
Japan			
Lithuania	Association of Textile Industries		
Poland	Supreme Technical Organization (NOT)	Universities	Government Research Institute (GIG)
Romania	Universities		
Slovak Republic	Slovak Cleaner Production Center and Regional Environmental Centers	Ministry of Environment	Slovak University of Technology
Turkey	Industry Associations	Clean Technology Institute of Marmara Research Center	
Ukraine	Pridneprovie Cleaner Production Center	Ukrainian State University of Chemical Engineering	Severodonetsk State Institute of Chemical Technology
United Kingdom	Center for Exploitation of science and Technology	Advisory Committee on business and the Environment	Consultants
United States	State Roundtable	Industry	U.S. EPA

Textiles
This industrial sector has emerged as an active arena for the development and implementation of cleaner production concepts. Some of these changes have occurred over as many as twenty years and thus a success profile or widely adopted (as commercially attractive) technology profile has emerged. These widely accepted cleaner production practices for textiles were summarized, Table 5 and Figure 4. The three most successful practices are,

1) water (and hence energy) conservation thus reducing the volume of effluents
2) a methodical evaluation and demand for reduced toxics in the large number of specific chemicals or proprietary formulations used in textile facilities
3) a recapitalization to obtain more efficient dye equipment.

The dynamics of new developments in cleaner production for textiles led to R & D concepts which appear promising. These emerging concepts were surveyed in each country and a number of technologies were identified, Table 6. However, the most frequently identified , as an emerging technologies, were the following:
1) use of membranes to achieve further water conservation
2) supercritical CO_2 processing.

One aspect of this NATO/CCMS project is to stimulate technology transfer. Such activity is facilitated by the broader knowledge of individuals with specific interest and expertise in textile cleaner production. Hence this project has sought to identify a pollution prevention network in the textile field. The results, Table 7, provide names and affiliation, but also means of direct contact (preference given to email, then fax, and then snailmail). This current work has facilitated the creation of a specialist network by the assembly of information. Network uses might be to summarize work and experience of each individual, to promote some joint projects such as collection or transfer of specific cleaner production information, development of new, leading edge cleaner production techniques for the textile field, or serving as experts in helping small and medium textile firms throughout the world.

Table 5. Generally Successful Textile Cleaner Production Concepts in Various Countries

Country	Approximate Start of Cleaner Production for Textiles	Most Commercially Attractive Cleaner Production Concepts in Textiles (3-6)
Bulgaria	No Formal Program	1) Use of Natural Fibers
Canada	No Formal Program	1) Reduction or Elimination of Toxics and Halogenated Chemicals 2) Equipment Change for Lower Bath Volumes per kg fabric 3) Operational Changes 4) High-Extraction, Low-Carryover Process Step Separations
Czech Republic	Ecolabelling (1994)	1) Reduction or Elimination of Toxics and Halogenated Chemicals
Denmark	1972	1) Reduction or Elimination of Toxics and Halogenated Chemicals 2) Equipment Change for Lower Bath Volumes per kg fabric 3) Water Reuse
Hungary	1999	No Current Changes
Israel	No Formal Program	1) Requirement for Biodegradable Detergents 2) Reduction or Elimination of Toxics (metals)
Italy		
Japan	No Formal Program	
Lithuania	1997	1) Good Housekeeping Improvements for Water , Energy, and Chemicals
Poland		
Romania	No Formal Program	
Slovak Republic	1994	1) Water Conservation 2) Toxic Dye Minimization
Turkey	1997	1) Detergent Elimination After Fixed Reactive Dyeing 2) Water Softening to Reduce In-process Chemical Use 3) Water Reuse
Ukraine	1990	1) Water Reuse
United Kingdom	1995	1) Reduction of Solvent Loss in Dry Cleaning 2) Reduction of Formaldehyde 3) Recycling of Water and Energy 4) Reduction in Toxics Use
United States	1985	1) Equipment Change for Lower Bath Volumes per kg fabric 2) Raw Material Quality Control to Lower Unwanted Chemical Inputs 3) Worker Training 4) Technology Transfer to Small/ Medium Firms

Figure 4 Broadly Cost-Effective Textile Cleaner Production Techniques - NATO/CCMS Study Members

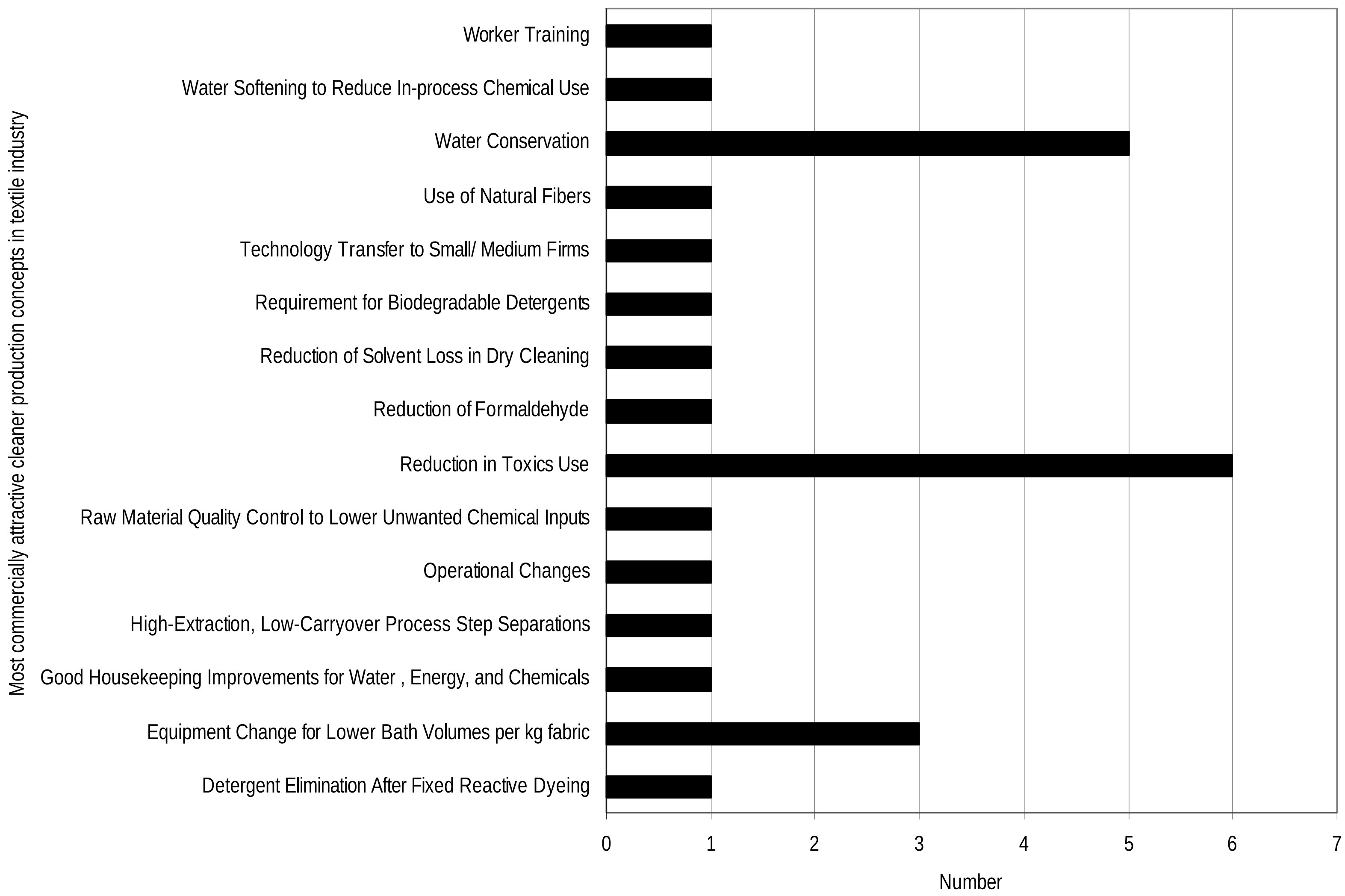

Table 6. Emerging Technologies in Various Countries for Increased Textile Cleaner Production

Country	New Concepts for Textile Cleaner Production
Bulgaria	1) Adoption of Wastewater Treatment 2) Waste Audit for Leather Industry
Czech Republic	1) Systematic Use of Environmental Management Tools (EMS, EMAS, ISO 14000)
Denmark	1) Water Reuse with Membrane Filters 2) Other Water and Energy Reuse
Hungary	1) Adoption of Ecotext Standards
Israel	1) Recycling of Water
Italy	
Japan	No Formal Program
Lithuania	1) Water Reuse 2) Energy Reuse
Poland	
Romania	No Formal Program
Slovak Republic	1) Water and Energy Audits and Minimization 2) Better Quality of Inputs
Turkey	1) Water and Energy Reuse with Membranes 2) Capture of Carbon Dioxide from Flue Gas
Ukraine	1) Vapor condensation to Impregnate Fibers
United Kingdom	
United States	1) Communication and Information Systems to Unify the Textile Complex 2) Supercritical Carbon Dioxide Processing

Table 7. Network of Specialists for Cleaner Production in Textile Industry

Country	Industrial or Technical Experts in Textile Cleaner Production		
Bulgaria	Prof. Nikolay Petkov Simeonov University of Chemical Technology and Metallurgy 8 Kliment Ohridski Str. 1176 Sofia, Bulgaria tel. 359-2-625-4488 fax. 359-2-989-0545	Prof. Ekaterina Ivanova Teriemezjan University of Chemical Technology and Metallurgy 8 Kliment Ohridski Str. 1176 Sofia, Bulgaria tel. 359-2-625-4433	
Canada	Dr. Jess Shen Crechem Technologies 1200 Montreal Road Building M-2, suite 209 Ottawa, Ontario K1A 0R6, Canada Tel. 1-613-993-4383 Fax. 1-613-941-1571	Chantal Roberge, Manager Strategic Options Process for the Textile Mill Effluents Environment Canada 105 McGill St. 4th Floor Montreal, Quebec H2Y 2E7, Canada tel. 514-496-6850 fax. 514-283-5836	
Czech Republic	Ing. Pavel Bartusek Inotex, Ltd. Stefanikova 1208 544 01 Dvur Kralove nad Labem Czech republic Tel. 42-437-820-140 Fax 42-437-820-149 Inotex@inotex.cz	Ing. Petr Janak Inotex, Ltd. Stefanikova 1208 544 01 Dvur Kralove nad Labem Czech republic tel. 42-437-820-140 fax 42-437-820-149 inotex@inotex.cz	Ing. Jan Marek Inotex, Ltd. Stefanikova 1208 544 01 Dvur Kralove nad Labem Czech republic tel. 42-437-820-140 fax 42-437-820-149 inotex@inotex.cz

Country	Industrial or Technical Experts in Textile Cleaner Production		
Denmark	John Hansen Danish Technological Institute P.O. Box 141 DK-2630 Taasatrup, Denmark Tel. 45-4350-4350	Hans Henrik Knudsen Institute for Product Development Building 424 Technical University of Denmark DK-2800 Lyngby, Denmark tel. 45-4525-4666 hhk@ipt.dtu.dk	Henrik Wenzel Institute for Product Development Building 424 Technical University of Denmark DK-2800 Lyngby, Denmark tel. 45-4525-4663 wenzel@ipt.dtu.dk
Hungary	Ms. Eszter Jancso Innovatext Rt H-1103 Budapest Gyomroi ut 86, Hungary Tel. 36-1-260-1809 ext 107 Innova@mail.datanet.hu	Mr. Robert Sczigel Ministry of Economics H-1051 Budapest Vigado u. 6, Hungary tel. 36-1-235-4551 robert.sczigel@gmv.gov.hu	
Israel	Prof. Rebhun Department of Civil Engineering Technion Tel. 972-4-829-2360	Dr. Noah Galil Department of Civil Engineering Technion tel. 972-4-829-2360	Prof. Amotz Weinberg, President Shenkar College of Textile Technology and Fashion tel. 972-3-575-9064
Italy			
Japan			

Country	Industrial or Technical Experts in Textile Cleaner Production		
Lithuania	Prof. J. Staniskis Institute of Environmental Engineering Kaunas University of Technology LT-3000, K. Donelaicio Str. 20 Kaunas, Lithuania Tel. 370-7-224-655 Fax. 370-7-209-372 Jurgis.staniskis@apini.ktu.lt	Dr. Z. Sasiskiene Institute of Environmental Engineering Kaunas University of Technology LT-3000, K. Donelaicio Str. 20 Kaunas, Lithuania	I. Kliopova Institute of Environmental Engineering Kaunas University of Technology LT-3000, K. Donelaicio Str. 20 Kaunas, Lithuania
Poland			
Romania			
Slovak Republic	Ing. Jaroslav Ceveik CHTF STU Radlinskeho 9 812-37 Bratislava, Slovak Republic tel. 421-7-5932-5251 sefcikj@cvt.stu.sk	Ing. Milan Kuuhavy MAYTEX, A.S. 1 Maja 136 031 17 Liptovsky Mikula, Slovak Republic tel. 421-849-553-5250 fax. 421-849-551-4831 maytex_sale@isternet.sk	Ing. Jioi Chlumsky Slovak Cleaner Production Center Pionierska 15 831 02 Bratislava, Slovak Republic tel. 421-7-4445-4328 fax. 421-7-4452-9015 sccp@cpz.sk

Country	Industrial or Technical Experts in Textile Cleaner Production		
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Ukraine	Prof. William Zadorsky Pridneprovie Cleaner Production Center P.O. Box 4159 Dnepropetrovsk-2, 320002 Ukraine Tel. 380-562-416-550 Fax. 380-562-416-590 Ecofond@ecofond.dp.ua		
United Kingdom	Chris Marshall Dept. of Trade & Industry 151 Buckingham palace Road London SW1W 9SS, UK 44-171-215-1451	British Textiles Technology Group Shirley House Didsbury, Manchester M20 8RTX, UK 44-161-445-8141	
United States	Prof. Brent Smith College of Textiles Box 8301 North Carolina State University Raleigh, NC 27695-8301, USA Tel. 1-919-515-6548 Fax. 1-919-515-6532 brent_smith@ncsu.edu		

Conclusions

The progress in development of cleaner production in various countries has occurred for about twenty years and continues even in the last five years. The typical process of bringing cleaner production to a country involves training and industrial demonstrations. A period of three to five years appears as average to achieve an introduction of pollution prevention, although the extent of adoption or implementation varies. In 1999, as a measure of current cleaner production activity, the most active sectors appear to be chemicals, metal finishing/electroplating, and textiles manufacturing; while universities and government organizations remain the most widely perceived advocates.

As a specific industrial sector, textiles is one of the most active over the last decade. Across numerous countries, the most types of cleaner production success (technically viable and economically feasible) were found to be

1) water conservation
2) methodical reduction of toxics through supplier requirements
3) more efficient dyeing equipment.

In the next decade, the development of technologies for membrane systems leading to water or energy conservation and supercritical carbon dioxide were felt to be likely candidates. Finally a network of about thirty textile cleaner production specialists was identified.

References cited

Sikdar, Subhas, Clean Processes and Products, NATO/CCMS Project, 1998-2002, Brussells, Belgium.

CLEANER PRODUCTION IMPLEMENTATION FOR WET PROCESSES OF COTTON TEXTILES

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Introduction

Turkey’s textile and ready wear sector plays a key role in the country’s industrialisation. In 1997, 20% of the total industrial establishments operating in the textile sector employed 30% of all industrial workers. The most successful sub-sector of the Turkish textile industry has been the cotton sector. Turkey is the seventh largest cotton producer in the world with a share of 4%.

Because of having a very important impact on the country’s economy, textile industry has been given priority from the point of Cleaner Production (CP) implementations. The qualitative and quantitative patterns of both the production process and the related resource utilisation are of great importance within the framework of CP. This study is carried out within the frame of project “ Conducting Research and Development aimed at Developing Cleaner Production Technologies to Assist Textile Industry to Manufacture in Compliance with International

Standards". It has been the first activity of the implementation of Cleaner Production Methodology Cleaner Production in Turkey.

Cleaner Production in Cotton Textile Industry for Turkey

The CP program for the textile industry in Turkey has to comprise of a set of organisational, administrative and planning activities that aim at enhancing the CP approach throughout the production the production of fabric.

Three of the six selected enterprises in this project are engaged with wet treatment processes of cotton textile industry. For this reason, the "possible CP options" are selected with special emphasis on wet processes.

Wet processing stages were taken into account from the point of resource(s) conservation. In general, wet treatment processes such as bleaching, dyeing and finishing are very important in terms of the environmental aspects of textile production, not only because of the vast quantity of water and variety of chemicals used, but also because of a high thermal energy requirement. Water and energy are, therefore, also significant cost elements for most production units.

The costs associated with the material and energy in and outflows were investigated. During the evaluation of water costs, both industrial water preparation and wastewater treatment were considered. Furthermore, discharge costs for treated wastewater were also included. With a clear insight into these costs, management can be usually convinced to agree to rapid implementation of CP, particularly with respect to chemical substitution. Within this framework, extensive CP options were subsequently developed.

Before the Feasibility Stage, the generated set of CP options were prioritised. The prioritised options which seemed to be most promising were then submitted to a feasibility study. The feasible options could subsequently be recommended to the enterprise, with implementation carried out under a regime of continuous monitoring and evaluation.

Evaluation of Possible CP Options

After the assessment phase being carried out to select the CP options for feasibility study, it has been observed that there are variety of operations leading to different types of energy and water consumption. Also dye stuff and chemical consumption due to teh differences in the processes vary to a high degree. For this reason it was quite hard to develop a reliable mass and energy balances for the whole and selected product systems . As a result of the feasibility study was carried out on the prioritised CP options by taking into account the environmental, technical and economical issues.

Since technology changes tend to be capital intensive, the selected CP options are preferred to be focused on modification of the existing processes and substitution of chemicals. The priority is always given to prevent the effects on the quality of the fabric.

The process that has been implemented frequently is selected for reduction in chemicals. In Table 2 the chemical and dyestuff input for one t-shirt in comparison with a more environmentally friendly t-shirt are compared. For the recipe reactive dye is used. The fixation of reactive dyes differ between 50-80%. The type of reactive dye used for this process has a fixation value of 48% which is very low in comparison with the range of the reactive dye stuff.

High amounts of salt is added during dyeing to increase the fixation values. The reactive dye stuff result in high content of Chloride (9800mg/l) color (3890) and disolved solids (12500 mg/l).

For an environmentally friendly t-shirt production dyestuff and auxiliary material consumption should be minimised. For this reason, detergent and acetic acid consumption is reduced. Forly BS-C has adverse effects on the wastewater. It has both ecotoxicity impact potentials and human toxicity impact potentials. It is usage is omitted completely (Table 2).

Table 2. Inputs and outputs of chemicals and dyestuff for the selected wet treatment recipe of the knitted conventional t-shirt and the environmentally friendly t-shirt.

Process	Inputs	Conventional t-shirt		Environmentally friendly t-shirt	
		Input amounts (g/ t-shirt)	Output amounts (g/ t-shirt)	Input amounts (g/ t-shirt)	Output amounts (g/ t-shirt)
Bleaching	Wetting agent (Albegal NF)	3.21	2.56	3.21	2.56
	Anticrease (Imacol S)	1.73	1.38	1.73	1.38
	Hydrogen peroxide	3.45	2.76	3.45	2.76
Dyeing	Acetic acid	1.73	1.38	1.38	1.10
	Anticrease (Imacol S)	1.73	1.38	1.73	1.38
	Sequestrant (Uniperol SE)	0.86	0.69	0.86	0.68
	Sodium Chloride	108.7	87	108.7	86.96
	Antiperoxide (Perzym Red DC)	1.73	1.38	1.73	1.38
	Dye (2%Ambifix Brillant Orange V-3R(reactive dye)	4.96	2.58	4.96	3.96
	Sodium Carbonate	4.96	3.96	4.96	3.96
	Detergent (Forly BS-C)	1.57	1.25	-	-
	Caustic	8.62	6.89	8.62	6.89
Finishing	Softener (Rottamin RC)	1.16	0.93	1.16	0.92
	Acetic acid	0.22	0.18	-	-
	Soap (Imerol XN)	0.15	0.12	0.06	0.05

Table 3. Information related to the “Material Safety Data Sheets (MSDS) of some chemicals).

Auxilaries	Physical Form	Hazard Symbol	According to EEC Biological Elimination	LD_{50} (mg/kg) [x]	LC_{50} (mg/kg) [xx]	EC_{50} (mg/kg) [xxx]
Imerol XN	Liquid		>80%	>2000	22	>100
Rottamin RC	Liquid dispersion	None	100%	>3000	10-100	>5000
Badena 243	Liquid dispersion	None	>90	>2000	>1000	>100
Roflex GA/PN	Liquid dispersion	None	>90	>2000	>1000	>100

[x] rat-oral
[xx] fish toxicity-salmo gairdneri, oncorhynchusmykiss, routine bioassay method of 1.11.74
[xxx] test of OECD 209
X_n : contains etoxylated fattyalcohol. Contains nonylphenol
X_I : contains salt of phophated fatty alcohol
None : No hazard classification according to EU Guidelines

After addition to the reduction in the chemical amount, research for substitution of chemicals is carried out. For this purpose Imerol XN (soap) and Rottamin RC (softener) are substitute with Roflex PAD (soap) and with Badena 243 (softener) respectively. From Table 3 it can be seen that with the substitution of chemicals the adverse impacts on the environment can be reduced.
In addition the Cp option mentioned above another option for which feasibility study was also done can be summarized as follows:

Description: To reduce the liquor ratio of the baths without creating any negative effect on the result of the process is the main target of this option. For the machine with 600kg capacitythe liquor ratio is decreased from 1:7 to 1:4. Also the enterprise has to pay 0.3884 DM/m^3 to Istanbul Sewage and Water Organization.
Investment : Neither capital investment nor running investment is necessary for this CP option.
Net income: 16.86 DM/day.
Others: There will be a labour work reduction by 0.9 DM/day.

In order to investigate the saving in chemicals and conservation of water and energy, the results are evaluated by taking into account the production per day and results can be seen in Table 4.

Table 4. Reduction on liquor ratio of baths for rinsing processes.

		Before implementation	**After implementation**	**saving**	**Environmental evaluation**
Input					
Electricity	(Kwh/d)	880.2	874.332	5.868	Energy Conservation
Chemicals H_2SO_4, Lime, $FeCl_3$	(kg/day)	1,923.08	1,909.58	13.5	Reduction of chemicals that are used for in the wastewater treatment plant.
	(DM/day)	291.32	289.30	2.02	

Water	(m^3/day)	1,800	1,788	12	Water conservation
	(DM/day)	1,818	1,805.88	12.12	
Output					
Chemicals H_2SO_4, Lime, $FeCl_3$	(kg/day)	1,162.5	1,153.2	9.3	Reduction of chemicals that are used for in the wastewater treatment plant.
	(DM/day)	160.5	159.22	1.28	
Wastewater (DM/day)		1176.6	1167.19	9.41	Water conservation and reduction in wastewater.

The same process modifications of liquor reudction are calculated for one knitted cotton t-shirt (Table 5).

Table 5. The comparison between conventional and environmentally friendly processes from the point of water and energy conservations.

Process	Input	Conventional t-shirt		Environmentally friendly t-shirt	
		Input	Output	Input	Output
Bleaching	Energy kW/t-shirt	13.93	13.93	13.91	13.91
	Water l/t-shirt	1.37	1.09	1.23	1.0
Dyeing	Energy kW/t-shirt	44.04	44.04	42.38	
	Water l/t-shirt	5.47	4.38	4.87	3.9
Finishing	Energy kW/t-shirt	35.18	35.18	34.17	
	Water l/t-shirt	5.47	4.38	4.87	3.9

Conclusions

A textile plant has been investigated thoroughly by means of a step-wise CP Methodology Application. The evaluation of the feasibility studies revealed that it is worth implementing CP options from the point of resource conservation and chemical substitution. The benefits obtained were not only attributed to cost savings, but better environmental awareness as well.

It should be noted that the CP options studied are feasible only for that production system for that selected enterprise.

It is concluded that the successful application of CP methodology in the Turkish textile sector will encourage other industrial sectors to take similar actions. It should also be noted that the managerial commitment of any enterprise is of utmost importance in CP, since without their commitment and financial support, there will be no real actions and no real results.

References

[1] Electrical Works Research Office. National Energy Conservation Centre. (1997). Principles of Energy Management in Industrial Sectors, Vol.1, Annex 2.

[2] DTI International, Cleaner Technology Assessment. (1995). Danish Technological Institute. Taastrup, Denmark.

[3] Unlu G. Arikol M. and Kaptanoglu D. (1985). Survey of Industrial Energy Requirements: Findings for Turkish Textile Industry. TUBITAK-Marmara Research Centre. Rep. No:40., Kocaeli, Turkey.

[4] Laursen S. E. Hansen J. Bagh J. Jensen O. K. and Werther I. (1977). Environmental Assessment of Textiles. Miljoproject No.20, pp. 132-174.

[5] Kýran N. and Ozdogan S. (1998). Integration of Process Energy Supply Options into Cleaner Production in Textile Industry. Proc. of the Kriton Curi International Symp. On Environmental Management in the Mediterranean Region. June 18-20. Antalya, Turkey, pp 947-955.

[6] Cooper S. G. (1978). *The Textile Industry Environmental Control and Energy Conservation*, ndc Press, pp. 104-117, 151-180.

CLEANER ENERGY PRODUCTION WITH COMBINED CYCLE SYSTEMS

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Energy demand in the world is increasing everyday due to the increase in population and economic developments. Electrical energy is the most favorable clean energy which is generally produced by conventional systems known as Pulverized Coal-Fired or Stoker-Fired Boilers with steam turbine and generator systems. In these systems, the energy conversion efficiency is around 30-35 %. Only about one-third of the heat generated can be converted to electrical energy.

There is a great amount of research going on in several countries to increase the energy production efficiency as well as the development of new processes and equipments which use much less energy than the ones developed decades ago.

A new technology for generation of electrical energy in a cleaner and more efficient way is the Combined Cycle (CC) system. The conversion efficiency of the system is about 50-53 %, which is considerably higher than the conventional systems. The presentation summarized the energy production capacity in Turkey with combined cycle systems by using several fuels. Updates were given on the development of sorbents used for gas cleanup of the IGCC systems by using the waste materials of the iron and steel industry.

THE DANISH CENTRE FOR INDUSTRIAL WATER MANAGEMENT – UPDATE

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The Danish Centre or Industrial Water Management (Danish acronym: CEVI) is a co-operation between five large Danish companies, three technological institutes and two universities. The aim of the centre is to develop concepts and solutions for reclamation and reuse of water and waterborne energy and chemicals in water consuming industry. Generic methods and tools must be developed for future anchoring and dissemination of the developed know-how, and solutions must be implemented within the industrial partners, being representatives from textile industry, industrial laundering, paper industry and food industry.

CEVI has been running now for one year out of four, and a number of results have been achieved ranging from generic methods to implementation of solutions. Among the methods developed, adjusted and/or applied are: Methods for mass-, energy-, and cash flow analysis, methods for characterising and specifying water quality and product quality, methods for process integration and pinch analysis, and methods for environmental feasibility analysis in shape of a simplified Life Cycle Assessment method.

In industrial laundering, being one of the case industries, direct water reuse saving 40% of the water has been implemented through establishment of central tanks for reuse water at one laundry. Moreover, biological treatment has been installed for further water reuse. Ultrafiltration of the wash baths has been successfully tested in lab- and pilot scale, and test are under conduction for full scale washing in UF permeate saving thus both the water and the energy and chemicals remaining in the water.

Present and future R&D comprises recovery of surfactants and phosphorus from UF concentrates from wash water, drying in overheated steam, membrane filtration (NF/RO) of process water from polyester yarn dyeing, aerobic and anaerobic digestion of process water from moulded pulp production, and much more. The following tables give an overall view of research, development and implementation progress.

Table 1. Status on generic methods May 2000

Type of method	Method/tool elements	STATUS
Overall procedures	• Process optimisation • Equipment modernisation • Chemical substitution • Reuse of water, energy and chemicals	Conceptually defined
Inventory	• Processes • Mass flows • Energy flows • Cash flows	Initially defined Adjusted and applied Adjusted applied Developed and applied
Analysis and system design	• Water quality characterisation • Product quality characterisation • Product quality specification • Water quality specification • Process integration/energy • Process integration/mass • Database of separation techniques • Guidelines in choice of water reuse Concepts and techniques • Database of residue management Options • Guideline in residue management	Developed and tested Developed and tested Not defined Defined on case basis Adjusted and tested Adjusted and tested Under consideration Under consideration Under consideration Under consideration
Modelling	• Water- and product quality in water reuse scenarios	Existing tools tested Excel tool developed and successfully tested
Feasibility study	• Technical feasibility • Economic feasibility • Environmental feasibility • Robustness/sensitivity analysis	Under consideration Applied Developed and applied Developed and tested on a case basis

Table 2. Berendsen Industrial Laundry Group. Status on research, development and implementation, May 2000

PROCEDURE LEVEL	Activity	Status
Optimisation	• Various water, energy and chemical savings • Automatic weighing of textile for optimal chemical dosing	Established at 3 laundries. Pinch analyses conducted Suggested
Modernisation		
Substitution		
Reuse	• Direct reuse via central water reuse tanks. Around 40% water savings • Biofilter for reclamation and reuse of wash water • Membrane filtration of the wash water • Membrane biofiltration of the wash water • Environmental comparison of alternative water reuse concepts • Heat recovery from drying. Drying in superheated steam	Implemented in one line (8 washing machines) at one laundry Installed at two laundries. Test of operation ongoing Successfully tested in lab-scale and pilot-scale. Washing tests with permeate ongoing Successfully tested in pilot-scale Conducted Under consideration

Table 3. Neckelmann polyester yarn dyehouse. Status on research, development and implementation, May 2000

PROCEDURE LEVEL	Activity	Status
Optimisation	• Spray system for CIP installed – substitutes two complete tank fillings • Liquor displacing unit used when cleaning dyeing apparatuses	Established in one out of 14 dyeing apparatuses Constructed and tested - minor reconstruction ongoing
Modernisation	• Reduction of water carry-over by vacuum suction of the yarn cones between the batches of the recipe	Under consideration
Substitution		
Reuse	• Direct reuse via central water reuse tanks • Reduce volume of oily UF concentrate by salt addition and subsequent gravitational separation • Membrane filtration of the heaviest polluted water types • Evaporation techniques and heat recovery • Heat recovery from drying. Drying in superheated steam	Reuse of water from last rinse as input to first rinse successfully tested Successfully tested and installed Successfully tested in lab-scale. Pilot-scale tests ongoing Process integration/pinch analyses carried out. Feasibility study ongoing Under consideration

Table 4. Hartmann moulded pulp producer. Status on research, development and implementation, May 2000

PROCEDURE LEVEL	Activity	Status
Optimisation	• Reduction of water content of products before drying	Under investigation
Modernisation		
Substitution	• Substitution of biocides by dispersing agents	Tests ongoing
Reuse	• Direct reuse via flotation and central water reuse tanks • In-line aerobic biological treatment for microbial growth control and for reducing use of biocides • In-line aerobic biological treatment for microbial growth control and for reducing use of biocides • In-line NF/RO membrane filtration for microbial growth control and for reducing use of biocides • Environmental comparison of alternative water reuse concepts • Heat recovery from drying. Drying in superheated steam	Implemented for many years Successfully tested in pilot scale Lab- scale tests ongoing Unsuccessfully tested in pilot scale Conducted Under consideration

INTERNATIONAL EXCHANGE AND DISSEMINATION OF INFORMATION ON CLEAN PRODUCTS AND PROCESSES: WITHIN THE PILOT STUDY AND TO INDUSTRY AND THE PUBLIC

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Summary

At the Belfast meeting in 1999 there was a discussion on how to improve communication and it was suggested to launch a new pilot project on communication. Horst Pohle, Germany, Adrian Steenkamer, Canada and Dan Murray have since discussed how to proceed, and the suggestion is to try and establish a web-page for the pilot study and use that as a focal point for communication.

