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Systems Analysis Department

Annual Progress Report 1995

Edited by Hans Larsen, Charlotte Olsson and Kurt E. Petersen

Risø National Laboratory · Roskilde · Denmark

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Abstract

The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1995. The department is undertaking research within Simulation and optimisation of energy systems, Energy and Environment in developing countries – UNEP Centre, Integrated environmental and risk management and Man/machine interaction. The report includes lists of publications, lectures, committees and staff members.

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Contents

Introduction

By Hans Larsen,
Head of Department

In 1995 the Systems Analysis Department expanded its international involvement in many areas both within the European Community and worldwide, and at the same time consolidated its collaboration with Danish industry, utilities, ministries and governmental agencies.

A new organisational setup was implemented in 1995 meaning that the former groups within the department were abolished , and activities are now organised in research programmes. The department is undertaking research within the following four research programmes:

- Simulation and optimisation of energy systems, *Hans Ravn*
- Energy and environment in developing countries, UNEP Centre, *John M. Christensen*
- Integrated environmental and risk management, *Kurt E. Petersen*
- Man/machine interaction, *Leif Løvborg*

The activities of the department are multidisciplinary, and conducts research and development on methods and models dealing with the interplay among various technologies, systems and humans. About one-third of the department's activities are financed by government appropriations, the remaining two-thirds by national and international research contracts.

In 1995 a major building activity was initiated with the aim of providing new improved premises for the UNEP centre; this activity will enable the whole department to assemble in one building complex by 1996/1997.

By the end of the year the total staff numbered 60 employees, 43 of whom are scientists or senior scientists, namely, engineers, natural scientists and economists as well as social and behavioural scientists, and 7 are either PhD students at various Danish universities or post docs. During the year several guest scientists visited the department for shorter or longer periods. In 1995 three staff members earned a PhD degree.

A significant proportion of the activities of the department is financially supported by various international organisations or research programmes such as EU and UNEP. In addition, the department has undertaken research and development projects together with international organisations such as the Intergovernmental Panel on Climate Change (IPCC), World Energy Council (WEC), the International Association of Energy Economics, the Nordic Council of Ministers and the OECD Halden Reactor Project in Norway.

During 1995 the department has been responsible for the WEC; Work Group on Local and Regional Environmental Energy Related Issues under the WEC Studies Programme. The outcome of the study was presented in a number of reports and articles and at the World Energy Conference in Tokyo in October in a special session dedicated to the group.

Simulation and optimisation of energy systems

The aim of this research programme is to undertake integrated assessments of energy, environment and economy in relation to long-term development and to the introduction of new energy technologies into complex energy systems.

The analysis of macro-economic aspects and modelling of energy use has continued relative to the interplay between "bottom-up" and "top-down" modelling approaches. A project with support from the Danish Energy Research Programme was initiated in 1993, and carried out in collaboration with the Ministry of Finance. The major activities in 1995 within this project are concerned with energy-related emission projections relative to the Danish macro-economic model, ADAM.

The programme supports and participates in various planning activities. In collaboration with the Meteorology and Wind Energy Department at Risø the programme has participated in Danida sponsored projects in Egypt and the Cape Verde Islands aiming at enabling the local authorities to formulate plans for establishing a wind energy supply. Projects on heat planning in the Katowice and

Silesian regions of Poland have been finalised. The aims of the projects were to propose changes in the technical installations, administrative procedures and in consumer behaviour, with the ultimate goal of improving the environment.

A project supported by the Danish Energy Research Programme "Danish Utilities in a Competitive Market" was initiated in 1993 in collaboration with Local Governments Research Institute (AKF) and Roskilde University. The work in 1995 focused on regulation and environmental aspects in an open European Market.

For many years the programme has been responsible for calculating the emissions of pollutants to the air from Denmark. Through Risø's partnership in ENERO the programme participates in the European Topic Centre on Air Emissions established by the European Environmental Agency. A verification of the CORINAIR-90 database was made for nine countries. An evaluation of the structure and development of the environmental effects of the Danish transport sector has been performed.