The proposed procedure was to start up by establishing the new web site, and see how it goes and then discuss it again at coming meetings. The web page has been established at:

http://www.epa.gov/ORD/NRMRL/nato/

The suggestions are to have a front-page giving

- overview of NATO CCMS Mission,
- description of Pilot Study,
- Link to NATO CCMS web site,
- and Annual reports

And secondary pages containing information on

- participating nations and delegates
  - national program descriptions
  - delegate's organization description and resources
  - Links to research centers, governmental organizations etc.
- Pilot project descriptions and information
- Pilot study participation information and announcements
- Other Cleaner Production information and links

EPA in Cincinnati can offer to maintain the pages.

Further ideas from the delegates for the web page were i.e. to have a discussion forum, to be able to advertise free jobs and to have procedures to ensure a reasonable frequent updating of information. Overall, the key being that everyone provides information to the page.

The main purpose of the web page is for communication and information sharing among the delegates and participants. In addition also to refer people to the work done within the pilot study and provide Cleaner Production information to others. A long-range goal is to make the page looked upon by many nations and individuals as one of *the* places to look for information on Cleaner Production and Cleaner Products. RETURN TO CONTENTS PAGE

INTRODUCTION TO INVITED PRESENTATION

A number of specially appointed speakers were invited by the Pilot Study directors and by the meeting host. Papers or summaries of these presentations are given in the following in the chronological sequence in which they were presented at the meeting.

ENGINEERING FOR SUSTAINABLE DEVELOPMENT – AN OBLIGATORY SKILL OG THE FUTURE ENGINEER

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Introduction

In the last few years it has become clear that our present industrial production and consumption culture is facing dramatic changes in the future due to:

- pollution and waste problems
- non-renewable resource consumption
- rapid growth in world population

The developing countries are fighting poverty and health problems and we have no choice but to support their struggle for economic growth, which is a prerequisite for a more stable world.
Our best contribution is to develop a new sustainable industrial culture, which can be scaled up by a factor of 5 – 6 compared to the present level without creating unacceptable environmental and resource problems. The term sustainability appears more and more often in literature, public debates, as research issues, etc., but it is used in many different meanings. Broadly, the content of the term is determined by the different value criteria of the various interest groups around a company (share holders, suppliers, employees, local community, national and international community, political interest groups etc.). A closer study of these criteria results in the conclusion that the term sustainability includes the three main responsibilities:

- economic
- environmental
- social/societal

The economic responsibility has for many years been the dominating one, but in the last few years the environmental and the social/societal responsibilities are surfacing more and more to parallel the economic responsibility. These responsibilities are interlinked and all have a major influence on business opportunities.

Product Life Cycle Management

In the last few years the environmental focus in industry and legislation has shifted from the production processes to the products themselves throughout their entire life cycles (material extraction, material production, product production, usage and disposal). This is due to the fact that environmental impacts are created in all life cycle phases. Therefore, it is necessary both from an environmental and resource viewpoint as well as from a business viewpoint (manufacturer is responsible for the whole life cycle) to consider the product's life cycle in a holistic way with the aim of optimising the product performance. [1]

For this purpose a product life cycle management (PLCM) system should be adopted. Table 1 shows the main elements in a PLCM system and each company will have to – based on its own market and objectives – adopt these elements to its own management structure.

Table 1: Main elements in a PLCM system

Element	Purpose
A. Strategic management issue	Integration in the management structure
B. Life cycle assessment (LCA	Environmental focus; product development; documentation; internal & external communication
C. Life cycle engineering (LCE)	Definition of business objective, engineering methods and activities to support all product life cycle issues
D. Life cycle information (LCI)	Information flow and data to support life cycle management
E. Technological plat-forms	Monitoring technological developments

Each of the elements in the PLCM system will be discussed in the following.

A strategic management issue

It is a top management responsibility to ensure that the company has full awareness and knowledge of the products' life cycles and the consequences they have in all life cycle phases (environmental impacts, resource consumption). The company must clearly define its business objectives seen in relation to the products' life cycle and identify and describe the interaction and transfer between the "owners/partners" of the product in its life cycle phases. Introducing the PLCM will ensure that the company has all the necessary documentation of the products to be used internally as well as externally (interest groups, authorities, purchasing, marketing, etc.). It is the responsibility of the management to have full knowledge of the products and their consequences in all life cycle phases, and to show how they are dealing with these consequences.

Management focus on the subject will in itself create a better performance, but introduction of the necessary engineering methodologies/tools in the various company functions will provide more significant results.

It is necessary that the PLCM system is integrated in the overall company management system.

Life cycle assessment of products

As mentioned previously, the environmental focus has shifted from the manufacturing processes to the products themselves in their life cycles. For this purpose a methodology for assessing environmental impacts and resource consumption associated with the existence of products throughout their entire life cycles has been developed. It is called LCA (Life Cycle Assessment) and is a result of many years of international scientific development. The procedure is now being documented in the ISO standards:

- 14040 Principles and framework (1997)
- 14041 Goal and scope definition, inventory (1998)
- 14042 Life cycle impact assessment (draft, 1999)
- 14043 Life cycle interpretation (draft, 1999)

SETAC (The society of Environmental Toxicology and Chemistry) has made important contributions to the methodology development.

Based on the LCA the environmental focus for the product development can be established and design guidelines can be developed. LCA results can be used for various purposes both internally as well as externally.

Life cycle engineering

The term life cycle engineering is used to cover the activities, methods and tools that are used to develop the products for their entire life cycle. The main issues are:

- business objective
- life cycle design/design of life cycle

Business objectives (new opportunities)

It is very important that a company very clearly defines its business objectives. Here it is important to recognise that the physical part of many products is becoming a smaller and smaller part of the value chain in a product's life cycle. The service parts are increasing and the company must decide what is its business objective:

- the product
- the function/service of the product, i.e. maintain control of the life cycles
- after sales service, maintenance, online monitoring/maintenance, availability
- take back (to remanufacture)

The life time of the product is determined based on the objectives. It must be remembered that the product manufacturers are responsible for the impacts and consequences of the products in their entire life cycle, and therefore it must be investigated if this also means that it is advantageous to make usage and disposal part of the business. It is important that "ownership/responsibility" for the different parts of a life cycle is visible and that the partners having ownership optimise their collaboration.

New business objectives may arise seen in the product life cycle perspective and new technologies (micro/nano/sensor technology, telecommunication, supply chain management, etc.) may offer possibilities of realising these.

Life cycle design

When designing the product for all life cycle phases, it is important to optimise its total performance. Many issues/requirements have to be considered at the design stage, here mainly environmental and other life cycle related topics are mentioned. These topics must be balanced against all other product requirements.

Design for environment
Based on the life cycle assessment it is found what the problem is (effect potentials, main contributors, etc.). The designer can now look at what can be changed (materials, processes, functional elements, structure etc.) and what the environmental improvements are. Seen from the costs and the competitive position of the product, it must be decided which improvements should be implemented in the new product. Design rules may be developed based on the LCA results, for example energy reduction in usage, certain materials preferred, avoid following chemicals, etc.)

Design for X
Many other environmental and life cycle related issues have to be dealt with at the design stage and they can be listed as design for X. The following design issues (X) must be considered:

- distribution including packaging and transport
- installation (facility requirements, self-integration, plug & play function, etc.)
- maintenance (self-diagnosis, self-repair, online services, monitoring, teleservices, upgrading etc.)
- ease of manufacture (materials, processes, assembly etc.)
- remanufacture (reuse/repair, dismantling, recovery)
- take back (reuse in new products, upgrading, downgrading etc.)

These design considerations are very important and their contents depend on the type of product and on the defined business concept.

Product life cycle information
Information supply and communication among the different life cycle partners is an important aspect. Information has to be provided regarding design, materials, processes, components, service concepts, operating strategies, etc. A product state model must be developed accumulating all information about a product at the present time. This enables documentation of the product, service and operating manuals, usage information and disposal information.

For many products it will be of value at any life cycle state to have access to all data. Therefore questions about:
- product data management (design data, LCA data, production data, maintenance/repair data, etc.)
- database (structure/access)
- tele-/multimedia services (installation, plug & play, monitoring, online services, diagnosis, repair, etc.)

must be answered.

It could be considered to have the product itself carry the information in a chip. The coming sensor technology also enables easy data collection. It seems that the possibilities in the modern communication technology will provide new and advantageous solutions.

Technological developments/technology platforms
The technological development is progressing very fast, and it is mandatory that the company all the time closely monitors its technological platform to ensure the full potentials of its products.

Typical trends are:
- miniaturisation of products (saving energy and resources)
- micro-/nanotechnology (sensors, functional units)
- new materials and processes
- information technology
- networking
- virtual reality/virtual enterprise
- telecommunication
- plug & play software
- better energy efficiency in functional units
- communication capabilities in functional units
- production is becoming a project in the product life cycle

These trends show that many new possibilities are presented to the companies and it is important that the company always has an updated technology platform combined with an updated business objective.

Conclusion
The presentation indicates that the technical contribution to sustainability is closely linked to the life cycle perspective, and that large improvements compared to the present situation can be obtained.

Product life cycle management is an important tool that focuses the company's attention on the business objectives seen in the product life cycle perspective as well as on all activities that optimise the co-operation between the life cycle ”owners”.

Life cycle engineering covers methods and tools to support development, manufacture, usage and service and disposal of products to optimise business and sustainability.

References
[1] E. Westkämper, L. Alting & G. Arndt: ”Life Cycle Management and Assessment”, CIRP General Assembly, Sidney, Australia, August 2000

[2] H. Wenzel, M. Hauschild & L. Alting: ”Environmental Assessment of Products”, Kluwer, 1997

MEMBRANES IN PROCESS INTENSIFICATION AND CLEANER PRODUKTIONS

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Introduction

Research progresses in Chemistry and Chemical Engineering have been made during the last decades with important contributions to the industrial development and to the quality of our life. An interesting case is related to the membrane science and technology continuous impact to innovative processes and products, particularly appropriate for a sustainable industrial growth. Reverse osmosis is today a well recognized basic unit operations, together with ultrafiltration, cross-flow microfiltration, nanofiltration, all pressure driven membrane processes. Already in 1992 more than 4 millions m3/day were the total capacity of RO desalination plants and in 1995 more than 180.000 m2 of ultrafiltration membranes were installed for the treatment of wheys and milk. In early 2000 the overall desalinated water produced worldwide by RO is overcoming the amount produced by thermal methods.

The concept of asymmetric structures realized with composite polymeric membranes made possible in the early 80s the separation of components from gas streams. Billions of cubic meters of pure gases are now produced via selective permeation in polymeric membranes.
The possibility of combining in a single step a molecular separation with a chemical conversion, realizing a membrane reactor, is offering new important opportunities for improving the efficiency of important productive cycles particularly in biotechnology and in the chemical industry. In September '97 five large petrochemical Companies made public their alliance for a research project devoted to the development of inorganic membranes to be used in the syngas production. This action came in parallel to the announcement of a 84 million dollars similar project, partly supported by the DOE in the USA, having Air Products and Chemical Inc. working together on the same objective. The availability of new high temperature resistant membranes and of new membrane operations as the membrane contactors is offering a important tool for the design of alternative production systems appropriate for a sustainable growth.

The basic properties of membranes operations make them ideal for a rationalization of the industrial productions; the fact they are athermal, (except membrane distillation) and don't involve phase changes or chemical additives, simple in their conception and in their operations, modular and easy in their scaling up, suggests significant reduction in energy consumption with a potential more rational utilization of raw materials and recovery and reuse of by-products. The membrane technologies, compared to those commonly used today, respond efficiently to the requirements of the so-called "process intensification", because they permit to bring drastic improvements in manufacturing and processing, substantially decreasing equipment-size/production-capacity-ratio, energy consumption and/or waste production and resulting in cheaper, sustainable technical solutions .
The potentialities of redesigning innovative integrated membrane processes in various industrial sectors characterized by low environmental impacts, low energy consumption and high quality of final products have been studied and in some cases realized industrially.

Interesting examples are in the dairy industry or in the pharmaceutical industry. Research projects are in progress, in the leather industry or in the agrofood industry based on the same concept.

Membrane Operations

It can be said that the existing membrane technology covers the widest spectrum of applications than any other single separation technology. In table 1 are summarized the most relevant processes and some examples of their mature applications.

Table 1: Applications of membranes operation in some industrial branches

Branch	Examples of matured implementations	Process
Chemistry	Concentration and recovery of substrates, catalyst's recycling, removal of organic components from water solutions, fractionation of hydrocarbons, crystal cleaning, recovery of cleaning agents, emulsion break-up, recovery and concentration of polymers, filtration of amines and glycols, purification and concentration of acids, purification of glycerin	RO, NF, UF, MF, PV, ED, DL
Petrochemistry	Fractionation of hydrocarbons, wastewater treatment, fuel dewatering, separation of azeotropes	PV, MD
Paper industry	Recovery of chemicals and reagents: pigments, chelating agents, emulsifiers, latex, defoaming agents, neutralization of wastewater	RO, NF, UF, MF
Textile industry	Recovery of oil finish, polyvinyl alcohol, latex, dyes and detergents	RO, NF, UF, MF
Leather industry	Recovery of tannin agents and chemicals from unhairing baths and tanning baths	RO, NF, UF, MF
Electronics	Preparing of ultra-pure water for flushing of integrated circuits, air filtration, water recycling	RO, NF, UF, MF
Metal industry	Regeneration of cooling emulsions for cutting, rolling drilling, etc, separation of condensates from compressors, neutralization of galvanic wastes, recovery of oils and greases from degreasing baths, concentration of washings with diluted electrophoretic paints	RO, NF, UF, MF
Transport	Removal of oil from washings after cleaning of transportation means and tanks	UF, MF
Energetic	Water softening, decarbonization, removal of radioisotopes	NF, RO, UF
Fuel	Manufacturing of ethanol from cellulose and starch, methane from agricultural and municipal wastes, hydrogen and hydrocarbons	UF, GS
Food industry	Recovery of proteins from animal and plant by-products, recovery of proteins from plants, soybeans, potato juice during starch manufacturing, desalting of vegetable dye, concentration of pectin and gelatin, cold sterilization of products	UF, MF
Sugar industry	Sugar refining, molasses removal, purification and concentration of cat and cane juice	RO, NF, UF
Beverages	Clarification of juices, syrups, wines spirits and liquors, concentration of fruit and vegetable juices, purification of organic acids, glucose and fructose. Cold sterilization of beer, wine and spirits	RO, NF,UF
Diary industry	Sterilization of milk, concentration of skim milk and whole milk during cheese making and powdered milk production, milk desalting, concentration of sweet and sour whey, manufacturing of protein concentrates from milk, recovery of lactose from whey	MF, UF, ED

Table 2
Sales of membranes & modules in various membrane processes

Membrane process	Sales 1998 [MioUS $]	Growth [% p.a.]
Dialysis	1,900	10
Microfiltration	900	8
Ultrafiltration	500	10
Reverse osmosis	400	10
Gas exchange	250	2
Gas separation	230	15
Electrodialysis	110	5
Electrolysis	70	5
Pervaporation	>10	?
Miscellaneous	30	10
Total	*4,400*	*>8*

Membrane operations shown their potentialities in molecular separations, clarifications, fractionations, concentrations, etc. both in liquid phase, gas phase, or in suspensions.
They cover practically all existing and requested unit operations used in process engineering. All the operations are modular, easy in their scale up and simple in their plant design. No moving parts; working totally unattended; lower cost; operational flexibility and when necessary, portability are other important aspects.
Several examples of successful applications of membrane technology as alternative to a traditional process may be mentioned.
The use of ion exchange membrane cells in chloro-soda production represent an interesting case study for analyzing the potentialities of membrane operations and one of the first success of their electrochemical application in minimizing environmental impact and energy consumption.
The success of this process suggested recently another interesting applications still based on cation transporting membranes as Nafion: the anhydrous electrolysis for chlorine recovery.

The recent development of nanofiltration and low pressure reverse osmosis membranes with interesting selectivity and fluxes, higher chemical and thermal resistance has been rapidly utilized for realizing innovative processes in various industrial sectors.
An interesting case studied in Italy is represented by the Iopamidol preparation in the pharmaceutical industry.
Also the integrated membrane processes proposed for the chromium recovery in the leather industry and the treatment of secondary textile effluents for their direct reuse, show efficient applications of nanofiltration and low pressure reverse osmosis operations.

In addition to the already mentioned membrane operations, gas separation, pervaporation and some others membrane processes which are showing in the last years significant potentialities for their application in various industrial areas must be cited; among these a class of membrane based unit operations (already known membrane systems and new ones) identified as membrane contactors, membrane bioreactors and catalytic membrane reactors.

APPROACHES TO CLEANER PRODUCTION IN ECONOMIES IN TRANSITION – THE RESULTS AND PERSPECTIVES OF THE CLEANER PRODUCTION CENTRES

Vladimir Dobes
Czech Cleaner Production Centre

Cleaner production is concept, which reflects general trends in environmental management:
- Increasingly clear limitation of environmental effectiveness and economic inefficiency of end of pipe solutions
- Increasing need for dematerialisation and increase of efficiency of processes, products and services
- Increasing need for avoidance of use of toxic materials
- More clear need for integrated and holistic approach to environmental protection.

These are trends, which are already starting to be reflected in new environmental policies and regulations worldwide (in Europe for example EC directive on Integrated Pollution Prevention and Control). There is also a broad understanding that these trends should be reflected in transformation of economies in transition and in restructuralisation of their industries as well.

Donor programs
The above mentioned trends together with high potential for reducing pollution through increased efficiency of industrial processes in economies in transition (CEEC´s) were one of the reasons why there were launched different donor programs in this field. Programs were focused on implementation of preventive environmental management in CEEC´s starting at beginning of nineties. These programs were at the beginning fully donor driven.

Practical implementation of preventive approach was promoted under different terms like cleaner production, pollution prevention, waste minimisation or clean technologies. We will utilise term cleaner production in this paper to refer to all these approaches and methodologies.

We can distinguish two basic approaches[1] in launching these programs:
1) **Demonstration of technology –** programs in field of direct assistance to concrete industrial branch and/or individual enterprise to solve concrete problem through technology transfer focused mainly on demonstration of hardware. This approach has impact mainly in innovation of equipment.
2) **Demonstration of methodology –** programs in field of capacity building with focus on training of trainers on demonstration projects in industry. This approach has impact mainly in developing local technical assistance, lecturing and managerial capacities.

The programs were normally mixture of these two approaches. They have created many concrete projects demonstrating double benefit of preventive environmental management in industrial enterprises (for example see enclosure, table 1).

Results and impacts

The programs were successful concerning their goals to demonstrate potential for cleaner production and to train domestic professionals in cleaner production (CP) methodology. There are being often discussed two problems related to these programs, which are interesting for our discussion.

The first is connected with reliability of presented results both in terms of environmental benefits and economic evaluation of measures. This was problem especially in cases in which the reports were developed by enterprise staff without reliable independent verification. However, we can see it also in cases in which international consultants developed reports without deeper questioning of data provided by enterprises.

We do not see this as a fundamental problem for two reasons:

- We have seen the not accurate presentation of results to vary on both sides (being higher or lower) and we estimate that the real theoretical results will be in sum corresponding with the presented ones. This difference is caused both by intentional and not intentional miscalculations and enabled by complexity of cleaner production measures. These measures have impact on different costs within and outside production process. We can state that many savings are omitted just because of poor identification of all aspects influenced within total costs assessment.
- There were already some improvements done in this area (for example verification of results through opposition of enterprise top management which has to pay percentage of savings from implemented measures and is therefore committed not to exaggerate the results).

The second problem, which we consider more serious, is problem of implementation of proposed measures, poor maintenance of implemented measures and lack of follow up actions. Many evaluation programs reported limited and or no follow up of activities implemented in enterprises after the external assistance is over. Enterprise managers perceived CP as tool, which is difficult to integrate into enterprise management and daily practice. This is especially perceived in situation in which enterprise face day by day survival problems (and this is normal situation of most of CEEC´s enterprises). There is a question if there are not the survival problems of these enterprises caused among others by lack of good strategical and preventive management and poor management of material and energy flows.

To understand better the second problem it is useful to make closer look on enterprises, which were successful in maintaining CP program ongoing after the external assistance was over. There were some common features like:

- management committed to strategical development of enterprise
- effort to involve employees into improvement of enterprise performance
- system approach to enterprise management and understanding importance of continuous improvement
- integration of CP with other activities within enterprise.

Concerning the question of general success of the donor programs we can conclude that the existing results proved and very well demonstrated that there is a high potential for double benefits from cleaner production measures in all different sizes and branches of industry.

On the other hand it become clear that it is much more difficult to achieve a broad spread of CP in respective countries than originally assumed. Training and demonstration does not lead to integration of CP into daily practice of industry and other stakeholders on its own.

Cleaner production centres

Some donor programs, which were aiming at broad integration of cleaner production into the industrial environmental management in target countries, introduced into their programs establishment of cleaner production centres (here we use term cleaner production also in its general meaning referring to all types of centres with different names).

The general purpose of these centres is not only to organise training and demonstration but also to go beyond demonstration and play key role in sustaining cleaner production programs in country after the international assistance is over.

We can distinguish two basic types of centres with understanding that the real centres are normally mixture of these two types:

1) Commercial consultant

The main functions of such a market driven centre are to provide information, training and technical assistance to industry and other stakeholders in such a way that this service recovers its costs and make it financially self sustaining. We can see that the successful centres, which have had this mission, are today operating as consultancy firms.

The main limitations here are:

- These centres are in order to survive in competition pushed by market to focus more and more on activities which are far from promotion of cleaner production.
- They are forced by market to keep their know-how for themselves to be able to sell it to their clients and therefore there is very limited or no multiplication effect.

2) Subsidised promoter

The main functions of such a mission driven centre beside basic promotional activities, training and technical assistance includes broad dissemination of the concept to different stakeholders, providing platform for cooperation of stakeholders, providing policy advice and facilitating establishment of financial mechanisms for investment needing cleaner production measures.

The main limitations here are:

- Donors and governments in CEEC´s are not committed for long-term financing of basic operation of any organisation even with very useful mission.

- Fully subsidised services are not so motivating both for providers and clients (there is a general perception in many CEEC´s that what is free of charge is not valuable).

Critical success factors
The centres, which survived and succeeded to keep their mission of focal point and source of know-how in field of cleaner production in their countries, are having features of both subsidised promoter but also of commercial consultant. The survival challenge for them is to keep revenue generating activities in field of cleaner production to be able to maintain their promotional functions. Other common strategy is to rise project based funding for the promotional activities.

There are some factors that we see critical for successful implementation of mission of cleaner production centres. They are illustrated on case of the Czech Cleaner Production Centre[2] in the enclosure.

1) *To build critical capacities within all stakeholder groups so that they can continue implementation of cleaner production on their own.*

Completion of this task is crucial for fulfilling the centres mission. We have to stress that the centre creates through this its own competitors. To cope with this challenge, the centre has to integrate the next success factor.

2) *To be source of new know how in field of cleaner production in the country.*

As the yesterday pilot activities are becoming standard ones and different stakeholders feel their ownership, centre can refrain from continuing in their direct implementation and has to come with something new what will be new interesting product to be spread.

This challenge is closely connected with experience that needs of enterprises are developing very quickly. The offer of cleaner production centre should follow this demand and changing conditions.

3) *To develop demand for cleaner production.*

This is the last and most complex success factor. We have already stressed that cleaner production programs in CEEC´s were donor driven at the beginning. We can see a slow-down of process of promotion of cleaner production in many CEEC´s due to a lack of domestic driving forces. Donors are withdrawing and new driving forces are not in place yet. These driving forces should be related to demand of local stakeholders, mainly governments and industry and should be reflected in relevant policies. For example investors or owners could play a driving role as well, however, there are not many precedents here yet.

There is a large set of tools, which can promote cleaner production to industry and create needed demand, which would utilise and enlarge cleaner production capacities developed within the initial programs. These tools can vary from soft information tools to compulsory systems, which work on principle of public access to benchmark information, or from market based economic tools to normative regulation based (for example on consideration of best available techniques within permitting system under Integrated Pollution Prevention and Control).

Commitment of governments is crucial here. Many have for example different schemes for support of end of pipe technologies. They can use cleaner production capacities for assessment of cleaner production potential before investing into end of pipe measures. The size of these measures and related investments would be significantly minimised as well as environmental risks.

The final goal concerning policies promoting cleaner production is to integrate them into sectoral policies. The “action ministries” are responsible for efficiency of their resorts and ministry of environment can play mainly facilitating and coordinating role here.

Conclusions

We can conclude that:

- Basic capacities in cleaner production were already developed or their development including establishment of cleaner production centres already started in many CEEC´s.
- CP programs have survival problems in many CEEC´s today as the driver of donor support is diminishing and domestic drivers are not in place yet.
- Governments and donors can play crucial role in establishment of self-sustainable cleaner production programs in CEEC´s through support of three critical factors mentioned above.

This support includes at the beginning building of domestic capacities, especially of consultants and lecturers. Institutionalisation through establishment of cleaner production centre proved to be very efficient. Centre plays role of an independent promoter and focal point, which brings different stakeholders together.

Development of new know how is very important as the next step. This can include for example:

- amendment of cleaner production methodologies, development of assessment tools etc.
- local authority cleaner production programs
- integration of cleaner production with quality and/or environmental management systems
- eco-design of products.

The third area of needed support is in field of governmental policies promoting cleaner production. This includes for example use of cleaner production for introduction of integrated pollution prevention and control or conditioning support for end of pipe measures by utilisation of preventive potential.

Cleaner production centres can develop their financial sustainability based on mix of products paid partly by clients and partly subsidised from public resources. This scheme often works only on a project base. This situation causes high uncertainty in centres strategical planning.

We can conclude that spread of cleaner production is an inevitable process considering the trends described at the very beginning of the paper. Cleaner production centres and other initiatives promoting preventive environmental management play important role in lowering our loses connected with slow adaptation of our processes, products and services to new demands.

Litterature

1) Rodhe, H.: Preventive environmental strategies in Eastern European industry, draft of doctoral dissertation. IIIEE, Lund University, 2000.
2) Christianova, A.: Industry and Cleaner Production – Making Business Profitable. Czech Cleaner production Centre, 2000.
3) Arbaciauskas, V.: Cleaner Production Centres in Central and Eastern Europe – Present situation and Future Directions, MSc Thesis. IIIEE, Lund University, 1998
4) Dobes, V.: Five Key Factors for Ensuring Sustainability of Cleaner production Programmes within a Country. Proceedings of Fourth European Roundtable on Cleaner Production, Oslo, 1997.
5) Kisch, P., Lindhqvist, T., Ryden, E.: Evaluation of UNIDO/UNEP National Cleaner Production Programme. IIIEE, Lund University, 1996.
6) OECD: Policy Statement on Environmental Management in Enterprises in CEEC/NIS. EAP Task Force, Paris, 1998.
7) Staniskis, J., Stasiskiene, Z.: CP Follow-up System in Lithuania. Proceedings of Sixth European Roundtable on Cleaner Production, Budapest, 1999.

CRITICAL SUCCESS FACTORS
EXAMPLE OF THE CZECH CLEANER PRODUCTION CENTRE

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The Czech Cleaner production centre (CPC) was established in 1994 as an independent not for profit organisation within a framework of the Czech-Norwegian Cleaner Production Project. It broadened its activities within the five-year support of the UNIDO/UNEP Program for National Cleaner production Centres. CPC has headquarter in Prague and two branch offices in the Czech Republic. It also created large pool of domestic lecturers and consultants who are being involved in different cleaner production projects. Close cooperation with four universities secures training capacities and integration of CP into curricula. Here follows description of selected CPC activities related to the critical success factors presented within the paper.

Building capacities

In the first years of its existence the CPC has been focusing on technical assistance and training with implementation of concrete projects in industrial enterprises in the Czech Republic. Projects, which constituted a core part of CPC activities, were carried out in the form of long-term training courses consisting of lectures and the on-job training.

The results of these projects showed high potential for cleaner production in the Czech industry. We present summary of the main results here to support statements given within the paper in the

Table 1. We have to stress that the results does not include all benefits as they represent only the first annual gains and they do not include for example avoided investments to end-of pipe measures.

Environmental benefits (it is reduction of emissions, wastewaters, waste and dangerous waste) were achieved by both non-investment good housekeeping measures and by investments, which has typically a short to payback.

Table. 1: Summary of results of CP projects in the Czech Republic

Year	1993	1994	1995	1996	1997	1998
Number of long-term projects	1	1	2	4	1	4
Number of participating firms	7	6	10	23	7	21
Number of people trained	27	31	64	74	21	71
Environmental effects						
VOC emission reduced (Ton per year)	0	1982	151	335	10	237
Waste water reduced (Thousand m^3 per year)	0	5	7	907	3438	77
Non hazardous waste reduced (Ton per year)	51	9216	6481	413	30	630
Hazardous waste reduced (Ton per year)	8172	110	1335	595	198	574
Financial savings at firms (Million CZK per year)	9,7	30,5	43,9	103,9	20,5	39,1

Being resource of new know how

Regional projects

The most important new approach in dissemination of CP especially to small and medium size enterprises was development of projects in cooperation with municipalities, following model of successful program ECOPROFIT Graz and closely cooperating with Stenum Graz developer of the know-how.

Regional cleaner production projects make use of natural relationships among local enterprises, state administration and self-government and other interested parties. All the local stakeholders have common interest in the improving quality of environment in their city or region and in the increasing competitiveness of the local companies. Projects are carried out in form of several-months interactive course, in which 6-10 enterprises are involved.

After municipalities have seen the results of the projects there were committed to contribute financially to their follow up. This was important contribution to sustainability of there projects based on financing from local industry and municipality. A good example of fruitful co-operation can be seen, for instance, in the established relationship with the National Network of Healthy Towns.

Integration of CP and EMS
Another important new know-how was integration of CP and Environment Management Systems (EMS). The need for changes in management system to sustain CP program in enterprises was clear already after implementation of the first projects. This proven to be one of the differences in comparison with enterprises in countries where the concept of CP come from. They could integrate CP into functioning management system. However, we have found in our projects that most of enterprises need to develop such a system and CP methodology alone does not provide tool to do it.

EMS focuses on changes in the management system of enterprises and provides an appropriate framework for the long-term implementation of the CP programme within them. CP methodology focuses on the optimisation of the operating system and represents a tool for the continual improvement of the enterprises environmental performance – the very purpose of EMS implementation.

CPC started with integration of CP and EMS already in 1995 again with support of Stenum Graz within the UNIDO/UNEP program. The first enterprise with the intergraded CP/EMS system was certified against ISO 14001 in 1997. First regional CP/EMS project was implemented in 1998 in three enterprises in Zlín - in two municipal companies (Technical services and Water supplies and sewerage) and a small building company. In 1999 another projects started in the co-operation with Carl Bro (Denmark) in Rož nov following the EMAS standard.

The aim of CP demonstration projects is to show the benefits of CP and build professional teams within companies so that they will initiate a process of continuous improvement of CP. This aim is totally met only by those enterprises, which have integrated CP into their management system.

The principle objective of the CPC's new projects is to develop a CP methodology, which will integrate voluntary strategies in the environmental protection. A special attention will be paid to eco-design. The CPC will develop drafts of demonstration projects for individual production branches and will focus on the environmental impact of their activities.

International projects
CPC amended methodologies, which are being used in other countries to the Czech conditions. Acquired long-term experience and results of demonstration and training programmes in the Czech Republic were the basis for assistance in building the base for cleaner production in Croatia during the period of 1997-1999 and in Uzbekistan during 1997-1998. The project in Croatia was implemented in the framework of multilateral development assistance programme of the Czech Government under the UNIDO/UNEP NCPC Programme.

Developing demand for cleaner production.
There were some important milestones in development of demand for CP through governmental support in the Czech Republic. The first was establishment of CP Program at the State

Environmental Fund. The program supports investment needing CP measures through soft loans. CPC provides technical assistance to the fund within this program.

The Minister of Environment has signed the International Cleaner Production Declaration Within the High Level Meeting of NCPC in Prague in March 1999.

The Czech government in February 2000 adopted the Governmental Decree on Cleaner Production. Part of the Decree is the National Cleaner Production Programme. The Program provides guidelines for each governmental sector. The adoption of the program started integration of CP programs into development and implementation of policies of particular ministries.

The promotion of CP concept to governments is a process, which is for the time being in CEEC´s very much driven by concrete individuals. In case of the Czech Republic the achievements presented above were possible only because of strong commitment of concrete people at Ministry of Environmental of the Czech Republic.

COMPUTER AIDED MOLECULAR DESIGN PROBLEM FORMULATION AND SOLUTION: SOLVENT SELECTION AND SUBSTITUTION

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Abstract
A framework for the identification of environmentally benign and alternative solvents is presented. The methodology for solvent design and selection contains multiple phases: pre-design, design and post-design. A multi level CAMD method capable of generating a selection of candidates meeting the required specification without suffering from combinatorial explosion is presented and the entire framework is illustrated with a case study. The case study identifies alternative solvents for Oleic acid methyl ester as replacements for Ethyl ether and Chloroform.
Keywords: Solvent, substitution, CAMD, group contribution, pollution prevention, process synthesis

Introduction
One of the principal causes of pollution is the presence of a substance (or substances) in amounts higher than the allowed maximum in one or more streams released to the surroundings. Substitution of the polluting substance (or substances) by another that performs the same function in the process but is environmentally benign is one way of dealing with such environmental problems. Computer Aided Molecular Design, commonly known as CAMD, is well suited to solving this class of environmental problems (pollution prevention and/or treatment) because it can design/find the candidate replacements more efficiently than other search techniques.

Current applications of CAMD within this area have addressed environmental concerns and constraints using simple property estimation methods based on the group contribution approach. Also, most CAMD methodologies so far have designed relatively simple compounds by collecting fragments into group vectors (Mavrovouniotis (1998) lists a series of examples with references in his review of CAMD). While the generation of group vectors suits property prediction using group contribution approaches, the generated compound descriptions do not contain the additional structural details needed for the QSPR or QSAR methods, for example, a 3D representation of the molecular structure. It is therefore necessary to generate more detailed molecular descriptions in the CAMD algorithm. In this paper, a process systems engineering approach is applied to prevention and/or treatment of pollution through an integrated set of computer aided tools.

Solution methodology

The method of solution for the compound design and selection problem is an iterative process consisting of 3 phases: pre-design, design and post-design. The result of a successful completion of the algorithm is a list candidate molecules. All the candidates fulfil the property requirements set as design criteria.

Pre-design Phase

In the pre-design phase, the causes of pollution are identified together with the polluting substances and their undesirable properties. Once the causes have been identified it is necessary to formulate the strategy for solving (curing) the pollution problem. The routes of information leading to the identification include simulation, engineering knowledge, regulatory requirements, and observations of existing practices as well as changes in environmental policy.

CAMD can be used in the instances where the cure either involves the replacement of a process fluid or removal of a pollutant by using a solvent based separation technique. In the case of replacement solvents the general process equipment and operations have already been fixed and the substitute must function in all of them. If the search is aimed at finding a compound for use in a removal (cure) operation there are additional degrees of freedom since the separation method has not been fixed. In such cases different searches can be performed for the various feasible separation techniques. Determining the set of feasible separation techniques to consider is a separate sub-problem involving process design techniques.

After the problem has been identified and a solution strategy selected the pollution prevention or treatment problems are formulated in terms of desirable and undesirable properties. From an environmental point of view it is obvious that the properties of interest include environmentally related properties. It is however also necessary that the compound fulfils its operational role and there are therefore additional specifications that depend on the type(s) of operation(s) the compound is to take part in. A knowledge base is used to assist in the selection of the application-related properties and their values.

Design Phase

In the design phase the identification of compounds possessing the desired properties is performed by generating compounds matching the specifications. This is achieved by assembling building blocks. The evaluation of properties is performed using predictive techniques. By combining fragments to form molecules a wide range of compound can be generated and screened.

The methodology used for the generation approach is a multi-level approach. The computational complexity is controlled using two techniques: (a) Partitioning: by subdividing the generation procedure into several successive levels with a screening step between each level (allowing only the most promising candidates to progress to the next level) ensures that computational efficiency is maintained. (b) Feasibility: ensuring that only chemically feasible structures are generated not only improves the quality and ease of interpretation and analysis of the results but also eliminates the computational resources spent on false solutions. The method consists of four levels. The first two levels operate on molecular descriptions based on groups while the latter two rely on atomic representations (Harper, 2000). In outline form the individual levels has the following characteristics:

Level 1
In the first level, a traditional group contribution approach (generation of group vectors) is used with its corresponding property prediction methods. Group vectors are generated using a set of building blocks as input. The employed approach does not suffer from the so-called "combinatorial explosion" as it is controlled by rules regarding the feasibility of a compound consisting of a given set of groups (Harper, 2000). Only the candidate molecules fulfilling all the requirements are allowed to progress onto the next level.

Level 2
At the second level, corrective terms to the property predictions are introduced. These terms (so called second-order groups) are based on identifying substructures in molecules. At this level molecular structures are generated using the output from the first level (first-order description) as a starting point. The generation step of this level is a tree building process where all the possible legal combinations of the groups in each group vector is generated.

Level 3
In the third level, molecular structures from the lower levels are given a microscopic (atomic) representation by expanding the group representations in terms of the atoms each group is made up from. This can generate further structural variations. Furthermore the conversion into an atomic representation (including connectivity) enables the use of QSAR/QSPR methods as well as structural analysis methods. The possibility of using QSAR/QSPR methods and structural analysis significantly increases the applicability of CAMD in environmental applications since many environmental properties are only possible to estimate using such techniques and the available techniques are very specific with respect to the compound types they are applicable to. As an added benefit the structural analysis enables the re-description of the candidate compounds into other group contribution schemes thereby further broadening the range of properties that can be estimated as well as giving the opportunity to estimate the same properties using different methods for comparison.

Level 4
In the fourth level the atomic representations from level three are further refined to include the 3D position of the individual atoms. This conversion gives the opportunity to create further isomer variations (cis/trans and R/S) and is performed in a way that the output is compatible with most molecular modelling applications. Since property prediction using molecular modelling is a task difficult to automate the estimation and screening process is done interactively.

Post-Design Phase
In the post-design phase, the final selection from the generated list of feasible candidates is made. The final selection is done after careful analysis of the identified candidate molecules. Even though the results from the design phase fulfil the property requirements there are properties and criteria that are difficult to handle using automated prediction methods. Examples of such criteria and properties are: Availability, Price, Regulatory restrictions, Long term health effects, Detailed environmental fate and Process-wide behaviour.
The methods used to assess the additional considerations include external databases as well as other computational tools such as process simulators, environmental fate models and phase behaviour calculators. Which tools to use depend to a large extent on the type of application the compound is being designed for and the available range of applicable tools. After analysing the candidate compounds the final candidates must be selected for experimental testing or rigorous simulation. Regardless of the approach used for the selection of final candidates, the primary function of CAMD – identifying a set of candidates having the properties needed for a particular application - has been achieved.

Case study
The fatty acid ester "Oleic acid methyl ester" ((Z)-9-Octadecenoic acid, Methyl ester) is an important compound in a variety of applications, such as: intermediate for detergents, emulsifiers, wetting agents, stabilizers, textile treatment, plasticizers for duplicating inks, rubbers, waxes, biochemical research and as a chromatographic reference standard (NTP, 1999). Reported pure component solvents for Oleic acid methyl ester are: Diethyl ether and Chloroform (NTP, 1999) with Diethyl ether being reported as the best solvent. While both of the reported solvents are effective they also have unwanted properties. Diethyl ether is very volatile and flammable (including the risk of formation of explosive peroxides) and Chloroform is a suspected carcinogen. It is therefore desirable to identify alternative solvents that are safer and more environmentally benign than the above mentioned.

Pre-Design Phase
Determine a solvent having the following characteristics: (a) Liquid at (ambient) operating conditions. (b) Is non-aromatic and non-acidic (stability of ester). (c) Has low environmental impact and poses limited health and safety problems. (d) Is a good solvent for Oleic acid methyl ester.
The goals can be formulated as property constraints using the following values: Melting Point (T_m) < 280 K, Boiling Point (T_b) > 340 K.

The requirement of low environmental impact can only be addressed in part using property and molecular type constraints (non-aromatic compounds). The true environmental behaviour of a candidate compound must be assessed in the post-design phase as part of the analysis. However, it is possible to address some environmental considerations via a property constraint: (a) Compounds must be acyclic and must not contain Cl, Br, F, N or S. (b) Octanol/Water Partition coefficient (logP) < 2 (lower is better).
The determination of solvent ability towards Oleic acid methyl ester should ideally be calculated using an activity coefficient approach. However, since the solute in question is quite complex and very few predictive methods (e.g. UNIFAC, ASOG) are capable of handling large compounds the solubility requirement is addressed using a solubility parameter approach. Based on the theory of solubility parameters, a good solvent has a solubility parameter that is close to that of the solute. In the case of Oleic acid methyl ester the solubility parameter is 16.95 $(MPa)^{0.5}$. The solubility criteria than then be formulated as: $15.95\ (MPa)^{0.5} < Solpar < 17.95\ (MPa)^{0.5}$

Design Phase
Using the formulated CAMD problem with the added constraint of only allowing two functional groups in a compound (prevents generation of very complex and thereby expensive compounds) the following results are obtained:

- In level 1 of the CAMD procedure 2691 vectors of groups were created. After screening against the constraints 425 representations remained and were passed onto the next levels.
- 4593 molecular structures were created in level 2 based on the input from level 2. After screening 1351 candidates were passed on to level 3.
- No additional isomer forms were generated in level 3 and no screening was necessary (all properties had been handled in level 2).
- The final result from the CAMD approach was a total of 1351 compounds.

Stage 4
In order to select the prime candidates from the 1351 alternatives obtained from the CAMD solution an extensive analysis must be performed on the candidates. If only performance considerations are taken into account (i.e. how close the solubility parameter matches that of the solute) the following candidates are the most promising: Formic acid 2,3-dimethyl-butyl ester, 3-Ethoxy-2-methyl-butyraldehyde, 2-Ethoxy-3-methyl-butyraldehyde.
A more rigorous analysis has been performed but cannot be reproduced here due to the page limitation. The results are obtainable from the authors on request.

Conclusion
The algorithm outlined above provides an opportunity to solve pollution prevention and/or treatment problems in a more rigorous manner since widely used and more accurate property estimation methods can be used without sacrificing efficiency of the method of solution. This enables the user to find solutions that not only protects the environment but also has a high environmental benefit and/or process efficiency. The process systems engineering approach has combined aspects of computational chemistry, property prediction and process design for the solution of problems of current and future interest. A case study involving replacement of solvents with environmentally acceptable substances has been presented.

References
NTP, 1999 "Chemical Health & Safety Data", National Toxicology Program, Online database.
Harper, P. M., 2000,"A Multi-Phase, Multi-Level Framework for Computer Aided Molecular Design", Ph.D. Thesis, Dept. Chem. Eng., Tech. Univ of Denmark.
Mavrovouniotis, M.L., 1998, "Design of chemical compounds", Computers and Chemical Engineering

THE FIRST STEP TOWARDS SUSTAINABLE BUSINESS PRACTICES: THE SB "DESIGN FOR ENVIRONMENT" TOOL KIT

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Abstract
This presentation will provide a general overview of several initiatives we are undertaking in the area of "Design for Environment" and our efforts to determine what "Green Chemistry/Green Technology" mean for our company. We will describe how we are using Sustainability Metrics (Environmental), provide an in-depth review of our chemistries, and explain our use of Lifecycle Inventory and total cost assessment (TCA) methods to answer the very difficult question of what is really "Green." Our findings to date suggest that no single methodology in isolation will yield the "correct" or best result; rather, each different methodology informs the other and provides different viewpoints and potential answers to many difficult questions. A lack of standardized approaches to using these methodologies, and differences in impact valuation, present very clear challenges as to how best interpret data and make sustainable business decisions. Preliminary results will be presented to show the types of learnings that we are gaining as we have developed our sustainability metrics, pursued a detailed lifecycle inventory of a major drug product, evaluated our chemistries,and collaboratively developed a TCA tool.

Summary of presentation
The presentation gave a brief overview of sustainable business practice at SmithKline Beecham with focus on the Design for Environmental Tool Kit. The most effective ways to integrate sustainable business practice are considered to be

- Life Cycle Assessment
- Total Cost Assessment and
- Green Chemistry

How do you weave the sustainability into an every day business practice in a multinational business? First of all, if you are not keeping score you are not acting. There a very different

Figure 1. Eco-Efficiency Metrics

paradigms for measuring. One of these are set by the World business Council as shown in figure 1. However, what we stress is that sustainable metrics are not environmental performance metrics or eco- efficiency metrics. Under the auspices of American Institute of Chemical Engineers' Center for Waste Reduction Technologies, SmithKline Beecham together with other large pharmaceutical companies and chemical companies has tried to define what sustainable metrics means and what will be useful to the companies. One approach is to combine efficiency type metrics with economic information. It is important to pick the right set of metrics. SB is working on moving the company from environmental performance metrics to sustainability metrics, see figure 2.

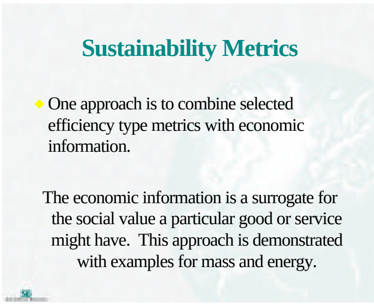

Figure 2. Sustainable Metrics

Why does SB want to design for an Environment Tool Kit? In essence, because of the nature of our industry, it is very difficult to make substitute changes after a product is in production. The company is highly regulated and if you make changes in the profile of i.e. a pharmaceutical product you have to re-do clinical trials, which is very costly.
So if you want to make changes you have to do it when developing the product. We want a tool that can be used by the chemical engineers as they are making their choices and highlighting issues as early as possible, so you have the time to come up with appropriate solutions.

Life Cycle Assessment
Beside metrics we focus on whole idea of LCA, Total Cost Assessment and Green Chemistry. However, the controversial issue of LCA is the evaluation of impacts. We know what the impacts are, but how the impacts are weighted is still a controversial question. At SB we are involved with LCA in two areas

- Packing
- Pharmaceutical R&D

Packing is in large part driven because of the European Packing Directive. Every new concept of packing has to go through a life cycle assessment as part of the decision process and an easy accessible tool is provided on the SB Intranet Site, see figure 3 and 4.

Figure 3. SB Intranet Site

Figure 4. Packaging Development

For pharmaceuticals R&D work has been ongoing for a couple of years. The goal is to develop a framework tool for the scientist, much like the packaging tool. The task of getting life cycle data is quite huge. We started out by contacting our suppliers to see if data was available but only a couple of companies were actually able to deliver data. SB is working with professor Michael Overcash, North Carolina State University to develop a database essentially from scratch. At present there is approx. 300 chemicals in the database whereof about 125 are SBs. A Life Cycle Inventory-model showed that solvents in the products cause major environmental impacts, and one of the first actions at SB was to develop a Solvent Selection Guide.

Total Cost Assessment

Another tool that is considered useful is Total Cost Assessment, which translates the impacts into dollars. We believe that we can sell this concept easier in the business environment. People can see dollars, whereas it is hard to see global warming or eutrophication, when they do not even know what that means. Dollars you can understand.
A prototype tool for total cost assessment has been developed and is being tested in different companies, but there are still a lot of gaps.

Green chemistry

With regard to Green chemistry, complex molecules, complex chemistry, and regulations constrain pharmaceutical companies more than perhaps other industries. Up till now focus has been on waste loads which mostly means waste minimization that is not the right driver for sustainability. To develop green chemistry in context with sustainability, we looked at all the chemistry that we could find in the company for the last 10 years. We ended up with over 200 examples from 35 products. These were categorized. 25 chemicals represented 80% of all the chemicals that we use. Now we are evaluating each of these for their greenness. The goal is to come up with metrics similar to the sustainability metrics.

BIOLOGICAL CONTROL OF MICROBIAL GROWTH IN THE PROCESS WATEROF MOULDED PAPER PULP PRODUCTION - AVOIDING THE USE OF BIOCIDES

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Abstract
Among the large water consuming industries are the paper mills, including paper mills based on recycled paper. Recycling of the white water results in a build-up of components released from the recycled paper and components added during the production. One of the serious problems encountered when decreasing the water consumption through increased recycling, is caused by the high concentrations in organics, COD, released from the paper. A major part of the COD is easily degradable by microorganisms, which give rise to excessive microbial growth in the water system, if not controlled. Such excessive growth of biomass in the water and production system may lead to various problems and nuisances, like foul smell, corrosion, clogging, reduced product quality, reduced hygienic quality of the working environment.

As part of a large Danish project on industrial water management, CEVI, various scenaria for optimising the water management at the recycled paper factories are being evaluated, aiming at avoiding the addition of biocides for controlling the biological growth. The most promising scenaria are being investigated experimentally. The scenaria comprise: avoiding the biofilm growth by addition of dispergents; aerobic removal of organics; anaerobic/aerobic removal of organics; membrane filtration for removal of organics and subsequent anaerobic digestion of the organics in the concentrate; The scenario evaluation activities include model simulations and technical/economic/environmental evaluations.

Introduction
As water is getting a limiting resource water reuse has become more and more attractive in the water consuming industries. Among the large water consuming industries are the paper mills including paper mills using recycled paper. Recycling of the white water has already been implemented in many mills, and the water consumption lowered significantly and even closed in some cases. Closed water circuits have until now in most cases required large dosage of biocides to control growth, and thereby avoid corrosion, bad odours and deterioration of the paper quality produced.

Attempts to control the growth of microorganisms in the water system have been described in literature. Some of these efforts have focused on optimizing the water circuit around the stock preparation and the paper machine, while others focus on removal of the substrate and microorganisms.

Biological treatment of the effluent wastewater from paper mills is well known and described in the literature. Möbius and Cordes-Tolle (1994) review the existing knowledge and best available technology and discuss the possibilities of further reuse of water in the paper industry by using biologically treated effluent in the process.

The most common way of controlling the microbial growth today is the addition of various biocides. However, due to the harmful impacts of biocides on the environment, the growth control by biocides addition is not an attractive long-term solution and new control measures are being investigated.

To control the biological growth in the water circuit without using biocides, different strategies can be used. In table 1 the different mechanistic ways to control the growth and possible technologies, which can be applied, are described.

Table 1. Control of microbiological growth: Mechanisms and Technologies

Mechanism	Technology
Removal of the substrate	Biological treatment, Membrane filtration
Removal of the microorganisms	Membrane filtration,
Killing of the microorganisms	UV, Ozone, Biocides

The increased reuse of paper leads to a steadily deteriorating quality of the raw material and an increased content of small organic molecules like volatile fatty acids. These organics are an excellent substrate for bacterial growth, and if sufficient nutrients are present the growth will be difficult to control. Removal of the substrate can be done by controlled biological growth in an aerobic or anaerobic stage or by membrane filtration.

Removal of the microorganisms will solve the problems with the suspended bacteria but biofilms will still develop in pipes and tanks and the effect will therefore be local. Killing of the bacteria by ozone or UV has the same limitations. It will only be efficient locally, while growth still is possible in pipes and tanks. The best solution thus seems to be removal of the growth potential from the water through removal of the easily degradable organics.

Hartmann waste paper processing mill

Hartmann produces egg trays and other products of moulded paper from recycled newspapers. The factory has implemented different water recycling methods to reduce the water consumption. The white paper from the paper machines is flotated before reuse for pulp preparation and at the paper machines, partly for adjustment of the consistency of the pulp and partly for spray water at the machines. The spray water requires low suspended solids content. A side stream of the flotated white water is sand filtrated and reused for special technical purposes. With the implemented water reuse technologies, the water consumption has been reduced to around 5-10 m^3/ton of the product. The cleaning methods implemented until now have focused on removal of fibres and other suspended solids leaving dissolved organics and inorganic substances unaffected.

The factory is now facing two major limits for further recycling:

– The content of dissolved organic matter has reached a level where growth in the water system is getting difficult to control.

– The concentration of different ions is reaching a level where precipitation in pipes and nozzles may cause problems.

The system consists of 4 stock preparation pulping units and 10 paper machines for moulded paper production. Part of the pulp is dewatered at a belt filter press before the paper machines to establish water recirculation around the stock preparation and water recirculation around the paper machines. A simplified flow sheet of the production and recirculating white paper is presented in figure 1.

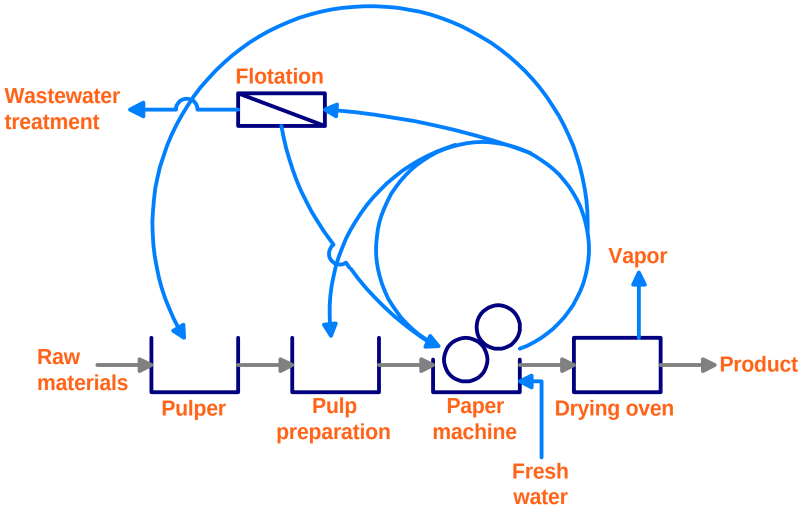

Figure. 1 Flow-scheme for production of moulded paper.

Scenaria for avoiding biocide addition to white water system

A system analysis has revealed three conceptually different scenaria for control of the biofilm growth potential in the white water system, without the addition of biocides. The scenaria are shown in Figs. 1, 2, and 3.

In the first scenario the growth potential in the white water system is reduced by biological removal of the easily degradable organics in the white water.

In scenario 2, the biological growth is suppressed by removal of the organics in the white water by membrane filtration. The organics in the concentrate are utilised by biogas formation through anaerobic fementation.

In the third scenario the pulp is washed and two water loops are introduced: one around the pulper and one around the paper machine. The organics are removed from the water loop around the pulper.

The three scenaria are subjects to technical/economic/environmental evaluations. Mathematical simulations and experimental investigations are applied in order to identify and design the optimal concept for bio-growth control without the addition of biocides.

Besides the above mentioned scenaria it is also being part of the study to investigate the substitution of biocides with the addition of dispergents to the process water system. The mechanism involved is that microbiological growth is allowed to take place, but formation of the problem causing biofilm is avoided through the addition of components affecting the tendency of the microorganisms to adhere to surfaces.

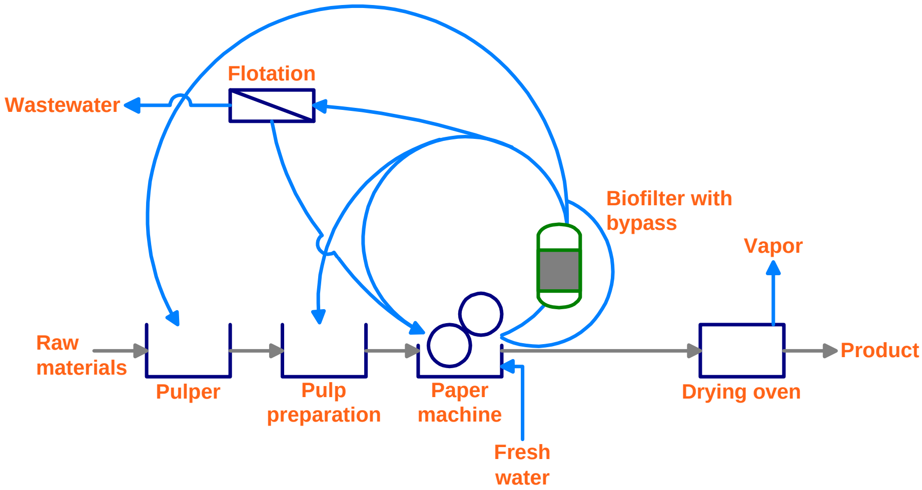

Figure 2. Scenario 1. Removal of organics by biological treatment at white water loop.

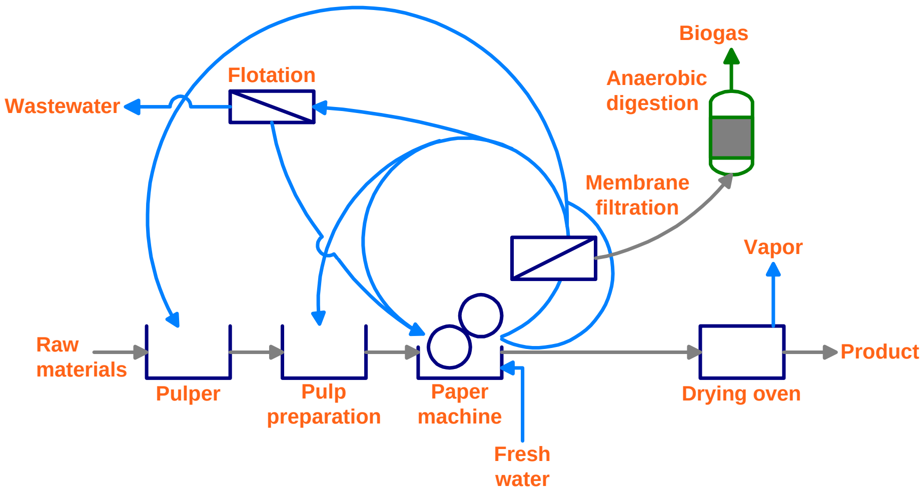

Figure 3. Scenario 2. Removal of organics by membrane treatment at white water loop.

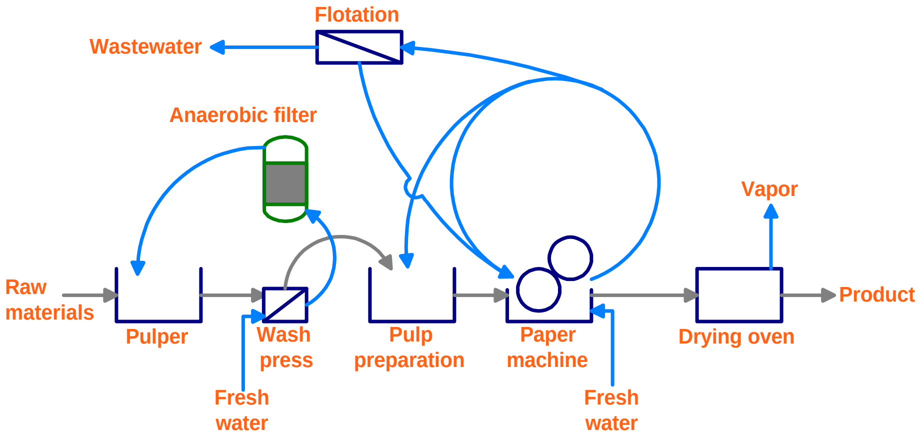

Figure 4. Scenario 3. Removal of organics by biological (anaerobic) treatment at pulper water loop.

Treatment and characterization of white water

Pilot plant experiments with bio-filtration at the Hartmann factory in Tonder (Jepsen et al., 1996) have shown that it is possible to remove efficiently the easily degradable organics, thereby reducing the growth potential in the process water system. Very high loads have been applied to the biofilter due to the favourable growth conditions: easily degradable organics and a high process temperature. Dosing of nutrients, nitrogen and phosphorus, to the biofilter were needed. Effective control of the nutrient dosage was essential, as excess nutrients were recycled with the treated water, resulting in an enhanced growth potential in the water system.

Oxygen utilization rate (OUR) measurements have been used to characterize the degradability of the COD in the white water before and after biological treatment. OUR measurements give the basis for calculating the different fractions of the carbon; easily degradable, easily hydrolysable, and slowly degradable (Kristensen *et al*., 1992). From the OUR experiments it can be calculated that about half of the COD content in the white water can be removed in the biofilter. The rest of the carbon will only cause minor problems with growth because it has to be hydrolyzed before the microorganisms can utilize it.

Experiments with membrane filtration have shown, that it is feasible to apply this technology on the white water (Knudsen et al., 1996). The experimental work was undertaken with ultra filtration and further investigations are needed to explore the possibilities for reverse osmosis.

Before implementing new technology in the paper mill it is important to evaluate possible new barriers for extended water reuse. At Hartmann the content of inorganic ions especially sulphate and calcium may cause problems with precipitation. To reduce the water consumption further it may be necessary to substitute aluminium sulphate with other chemicals in the production.

Conclusions

From pilot plant experiments it was found that the biological filtration was an efficient way of reducing the content of easily degradable organics; thereby reducing the growth potential in the process water system.

Membrane filtration by reverse osmosis is another possible way of reducing the content of easily organics in the white water. However, long-term experiments need to be undertaken if the technical/economical/environmental evaluation points at this scenario as being attractive.

Separating the process water system into two systems; one system around the pulper and one system around the paper machine; might be an attractive solution for removing the organics released from the raw materials. The biological processes applied to remove the organics from the pulper water loop are well known and process wise the scenario is considered feasible.

The mathematical simulation is considered a valuable tool for optimisation of each scenario, once the scenario is identified.

Large scale experiments are recommended with all scenarios before full scale imlementation, in order to evaluate/quantify the impact; i.e. the biofilm growth control; on the process water system.

References

Jepsen S.E., G.H. Kristensen, H. Wenzel, H.H. Knudsen, A.L. Mortensen, U. Ringbæk (1996). Control of Microbiological Growth in Recycling Water in a Waste Paper Processing Mill. *Wat. Sci.Tech.* Vol 34, No.10, pp 105-112.

Knudsen, H.H., H. Wenzel, J. Wagner, S.E. Jepsen, G.H. Kristensen, A.L. Mortensen, U. Ringbaek (1996). Membrane separation processes in recycling paper processing mills. Presented at 5. IAWQ Symp. on Forest Industry Waste Waters. Vancouver, Canada, 10-13 June 1996.

Kristensen, G. Holm, P. Elberg Jørgensen and M. Henze (1992). Characterization of functional microorganism groups and substrate in activated sludge and wastewater by AUR, NUR and OUR. Wat. Sci. Tech. Vol 25 No 6, pp 43-57.

Möbius C.H. and M. Cordes-Trolle (1994). Production Dependant Specific Data of Paper Mill Wastewater: Information for Treatment and Reuse. *Wat. Sci.Tech.* Vol 30, No.3, pp 193-198.

ENVIRONMENTAL LIFE CYCLE ASSESSMENT OF ALTERNATIVE SCENARIOS FOR BIOLOGICAL CONTROL OF MICROBIAL GROWTH IN THE PROCESS WATER OF MOULDED PULP PRODUCTION

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Abstract
This paper comprises the environmental feasibility study of 7 different scenarios for biological control of microbial growth in the process water of moulded pulp production at Brdr. Hartmann A/S. The study is a simplified Life Cycle Assessment of the environmental consequences of each scenario compared to the present operation as reference. The Life Cycle Assessment comprises material and energy flows within the cradle-to-grave system of all equipment to be installed in the scenarios in question. The assessment proves an in-line anaerobic treatment to be environmentally preferable and shows that the energy flows in the operation of the biological plants are key to the environmental profile of the scenario.

1. Introduction

The Danish moulded pulp producer Brdr. Hartmann A/S continuously strives to improve the environmental performance of their processes and the environmental profile of their products. The company produces moulded pulp products, mainly egg trays, based on waste paper. A high degree water reuse is implemented. Like for all paper mills of this kind, control of microorganisms in the water system is a necessity, and like other paper mills, Hartmann uses biocides. Hartmann seeks, however, alternative ways of controlling the microbial growth in the system in order to avoid the use of biocides, and the feasibility of biological control is being investigated. Several scenarios for aerobic and anaerobic in-line treatment of the process water is being studied, and their technical, economic and environmental feasibility assessed.

As the means of studying the environmental feasibility of a scenario, Hartmann uses Life Cycle Assessments and this was the case also for studying these water reuse scenarios. Life Cycle Assessment is, however, a time consuming discipline, and in this case, a simplified approach was used, developed by Wenzel et al. (1999).

1.1 The Concept of Life Cycle Assessment

Environmental Life Cycle Assessment (LCA) is a tool for assessing the environmental impacts of a product, or more precisely, of a product system required for providing a particular unit of function. The term product system is taken to mean the product throughout its entire life-cycle, from cradle to grave, in terms of all the economic processes involved. The term economic process – employed as the converse of environmental process – refers to any kind of process producing an economically valuable service such as e.g. a manufacturing process, a transportation or a waste handling. LCA takes as its starting point the service provided by a product system and, in principle, takes into account as far as possible all the environmental impacts of all the processes needed to provide this service – from resource extraction, through materials production and processing, consumption or use of the product, to waste processing of the disposed product.

LCA is not one specific method, but rather a framework for a systematic and comprehensive environmental assessment of goods and services. Traditionally, only detailed, quantitative LCAs have been accepted as "real" Life Cycle Assessments, but both on the methodology side and in practical applications more simple approaches are being developed and used. Three types of LCA approaches can be identified (Christiansen ed., 1999):

(i) **Life Cycle Thinking** is commonly used term for qualitative discussion to identify the stages of the life cycle and/or the potential environmental impacts of significance e.g. for use in a design brief or in an introductory discussion of policy measures. The greatest benefit is that it opens for a holistic view and helps addressing potentially essential implications of a given decision in a wider scope. Life Cycle Thinking is mainly qualitative and does not support addressing proportions.

ii) **Simplified LCA** is an application of the LCA methodology for a comprehensive screening assessment, i.e. covering the whole life cycle but in an overall manner without a great degree of detail e.g. using generic data (qualitative and/or quantitative), standard modules for transportation or energy production – followed by a simplified assessment, i.e. focusing on the most important environmental aspects.

iii) **Detailed LCA** is an application of the LCA methodology for a detailed, quantitative life cycle inventory analysis and life cycle impact assessment of all important environmental aspects of the product system.

1.2 Simplified Life Cycle Assessment

LCA is commonly perceived as being complex, time consuming and expensive, and many potential users of LCA are put off as a result of that. However, a "full" LCA, if such a thing exists, may not be required. In many cases, all that is needed is a simplified, cost effective LCA.

Simplification, however, may affect the accuracy and reliability of the results of the LCA. This may make the LCA results of little value. What is needed is an LCA that involves less cost, time and effort, yet provides answers/results that meet the goal of the LCA with a sufficient accuracy. Thus, the aim of simplification must be to identify those areas within the LCA, which can be omitted or simplified without jeopardising reliability.

A simplified LCA should cover three steps, which are iteratively linked (Christiansen ed., 1999):

i) **Screening**: Identifying those parts of the system or of the elementary flows that are either important or have data gaps

ii) **Simplifying**: Using the findings of the screening and focusing the work on the important parts of the system or of the elementary flows. Doing the LCA on these parts.

iii) **Assessing reliability**: Checking that simplifying does not significantly reduce the reliability of the overall result.

In all cases, an LCA study covers *four* interrelated phases named 1) Goal and Scope Definition, 2) Life Cycle Inventory Analysis, 3) Life Cycle Impact Assessment and 4) Life Cycle Interpretation. The goal and scope definition should not be simplified, but the other phases can be simplified by applying methods of screening, simplifying and assessing reliability.

Goal and Scope Definition
All LCA studies should start with a goal and scope definition. The goal and scope definition should state unambiguously the intended application, including the reasons for carrying out the study and the intended audience, i.e. to whom the results of the study are intended to be communicated. Because LCA is an iterative process, the scope of the study may be altered during the study as the insight increases and/or additional information is collected.

Inventory Analysis
In order to develop *effective simplification methods*, it is obvious to address the *Life Cycle Inventory Analysis,* which is typically the most time consuming phase, with the greatest potential for savings. The Life Cycle Inventory Analysis phase offers the greatest scope for simplifying due to its data intensive nature. The majority of methods to simplify the life cycle inventory analysis are therefore aimed at reducing the data collection requirement.

In comparative LCA studies, it is important to ensure that the system boundaries, data quality and data sources are as similar as possible for the product systems being compared, otherwise an incorrect result is likely to be produced. The essential topics that have to be taken into consideration during simplification are categorised below:

i) Data Priorities: The availability of data is a common problem in LCA. One, therefore, often has to accept data that are not highly accurate. Some methods of dealing with data gaps are given below with a descending order of accuracy:

- Use calculated/ measured data
- Use best available data from a similar product or process
- Make estimates, e.g. educated guesses, estimated data from design and engineering figures or from past experience and process knowledge.
- Use data from regulatory requirements/legislative limits
- Use qualitative data, e.g. as often done in eco-labelling.

Since primary data that is specific to the product system under consideration is rarely available and necessitates very extensive data collection, secondary or generic data sources can be used i.e. from literature or databases.

The problems that arise when using secondary data sources are mainly due to the poor transparency of the data quality i.e. on how well the data represent the process/system in question. Also, as final results are typically published, it is difficult to determine the relative environmental impacts of the various stages of the life cycle and the contributions made by energy generation, transportation, waste management etc. Difficulties also occur in comparing different secondary data sources due to variations in data quality and system boundaries. In addition, secondary data may not be representative of the whole industry, particularly if the data is based on only a small sample of the industry.

ii) Use of a limited number of inputs and outputs: Ideally, data should be collected on all the environmental inputs and outputs, i.e. energy and raw material consumption and emissions to the air, water and land. However, it may be adequate to focus on only one area, e.g. energy consumption, if other areas are equal for the compared systems.

Life Cycle Impact Assessment

The life cycle impact assessment phase will be simplified by regarding the choice of environmental problem themes and issues and the calculation of theme scores and weighting factors.

One approach is to use impact indicators like for instance 'energy use'. Several simplified LCA method use such an approach (Leffland et al., 1997), (Wenzel et al., 1999) using indicators for energy related impacts, impacts related to chemicals and resource consumption.

Assessing Reliability

The aim of simplification in LCA is to derive results that are sufficiently reliable for the required purpose, while putting in less effort than in a detailed LCA study. In order to check that a simplified LCA achieves this, the final step in a simplified LCA needs to be the reliability assessment.

The reliability of a simplified LCA will depend on the same factors affecting the reliability of a detailed LCA. The factors can be briefly categorised as:

i) Data quality and relevance, which ensures that appropriate data with respect to time period, geography and process, are used. In addition to that, the data gabs have to be filled. This can only be done by expert judgement.

ii) Methodological choices. The overall reliability of the conclusions has to be related to the goal and scope of the LCA study. For the overall the choice of functional unit, system boundaries, goal definition, screening arguments are addressed.

iii) In simplified LCA, the data used may often be of lower quality/relevance than of a full LCA. One way to check the reliability of the final result is to identify the key data (those that most affect the final result) and then to check their level of uncertainty. This can be done using sensitivity analysis. This analysis is performed on selected parameters.

1.3 The simplification approach used in the study

The simplified LCA method used in the study was developed by Wenzel et al. (1999). The approach to simplification is:

i) to limit the scope of the study by using only very rough estimates for the life cycle stages of product manufacturing and transportation. The method guideline (Wenzel et al., 1999) justifies this and guides through how it is done,

ii) to limit the inventory to look at inputs and, thus, use inputs as indicators of outputs. This has been found to be adequate and often even better than to use data on measured outputs/emissions,

iii) to base the impact assessment on impact indicators in the categories: 1) materials consumption, 2) energy consumption, 3) chemicals consumption and 4) “other”. This has proven to be an operational way of covering relevant impact categories.

This approach saves a lot of time and effort and is sufficient for many applications. The difference between this simplified approach to the standard for detailed LCA’s (ISO, 1997) is illustrated in table 1.

Table 1. The components of a detailed LCA according to ISO 14040 compared to the used simplification method (Wenzel et al., 1999)

LCA (ISO 14040)	- *Simplified LCA (Wenzel et al., 1999)*
GOAL DEFINITION	- *Goal Definition*
- *Scope Definition* - Materials - Manufacture - Use - Disposal - Transport	- *Scope Definition* - Materials - (Manufacture) - Use - Disposal - (Transport)
Inventory Analysis - *Input data* - Output data	- *Inventory Analysis* - Input data
Impact Assessment - Classification - Characterisation - *(Normalisation)* - Valuation	**Impact Assessment** - Using aggregated environmental indicators
Interpretation	**Interpretation**
- *Decision*	- *Decision*

2. Life Cycle Assessment of water reuse scenarios in moulded pulp production

In pulp and paper industry, reuse of process water is in focus, and most companies strive to achieve a high degree of recycling without compromising product quality or working environment conditions. A high degree of recycling, however, improves conditions for microbial growth in the system, and to control the growth, companies most often use biocides. Other problems may follow a high degree of recycling, and the most commonly reported are:

i) Problems related to biocides.
ii) The concentration of salts giving rise to precipitations.
iii) Corrosion of equipment.

In the effort to seek environmental improvements, Hartmann look for options to avoid the use of biocides but still remain the same degree of water recycling or even increase this. One approach of achieving this is to remove the substrate of microbial growth instead of combating the growth. This could be done by an in-line biological treatment the plant. The biological processes may be aerobic or anaerobic, or a combination of these modes may be used.

2.1 Scenarios for water treatment and reuse

A number of scenarios using in-line aerobic or anaerobic treatment to remove the substrate for microbial growth in the back-water was studied. They can be implemented in the back water at different points, either close to the pulper or after the paper machine, see figure 1.

INVITED PRESENTATIONS

There was a wish to include anaerobic treatment, because it was intuitively believed to be potentially environmentally feasible due to the fact that energy (from methane) is *produced* during the COD removal as opposed to aerobic treatment *using* energy for the COD removal.

Initial modelling in the PC-tool WinGEMS from the company Pacific Simulation allowed an assessment of the steady-state conditions of the recycled water at various points of intervention of the treatment plant in-line in the system. The following key information was available:

- The water flow varies at the different points in the system. The dry matter concentration of the pulp is highest in the pulper (4%) and lowest down stream in the paper machine (1.3%). The water flow is, thus, highest just behind the paper machine. For the studied production volume (which is just part of the total production), the backwater flow at this point is around 200 m3/h.

- For the studied production volume, the COD load from the raw materials amounts to 24 kg/h of which around 50% is readily degradable in a biological treatment plant. The COD load of the added chemicals corresponds to around 12 kg/h of which 75% is judged to follow the product into the oven while 25% stays in the backwater. This COD is judged to be readily degradable. The load of readily degradable COD to the backwater is, thus, assessed to be around 12+3 equal to 15 kg/h in total.

- If a treatment plant is located to treat the total backwater flow and removes the readily degradable COD, it is, thus, evident that the steady-state COD concentration in the inlet of this plant is around 75 mg/l.

This modelling clearly shows that anaerobic treatment is not feasible at this point of intervention, the concentration of degradable COD is much too low. For an anaerobic plant to be attractive, the concentration of degradable COD should be at least five times higher, maybe even ten times higher. Moreover, aluminiumsulphate is added to the system, and the sulphate concentration is relatively high implying a high hydrogensulphide concentration in the gas.

The idea of segregating the system therefore arose, making a closed loop around the pulper, where the water flow is much smaller and where sulphate is not yet added. The release of COD to the water phase from the raw material was tested (Figueroa and Sanz, 2000) and found to be very quick. After just 10 minutes, all degradable COD was released. This would allow for segregating the system after buffer tank 1, filtering (and washing) the pulp at this point, and keeping the COD in a closed loop around the pulper at much higher concentrations – four to five times higher, and with only a small concentration of sulphate deriving from the raw material. If anaerobic treatment should be technically/economically feasible at all, it should be at this point of intervention. It might be necessary to treat the effluent from an anaerobic plant by an aerobic afterpolish in order to remove volatile fatty acids generated in the anaerobic plant. And it still might be necessary to have an aerobic treatment in the loop around the paper machine.

Therefore, a number of scenarios were modelled comprising a number of such combinations. One scenario without segregation of the system in two loops comprising, thus, aerobic treatment of the backwater in one system. Plus a number of scenarios with anaerobic treatment in a pulper loop and aerobic treatment in a paper machine loop as illustrated in figure 1. Moreover, the implications of by-passing part of the water and treating only part of it were modelled and included as scenarios.

In total, eight scenarios were assessed. It turned out, though, that the significant difference stood between anaerobic treatment and aerobic treatment in general, and the comparison is, therefore, shown here on four scenarios only.

2.2 Goal definition

The goal of the study was to compare alternative in-line biological water treatments to effectively remove the substrate for microbial growth in the process water and, thereby, avoid the use of biocides.

2.3 Scope definition

Only part of the total production volume at the company was studied, namely a production of 2500 kg/h of final product with a dry matter content of 95%. This is the overall service provided by the studied system, and this service should be provided unchanged by whatever solution is taken for the water treatment. Moreover, the service is specified to be provided for 25 years. The period of 25 years is selected, because it corresponds to the life time of the treatment plants.

In order to effectively remove the substrate for microbial growth in the system, the treatment plants would have to remove around 15-20 kg/h COD equivalent to around 3,300 – 4,400 tons COD per 25 years. This removal of COD from the process water corresponds to the daily COD addition with raw materials and chemicals and has been judged to be sufficient to avoid the use of biocides.

All candidates for a solution should provide this service, and should, moreover, be comparable on a number of other properties as well, see table 2.

Functional unit

Table 2 illustrates the qualitative and quantitative properties that the treatment plants used in the scenarios have to fulfil.

Table 2. Functional unit of the studied scenarios for water treatment and reuse

Qualitative properties	• Allow to operate the system without the use of biocides • Low manpower requirements for operation and maintenance • Not increase the amount of nutrients available for microbial growth in the overall system
Quantitative properties	• The removal of 15-20 kg/h COD continuously at the water conditions of the system
Duration	• 7 days a week for 25 years

The reason for specifying that the solutions should not give rise to an increase in available nutrients is, that nutrients, especially nitrogen, has been found to be limiting to the growth. A nutrient increase might, thus, counterweigh the COD removal to some extent.

Secondary services of in-line process water treatment plants
Besides providing the service described above, the aerobic and/or anaerobic plants in question will lead to the secondary services through the following by-products:

- Energy production from methane
- Sludge as compost and/or energy recovery source

A treatment plant would, thus, not only provide the service of water treatment for which it was intended, but also other useful services. The practical implication of the fact that these other services are provided would be, that alternative ways of providing these services would be substituted. In other words: if methane is produced and used, e.g. in Hartmann's own heat & power plant, which already runs on gas, natural gas would be substituted. And if biological sludge from the plant is being incinerated in a municipal waste- or sludge incineration plant from which energy is utilised (which is the case for such plants in Denmark), district heating and electricity produced by this sludge incineration will substitute conventional fuels for producing these utilities.

Of course, such substitutions caused by the secondary services imply environmental benefits, and it often turns out to be the most important issues in the study, because the flows related to these secondary services are relatively large. This turns out to be the case in this study as well, just consider the flow of 3,300 – 4,400 tons COD/25 years compared to the flow of materials for constructing the treatment plants. In an anaerobic plant, this flow of COD is either turned into gas or biomass (sludge) both giving rise to energy production in a subsequent incineration.

Another important flow being affected by the treatment plant is the final product:

- Removing COD from the process water of course implies that less COD will follow the product into the oven. This will lead to a slightly lighter product, as the COD is not contributing to the product's intended properties, wherefore the weight loss will not be compensated. As part of the product will be incinerated end-of-life in incinerators with energy utilisation, this will imply a loss of energy production at this point, which has to be supplied by conventional energy sources instead.

As the COD removal is specified in the functional unit, the implication of this will be the same for all solutions. But the significance of it will have an influence on the magnitude of the difference between the scenarios, and therefore it is included.

Impact categories
There is no difference in chemicals consumption between the scenarios. On the contrary, the functional unit implies the same impact on use of biocides from all scenarios and other chemicals are not judged to be affected. The main difference between the scenarios lies in the implications

on total energy consumption. No other impact categories are believed to be significantly different from one scenario to the other. The study is thus a comparison on energy, taken as primary energy consumption.

2.4 Inventory Analysis

Various data sources were used:

- Basically, the production data was gathered from the company, Hartmann, itself.
- Data on the treatment plants were taken from a number of sources having reported data on wastewater treatment in anaerobic and aerobic plants. The essential data are electricity consumption by the plants and sludge and methane production. The data quality of these data is believed to be quite good.
- As earlier described, the data for characterisation of process water are calculated by using simulation that is made in a program called WinGEMS from Pacific Simulation. The model is based on a steady state mass balance of water, suspended solids, sulphate and COD. Specifications are production rate, water flow constraints, sulphate addition during production, suspended solids concentrations and the COD release from the pulp with time.
- Data on materials production for the various plants and on disposal processes were taken from the EDIP LCA database (Frees, 1996). The data quality of these is good considering that only energy data is used in the study.

The mass and energy flows related to each scenario were compiled, see table 3. The table compares four scenarios: two scenarios in which the COD removal is done aerobically on the backwater after the paper machine (one with a by-pass), and two scenarios in which the COD removal is done anaerobically (in two different treatment plant types) in a closed pulper loop. In the two anaerobic scenarios, 20% of the COD is anticipated to be removed in an aerobic afterpolish.

Table 3. Reference flows per functional unit in two aerobic and two anaerobic scenarios - = none. UASB = Upflow Activated Sludge Blanket, ICR = Internal Circuit Reactor

Flows	Unit	Scenario			
		Aerobic		**Anaerobic**	
		Full	With by-pass	Full	
				UASB	ICR
MATERIALS					
Concrete	kg	7500	3750	21750	21750
Cast iron	kg	530	510	770	770
Steel	kg	1000	520	1230	1230
Stainless Steel	kg	2100	2100	2260	7550
Copper	kg	220	120	200	200
Aluminium	kg	-	110	190	190
PE	kg	2630	700	700	700
USE					
Electricity	MWh	10000	8000	2000	2000
Phosphorus	kg	25600	21800	14800	14800
Nitrogen	kg	128600	109200	73900	73900
Product COD incineration	kg	1700000	1700000	1700000	1700000
CREDIT					
Wastewater COD degradation	kg	-2800000	-2800000	-2800000	-2800000
Methane	kg	-	-	-854100	-854100
Sludge (dry matter)	kg	-1073100	-908850	-547500	-547500
DISPOSAL					
Shredding	kg	50	26	44	44
Manual Separation	kg	6000	4200	6800	11900
Incineration	kg	2370	640	640	640
Landfill	kg	6270	3250	17360	17470
REUSE/RECYCLE					
Remelting					
Stainless steel	kg	2060	2060	2210	7400
Al/Silicon	kg	-	-	-	-
Copper	kg	50	26	44	44
Steel	kg	1530	1520	3870	3870
Concrete	kg	-	-	-	-
CREDIT					
Stainless Steel	kg	-2060	-2060	-2210	-7400
Al/Si	kg	-	-	-	-
Copper	kg	-50	-26	-44	-44
Steel	kg	-900	-470	-1100	-1100
PE incin. (energy credit)	kg	-2370	-640	-640	-640
Concrete	kg	-	-	-	-

Materials

As is evident, the anaerobic scenarios requires more materials that the aerobic, because the needed hydraulic retention time in the anaerobic reactor is much higher than in the aerobic reactor. This implies a material consumption of the anaerobic scenarios of around twice the amount of the aerobic scenarios – equal to around 14 tons – primarily in concrete and steel.

Manufacture
No significant differences are believed to lie in the manufacture of the plant, compared to materials consumption, use and disposal of the plant, and the manufacturing stage is not included at all.

Use
Data on electricity consumption of an aerobic biofilter in another aplication is known to be around 2.5 kWh per kg COD removed, and this figure is used here. As seen, it amounts to 10,000 MWh for the full aerobic scenario compared to 2000 MWh for the anaerobic scenarios, being the electricity used for aeration in the aerobic afterpolish of 20% of the COD.

Nitrogen and phosphorus addition to the water just prior to the plants are needed for optimal COD removal, and this can be done without increasing nutrient content of the effluent of the plants as the nutrients are fully taken up by the biomass of the plants. Evidently, the aerobic scenarios need more nutrients than the anaerobic ones, because of the higher sludge production of the aerobic plants.

In today's steady-state situation, COD in the circulating process water is around 3000 mg/l. Moreover, around 40% of the water leave the system through the ovens and the rest via the wastewater effluent. This implies that 40% of the COD follows the product, equivalent to around 1700 tons per 25 years. As a conservative estimate, this is taken as being fully incinerated in order to see the significance of this. The flow is equal for all scenarios, but is included because it is altered compared to today's reference and in order to see the significance of it compared to the differences between the scenarios.

The rest of the COD leaves the system via the wastewater, where it is first let to Hartmann's own wastewater plant and subsequently to the municipal plant further downstream. In these plants, electricity is used to remove the COD. This flow is, of course, also equal for all scenarios, because the COD removal is specified in the functional unit, but it is included for the same reasons as above.

Methane production is of course only present in the anaerobic scenarios, and here in an amount of around 850 tons per 25 years equivalent to around 1.2 mill. m3. Sludge production is highest for the aerobic scenarios, judged to be twice as high (remember the 20% aerobic COD removal in the anaerobic scenario), equivalent to around 1000 tons of sludge dry matter per 25 years.

Disposal
On disposal, concrete will be deposited, metals primarily recycled and plastic incinerated – as seen from table 3.

Most significant flows
As evident from table 3, already at this Inventory Analysis phase of the LCA, the flows of the operation of the wastewater treatment plants are seen to be the significant flows. The other life stages of the plants seem to be of no significance to the total burdens from the scenarios. The key

is the fate of the COD in the scenarios, and the energy flows this fate gives rise to. This is subsequently assessed in the impact assessment phase.

2.4 Impact Assessment

Data on energy consumption of the materials, energy efficiency of electricity production, energy utilisation in waste- and sludge incinerators etc. has been available (Frees, 1996), (Wenzel et al., 1999), and the mass-and energy flows per functional unit as presented in table 3 have been translated into consumption of primary energy. Primary energy is the energy content of the resulting fuels entering the system, when all flows are followed to the initial extraction of raw materials and fuels from ground.

The primary energy flows of the four compared scenarios are shown in table 4.

Tabel 4. Primary energy flows per functional unit in two aerobic and two anaerobic scenarios
- = none. UASB = Upflow Activated Sludge Blanket, ICR = Internal Circuit Reactor
? = no data available

Flows	**Unit**	**Scenario**			
		Aerobic		**Anaerobic**	
		Full	By-pass	Full	
				UASB	ICR
MATERIALS					
Concrete	MJ	15,150	7,496	43,500	43,500
Cast iron	MJ	30,475	29,440	44,160	44,160
Steel	MJ	35,028	18,284	43,050	43,050
Stainless Steel	MJ	181,040	168,080	180,720	604,320
Copper	MJ	20,000	11,000	18,000	18,000
Aluminium	MJ	-	19,000	32,000	32,000
PE	MJ	210,000	56,000	56,000	56,000
USE					
Electricity	MJ	36,000,000	28,800,000	7,200,000	7,200,000
Phosphorus	MJ	?	?	?	?
Nitrogen	MJ	?	?	?	?
Product COD incineration	MJ	30,600,000	30,600,000	30,600,000	30,600,000
CREDIT					
Wastewater COD degradation	MJ	-25,200,000	-19,000,000	-25,200,000	-25,200,000
Methane	MJ	-	-	-50,400,000	-50,400,000
Sludge	MJ	-10,731,000	-9,088,500	-5,475,000	-5,475000
DISPOSAL					
REUSE/RECYCLE					
Remelting					
Stainless steel	MJ	60,000	60,000	66,000	222,000
Copper	MJ	2,500	1,300	2,200	2,200
Steel	MJ	23,000	23,000	58,000	58,000
CREDIT					
Stainless Steel	MJ	-60,000	-60,000	-66,000	-22,000
Copper	MJ	-4,500	-2,300	-4,000	-4,000
Steel	MJ	-900	-470	-1,107	-1,106
PE (incineration)	MJ	-71,000	-19,000	-19,000	-19,000
å **LIFE CYCLE**	MJ	31,000,000	31,000,000	-43,000,000	-42,000,000

2.5 Interpretation

The significance of the use stage of the plants is now fully evident, and it is seen that the difference between the aerobic and the anaerobic scenarios is quite significant as well. A magnitude of 74,000,000 MJ is equivalent to almost 2000 tons of oil. In monetary terms, this amounts to around 2.2 mill DKK or around 0.3 mill US$ with the Danish oil-price of 1,1

DKK/kg of fuel oil (0.14 US$/kg). Per years, this is a quite low economic difference – around 12,000 US$/year.

Hartmann sees around the same difference, namely the difference between electricity consumption of the plant and methane production, and this amounts to around 80,000,000 MJ/25 years, the yearly difference on operation costs, thus, being around the 12,000 US$/year.

It is, therefore, clear that the anaerobic plant should not be much more expensive than an aerobic one, if economy is decisive. Moreover, an aerobic plant is less troublesome and time consuming to run and gives less odour problems in the factory. Technical criteria are, therefore, in favour of the aerobic plant.

References

Christiansen K (ed.) (1999): Simplifying LCA – Just a Cut? SETAC Europe Working Group in Simplification of LCA, 1999.

Wenzel H, N Caspersen and A Schmidt (1999): Life Cycle Check – A Guide. Institute for Product Development, 1999 (In Danish). An English version of 2000 exists.

Leffland K and H Kærgaard (1997): Comparing Environmental Impact Data on Cleaner Technologies. European Environment Agency, Technical report, no. 1, December 1997.

Figueroa M C and D Sanz (2000): Laboratory Scale Characterisation and Simulation of Pulp and Process Water of Moulded Pulp Production. Identifying Options for Preventing Growth of Micro-organisms by Removing their Substrate. Master Thesis, Technical University of Denmark, IPT-098-00.

Frees N and Pedersen MA (1996): EDIP Unit Process Database. Ministry of Environment and Energy, Danish Environmental Protection Agency. Copenhagen 1996. ISBN 87-7810-547-1

International Organisation for Standardisation, ISO (2000): Environmental management – Life cycle assessment – Principles and framework. International standard ISO14040: 1997 (E).

POTENTIAL AND FRAME PROGRAME IMPLEMENTATION OF CLEANER PRODUCTION IN THE ARMY OF THE CZECH REPUBLIC

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The transformation of the Army of the Czech Republic which is in progress in connection with significant international-political changes, out of which joining the NATO structures is undoubtedly dominant, brings a lot of tasks which must be solved promptly. In relation to the environment protection, it must be admitted, the Army adopts the legislation traditionally, nevertheless, from the viewpoint of active approach to environmental problems there are still many reserves. Namely, there are qualitatively new instruments, the application of which can make using resources significantly more effective and can reduce the impact of training and peacetime life of troops on the environment in economically effective terms. Undoubtedly, the implementation of environmental management systems, energy audit performance, risk assessment, the application of Life Cycle Assessment method and, last but not least, the Cleaner Production method [1].

The mentioned issues are taken into account accordingly on national levels of developed countries as well, which, namely in the Czech Republic, is demonstrated by the acceptance of the Government Decree concerning the National Programme of Cleaner Production which the defence sector belongs to. [2].

The interest of the armies of developed countries in the cleaner production implementation is not accidental. It results from the high potential for the cleaner production in the defence sector. The origin of the potential is affected by the variety of army´s tasks within the framework of fulfilling its mission with regard to the society, consequently the extensive spectrum of activities and materials used. The cleaner production potential in the defence sector must be taken as the possibility of reducing the production of waste and pollution by the more effective use of inputs and at the same time reducing material and energy costs while the existing quality of training and all functions of the armed forces are preserved.

From the viewpoint of the analysis concerning the possibilities of applying cleaner production it is necessary to divide the defence sector into individual sub-areas. In our opinion the following classification is optimal:

a) Material management.
b) Operation, maintenance and repairs of equipment.
c) Building resources
d) Training.

It has been claimed that the quantity of material classes used in the army is considerable and very heterogeneous by its character. They can be divided based on various aspects. However, concerning the cleaner production their division will be effective pursuant to the time durability:

a) Materials, the consumption of which is limited by time and which must be disposed after a certain time if they are not used. This class includes e.g. major part of ammunition, decontamination liquids, foodstuffs, most of medical and veterinary material, medicaments etc.

b) Materials, the use of which is limited exclusively by the development of new types and procedures and are substituted owing to the modernisation (rearmament). For example, armament, particular kinds of engineer, chemical, signal and building material, electronic systems etc. belong to this class.

c) Other material which is usually characterised as consumption material with undefined durability, such as for example some kinds of personal use material, cleansing articles etc.

In the sphere of the **material management** the high potential is expected, especially in connection with organisational measures which will certainly allow to reach the fast eco-economic effect without expending higher investments. The potential lies mainly in the field of communication among individual military units and institutions or the civilian sector so that materials can be handed over, exchanged or sold before the durability date expires. The measures presume the provision of developed material logistics, partially expending investments to build necessary information networks. Logistics is related to ordering, purchasing, accounting, storing, and consuming materials. Certain possibilities of the mentioned type can be also found with materials having the lapse term of persistence (certain kinds of chemical, engineer and other materials). These materials have the character of relatively clean substances. Their processing in some of appropriate chemical industry branches is possible even if changes in the chemical composition caused by time and storage conditions can prevent from using some substances. Moreover, the type of improvement already presented is not included in the cleaner production. The potential can be also found in the method of rate and composition prescription of emergency rations, namely concerning the ACR membership in the NATO structures and the possibilities resulting from this [3].

Regarding the **operation, maintenance and repairs of equipment,** the significant potential can be expected here as well. In the sphere of logistics it is mainly a matter of transport exploitation, which in the final consequence could lead to the reduction of kilometres covered and thus the reduction of fuel consumption. The assessment of appropriate use concerning existing kinds of tyres and their possible change would probably require higher investment costs with the longer pay-off period. Logistics relating to fuel, spare parts, preventive maintenance and equipment preservation would certainly detect the other reserves. These, undoubtedly, can be found when refuelling, changing oils, handling them etc. The method of washing equipment on conveyor washes has a specific position in this group where, for example, using the circulation of rinsing water and continuous water cleaning can affect the water requirement markedly and especially the degree of surface moisture pollution. By analogy, as in the previous class of materials, the interesting potential exists here as well, namely in the rate prescription of emergency rations.

Problems of **building resources** are parallel in the civilian sector. The potential can be found especially in the reduction of the energy demand factor of buildings which are heated. These are often old, designed in the past when only the irrelevant attention was paid to thermal insulating parameters of constructions. The heat distribution usually is in emergency conditions and does not allow temperature control.

Concerning the financial aspect the highest potential can be found quite certainly in the area of **training** which is often carried out using mock-ups and simulators. Higher quality of training is provided, costs are reduced significantly, safety is higher, the effectiveness of using armament is increased, operational research is exploited and at the same time ill-effects on the environment are eliminated. Simulators and simulating activities represent the most effective approach concerning the training of armies when trends of sustainable development are integrated at present. [4]. Nowadays, up to 65% of training using simulations is implemented in NATO armies and the mentioned percentage is going to increase in the future. Moreover, consumption logistics plays a significant role in the system of classical training, which represents another potential.

Based on the above-mentioned analysis it is obvious that in the defence sector there is an enormous potential of cleaner production in agreement with theoretical considerations. In the next period of time it will be necessary to find appropriate forms of possible implementation and to define possible obstacles which could affect the implementation of the mentioned process in a negative way. The mentioned obstacles will have to be eliminated on a large scale.

We consider the most significant obstacles to be:

a) **Classified matters security** [5]. Removing this obstacle can be carried out by the training of selected army personnel. They will participate in developing demonstrational projects while civilian experts are supposed to provide general methodological instructions.

b) **Minimal interest in co-operation on the level of bases**, e.g. input-output analyses. This obstacle can be partially eliminated by the appropriate choice of facilities, by explaining tasks in detail and training personnel involved. It will be necessary to explain which effects the project will bring and further that it is not a matter of revision which possible sanctions will result from.

c) **Low motivation to achieve savings**. It is necessary to find a suitable mechanism to motivate entire units, personnel of military facilities. There are several opportunities the most important of which, we believe, are the following:

   - perfect management structure inside the army which will be able to use to manage cleaner production projects
   - further improvement of the accounting system of all materials, their consumption, using equipment etc.

The goals of cleaner production implementation are to enhance the exploitation of resources in the military sector and to reduce environmental impacts in economically effective terms. To achieve these goals we propose to train selected personnel from the army in the first phase. These should be regional ecologists and ecologists or experts having cumulated duties of an ecologist in selected units and military facilities. Also selected experts from military universities possessing appropriate specialised orientation. Some of them are expected to start developing demonstrational projects under the leadership of experienced consultants from the Cleaner Production Centre. These projects should be chosen specifically to prevent the leak of classified matters. We recommend to involve for example military kitchens, laundries, steamboiler plants, equipment to repair personal use material etc. The second part of participants should manage the demonstrational projects in selected bases where they are going to work with classified matters. The co-operators from the civilian organisation will not participate directly. They will provide methodological advice without any familiarisation with concrete military data.

The measures where there are no investments should be prioritised, namely of organisational character which will be found in the course of the project development. By the application of these projects financial means should be gained for the gradual implementation of the capital-intensive measures which should have the rate of return shorter than three years. In this way further means should be achieved, but relevantly higher which should later serve to cover the most capital-intensive project.

Costs to execute demonstrational projects should not exceed a certain value – in our opinion – 5 million crowns related to our army including extra payments for army workers who will be involved in the project development.

In conclusion it is necessary to remark, that Cleaner Production is one of the significant proactive tools which is used by civilian enterprises to reduce of quantity of produced waste and production effectiveness increasing. Its implementation can lead to relevant improvement environmental safety in the military sector.

Literature:

1. BO_EK, F. a URBANOVÁ, R. Dangerous Waste Handling in the Army of the Czech Republic and possibilities of its making more effective. In Proceedings of International Conference CATE´97, Brno: Fairs and Exhibitions Venture, 7th May 1997, p. 49-58.

2. Government Decree concerning the National Programme of Cleaner Production No. 165/2000 Coll. Prague, 2000. 1 p.

3. The NATO Handbook. Brussels: Office of Information and Press, 1998. 400 p.

4. NATO/CCMS Pilot Study. Use of Simulators as a Means of Reducing Environmental Impacts caused by Military Activities. Report No. 210, November 1995. 66 s.

5. Law No. 148/98, Collection of Laws, on Classified Matters Security.

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INTRODUCTION TO COMPUTER TOOL CAFE

On initiative of the pilot study directors and the Danish host, participants involved with development or working with PC-tools and databases supporting cleaner production were invited to present and demonstrate these tools. The computer tool cafe was organized as a hands-on demonstration event. Descriptions of the demonstrated tools are presented here.

Computer Tool Cafe

CHEMICAL LIFE CYCLE DATABASE.

Demonstrated by
Michael Overcash, USA

Description:

Extract from the abstract to Concepción, J-G., Seungdo, K. and Overcash, M.R. (2000): Methodology for Developing Gate-to-Gate Life Cycle Inventory Information. Int. J. LCA, 5 (2000)

This work presents an option to generate gata-to-gate life cycle information of chemical substances, based on a transparent methodology of chemical engineering process design (an ab initio approach). In the broader concept of a life cycle inventory (LCI), the information of each gate-to-gate module can be linked accordingly in a production chain, including the extraction of raw materials, transportation, disposal, reuse, etc. to provide a full cradle to gate evaluation. The methodology aims to help the LCA practitioner to obtain a fair and transparent estimate of LCI data when the information is not readily available from industry or literature. The LCI

information from this methodology can be used more directly in exploring engineering and chemistry changes to improve manufacturing processes.
Further information: Overcash, M. Chemical Life Cycle Inventory Library, North Carolina State University, Raleigh, N.C. 27695-7905, 2000. E-mail: overcash@eos.ncsu.edu

CAPEC SOFTWARE TOOLS FOR CHEMICAL AND PROCESS SYSTEM ENGINEERING.
Demonstrated by
Peter Harper, Denmark

Description
ProCamd: Program based on computer aided molecular design that can be used for solvent selection, search and design

ProPred: Pure component property prediction package. An easy to use program package that is able to predict pure component properties of most organic compounds from molecular structural information.

ICAS: An integrated computer aided system through which various problems related to a process, product and/or operation could be investigated and solved efficiently, consistently and reliably. Various computer aided tools such as proCamd, proPred, and design tool-box have been integrated with databases and simulation engines within ICAS.

CAPEC database: A database of pure component and mixture properties and, solvent properties for a very large range of compounds, including amino acids and steroids.

Further information: Rafique Gani, Deparment of Chemical Engineering, Technical University of Denmark, e-mail: rag@popeye.kt.dtu.dk or www.capec.kt.dt.dk

Explaining the EDIP LCA-software needs standing argumentation

THE EDIP (ENVIRONMENTAL DESIGN OF INDUSTRIAL PRODUCTS) LIFE CYCLE ASSESSMENT TOOL.

Demontrated by
Morten Als Pedersen, Denmark

Description

The EDIP-PC tool, betaversion 2.11 was released by the Danish Environmental Protection Agency in June 1998. The betaversion contains the necessary functionality to support the work process of life cycle based environmental assessment of products and systems. The betaversion 2.11 system contains three functions:

- the Unit Process Database,
- the Modelling Tool and
- the Calculation Facilities.

The EDIP PC-tool contains the neessary functionality to fully support the work process in life cycle based environmental assessment. The in-built Unit Process Database contains approx. 750 process cards, covering all types of systems. Approx. 200 of these are in the category “substances” leaving over 500 unit processes, which are categorized in: materials, auxillary materials, transport systems, production processes, disposal systems/scenarios, energy systems, etc. Unit processes are the basic building blocks of the EDIP Life Cycle Model. The quantitative part of the process data is scalable, making it possible for students and other users to apply the data in other contexts.

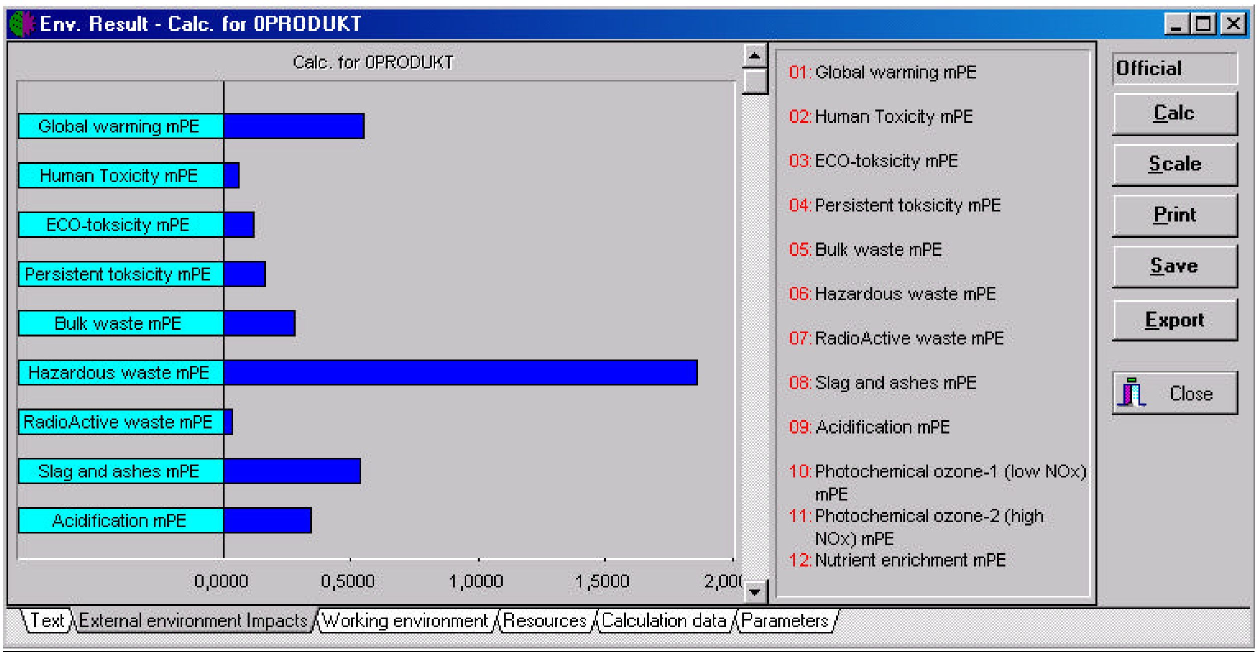

Figure: screen dump from the EDIP tool showing grachical desplay of results

The modelling process is done in a Windows file-manager-alike structure. With the calculation facilities it is possible to calculate an inventory or to assess the environmental impacts for the whole system or any part of this. Above figure shows a graphical display of results.

Further information: Morten Als Pedersen, Department of Manufacturing Engineering and Institute for Product Development, map@ipl.dtu.dk.
Danish version of software and software licence can be obtained at Danish Environmenal Protection Agency Center for Information http://www.mem.dk/butik/ Information on English version can be obtained at Department of Manufacturing Engineering and Institute for Product Development, cm@ipl.dtu.dk

PARIS II – AN ENVIRONMENTAL FRIENDLY CHEMICAL SUBSTITUTION IN INDUSTRY.
Demontrated by
Dan Murray, USA

Description
PARIS II is a solvent design software. It has been completed and transferred to the private enterprise TDS, Inc. (New York City) for marketing. Beta testing has just started with 50 companies participating. PARIS II program designs, in the computer, solvent mixtures with reduced environmental impact (such as toxicity and other measures) that match the property profile of the solvent mixture being used currently.

User inputs are chemical composition of solvent, operating conditions, and the tolerance ranges for solvent physical parameters including environmental parameters and the output of the software analysis is a ranked list of solvents based on closeness in meeting the specified criteria

PARIS II can be used by the designer or producer of solvents or by the solvent user or decision-maker to evaluate the effectiveness and environmental impacts of solvent substitutes or to develop custom solvents to meet specific needs based on chemical properties and environmental considerations.

Further information:
Point of contact at USEPA is e-mail: cabezas.heriberto@epamail.epa.gov.
PARIS II is further described in the paper dated September 16, 1999 entitled Environmental Improvement Toolbox, published by EPA, National Risk Management Research Laboratory, Sustainable Technology Division, Systems Analysis Branch. The toolbox contains a description of fifteen pollution prevention/environmental analysis tools, and is continually updated as tools are refined and new tools added. Point of contact at EPA is e-mail: hoagland.theresa@epamal.epa.gov.
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POSTER PRESENTATION – NATO FELLOW

Application of life cycle assessment and sustainable process index to process design

Teresa M. Mata and Carlos A. V. Costa LEPÆ – Laboratory of Energy, Process and Environmental Engineering Chemical Engineering Department, Faculty of Engineering, University of Porto Rua dos Bragas, 4050-123 Porto, Portugal

In this work a general approach for the flow and generation of potential environmental impacts through a chemical process is introduced. Sustainable process indexes (SPI) and Life cycle assessment (LCA) are powerful and general analytical tools. They help to identify more sustainable solutions in the process industries and assess their potential environmental impacts (PEI). In this work a process simulation model is presented as case study and analysed from an environmental impact perspective. It was built using the process simulation program: PRO/II® of Simulation Sciences Inc.

Introduction

Companies facing the task of promoting sustainable development must have ways of measuring progress towards that goal. The use of SPI is a simple way of substituting all the available information in order to support a decision making process. It is based on the balancing of a process over material and energy flows, i.e. an environmental input-output analysis and gives a picture about the environmental status of an activity. LCA is widely accepted as a methodology that enables quantification of environmental impacts and evaluation of the improvements throughout the life cycle of a process, product or activity.

Design and retrofit of processes is a creative activity whereby we generate ideas and then translate them into equipment and processes for producing new materials or for significantly upgrading the value of existing materials. The purpose of design and retrofit of processes is to find the best process flowsheet, i.e., to select the process units and interconnections among them and estimate the optimum design conditions. There are some constraints that must be considered during the process design including safety, environmental, operational, economic and others. Therefore tools are needed for design decisions.

NATO-fellow poster presentation

In the design and retrofit of processes with environmental care, some existing or new technologies could be integrated to minimise the wastes generated by the process (e.g., absorption, adsorption, condensation, membrane process, a new catalyst, expert systems) or simply by recycling and reuse some waste streams. A list of alternative solutions can be proposed for each decision, therefore generating a list of process alternatives. In many cases, no heuristic rules or guidelines are available to make decisions about the structure of the flowsheet and/or to set the values of some of the design variables. Using sustainable processes indexes, the penalty paid in the time required to screen more alternatives is not very high and thereby an increase in efficiency could be obtained. The use of indexes or indicators are not new; several authors have implemented them to evaluate the potential impact that chemical emissions have on the environment. RETURN TO CONTENTS PAGE

INTRODUCTION

Product Oriented Environmental Measures and Integrated Product Policy (IPP) in the European Union was the special topic chosen for the Copenhagen meeting. One day of the meeting was allocated to presentations within this subject and presentations were given by industrial companies, academia and authorities. In the following abstracts, papers or summaries covering the special topic presentations are given. A specially edited and supplemented version of the full special topic theme and discussions are planed published by an international publishing house. This publication should be available ultimo 2001/primo 2002. The abstracts presented here are grouped under the following headings: authorities, academia and industrial companies

AUTHORITIES

A CHALLENGE FOR MODERN SOCIETY: UNCOUPLING GROWTH AND POLLUTION

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Abstract
Steen Gade addressed the issue of uncoupling economic growth and increased pollution. The point of departure was the European Unions efforts to integrate environmental policy and sector policies. Another important point was the study by European Environment Agency (EEA) on the state of the environment and its future development. Thus having addressed the necessity for and the political commitment to uncoupling economic growth and pollution, attention was drawn to challenges that must be overcome in order to secure a sustainable development. Knowledge, tools and principles that can be helpful include the concept of ecological space and the ideas behind a Integrated Product Policy (IPP). IPP uses a number of different elements and tools that is expected to support this goal e.g. sector integration, active involvement of relevant parties such as companies, retailers, consumers etc., market based approach, product information, lifecycle thinking just to mention a few of the more central elements.

Summary of the presentation

Decisions in Helsinki 1999

The EC Amsterdam Treaty states that environmental protection requirements must be integrated into the definition and implementation of the Community policies and activities. The aim is to promote sustainable development. In June 1998 in Cardiff the European Council initiated a process of integration. All relevant formations of the Council were encouraged to establish strategies for integrating environmental concerns and sustainable development in their respective policy areas.

Special focus sectors are transport, energy, agriculture, industry and internal market development.

In December 1999 in Helsinki, the European Council again had integration and strategies on the agenda. One major objective is improving the eco-efficiency of production and consumption in order to break the link between economic growth and adverse environmental effects. The succes of integration can be measured by the extent to which the sectors de-couple their economic activity from environmental impact.

EEA 1999

In 1999 the European Environmental Agency (EEA) made its third state of the environment report: “Environment in the European Union at the Turn of the Century” about the state of the environment in Europe after 25 years of EU environmental policies and the 5th Environmental Action Plan.

In EU only air pollution parameters have attained absolute uncoupling from GDP since 1990. To achieve sustainable development an absolute reduction in the total load on the environment is necessary with regard to pollution parameters. And relative- or absolute decoupling are key issues.

Environmental space

It is obvious that there are limits to amount of resources that can be consumed in Europe, if the Europeans are to share fairly with other parts of the world. Today approx. 20% of the world’s population is responsible for approx. 80% of the resource consumption. Factors 4 and 10 have been mentioned as the orders of magnitude needed to increase eco-efficiency and decrease environmental pressure to obtain sustainable development. Environmental space is not yet an instrument in regulation, but it promotes policy and useful technical analysis related to given resources.

Sustainable development

As presented in UN’s Brundtland report “Our common future” the three pillars of sustainable development are economic development, social development and environmental protection. Since the world-wide political commitment in 1992, sustainable development has been on the international political agenda, and in these years before Rio+10 in 2002 it sets national agendas in Denmarks as in many other countries.

A major challange when dealing with products and processes is to make a balanced assessment of social, economic and environmental impacts. The market plays a major role in achieving sustainability. But the market will not provide sustainability by itself; Integrated Product Policy (IPP) may well be a corner stone in getting there.

IPP and the Life Cycle approach

It is widely accepted that use of products poses a potential thread to the environment. It is also more and more accepted that the life cycle approach is required to get a full picture of all the potential problems connected to a specific product. It is not possible to use standards, rules, and legislation for each product put on the market. IPP must be a voluntary process and we have to change attitudes by putting IPP and cleaner products on the public agenda. But how do we get from attitude to action where the manufacturer not only wants to create cleaner products, but actually has the ability to do so. Many countries have put many resources into establishing methods and tools for Life Cycle Assessment. In Denmark we developed a life cycle assessment tool known as the *EDIP* methodology, PC-tool and database, but getting these tools into everyday life of companies is a problem with no easy solutions. To provide knowledge, tools as ecolabels, environmental product declarations and databases are necessary but traditional activities for authorities. Another thing is actually influencing the market by stimulating sales of specific environmentally sound products by influencing consumers and by green public procurement. Such activities are new and challenges our public way of thinking. Nevertheless, we have to find ways to meet the challenge and find our role not as bystanders but as actors on the market.

Steen Gade, Director General, Danish EPA giving a presentation on De-coupling of growth and environmental pressure

THE DANISH PRODUCT ORIENTED ENVIRONMENTAL INITIATIVE – SCOPE AND CHALLENGES

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Introduction

The understanding of the complexity of the sources for environmental contamination and the development of methodologies for reducing the contamination has significantly increased during the last decade. Few years ago an end-of-pipe approach for reducing the contamination from point sources was one of the corner stones. Within the last 15 years cleaner technology measures has been introduced as a source oriented approach for reducing the amount and increasing the quality of the waste. Both cleaner technology and end-of-pipe methodologies have significantly improved the environmental quality of point sources. To-day we have realised that a further improvement of environmental quality necessitate a focus on all life stages of products - from cradle to grave - in addition to the end-of-pipe and clean technology approach.

An approach which focus a prioritised improvement of the environmental quality of all stages of the life cycle of products calls for new thinking not only by the industrial sector, but also by the authorities. While the end-of-pipe era was governed by traditional authority regulation and control, a holistic life cycle approach in addition call for an extended co-operation between the authorities and all stakeholders involved, as the traditional market forces need to be addressed. Of crucial importance for implementing this new approach is, 1) that the producers are producing and marketing environmentally cleaner products and are passing on credible and sufficient information regarding the environmental properties of the products to the down stream users and 2) that the down stream users request and purchase such products irrespective of the possible higher costs (and thus set priority to environmental quality in parallel to costs and use quality).

One of the central issues of the Danish government's Nature and Environmental Policy report in 1995 /1/ was the concern about the environmental impact from production, use and disposal of products. The report stated, that the serious environmental problems, global as well as local, call for the environmental protection measures provided so far to be supplemented by measures dealing with all aspects of product life-cycle. The background for this statement was, that the various measures implemented for reduction of the environmental impact - waste treatment, clean production processes, environmental audit systems, a.o. - would only reduce the environmental load to a certain degree and that there in addition was a need for addressing other stages in the life of products and to set the environmental quality of products on the agenda for both producers and consumers in line with other quality aspects.

As a follow-up of the above report, the agency issued in 1996 a document for initiating a discussion between all stakeholders on the objectives and means for an Intensified Product-oriented Environmental Initiative (a "green paper") /2/. The document set focus on the national and global environmental problems, propose overall environmental goals for such an action and analyse the needed framework and terms for the market and for the stakeholders. In this light the document propose a number of new activities as well as a consolidation of present activities with the aim to increase the production and use of environmentally cleaner products.

In February 1998 a Product Oriented Environmental Action Plan was issued (1998-2002) /3/. The document outlines a number of initiatives for the support of an integrated product policy: Development of pragmatic tools for Life Cycle Assessments (LCA) for the design and improvement of cleaner products; systems for facilitating information flow within the chain of goods from industry to the users regarding such products (e.g. eco labels, environmental product declarations); activities for promoting green public procurement, among others by elaboration of environmental product guidelines for public purchasers; activities for promoting market co-operation amongst others by the development of stakeholders panels within certain product classes; etc. The Product Oriented Environmental Initiative, which focus all major life stages of the product, is supported by a financial support program of approx. 120 million DKK a year (2000 budget).

Also Sweden has launched a number of initiatives with the overall goal to approach a sustainable development and thus to reduce the environmental impact (including the use of resources) from products in its entire life cycle. The Swedish Government proposal for promoting a sustainable development was presented to the Parliament in may 1998 /4/. Since then Sweden has increased its activities within this area and Sweden has this spring announced, that the Integrated Product Policy will be one of the priorities during its Presidency of the EU in spring 2001

A Nordic co-operation in the area of product-oriented environmental policy under the Nordic Council of Ministers was initiated in 1996. A seminar on this issue was helt in Salsöbaden in Sweden in January 1998. The objective of the seminar was to promote a common Nordic understanding of the framework and the elements of the product-oriented environmental policy and to discuss measures for promoting this environmental policy. Based on the recommendations from this seminar a cross sectorial working group was formed under the Nordic Councill of Ministers in 1999. The objective of the group is to develop a common Nordic position on Integrated product policy (IPP) and to promote a further development. In february this year a technical study regarding the provisions for a common Nordic IPP was presented at another seminar at Salsöbaden.

In Marts 1998 EU issued a consultant report for debate on Integrated Product Policy (IPP) /5/. Based on an analysis of national and international developments in this area, elements of a possible EU-policy was proposed. The document was later discussed at an EU-workshop and in May 1999 the EU Member States gave the Commission a broad mandate to initiate the process for the elaboration of an integrated product policy in the European Union. The Commission intends to publish a Green Paper on a strategy on IPP during 2000. Sector integration is an important condition for the successful development of IPP. It is therefore important to note, that not only the Nordic countries ministry for consumer, for industry and for environment is represented in the Nordic cross sectorial group but also the EU Commissioner for Enterprise support the idea for an Integrated product policy.

Challenges for promoting an environmental product policy
An important challenge is to move the focus from fragments of the life cycle of products (eg. clean production processes, waste handling technology) to a prioritised action based on an analysis of the environmental aspects of the entire life cycle of the product: Use of raw material, emission during production and manufacture, environmental aspects of transportation and product use including the services linked to the use and finally waste handling, reuse/recycling and disposal.

Another important challenge is to facilitate credible and sufficient information of the properties and proper handling of the products to all the stakeholders involved in the product life chain. The request for proper information will lead to a placement of an extended responsibility to producers and manufactures for the environmental properties of the product.

A third challenge is to promote the creation of a market for cleaner products. The starting point may be the national market but the succes will depend on the international implementation. Although the focus most often are on private households as buyers of goods, all steps of the supply chain comprises purchasers. It is a major challenge to increase and to maintain the environmental issue as a quality parameter in parallel to traditional quality aspects and cost of the product. To maintain the focus is perhaps the most difficult issue and require that the improvement of the environmental quality is accepted to be significant by the consumers.

Finally the challenges for the authorities are to elaborate a framework for the product policy, to provide good conditions for a green market and to promote the co-operation between stakeholders and relevant authorities.

Initiatives in Denmark for supporting an intensified product-oriented environmental policy
The array of initiatives taken by the Danish EPA according to the Product oriented environmental action plan are briefly outlined below.

Development of know-how and methods
The LCA method: Environmental Design of Industrial Products (EDIP) /6,7/ is to be further developed: Improvement of the Chemical assessment methodology and the assessment of the waste aspect. An important activity will be to elaborate operational guidelines and tools for the various stakeholders. In addition to the EDIP-method a data-base has been developed covering data of interest for many industries in their LCA-work. This data-base will be further supplemented amongst others by data generated in projects financed by the Agency. Also the transfer of knowledge within this area to major stakeholders (designers, enterprises, public purchasers a.o.) are prioritised. The Agency is presently analysing the future organisational structure to provide a long term availability of up-dated operational LCA tools as well as high quality LCA data to the users.

Information systems
It is the intension of the Agency to initiate the development of information systems which is targeting the various stakeholders and taking into account the nature of the product groups.

Presently the EU-eco-label (the “flower”) and the Nordic “Swan” has been implemented, partly organized by the Danish eco-label secretariate. The eco-label is not able to cover all type of products and the need for information by all stakeholdres. The Agency is therefore presently considering other types of information systems and has taken the initiative to analyse frames for a national business to business environmental product declaration system based on the provisional ISO documents (type III) (3. Part certified system, LCA framework).

To support the green public procurement, environmental guidelines for a number of product groups are elaborated. During a 5 year period 50 product groups are to be covered by such guidelines. The guidelines are giving advises to purchasers (private or public) regarding the major environmental impact of the specific product group in a life-cycle framework and identifying the areas where producers should be able to improve the environmental quality of the product and offer such products to the purchasers.

Creating markets
One of the major challenges of the integrated product policy is to promote the development of a significant market for green products. Without a significant market the producers are not likely to initiate or to increase a production of clean products. A crowbar for the opening of the market is the public procurement. In Denmark the value of public procurement is amounting to more than 100 billion DKK a year. The use of a fraction of this sum for green goods will make a significant difference for the market and thus be a kick starter for the product policy. At the same time, the very attitude by the public will presumably influence also the attitude of private households. Since 1995 a ministerial circular has obliged governmental institutions to elaborate a policy for green procurement. Also in a number of counties and municipalities green public procurement has been organised.

In 1998 an agreement was made between the Minister of Environment and Energy and the municipalities and counties to set up a common framework for public procurement for the entire public sector. The agreement also include an objective to set up overall goals for green procurement and to develop report format and benchmark indicators for a future reporting of the progress of the green procurement in relation to those goals. Some of the initiatives in 2000 for promoting the entire public sector to increase the purchase of green goods will be focussed on 4 product areas: Electronics, furniture, textile detergents and textile cleaning services, cleaning agents and cleaning services.

The success of an integrated product policy is very much dependent of the establishment of an international market. Therefore the Danish EPA find it very important to participate actively in the development of international policies within this area. To increase and maintain an international green market, a number of aspects should be focused: The development of high environmental quality CEN product standards are important for the possibility to improve the environmental quality of products. Also the EU tender directives for public purchase should give better possibility for taking environmental considerations into account

Stakeholder co-operation
It is important that the major stakeholders are invited for a co-operation on these issues. The Agency therefore initiated a number of round-table discussions on the means and methods for an

integrated product policy. In 1998 product-panels was established for goods transportation, textiles and electronic devices and in 2000 a new panel will be formed for "buildings". The members of the panels are major stakeholders representing all important stages of the product lifecycle (producers, users, waste managers, authorities). The 3 panels formed in 1998 have elaborated action plans for promoting a green market suggesting initiatives related to the specific product areas and have taken a number of initiatives according to these plans (Workshops, information materials, development projects). The Textile panel has established an environmental information centre and is planning a campaign for green products labelled with the EU ecolabel next year. The goods transportation panel is elaborating a bench mark system and an environmental management system.

Waste management
Reducing the amount of waste generated and increasing the reuse and recycling of the waste generated is an important aspect in the Danish integrated product policy. The experiences regarding the environmental problems related to reuse/recycling and disposal are very important also for the future design of cleaner products. An action plan covering this area was issued last year (Waste 21).

Financial subsidy scheme
To support the integrated product policy a subsidy scheme of approx. 110 mill DKK a year (2000 budget) is in operation. The Environmental Council of Cleaner Products – a council with representatives from the major stakeholders (producers, consumers, environmental organisations, authorities, academia a.o.) – elaborate a yearly plan of priorities for the subsidies. The Danish Environmental Protection Agency grants specific projects within the priority plan.

References
/1/ Ministry of Environment and Energy, Denmark: Nature and Environmental Policy Report, June 1995
/2/ Danish Environmental Protection Agency: Intensified Product-oriented Environmental Action - A Green Paper. Proposal from the Danish Environmental Protection Agency. November 1996 (preliminary translated edition)
/3/ Danish Environmental Protection Agency:The Product-oriented Environmental Actions, February 1998 (in Danish)
/4/ Ministry of the Environment, Sweden: Swedish Environmental Quality Objectives, a summary of the Swedish Government's Bill 1997/98: 145. Environmental Policy for a Sustainable Sweden June 1998
/5/ Integrated Product Policy, Final Report to the European Commission: DG XI. Ernest & Young, March 1998 (confidential)
/6/ Wenzel, H., M. Hauschild and L. Alting: Environmental Assessment of Products. Vol. 1: Methodology, tools and case studies in product development. Chapman & Hall 1997
/7/ Hauschild, M. and H. Wenzel: Environmental Assessment of Products. Vol. 2: Scientific background. Chapman & Hall 1998

ACADEMIA

THE CONCEPT OF ECO-DESIGN AND RESULTS FROM THE DUTCH ECO-DESIGN PROGRAMMES

Tom van der Horst
Sustainable Product Innovation Department
TNO, The Netherlands

Huge public programs have been undertaken in The Netherlands and a large number of products have undergone considerations of environmental improvements. Tom van der Horst has been involved from the beginning and is today Manager of Sustainable Product Innovation Department at TNO.

INDECOL - NTNU'S INDUSTRIAL ECOLOGY PROGRAMME

Annik Magerholm Fet
Department of Industrial Economy and Technology Management,
Norwegian University of Science and Technology (NTNU)

Introduction to Industrial Ecology

The transformation into a sustainable society does not only require an environmentally sound technology. Industrial ecology (IndEcol) is about designing sustainable structures - technologically, economically as well as socially and individually. There are several important elements within IndEcol; improving the metabolic pathways, creating loop-closing, dematerialising industrial output, patterns of energy use, balancing industrial input and output to natural ecosystem capacity, policy to conform with long-term industrial system evolution, and new action-co-ordinating structures, communicative linkages, and information.

Tools and methods

The future focus of environmental concerns seems to change from site specific towards the life cycle perspective. This means that the holistic perspective must be taken into consideration when an industry wants to improve its environmental performance. A company’s environmental performance is not only a measure of the impacts caused by the production processes, it is also a total measure of the environmental impacts caused by the products and the activities, idealistically viewed in a life cycle perspective. The goal must be to reduce the environmental impact in every phase of the life cycle. To reach this goal, appropriate methods for evaluating and improving the environmental performance must be taken into use. A model of the levels of environmental performances is shown in figure 1. The first axis is the time axis, the product’s lifetime with its phases in planning, manufacturing, use and disposal, human lifetime and the civilisation span. The second axis indicates the scope of the environmental concern, ranging from a single product life cycle, to x products within one manufacturer and towards x manufacturers and the society.

The areas in figure 1 represent environmental performance efforts at different levels; 1.Environmental Engineering, 2.Pollution Prevention, 3.Environmental Conscious Design and

Manufacturing, 4.Industrial Ecology, and 5.Sustainable Development. Environmental Engineering includes here various types of engineering and production. Pollution Prevention takes system thinking into account, and the planning process is essential. The other concepts, Environmental Conscious Design and Manufacturing are related to product design and improvement of products concerning the manufacturing process, the distribution, the use and final disposal of the products. Both Sustainable Development and Industrial Ecology are concepts for the macro (and meso) level, taking environmental, economic and social issues into consideration. Companies may find themselves within these areas. A shift or movement from one area to the next area represents a change towards more holistic thinking and focus on the life cycle performance.

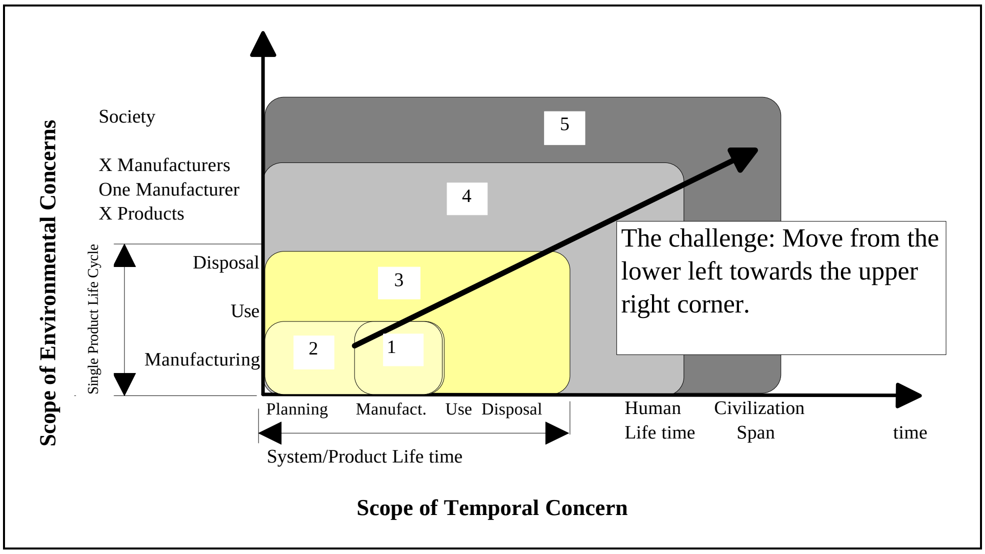

Figure1: Classification of environmental performance levels. Modified after Bras (1996).

There are different tools and methods for improving the life-cycle environmental performance. For production systems (”process oriented tools”) material flow and energy analysis, Environmental Accounting (EAc) and Cleaner Production (CP) are frequently used. These outline procedures for conducting assessments to identify opportunities for waste reduction or elimination. Further it describes how to use the results to develop pollution prevention options, recycling and recovery, and how to implement those options that withstand feasibility analyses.

For product systems Life Cycle Assessment (LCA), Life Cycle Screening (LCS), Design for Environment (DfE) and Eco-labelling are important (”product oriented tools”). The main steps in an LCA/LCS are *Goal and scope definition, Inventory analysis, Impact assessment* and *Interpretation.* According to goal and scope definition the application, depth and subject of the study, the functional unit and the system boundaries must be defined. Interpretation is the phase in which a synthesis is drawn from the findings, and they may form conclusions and recommendations to product improvements. When the intention is to identify key issues for further investigations, e.g. identify parts of a life cycle that needs further research, an LCS should be carried out. An LCS is a simplification of an LCA. Based on information drawn from LCA /

LCS, the traditional list of product design criteria should be supplemented with environmental conscious design requirements. Eco-labels are used to provide information about the environmental impact of a product.

Companies that adopt CP, LCA, DfE etc., normally improve their overall environmental performance because of better housekeeping and better products. To achieve continuous improvement, their management systems should build on principles of environmental consciousness. Formal Environmental Management Systems (EMS), Environmental Auditing (EA), or Environmental Performance Evaluation (EPE) in accordance to given standards, help companies in this work. Environmental management systems and environmental regulations are of great importance both for organisational and societal systems.

The presented methods are systematised into a framework similar to the one shown in figure 2. Area 1 is related to manufacturing processes, and appropriate tools are CP (in the narrow sense) and EAc. The next area is related to products and their life cycles. Appropriate tools are LCS, LCA, and DfE for the purpose of environmental conscious product development. Area 3 represents one company, EMS, EA and EPE are important here. At society and global system level, policy programs and international regulations are drawing up the guidelines for how to improve environmental performance in a broader term perspective.

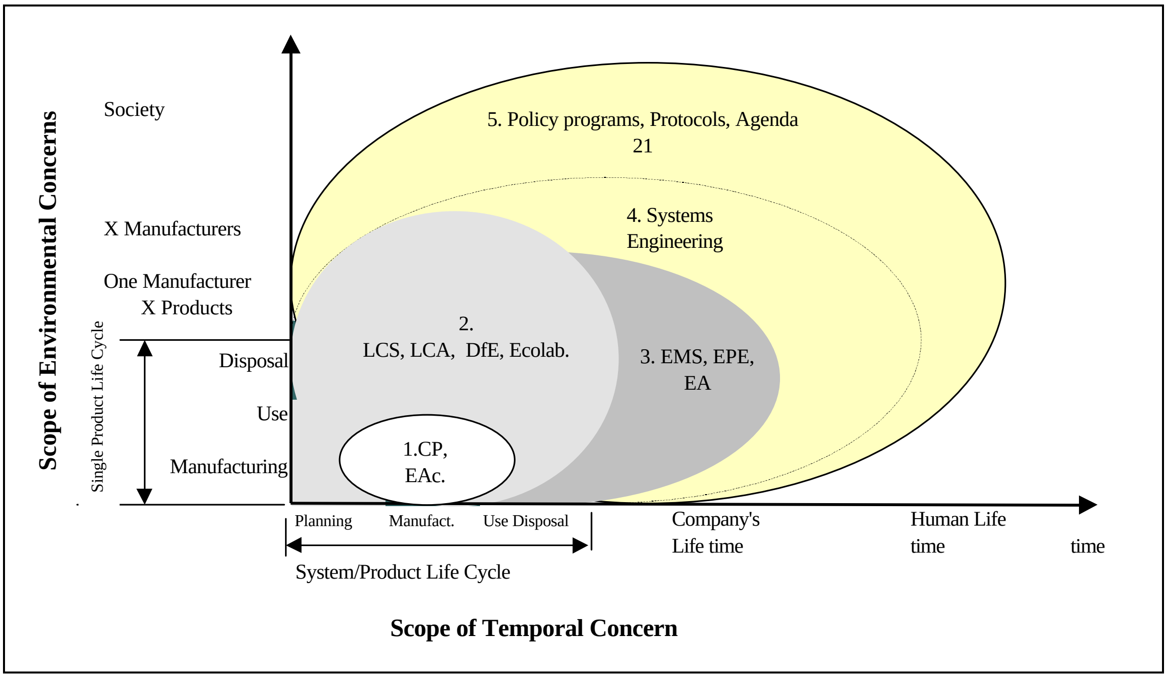

Figure 2: A classification of methods and tools for environmental performance improvements.

Study programme
An interdisciplinary study programme on IndEcol is established at NTNU. The intention of this programme is to create an academic basis for IndEcol in close collaboration with our partners in industry and government administration. Our activities are organised around three main focus areas: *Education, research, and outreach activities.* The study programme has ten courses, all with a focus to industrial ecology principles, see Table 1.

In addition we are also involved in a few other courses where we make use of distance learning courses delivered over the internet. The study programme has a horizontal organisation, and works across the structure of five faculties; the faculties of Civil and Environmental Engineering (the host faculty); of Mechanical Engineering; of Chemistry and Biology; of Social Sciences and Technology Management and of History and Philosophy. The organisation of IndEcol is shown in figure 3.

Table: Courses in the IndEcol study programme 1999 - 2001

Environment and resource economy	Fall 1999
Environmental Science Environment & Safety Introduction to Industrial Ecology	Spring 2000
LCA - Methodology & Application Environmental Politics Energy and Industrial Ecology Geo-Resources Ecotoxicology and Environmental Resources	Fall 2000
Material Loop Closing Interdisciplinary Project 1	Spring 2001
Interdisciplinary Project 2	Fall 2001

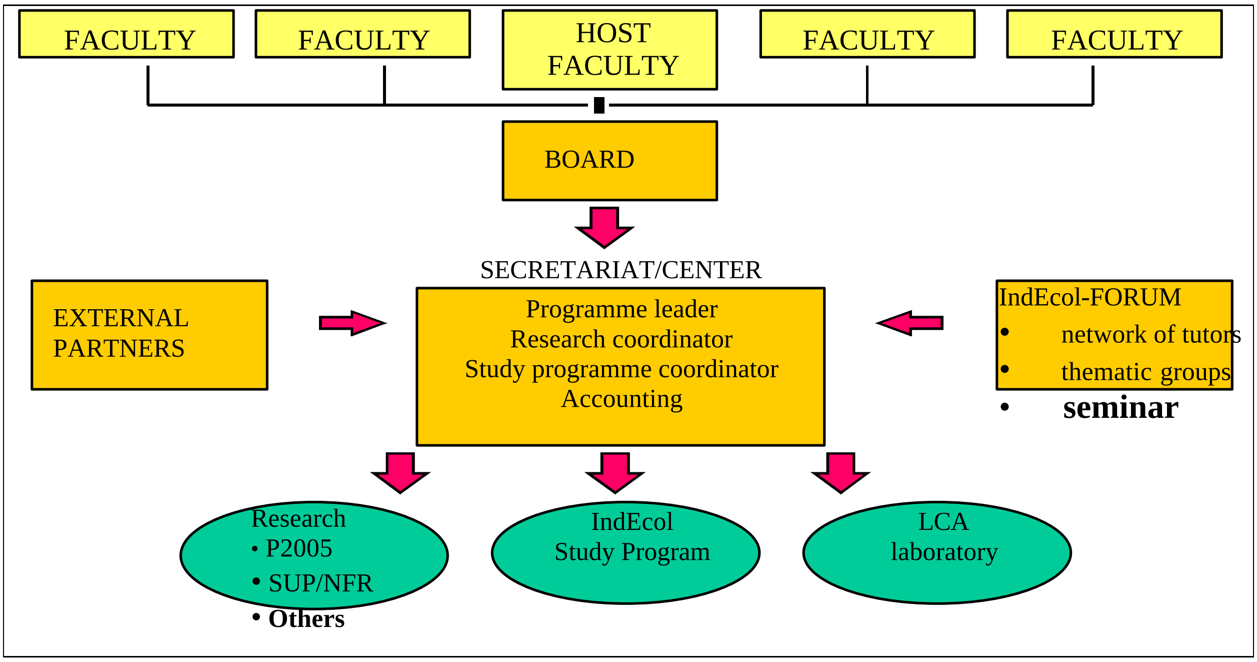

Figure 3: Organisation of IndEcol.

Research programme

Closely related to the study program there is a research programme called Productivity[1] 2005. The main objective is to increase know-how and knowledge in alliances between Norwegian manufacturing industry and NTNU/Sintef. It aims at high international level of strategic competence within technology, organisation and management. Main projects are Integrated product development (IPU), Companies in networks (BiN), Industrial Ecology (IndEcol), and Flexible, effective, reliable production (FEPP) . Our project "P2005 Industrial ecology" is one of the key focus areas in P2005, and gives us a long-term financial basis for the development of theory and methodology in the area of IndEcol. The strategy of research activities at IndEcol is to focus on collaboration in a multidisciplinary setting, but with an emphasis to issues that we believe have potentials for advancing the area of IndEcol within our university. We want to give a high priority to research projects at the PhD and Post-doctoral level, as well as students' research projects at the graduate level. Objectives of P2005 Industrial ecology are to raise the level of expertise at NTNU, and disseminate knowledge on *product, production and recycling systems*, through research and networking in such a way that the Norwegian manufacturing industry has access to candidates, expertise and methodology that will help companies implement more eco-effective and competitive solutions in such systems.

[1] Research program supported by Norway's Research Council, 1998-2005.

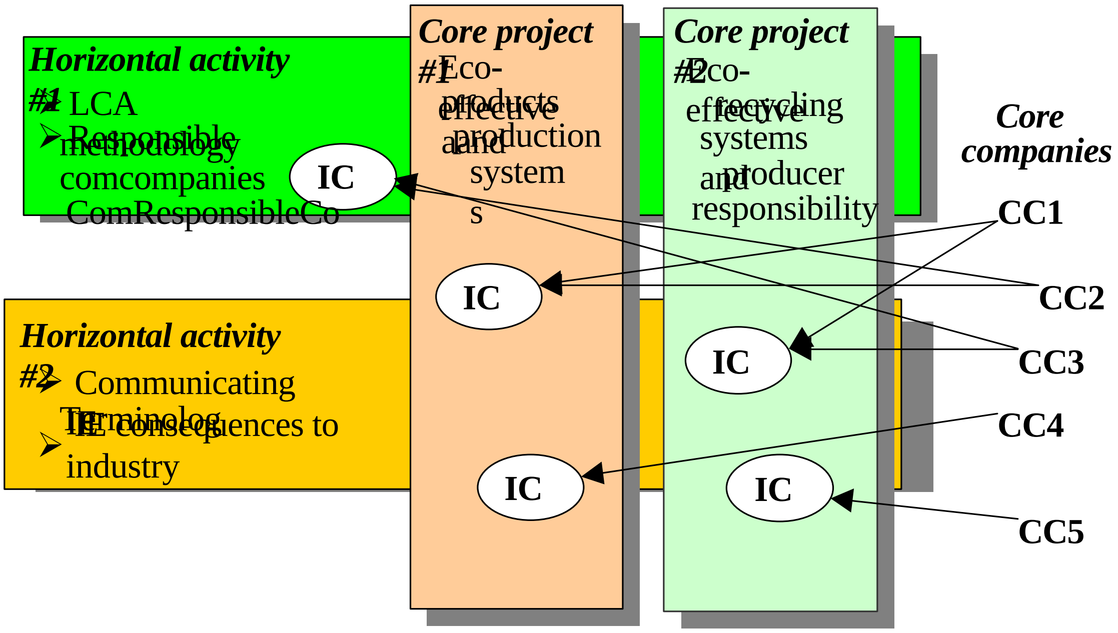

Figure 4: P2005 IndEcol structure

The P2005 IndEcol is structured in two core projecst. The first one is *Eco-effective products and production systems* with the research activities undertaken within two main research strategies: *Eco-effective value chain management in industry* and *Factor X development of technical systems* Both activities are directly connected to industrial cases. Three general research subjects will be covered with reference to each of the research strategies: 1) Methodologies for quantification of eco-effectiveness with regard to products, companies and networks of companies, and how to use this information in specific industrial cases. 2) Governmental regulations and financial instruments as promoters or barriers to development of eco-effective solutions in product and production systems, and 3) Organisational learning and new ways of managing eco-effective companies and networks of companies in relation to product and production development.

The second core project is *Eco-effective recycling systems and producer responsibility*. The research activities hereunder will be carried out within the main research strategies *Evaluation of eco-effectiveness in recycling systems* and *Principles of good practice in local and national recycling systems.* They will cover the same strategies as mentioned above.

One central activity in the IndEcol program is the LCA-laboratory. This will help students and persons employed at NTNU to get a more holistic view of the challenges we are facing. This research is to be carried out in accordance with the same principles used in the vertical core projects.

P2005 IndEcol Industrial case-projects in 1999 – 2000 are:

- Eco-effective value chains in the food industry
- Environmental Indicators and accounting methods in furniture production systems

- From eco-design to factor 4/10 development in eco-effectiveness
- Eco-efficiency of beverage container recycling systems
- Eco-parks as strategy in Industrial ecology and local agenda 21 programmes
- Principles of good practise towards loop closing
- Development of information network system of Norwegian LCA databases
- Responsible companies in manufacturing industry

IndEcol Partners
In addition to the companies that are directly involved in the projects, there are several important contacts. International contacts to be mentioned are:

- Massachusetts Institute of Technology - Technology, Business & Technology Programme
- Yale University - Industrial Environmental Management Programme
- Georgia Tech - Centre for Sustainable Technology
- Delft Univ. of Technology - Industrial Design Programme; Systems Engineering & Policy Analysis
- Ecole des Mines de Paris - ISIGE

There is also a close contact to World Business Council for Sustainable Development: North Sea Region, and to Interreg (a co-operation between Norway and Sweden), to Cre-copernicus among others.

Future perspectives
The study programme is running fulltime this year with approximately 35 students. They say that *"The educational program is interesting, we have skilled professors, guest professors, and we feel that we are highly appreciated. The educational program is intimate and engaging, the education is bases on practical training in projects groups from different departments, and several specialists and guest professors are from industrial companies".* A few criteria to measure the success of the IndEcol activities (both the study programme and P2005) are the number of publications, PhD-degrees, diploma thesis, seminars and conferences during a year. Over time it is also the intention to develop new multidisciplinary courses with an environmental contents for other students, or that students from traditional studies can participate in IndEcol-courses part time.

THE EUROPEAN PERSON EQUIVALENT: MEASURING THE PERSONAL ENVIRONMENTAL SPACE

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The European person equivalent (PE) is a quantification of the environmental impact caused annually by the activities of an average European. It comprises contributions to all the major environmental impacts from global to local as well as our consumption of resources.

Similarly, the targeted European person equivalent (PET) is a quantification of the average person’s environmental impact in a near future according to the current politically set environmental targets. In addition to expressing the current societal priorities in pollution reduction, the targeted PE expresses the environmental space available to all of us according to the current environmental policy.

Table 1 European PE and PET for a number of environmental impacts

Impact category	**UNIT**	**European PE** *(impact level per average European, 1994)*	**European PET** *(politically targeted impact level per average European, 2004)*
Global warming	g CO_2-eq/person/yr	$8.2 \cdot 10^6$	$7.9 \cdot 10^6$
Ozone depletion	g CFC11-eq/person/yr	0,081	0
Photochemical ozone formation	g C_2H_4-eq/person/yr	25	20
Acidification	g SO_2-eq/person/yr	74	49
Nutrient enrichment	g NO_3^--eq/person/yr	120.000	85.000
Chronic ecotoxicity in water	m^3 water/person/yr	350.000	290.000
Human toxicity via water	m^3 water/person/yr	52.000	35.000
Human toxicity via air	m^3 air/person/yr	$3.1 \cdot 10^9$	$2.9 \cdot 10^9$

While the PE is a measure of the current level of environmental impact from the European society’s activities, the PET is a measure that on a per capita basis expresses the level that the European society aims to reduce its environmental impact to in the year 2004. The ratio between the PE and the PET is a measure of the ambitions of current environmental policy for each of the environmental problem areas. The more ambitious, the lower the PET. At the same time, the PET is a prediction of what the average impact per person (i.e. the PE) will be in the near future (provided that society pursues its environmental targets).

Both concepts were developed in the mid-nineties for use in life cycle impact assessment to help comparisons across different environmental impact categories (Wenzel et al., 1997, Hauschild and Wenzel, 1998). Since then they have shown their value as a pedagogic tool in the presentation and interpretation of environmental impacts from all kinds of man-made activities, technologies and systems.

An environmental assessment is performed of the possible introduction of technologies to treat the wastewater emission from a plant. The assessment results in the environmental profiles shown in Table 2 for the situation without and with treatment

Table 2. Environmental profile for plant (per year) before and after a proposed introduction of wastewater treatment.

Impact category	*Unit*	No treatment	Treatment
Global warming	kg CO_2-eq /yr	174.000	461.100
Ozone depletion	kg CFC11-eq/yr	0	0,808
Acidification	kg SO_2-eq/yr	868	2.480
Photochemical ozone formation	kg C_2H_4-eq/yr	200	720
Nutrient enrichment	kg NO_3^-eq/yr	3.576	5.364
Human toxicity	m^3 air/yr	$3,40 \cdot 10^{11}$	$1,38 \cdot 10^{11}$
Ecotoxicity	m^3 water/yr	$2,16 \cdot 10^{7}$	$9,60 \cdot 10^{6}$
Land use	ha·yr/yr	170	50
Volume waste	kg/yr	9.450	40.500
Hazardous waste	kg/yr	248	165

The example reveals a number of trade-offs between the two situations. The ecotoxicity and human toxicity caused by the emissions are strongly reduced by the treatment but the reduction is accompanied by a considerable increase in the energy-related impacts, global warming, acidification and photochemical ozone formation. So is it a good idea to treat the discharge from an environmental perspective?

No unambiguous answer can be given to the question but by expressing the environmental impacts in person equivalents they are expressed at a common scale and their relative size is displayed on the background from society's environmental overall environmental impacts as illustrated in Figure 1.

	A	B	
Global warming	174.000	461.100	kg CO_2-eq
Acidification	868	2.480	kg SO_2-eq
Photochemical ozone formation	200	720	kg C_2H_4-eq
Nutrient enrichment	3.576	5.364	kg NO_3^--eq
Human toxicity	$3{,}40.10^{11}$	$1{,}38.10^{11}$	m^3 air
Ecotoxicity	$2{,}16.10^{7}$	$9{,}60.10^{6}$	m^3 water
Land use	170	50	ha.yr
Volume waste	9.450	40.500	kg
Hazardous waste	248	165	kg

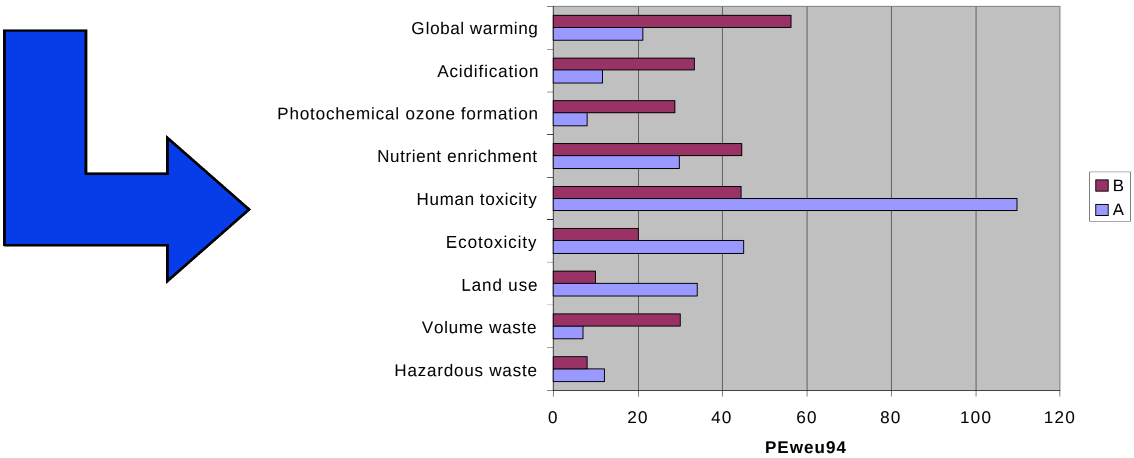

Figure 1. The environmental impacts are expressed in common units through translation into person equivalents, PE.

Expressing the impacts in PE's does enlighten the user on their relative sizes. It can be seen from Figure 1 that when compared to the societal background load, none of the impacts is completely insignificant compared to the others for either alternative. We are, however, still not able to answer the question whether we should treat the discharge or not. In order to do so, we must know how important the different impact categories are relative to each other. "Is global warming more important than acidification" and if it is, how much more important? In other words, we must have some values introduced into the comparison. Evidently, a valuation can not be objectively – we must decide whose values should be the basis for the final comparison.

When the impacts are expressed in targeted person equivalents, PET, instead of in PE's, the priorities of the current European environmental policy are introduced as values into the comparison. Now, an expression of the relative importance of the different impact categories has been introduced into the comparison. It is thus permissible to compare the impacts directly across impact categories when they are expressed as targeted person equivalents.

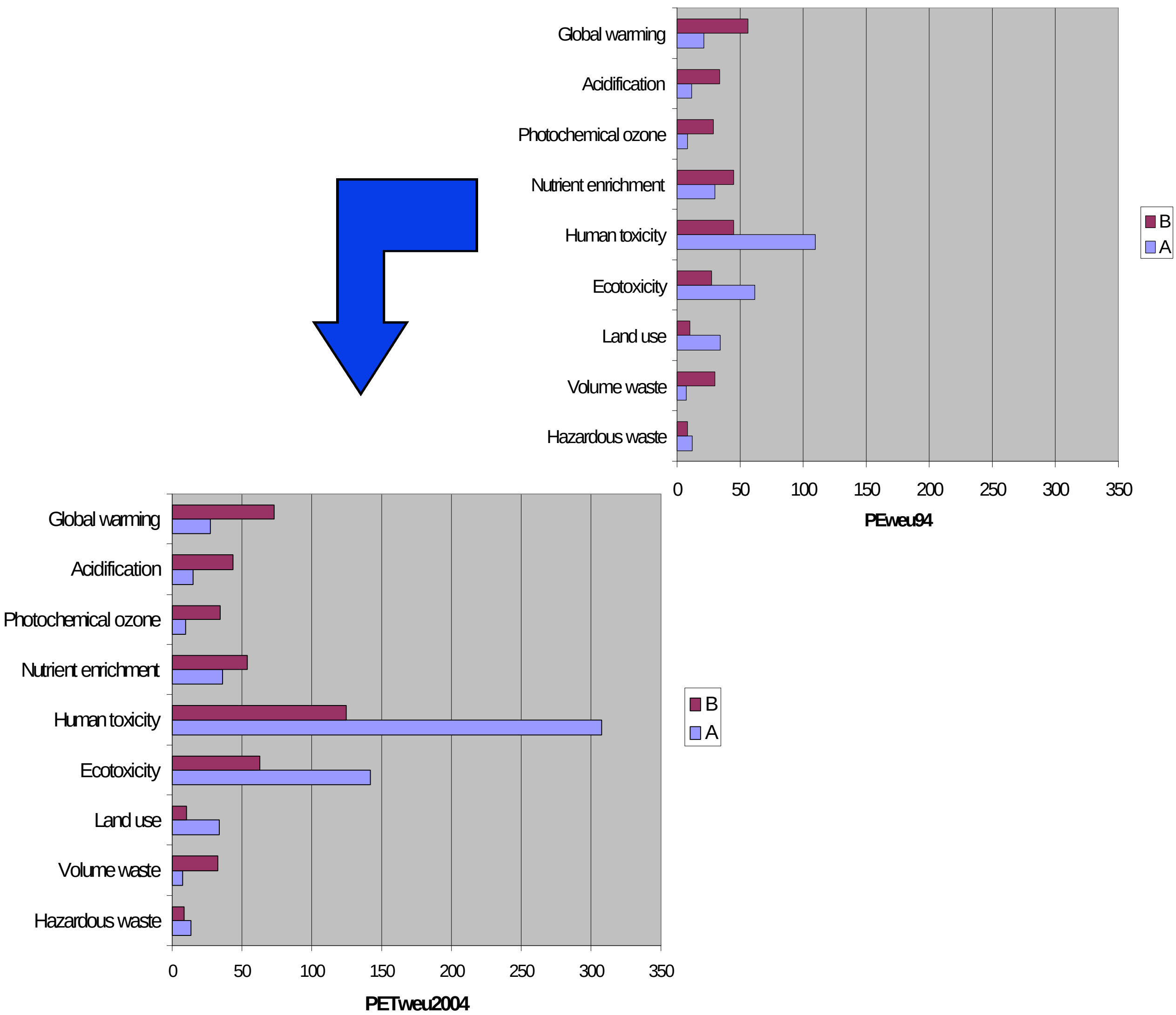

Figure 2. Introducing the priorities of current European environmental policy as values into the comparison by expressing the impacts in targeted person equivalents, PET

Accepting the current political reduction targets as a relevant expression of environmental importance, it can be concluded from Figure 2 that treatment should be preferred to non-treatment from an environmental perspective. Applying these values, the reductions in particularly ecotoxicity and human toxicity impacts are more important than the accompanying increases in the energy-related impacts.

The "environmental latitude" or “ecological space” is used to define the environmental impact that each person can cause in a sustainable society. In the same way, the PET is the "environmental policy target latitude" for the target year, i.e. the impact which we on average may cause for each of the impact categories if the targets for reductions are to be fulfilled.

The size of the environmental policy target latitude will gradually approach the size of the environmental latitude as the environmental policy targets approach the targets for sustainability. Table 3 shows a comparison between current political targets for 2004 and an approximate estimate of the needed reductions for sustainability.

Table 3 Current political reduction targets and sustainability reduction targets for a number of environmental impact categories

Impact category	**Reduction for 2004 %**	**Reduction for sustainability %***
Global warming	4	65
Ozone depletion	100	<100
Photochemical ozone formation	20	50
Acidification	34	90
Nutrient enrichment	29	90
Chronic ecotoxicity in water	17	85

** highly approximative, sustainability targets ambiguous*

In conclusion, the targeted person equivalent has properties which makes it suitable as a yardstick for industry's environmental performance:

- It is centrally determined, indirectly derived from actual emission levels and current political reduction targets, and it is common to all
- It is reflecting society's priorities and the most probable development in environmental impacts
- It is providing an estimate of the personal environmental space in the near future
- It is suitable as a yardstick for industry's communication of environmental performance
- in green accounting
- in system and process optimisations
- in product documentation

References

Wenzel H, Hauschild M and Alting L (1997): Environmental Assessment of Products. Volume 1: Methodology, tools and case studies in product development. Kluwer Academic Publishers, second printing 2000, ISBN 0-412-80800-5 (hardbound), ISBN 0-7923-7859-8 (paperback).

Hauschild M and Wenzel H (1998): Environmental Asssessment of Products. Volume 2: Scientific Background Chapman & Hall 1998. Distributed by Kluwer Academic Publishers, ISBN 0 412 80810 2 (hardbound)

Associate professor Michael Hauschild from Department of Manufacturing Engineering, Technical University of Denmark explaining the European Person-Equivalent

INDUSTRIAL COMPANIES

DESIGN FOR ENVIRONMENT AT DANISH A/V PRODUCER BANG & OLUFSEN –
CASE : COOL POWER, NEW AMPLIFIER TECHNOLOGY WITH 80-90% ENERGY REDUCTION

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Abstract
The lecture focused on the following questions: Who is Bang & Olufsen and what is ”environmental concerns” at Bang & Olufsen ? What is the company’s Environmental focus ? How do Bang & Olufsen handle environmental issues during product development ?
Case: The ICE-power amplifier

ENVIRONMENTAL IMPACT ASSESSMENT (LCA) ENERGY AND RE-CYCLING FOR A CIRCULATOR

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Abstract
The use of LCA in the product development process points out two clear areas of improvement of the environmental impact of a Circulator. Most of the energy used in the whole life cycle, from cradle to grave, is used in the use phase of the circulator, with the end user of the product. Typically, 99% of the whole life cycle energy is consumed in this phase.

All other phases like raw material productions-, transport- and the disposal phase consume 1%. The main environmental improvement will therefore be development of highly efficient pumps, and secure the right dimensions of the pump to the system were in it has to operate.

An other important environmental improvement of the pumps environmental performance, is to make sure, that the resources, bound in the product, can be recycled on disposal. The most important material in a typical Circulator is the Copper. Therefore, the Circulator should be constructed in a way, that the copper can be recycled in the disposal stage.

The conclusion from the LCA of the circulator is valid for almost all types of pumps, which run daily during the use phase. Only "special" pumps like "pumps in fire fighting equipment" have a different environmental impact profile.

At Grundfos we use the Danish LCA-tool EDIP (Environmental Design of Industrial Products) to secure that the environmental performances are documented in the product development process.

PRODUCT ORIENTED ENVIRONMENTAL MEASURES AT VOLVO

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Abstract
This presentation aims to show a variety of product oriented environmental measures that have been and are taken within Volvo Companies, including Cars, Trucks, Buses, Construction Equipment, Marine powertrains and Aerospace products. Some examples from the past up to now will be covered in the presentation, and also some aspects on present work which will contribute to reduced impact in the future, relating to for example:

- Fuel consumption

- Alternative fuels
- Alternative powertrains
- Lightweight materials
- Emissions
- Tools and working methods for environmental care in product development

Volvo (AB Volvo & Volvo Car) has been a forerunner and a major driving force in the development and use of Product oriented environmental measures in Swedish companies, especially from the late 1980's and onward. Volvo Car was also the first company to publish a third-party certified Environmental product declaration, in connection with the launch of the sedan S80 in may 1998. Volvo Technological Development Corporation is a corporate, task driven, R&D unit
operationally integrated in Volvo´s different business areas.

FACTOR 2 PROJECT ON TELECOMMUNICATION AT ERICSSON ENTERPRISE SYSTEMS AB

Lars Lenell, Ericsson Enterprise Systems AB
Ulf Östermark, Chalmers Industriteknik

An extensive Life Cycle Assessment project at the Enterprise Systems has been concluded during year 1999. About ten persons from Enterprise Systems have together with Flextronics International Inc. and Chalmers Industriteknik, collected a large amount of inventory data at a detailed level. Almost everything. Raw material extraction, component manufacturing, the product production at the Flextronics factory, the Ericsson “office parts” (design process, marketing, sales, distribution, service, installation and maintaining), the use stage and the end-of-life treatment were included in the study.

The purpose of the project was to create a ”base platform” for the future system design goals and work of the Private Branch Exchange MD110. The study resulted in concrete design guidelines, which are important to focus on in future product development, and has given a large material- and inventory database for the Business Unit.

A new (BC10) and an old (BC8) model of the private branch exchange MD 110, produced and sold by Ericsson Enterprise Systems, in this case for the EU market, has been compared. The Life Cycle Assessment (LCA) is a technique for assessing the environmental aspects and potential impact, associated with a product’s whole life cycle from the “cradle to the grave”.
This study meets the requirements of the international standards EN ISO 14040:1997 E, ISO 14041:1998 E and the draft standard ISO/DIS 14042 and 14043 from the International Organisation for Standardisation. A third party reviewer has also critically reviewed the study.

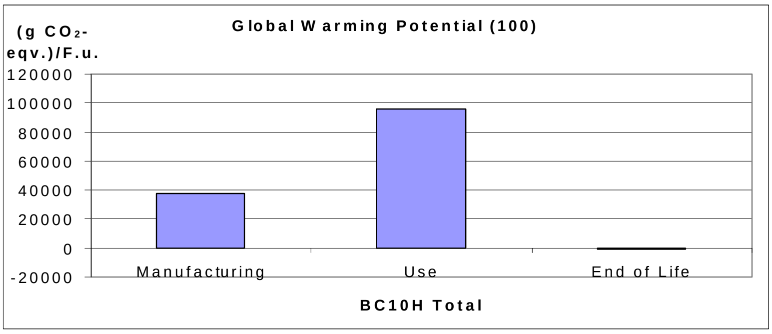
The modelling of the system includes manufacturing (hardware and Ericsson’s organisation), use stage (electricity consumption), end-of life (recycling processes) and transports. Electronic devices are modelled in depth (16 groups of components) and data from over 40 suppliers have been collected. Ericsson’s organisation (development, marketing&sales, supply, installation, service and sustaining) is modelled for use of offices and business travelling.

The comparison between the two generations of the system showed that the technical development towards reduced electricity consumption and more compact design resulted in a reduction of the environmental impacts.

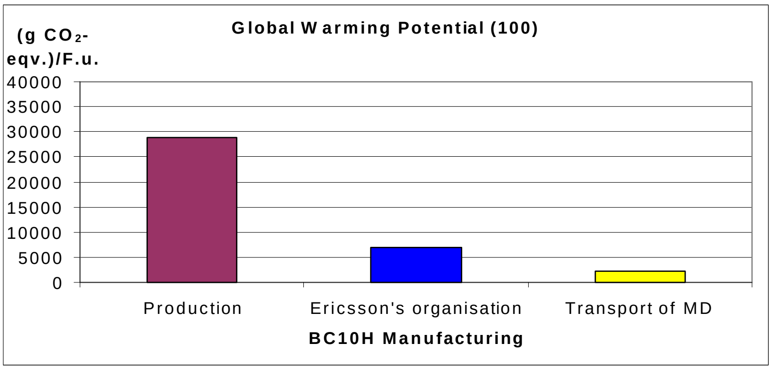
The following main conclusions of the project are based on results for potential contributions to the environmental impact categories acidification, global warming and eutrophication, which were chosen to be the most relevant. The results predominantly reflect energy use, whereas toxicological aspects needs separate attention (could not be reliably assessed due to lack of data and reliable methods). The technology improvements shown for BC10 compared to BC8 do only describe design improvements made by Ericsson, and does not take into account potential technology production improvements made by suppliers.

The following main conclusions are illustrated with results for global warming. The unit is grams of carbon dioxide equivalents per functional unit (one extension line during use in 15 years).

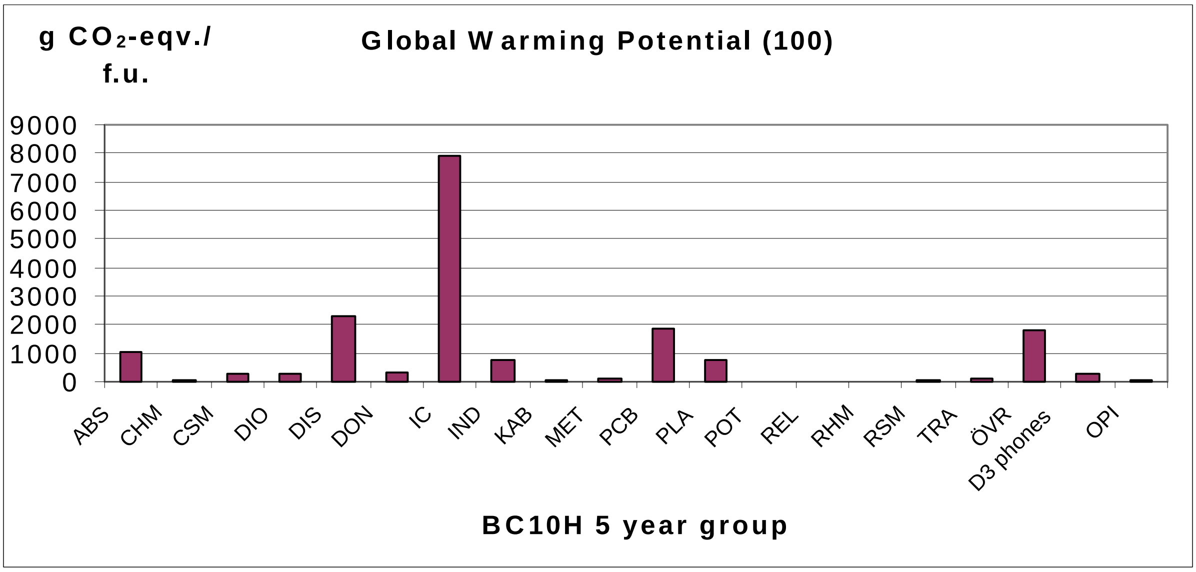
- As illustrated in the diagram below, the use stage and the manufacturing stage are the most important stages of the products' life cycle.
- The end-of-life stage appears to be of low or moderate importance for the energy-related impacts, but may be of large importance for toxicological impacts not reliably covered in this study.



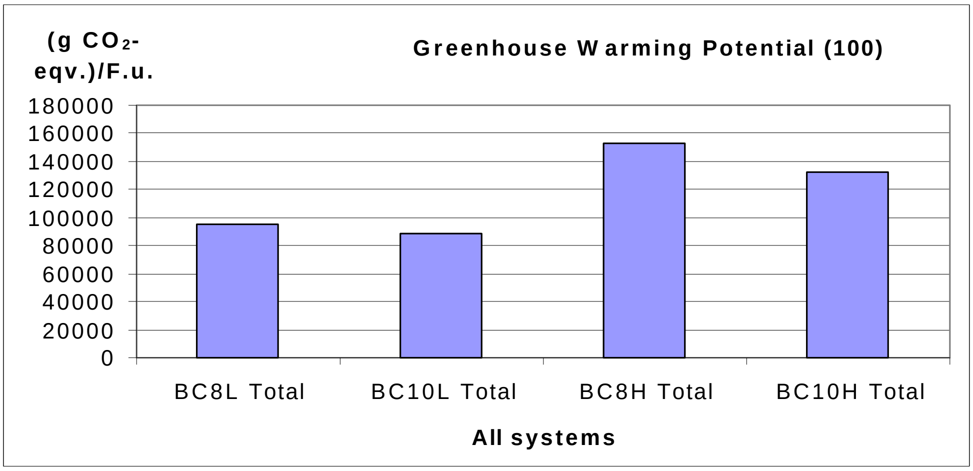
- In the manufacturing stage, the hardware production is dominating and Ericsson's organisation is secondly most important.



- Production of integrated circuits (IC) appears to be the individually most significant issue of the hardware production (approximately 20-40%). Printed circuit boards (PCB) contribute approximately 10% of the total score for hardware production.



- The environmental impact improvements of the new model compared to the old are approximately 10%, and the uncertainty of the results is judged to be smaller than the difference between the systems.



The conclusions lead to the following design guidelines:

- For existing MD 110 system, focus on decreasing the electricity consumption during the use stage.

- When possible, reduce the total area of silicon and the total size of capsules for ICs by substitution of standard ICs with application specific integrated circuits (ASICs).

- In future product development, the largest possibilities for the hardware appears to lie on a conceptual level (system design level). It appears to be difficult to reduce environmental impact significantly only by component substitution or detail construction adjustments.

- In future product development it is also recommended to include organisational development as a possibility for decreased environmental impact.

PRACTICAL EXPERIENCES IN THE FIELD OF PRODUCT-ORIENTED ENVIRONMENTAL MANAGEMENT IN THE TEXTILE INDUSTRY .

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Novotex , a traditional Danish garment maker began as early as 1986 to consider the environment as an important part of a garment. From the beginning very simple ideas – but despite this the first life-cycle assessment was mad as early as 1988.

Novotex began as one of the first companies in the world growing their own certified organic cotton (beg. in Turkey in 1988). We realized that Novotex is not a farm-company - and the idea costs a lot of money. When the first ideas about environmental management were introduced Novotex was again in front and introduced – supported by the Danish EPA – the BS 7750 . Later up-grated to EMAS and to ISO 14.001.

The strategy of ECO-labeling fitted Novotex well – and I was a member of the working group from the very beginning. To day the strategy of Novotex is to use ISO 14.001 (EMAS) on very product-level to prove the impact on the environment. By using the environmental management-system one can prove the fulfillment of the criteria in the eco-labeling - and thus integrating the two systems.

The VISION is to add working conditions to the requirements in ISO 14.001 (has happened) . Social responsibility is another important question which can be delt with by talking the rules of ILO and add those to the ISO 14.001.
Culture and commitment is necessary not to forget - but difficult to quantify

Where no ISO 14.001 is available - by some smaller suppliers – a questionnaire of ”Environmental impact assessment” is used. The above strategy – documentation - is used to prove the 4th marketing-tool : Environment

For 100 years three marketing tools only have been used in textile.

1. Price
2. Quality
3. Design - now adding the fourth
4. environment

All build on existing tools. Just simple coordinated into a integrated approach for textiles.
The only problem: A strategy to inform the consumer, to convince the consumer, to educate the consumer.

THE STEP MODEL – THE ENVIRONMENTAL MANAGEMENT TOOL IN HARTMANN, INCLUDING LIFE CYCLE MANAGEMENT

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Summary
Hartmann was founded in 1917 and has specialized in the production of moulded pulp packaging based on recycled paper. Hartmann has approx. 2000 employees. The products include egg and fruit packaging and also customized packaging for large industrial customers.

The STEP model describes the environmental demands put on the different production sites in the Hartmann Group. Or even before, since it is included in the work right from the initial considerations and examinations in connection with the acquisition of a new company. Hartmann developed the STEP-model in 1997. STEP stands for Systematic Tool for Environmental Progress and it is a all-in-one management model.

Activities within the STEP model

Tools	STEP 1	STEP 2	STEP 3	STEP 4	STEP 5
Network		Appointment of responsible person	Project groups are established	Audit-teams are established	Audit-teams are improved
Environmental management	Risk analysis, preliminary investigations, soil examinations, etc.	Preliminary environmental review	Building-up of an environmental management system	Certification of the environmental management system in ISO 14001, EMAS	Continuous improvements and audits
Cleaner technology		Overall targets for cleaner technology efforts	Cleaner technology projects to be carried through	More cleaner technology projects to be carried through	More cleaner technology projects to be carried through
Lifecycle management			Generation of data from subsuppliers	Preparation of basic lifecycle assessments	Implementation of lifecycle management
Communication		Internal environmental report	External environmental report	External environmental report, EMAS	External environmental report, EMAS
In-service training		Education kit: Why do environmental work?	Education kit: Why do systematic environmental work?	Education kit: Why do holistic environmental work?	Education kit: Lifecycle management

HARTMANN

Figure 1. the STEP-model

The STEP model operates with a horizontal development dimension (STEP 1-5, from basic to advanced) and a vertical tool dimension. The vertical tool dimension is built upon six environmental tools, which are all considered necessary in order to achieve a sustainable development: Network, environmental management, cleaner technology, lifecycle management, communication and in-service training

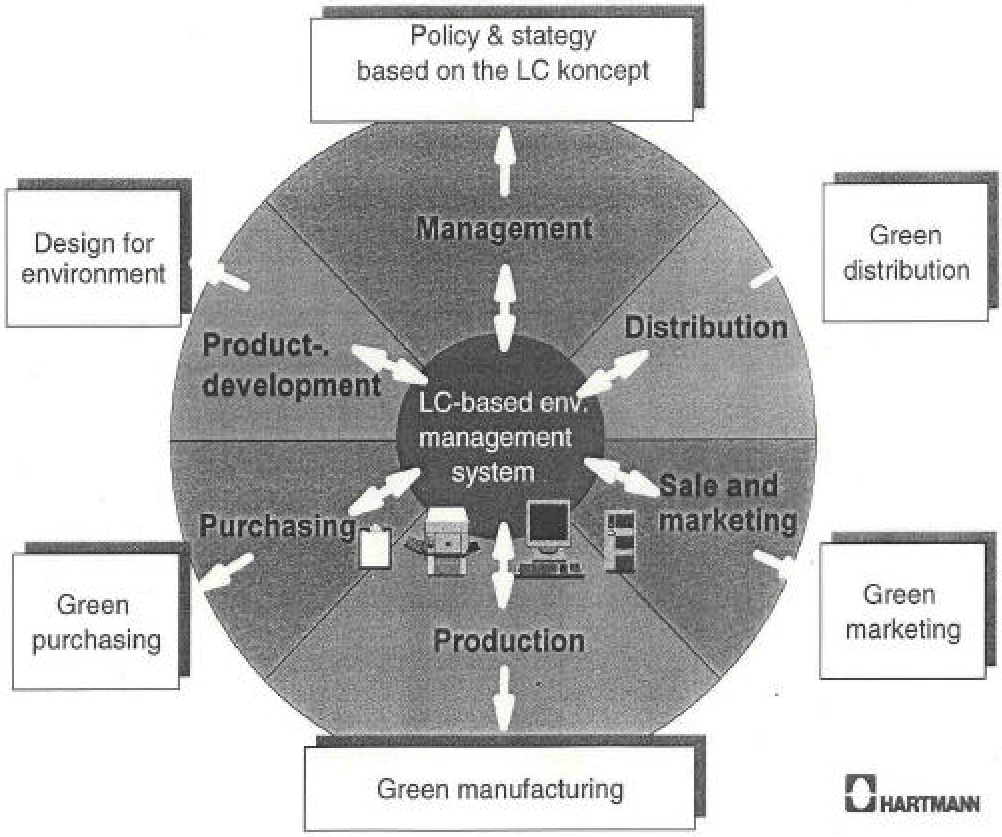

Figure 2. Life Cycle based environmental management system

The corporate environmental department has developed a number of implementation tools for the production sites. These tools range from report guidelines to advanced life cycle based management tools, which support and facilitate the implementation of the STEP model.

SPECIAL TOPIC DAY CONCLUSION

By Henrik Wenzel, Associate Professor, Technical University of Denmark, wenzel@ipl.dtu.dk

On this special topic day, we have learned about environmental achievements of a number of Nordic companies. Environmental improvement in the order of 50% in one step, and even more over a limited period of time, have been presented for us for products like pumps and egg trays. Yesterday, we learned that electronics' stand-by energy could be reduced by a factor of 10 or maybe even 20, and we met ICEpower®, the newly developed amplifier using only 10% of the energy of conventional amplifiers.

Environmental product improvements of this magnitude have come through in a very short time period of say 4-5 years. It is our experience from doing a large number of Life Cycle

Assessments and Eco-design initiatives of industrial products that very large improvement potentials exist for most products.

Products are produced to fulfil human needs. And human needs are increasing. With increasing population and increasing material standards of life, the need of products and services of human beings seem to increase by a factor of 5 or more over 50 years. The task is, thus, to increase the environmental- and resource efficiency of the way in which we fulfil these needs, i.e. to reduce the resource consumption and environmental impacts per service provided/need fulfilled. This task can be solved by measures on different level. Figure 1 illustrates these levels:

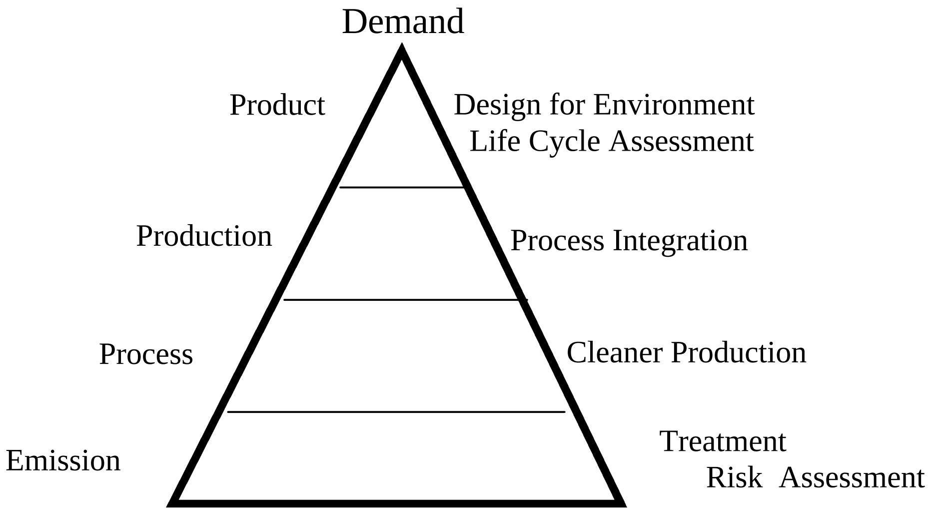

Figure 1. Levels of environmental improvement measures. A demand and supply chain

The figure shows a cause/effect chain – or one might say a demand/supply chain:

The human need is the demand of the product. If this need could be reduced, less products would be produced in the world. Unfortunately, it seems that this need will increase, as mentioned above.

The product is the supply fulfilling the need. At the same time, however, the product is the demand of the production. Productions throughout the world only take place, because they as part of a supply chain contribute to final end-user products fulfilling end-user needs somewhere. If the product were intelligently re-engineered/re-developed, using e.g. life cycle assessment and eco-design techniques, the demand for production volumes and/or hazardous production types might decrease. Cf. the development of a new amplifier implying a demand of electricity production of only 10% of the conventional amplifiers during use. A lot of effort goes into reducing environmental impacts from electricity production – like we have learned from Dr. Atimtay on Tuesday. Improvement measures on products will reduce the effort needed on productions.

The production is the supply providing the product through the supply chain. At the same time, however, it is the demand of the individual process. Processes in the company only take place, because they as part of the chain/network of processes at the production site contribute to the final output from the production. If the production were intelligently re-engineered/re-designed, using e.g. process integration techniques like the ones we learned of last year in Belfast, the demand for process volumes and/or hazardous processes might decrease. The Industrial Symbiosis in the city of Kalundborg, that we saw yesterday, is an example of process integration reducing the needed volume of the individual processes in the symbiotic industrial network. Improvement measures on productions will reduce the effort needed on the individual process.

The process is the supply providing the output from the production site through the chain/network of processes on the site. At the same time, however, the individual process is the demand for the resulting input from nature (resource consumption) and the cause of the final output to nature (emission). Inputs and outputs only take place, because they are the precondition of the process providing its service. If the process were intelligently re-engineered/re-designed, using cleaner production techniques, like we saw in electroplating two years ago in Cincinnati, the demand for resources and the emissions would decrease. And with it the need for treatment measures.

Measures are possible at all levels of this demand-supply chain, and very large improvement potentials exist at all levels. There are no overlaps between measures at the different levels and they truly supplement each other.

Working on one level without the other is a misunderstanding and will never be cost-effective. Why struggle and fight on the production level with reducing the negative impacts of electricity production if it were much more cost-effective to reduce the demand for electricity on the product level? Measures on the product level taken by Nordic companies have been presented on this special topic day. The product focus is, however, very new in environmental policy, and Nordic companies are among the world leaders. There are still many lessons to be learned still in this area, and still very large perspectives in working in it. RETURN TO CONTENTS PAGE

INTRODUCTION TO TECHNICAL TOUR

The field trip schedule included a visit to three institutes at the Technical University of Denmark and to the industrial symbiosis in Kalundborg. Between the technical venues, the group visited the Viking ship museum in Roskilde, and after a very long day, the group relaxed over dinner in a picturesque but haunted old Danish castle.

Although in the homeland of the Vikings, astonishment at the means of transportation provided for the field trip

The NATO/CCMS group in life jackets going out to sea

And as the day passed the means of transportation got even quainter.

The NATO/CCMS Pilot Study group waving to the photographer

FIELD TRIP PRESENTATIONS

The Technical University of Denmark - DTU

As a modern technological university, DTU, the Technical University of Denmark, operates at a high international level in a wide array of activities in fields such as biotechnology, communications technology, nanotechnology and development of technologies for sustainable production and renewable energy. The University's research and teaching is provided by 32 institutes, a number of major independent centers established as joint ventures between DTU and companies and research institutes in the region. Like all modern universities, DTU also operates a number of transient and dynamic centers in which the driving force resides in collaboration across different fields of research and organizations.

DTU's physical presence in the north of Copenhagen gives it a natural part to play in fostering the Øresund region as a new "powerhouse" for research, the development of production facilities and educational provisions. The platform for this drive is made up of the region's 11 universities, 5 science parks and a heavy concentration of both old and new companies. For DTU, the most essential task is to secure and maintain the best possible framework for national and international cooperation in both State-funded and private research. This is the Alpha and Omega in the creation and communication of new knowledge for contributing sustainable added-value to society. The task is achieved in collaboration with R&D divisions in private companies, through patenting, the establishment of new enterprises and through the University's Bachelor and Masters courses, and training of new young researchers.

The University embraces most of the engineering disciplines, and trains engineers to Bachelor, Masters and PhD level. In addition, the University offers a comprehensive continuing education program, with a number of courses taught in English. The University has 6000 students preparing for Bachelor and Masters degrees, 600 PhD students and takes 400 foreign students per year on English-taught courses. DTU also has a permanent 400 of its Danish students away on varying length courses at foreign universities.

INSTITUTE PRESENTATIONS - TECHNICAL UNIVERSITY OF DENMARK

New technology for gasification of biomass.

Ulrik Henriksen, Biomass Gasification group

The Biomass Gasification group at ET, DTU have more than 15 years of experience within R&D and design of pyrolysis and gasification processes. The group is the Danish knowledge centre of biomass gasification. We are doing fundamental research, mathematical modelling and process design and optimisation. The two stage gasification process was developed here.

The two-stage gasification process

In the two-stage gasification process, the pyrolysis and the gasification process are separated into two different zones. In between the pyrolysis and the gasification zones, the volatiles from the pyrolysis are partially oxidised. Hereby, most of the tars are decomposed into harmless gas

molecules. To enable high energy efficiency, the thermal energy in the gasification gas and the exhaust gas is being used for drying, air preheating and for pyrolysis.
For small gasification plants (up to about 6 MW thermal), the traditional two-stage gasification process is well known. For larger gasification plants, a new way of integrating drying, pyrolysis, gasification and combustion unit is developed where the advantages of the traditional two-stage gasifier are maintained.

The most important advantages of the two-stage gasification process are:

- High gasifier and overall energy efficiency (above 90% cold gas efficiency).
- Low tar content in the produced gas (below 25 mg/Nm^3).The two-stage gasification process is a combination of well-known technologies.
- Uncomplicated gas cleaning system.
- Good process for fuels with high moisture content (up to 55% moist on wet basis).
- Low particle content in produced gas when the fuel has a high moisture content.
- Flexible choice of fuels (successful tests on straw, briquettes and woodchips).
- High temperatures limited to a minor, fully temperature controlled zone.
- Can be built in sizes of 0,5-100 MW (thermal input).
- Low emissions from thermal conversion unit and clean condensate when product gas is cooled.

Small-scale power production based on Stirling engines
Henrik Carlsen,

One of the activities in a large research and development program in Denmark concentrating on the development of decentralised combined heat and power (CHP) systems for biomass is the development of Stirling engines. The Stirling engine has external combustion, which makes it very attractive for this purpose.

Up to this point two different sizes of engines are considered. A Stirling engine designed for an electric power output of 35 kW has been built and tested using wood chips as fuel, and two 9 kW engines have been built and tested using natural gas and biogas as fuel.

After the 35 kW_{el} engine was tested in the laboratory for more than 600 hours it was mounted on a wood chip combustion system specially developed for this purpose. Currently this plant has run for more than 1400 hours using wood chips with very satisfactory results, and the field test is now continued. The plant is fully automated and it has been running unmanned most of the time.

Only minor problems with thermocouples and the wood chip feed have resulted in unplanned stops.

A new and improved 35 kW Stirling engine is now tested in the laboratory with natural gas as fuel. The test results so far has been very satisfactory, but a few changes have to be made. This engine is expected to be ready for field test in August 2000.

The 9 kW_{el} engines have been performing very well. They have been tested for more than 250 hours respectively, and they have showed, that they can produce a maximum output of 10.5 kW_{el}.

The Stirling engine development projects are funded by the Danish Energy Agency and it is carried out as a co-operation between Department of Energy Engineering, Technical University of Denmark, and several industrial companies.

ICEpower® - Switch-mode audio power amplifiers.
Associate Professor Michael Andersen

A research co-operation with the Danish audio/video manufacturer Bang & Olufsen has resulted in a break-through in amplifier technology. Project results shows that switch-mode (class D) techniques can now be used to realise high quality audio power amplifiers with an efficiency at full output power at ~94% and an energy efficiency in a normal user situation of ~30% (compared to a class B power amplifier with respectively ~60% and ~1%). This implies energy savings during operation of around 80%. The different parts of a switch-mode audio power amplifier with either an analogue or a digital input will be presented, and there will be focused on the techniques that has enabled these results. Moreover, there will be a short demonstration.

Low energy stand-by function
Associate Professor Michael Andersen and PhD Nils Nielsen

Stand-by lamps and power supply for electrical equipment uses a large part of the total electricity production world wide. This means, that even when the equipment is switched off, there is major electricity consumption. A solution to this problem has come closer with the development of a prototype stand-by power supply with losses as low as 0.025W-0.2W - a significant reduction when acknowledging that 3-5 W in e.g. televisions is considered low.

Newest developments in cleaner surface technology and micro technology.
Per Møller, Department of Manufacturing Engineering,

Materials technology and environment is becoming more and more integrated factors. In the future, material science will be the key for solving environmental problems in several industries. Therefore research in improvement of both process technology and products has to be an important area. The type of problems to be solved will be minimizing of material resources by producing of products with improved lifetime by intelligent material selection and surface engineering, minimizing of the material consumption by miniaturizing of components (micro technology) and development of new processes and methods for reduction of waste and at the same time.

In this short introduction, some cases will be shown:

Case 1. Improvement of the efficiency for big power generators for power production by selecting of new materials for slip rings.

Case 2. Some examples of minimizing of material resources by application of micro technology.

Case 3. Design of a new multiflexible electroplating equipment for plating zinc and zinc/iron combined with 4 different conversion coatings, 3 different sealer systems and heat treatment to eliminate hydrogen embrittlement. The new equipment, with a capacity of 4000 metric ton/y is able to produce more than twenty useable combinations of zinc coating, conversion-coating and sealer. Furthermore the equipment is designed for waste minimization.

The cases show the philosophy behind the multidisciplinary way of thinking, when the goal is to obtain a holistic concept in the improvement of product quality and flexibility and at the same time reduce or eliminate the environmental problems. In many cases, there do not need to be a conflict between better quality and better environment .

INDUSTRY PRESENTATIONS

The Industrial Symbiosis at Kalundborg

Valdemar Christensen, Asnæs Power Station

In the industrial symbiosis of Kalundborg, several enterprises utilise each other’s residual products in a network: Asnæs Power Station, Gyproc – a plasterboard manufacturer, the pharmaceutical and biotechnology group Novo Nordic, the Statoil Refinery, and the Municipality of Kalundborg. This mutual use of residues saves resources and reduces the burden on the environment significantly in an area with many heavy process industries. Moreover, it offers economic advantages to the parties involved, because all contracts within the symbiosis are based on commercial principles.

Asnæs Power Station

Valdemar Christensen, Asnæs Power Station

Asnæs Power Station is owned by SK Power, Denmark and is the country’s largest power station, employing 500 people. The station is coal fired and covers about half of the demand for electricity on Zealand. Since 1980, Asnæs Power Station has supplied district heat to the town of Kalundborg and process steam to the Statoil Refinery and Novo Nordic.

Co-generation of heat and electricity means better fuel utilisation and cheaper heat than the customers can produce themselves, and the amount of heat wasted with the cooling water discharge to Kalundborg Fjord is reduced too. Some of the residual heat is used in a fish farm producing 200 tons of trout a year. The fish grow more rapidly in the warm cooling water. sludge from the fish farm's water treatment plant is used as fertiliser on nearby fields.
The desulphurisation unit at Asnæs Power Station, which has been in operation since the middle of 1993, produces about 100,000 tons of gypsum a year. The gypsum is sold to Gyproc, which makes plasterboard products for building industry.

Earlier, all water for steam production was ground water. Now water for steam has been replaced by surface water from Lake Tissø and by cooling water from the Statoil Refinery. The power station, then, returns some of the reused water to the refinery as steam.

The NATO/CCMS Pilot Study Group at Asnæs Power Station

Novo Nordisk
Anders Brinck Larsen, Novo Nordisk A/S

Novo Nordisk makes insulin and industrial enzymes. Its Kalundborg plant has about 1,200 employees. Novo Nordisk buys process steam from Asnæs Power Station and surface water from Lake Tissø. The company's enzyme production, which involves fermentatioon of raw materials such as potato flour and corn starch, produces large quantities of biomass containing nitrogen. the biomass is piped or transported by tanker to farms in West Zealand, where it is spread on the fields, replacing commercial fertiliser. Surplus yeast from the insulin production is now used as fodder. RETURN TO CONTENTS PAGE

INTRODUCTION

In 1989, Queens University in Belfast and a number of industrial companies established a centre for co-operation on environmental issues, the Queens University Environmental Science and Technology Research Centre, QUESTOR. At the 2nd meeting of this pilot study held in Belfast in 1999 the centre concept, history and activities were presented. The interest among the meeting delegates was great, and it was decided to plan a more in depth tutorial in 2000 for delegates, who would like to have a *do-it-yourself guidance*. Professor Jim Swindall of QUESTOR was invited to and kindly accepted to give this tutorial at the Copenhagen meeting.

INDUSTRY/UNIVERSITY CO-OPERATIVE RESEARCH

A powerful mechanism for involving industry in basic research in co-operation with universities was developed by the US National Science Foundation (NSF) in the seventies. This concept was called Industry/University Co-operative Research Centre (IUCRC) and it has been continuously refined until there are now 53 Centres throughout the USA. A feature of almost all of these Centres in their interdisciplinarity and the areas addressed by them range from Applied Polymer Research to Web Handling.

Surprisingly, the concept has been little copied outside the USA except for two centres in Queen's University in Northern Ireland, one called QUESTOR, for environmental research founded in 1989 and a second one called QUILL, for ionic liquid research founded in 1999. A third one called QUMED, for medical device research is in the planning phase.

The concept provides a win-win-win scenario,

1. The university gains funding from industry in the form of membership subscriptions, these typically range from $30,000 to $50,000 per annum and as an average centre membership is 15 companies the funding is significant. Additionally, hard cash from industry in support of basic research assists the participating university staff with grant applications to Government because it demonstrates the relevance of the proposed research. The research staff and students working in the Centre gain valuable feedback from the industry partners on their research and their frequent contact with senior industrialists gives them valuable contacts and confidence when seeking jobs.
2. The industry members gain from the leverage effect whereby their subscriptions are added to those of all the other members. In addition the industry members will have first sight of the results of research supported by government grants secured by the centre. A close relationship develops with the University and this can lead to additional contacts. The members also have the opportunity to appraise the research staff and students during their time with the centre and make an informed decision on their recruitment.

3. Government wins by the increased industry input into, and involvement in, basic research and this inevitably leads to increased technology transfer. Government funding is also leveraged by the industry subscriptions.

Setting up an IUCRC is a major task that requires a lot of time commitment. If this is to be done by a senior academic with a reputation in the chosen field then he/she will need a manager with the freedom to devote the required time to visiting companies and drumming up support, organising a planning meeting, encouraging academic colleagues to participate in the planning meeting etc. When the centre is set up a sound management structure needs to be put in place with a manager charged with fostering the relationship between the centre and the industry members. It is not possible for a Senior Academic, with academic duties, which will always take priority, to both lead and manage a centre.

The benefits of an IUCRC to a university can be illustrated by the following: in 11 years the QUESTOR Centre attracted funding of over £15m from industry, government and the EU. The QUILL Centre, developed from it, has attracted £1.7m in two years and is growing rapidly. In the USA the IUCRC programme attracts an annual sum of $75m for industry relevant basic research of which the NSF contribution is only $5m.

That two centres, following the IUCRC concept, have been successfully set up in a tiny region such as Northern Ireland demonstrates in the most positive way that the concept is fully transferable. Furthermore, of the 18 members of the QUILL Centre, six are located in the USA, two in Germany, one in Holland and one in South Africa, demonstrating also that such a centre has sufficient relevance to industry needs to attract Members internationally.

The mechanisms for setting up and running an IUCRC are set out in great detail in a 322 page book by S. George Walters and Denis O. Gray entitled ‘Managing the Industry/University Cooperative Research Centre: A Guide for Directors and Other Stakeholders’ published in 1998 by the Battelle Press of Columbus, Ohio. ISBN 1-57477-053-5. A careful reading of this book will pay handsome dividends for anyone contemplating setting up an IUCRC and emulating the success of the US centres.

Professor Jim Swindall OBE
22nd March 2001

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OPEN FORUM ON CLEAN PRODUCTS AND PROCESSES AND FUTURE DIRECTION OF THE PILOT STUDY

Subhas Sikdar and Dan Murray

Summary

The pilot study director, Dr. Subhas Sikdar opened the discussion by reviewing the concept behind this pilot study: there is a definite mission behind CCMS pilot programs, namely to facilitate a cross national dialogue and support cross national collaboration. Moreover, we are not here due to our own professional interest only, we are approved delegates speaking for the countries we represent. This makes the pilot study a very unique experience.

To satisfy the goal, the pilot study should stimulate discussions among nations and catalyse collaborative work, also through other auspices. Such spin-offs have already happened. Subhas Sikdar encouraged everyone to keep possibilities of collaboration in mind. The pilot study web-site could be one good catalyst for this.

Another aim of the study is to facilitate assistance CP nations – former European east block countries. Speaking of environmental performance of technology, NATO countries are perceived to be somewhat ahead, and an aim of the NATO CCMS is, that the study should be a helping hand to those countries in need. Therefore, collaboration between NATO countries and CP countries is desirable.

During the meeting it was mentioned that funding opportunities are available in e.g. NATO's science for peace program and various EU programs.

Dr. Sikdar urged delegates to go back and get in touch with their country representative of CCMS – or for CP nations ministry contacts or environmental protection agency contacts – and supply them with a summary report and maybe a copy of the meeting agenda. The purpose being to explain the benefit of the pilot to the people supporting the study and thereby prepare the land for future participation. Some NATO countries had for this meeting stated their interest in participating, but had not been able to raise funding. It is in-excusable for advanced countries like Netherlands, France etc. not being able to find the money to support a delegate. The country CCMS representative has an obligation to support the pilot study and the delegate.

Dr. Sikdar thanked the Copenhagen meeting hosts and complimented the meeting agenda. The special topic day provided very fruitful discussions. The question of how to proceed along the lines of such a special topic day was raised.

This year, a special focus on textiles was given by Professor Michael Overcash who had compiled inputs on Cleaner Production in textile industry from all participating countries . A discussion on how to proceed was opened ending with the conclusion to continue this project with metal finishing industry and food & agriculture.

Between meetings there had been established bi-national collaboration already, one example being, that Dr. Russell Dunn, who was invited speaker last year at the Belfast meeting had been invited as guest professor at the Technical University of Denmark and was going to come back there one more time in August 2000.

Dissemination of the meeting report was discussed, and various options were mentioned. One option is to have NATO CCMS print special booklets on elected topics, like e.g.a publication on the special topic day. Another option is to have the full report available on the pilot study web-site.

A discussion on the duration and structure of the next meeting concluded to follow much the same concept as known from previous meetings.

The issue of special topics was raised and a number of suggestions were put forward and discussed: Simplified methods and tools (e.g.LCA, Env. Management, etc.), the Military sector, Water reclamation and reuse a special topic? Cleaner Products and Processes in University Curriculum.

It was pointed out that the special topic to some extent would depend on the meeting location.

It was mentioned that the idea of having a Computer Café was good and should be continued.

Finally, as location of next years meeting: Spain was unanimously agreed on.

SUMMING UP

The pilot study director, Dr. Subhas Sikdar finalised the meeting by summing up and thanking organisers and sponsors: NATO CCMS, Danish EPA, US EPA, the Technical University of Denmark and the Danish Research Councils. RETURN TO CONTENTS PAGE

APPENDIX 1

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APPENDIX II: PROGRAM FOR THE MEETING IN COPENHAGEN 2000

SUNDAY, MAY 7, 2000
18:00
Delegates/participants gather in the Komfort Hotel, Copenhagen
18:30-21:00
Reception, registration and get-together at Danish Design Centre,
H C Andersens Boulevard 27 (5 min. walk from Komfort Hotel)

Welcome:
Dr. Subhas Sikdar, Pilot Study Director
U.S. Environmental Protection Agency
National Risk Management Research Laboratory
Cincinnati, Ohio, USA

Associate Professor Henrik Wenzel
Institute of Product Development/
Department of Manufacturing Engineering
Technical University of Denmark, Lyngby, Denmark

MONDAY, MAY 8, 2000
08:30
Arrival, Coffee/Tea - Association of Danish Engineers' Conference Centre
08:45
Welcome – *Dr. Subhas Sikdar*, Pilot Study Director
09:00
Introduction round of country delegates and participants
09:30
Overview of Meeting Agenda, Field Visits and Events. *Daniel Murray*, Pilot Study Co-Director
09:45
Break – Coffee/Tea

MORNING SESSION ORIENTATION: ENGINEERING SKILLS, TECHNIQUES AND TOOLS
10:00
Engineering for Sustainable Development – an Obligatory Skill of the FutureEngineer.
Invited speaker: *Dr. Leo Alting*, director of Institute for Product Development, and professor at the Department of Manufacturing Engineering, Technical University of Denmark.
10:30
Pilot Project Updates (20 minutes each)

- **Pollution Prevention Tools**, *Subhas Sikdar,* USA
- **Water conservation and recycling in Semiconductor Industry: Control of Organic Contamination and Biofouling in Ultra Pure Water systems**, *Farhang Shadman*, USA, *Mike*

Larkin and *Jim Swindall*, UK

11.10
Membranes in Process Intensification and Cleaner Productions. Invited speaker: *Dr. Enrico Drioli*, Professor at Department of Chemical and Material Engineering, University of Calabria, Italy
11:40
Departure for lunch at the City Hall of Copenhagen (walking distance of conference centre)

12:00
Copenhagen City Hall. Welcome by Copenhagen Major of the Environment, *Mr. Bo Asmus Kjeldgaard*. Lunch buffet followed by a tour of the City Hall.
13:10
Departure for the conference centre
13:30
Tour-de-Table presentations (15 minutes each)
Spain, Greece, United Kingdom, Denmark
14:30
Break – Coffee/Tea

AFTERNOON SESSION ORIENTATION: CLEANER PRODUCTION DISSEMINATION
15:00
Approaches to Cleaner Production in economies in transition – the results and perspectives of the Cleaner Production Centres. Invited Speaker: *Vladimir Dobes*, Czech Cleaner Production Centre, Czech Republic
15:30
Tour-de-Table presentations
Poland, Czech Republic, Slovak Republic, Moldova
16:30
Technology dissemination – discussion. Moderator: *Vladimir Dobes*

POSTER- AND COMPUTER TOOL CAFÉ
17:00
Coffee/Tea and sandwiches. Beers and soft drinks will be for sale.
- **Chemical Life Cycle Database**

Michael Overcash, USA
- **CAPEC software tools for chemical and process system engineering**

Peter Harper, Denmark
- **FIBRESAVE Integrated Environmental Information System**

João Dias, Portugal
- **The EDIP LCA tool**

Morten Als Pedersen, Denmark
- **Paris II – environmnetally friendly chemical substitution in industry**

Dan Murray, USA

- **Application of Life Cycle Assessment and Sustainable Process Index to Process Design**.

Teresa M. Mata and Carlos A. V. Costa, Portugal
19:00
Adjourn

TUESDAY, MAY 9, 2000
08:30
Arrival, Coffee/Tea - Association of Danish Engineers' Conference Centre
09:00
Computer Aided Molecular Design Problem Formulation and Solution: Solvent Selection and Substitution. Invited speakers: *Rafiqul Gani* and *Peter Harper*, Department of Chemical Engineering, Techn. University of Denmark
09:30
Tour-de-Table presentations
Israel, Italy, Turkey, Portugal
10:30
Break – Coffee/Tea
10:45
Pilot Project Updates

- **Nato/CCMS Project Members Evaluation of Cleaner Production**,

Michael Overcash, USA

- **Clean Processes in the Turkish Textile Industry,** *Nilgun Kiran,* Turkey
- **Energy efficiency in Moldova**, *Sergiu Galitchii,* Moldova

11:45
Tour-de-Table presentations
Bulgaria, Ukraine, Romania, USA
12:45
Lunch

14:00
The first Step Towards Sustainable Business Practice: The SB (SmithKline Beecham) Design for Environment Tool Kit. Invited Presentation: *Virginia L. Cunningham,* SmithKline Beecham, USA
14:30
Pilot Project Updates

- **Cleaner Energy Production with Combined Cycle Systems**, *Aysel T. Atimtay*, Turkey
- **CEVI, The Danish Centre for Industrial Water Management**, *Henrik Wenzel*, Denmark

15:10
Break - Coffee/Tea
15:40
Biological Control of Microbial Growth in the Process Water of Moulded Pulp Production – Avoiding the Use of Biocides. Invited speaker: *Gert Holm Kristensen,* DHI – Water and

Environment, Denmark
16:10
Environmental Life Cycle Assessment of Alternative Scenarios for Biological Control of Microbial Growth in the Process Water of Moulded Pulp Production. Invited speaker: *Nilgun Kiran, TUBITAK – Marmara Research Centre, Turkey*

UNIVERSITY-INDUSTRY CO-OPERATION – OPTIONAL TUTORIAL

16:30
Mini tutorial on the set-up of university-industry co-operation centres – do-it-yourself. Invited tutorial: *Dr. Jim Swindall*, Questor Centre, Queens University, Belfast, United Kingdom
17:30
Adjourn
19:00
Banquet at The Tivoli Gardens, restaurant Nimb, Brasseriet, the garden lounge

WEDNESDAY, MAY 10, 2000

FIELD TRIP
07:50 – 08:00
Boarding the coach at Komfort Hotel – be there on time
08:00
Departure for the field trip. The coach leaves at 08:00

TECHNICAL UNIVERSITY OF DENMARK
08:30
Arrival at the Technical University of Denmark. The delegation is divided into three groups and guided through the following visits and presentations. Each visit will endure around 30 minutes:

1. Department of Energy Engineering: **New technology for gasification of biomass and new development of the Stirling motor for small scale heat and power co-generation directly on biomass.** Invited demonstrations and presentations: *Ulrik Henriksen* and *Henrik Carlsen*

2. Department of Applied Electronics: **New developments of low energy stand-by function and low energy amplifier.** Invited demonstrations and presentations: *Michael Andersen* and *Nils Nielsen*

3. Department of Manufacturing Engineering: **Newest developments in cleaner surface technology and micro technology.** Invited demonstrations and presentations: *Per Møller*

10:30
Departure from Technical University of Denmark

THE VIKING PERIOD AND MIDDLE AGE
11:15
Visit to Viking Ship Peninsula in Roskilde. Guided tour of the museum
12:00
Traditional Danish Heering&Snaps lunch on the Viking Ship Peninsula
13:00
Departure on a time journey around 1000 years back. Optional choice between three destinations (we recommend first destination):

- The Viking period: sailing on the fjord in a Viking Ship
- The Viking period: visit to the Viking Ship workshop
- The Middle Age: visit to the Cathedral of Roskilde

14:15
Back in present time. Departure from the Viking Ship Peninsula

THE INDUSTRIAL SYMBIOSIS IN KALUNDBORG
15:15
Visit to **Asnæs Power Station**. Invited presentation: *Valdemar Christensen*
16:30
Visit to **Novo Nordic A/S**. Invited presentation: *Anders Brinck Larsen*
18:00
Departure from Novo Nordic, Kalundborg

THE MIDDLE AGE
18:30
Back in the Middle Age. Change to horse-powered vehicle
19:00
Arrival at Dragsholm Castle by horse carriage. Guided tour of the Castle
20:00
Dinner in the hall of knights of the haunted castle of Dragsholm
23:00
Departure for Copenhagen

THURSDAY, MAY 11, 2000

SPECIAL TOPIC DAY: PRODUCT ORIENTED ENVIRONMENTAL MEASURES
08:30
Arrival, Coffee/Tea - Association of Danish Engineers' Conference Centre
08:55
Introduction to special topic day - *Henrik Wenzel*

09:00
The Concept of Eco-design and Results from the Dutch Eco-design Programmes. *Tom van der Horst,* TNO, The Netherlands

09:30
Design for Environment at Danish A/V producer Bang & Olufsen
Case: IcePower®, new amplifier technology with 80-90% energy reduction. *Jesper Olesen,* Bang & Olufsen A/S, Denmark
10:00
Product Oriented Environmental Measures at Danish pump producer Grundfos. Case: new generation circulator with 40% energy reduction. *Nils Thorup*, Grundfos A/S, Denmark
10:30
Break - Coffee/Tea
11:00
Product Oriented Environmental Measures at Volvo A/B. *Tomas Rydberg,* Volvo A/B, Sweden
11:30
Factor 2 project on telecommunication at Ericsson A/B. *Lars Lenell,* Ericsson A/B, Sweden and *Ulf Östermark*, Chalmers Industriteknik, Sweden
12:00
Industrial Ecology programme at Technical University of Trondheim, Norway, *Annik Magerholm Fet*, NTNU, Norway
12:30
Lunch

13:45
A challenge for modern society: uncoupling growth and pollution. *Steen Gade,* Director-General of the Danish EPA, former Member of Parliament, Denmark
14:15
Green CottonÒ - Selling Environmental Success. *Leif Nørgaard,* Novotex A/S, Denmark
14:45
Environmental Life Cycle Management at Danish moulded pulp producer Hartmann A/S.
Anna Lise Mortensen, Hartmann A/S, Denmark
15:15
Break - Coffee/Tea
15:45
The European Person Equivalent: Measuring the personal environmental space.
Michael Hauschild and *Henrik Wenzel,* Technical University of Denmark
16:15
The Danish product oriented environmental initiative and the international development,
Preben Kristensen, Head of Division for Cleaner Products, Danish EPA, Denmark
17:00

Summing up/discussion, moderator *Henrik Wenzel*

17:15
Sightseeing and picnic on the old Copenhagen canals. Departure by boat directly from the Harbour front of the conference centre. The first course of this evening's dinner will be served on the boat
18:15
Return to conference centre's restaurant and continued dinner. Adjourn.

FRIDAY, MAY 12, 2000

SESSION ORIENTATION: INTERNATIONAL INFORMATION EXCHANGE
08:30
Arrival, Coffee/Tea - Association of Danish Engineers' Conference Center
09:00
New Pilot Projects

- **International Exchange and Dissemination of Clean Products and Processes Information: Within the Pilot Study and to Industry and the Public**, *Dan Murray*, USA

09:30
Discussion. Moderator: *Dan Murray*
10.00
Break – Coffee/Tea
10:30
Open Forum on Clean Products and Processes - *Subhas Sikdar*
11:30
Discussion of Future Directions for the Pilot Study - *Dan Murray*

- Themes and Focus for Next Meeting
- Host Country, Location, and Dates for 2001 Meeting

12.15
Summing up and Meeting Wrap Up - *Subhas Sikdar*
12:30
Adjourn and Lunch

INVITATION FOR ACCOMPANYING PERSONS

Accompanying persons are invited to participate in the following events:

May 7, 18:00 – 21:00 Reception
May 8, 11:45 – 13:30 Lunch at City Hall. Departure from the conference centre
May 9, 19:00 – onwards Dinner at Tivoli Gardens, restaurant Nimb
May 10, all day Field trip
May 11, 17:15 – onwards Copenhagen canal sightseeing, picnic and dinner
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