The post-doctoral project dealing with environmental planning under uncertainty has been finalised. The aim of the project was to analyse environmental planning activities both with regard to technical and policy management aspects in terms of the associated uncertainties, and to investigate how multicriteria models can be used in planning.

The evaluation of system aspects of energy technologies has been continued. The project on large-scale application of renewable energy in the electrical power system was finished. A life-cycle analysis project supported by the Danish Energy Research Programme has been carried out in collaboration with Danish Energy Analysis. The subject was the development of a methodology for assessing the consequences of implementing energy saving technologies in industry. Finally, strategies for reducing CO_2-emissions from the manufacturing industry have been analysed in an ongoing PhD project.

Energy and environment in developing countries

The UNEP Collaborating Centre on Energy and Environment is the major activity of the programme.

In 1995 UNEP-related energy-environment activities were characterised by the transition to a new overall programme structure for UNEP. The major Centre supported UNEP projects in India and China on incorporating environmental concerns in the national energy planning have been successfully completed. These projects were the last activities under the "old" programme structure and in parallel with their finalisation the Centre has been involved in developing the new UNEP work programme to start implementation in 1996. The focus will be on some of the present key issues in energy sector development like institutional reforms, environmental regulatory frameworks for private sector involvement and implementation barriers, and its delivery will have a clear regional focus.

In 1995 a Scientific Advisory Panel has been established aimed at providing guidance on future strategic directions of the activities of the Centre. The panel members were selected based on their perso-

nal professional standing as well as the desire to achieve a reasonable regional distribution. The panel met for its first meeting in December at Risø.

A special event in 1995 was the finalization and presentation of the WEC Work Group Report on Local and Regional Energy Related Environmental Issues where the Centre had been providing the secretariat.

In the area of climate change mitigation studies, the major activity has been the preparation of a UNEP/GEF project on "Economics of GHG Limitations", which will be implemented by the Centre and provide a direct follow-up on the work over the last years on GHG Abatement Costing. Preparation activities involved setting up 8 national sub-projects in Africa, Asia, Latin America and Eastern Europe and coordination with all multi- and bilateral funders of climate change country studies.

Phase III of the Abatement Costing Project involving case studies in Venezuela and Zimbabwe was concluded in 1995 and will provide valuable input to the new major project which is expected to commence early 1996. The technical support to a mitigation project in Tanzania, funded by the German Agency for Technical Cooperation, was completed, but a follow-up activity on the sub-regional level is being planned. In addition, the Centre provided assistance in setting up national mitigation projects in Egypt and Jordan for UNDP and in Peru for Danida. For all three projects the Centre will be providing technical assistance also in the implementation phase.

Integrated environmental and risk management

The aim of the research programme is to develop methods for analysing the safety and reliability of technical systems and facilitate integrated environmental and risk management taking into account human and organisational aspects.

A significant part of the work in 1995 was carried out with support from the EU research programmes ENVIRONMENT and TELEMAN covering work on the development of methods for reliability in design and operation and studies of the consequences of industrial accidents.

Within TELEMAN the work on methods for reliability of a generic teleoperated manipulator was continued and the methods were further developed and targeted to specific robotic systems. A post doc study was started to develop a control system for underwater vehicles for inspection purposes incorporating safety and reliability considerations, using similar methods and approaches.

An assessment of the consequences of industrial accidents supported by the EU ENVIRONMENT programme has focused on analyses of fires in warehouses containing chemical substances and dispersion of dense gases from releases or fires. The micro scale fires simulated in laboratories have been extended and compared with experiments in various scales up to volumes of 150 kg. The work on dense gas dispersion comprised finalization of the field experiments with releases of ammonia and establishment of a data base containing dense gas dispersion experiments including the field experiments with ammonia.

The latter work constitutes an element in the EU emphasis on improving model quality, where the work in 1995 on the EU-supported activity (Model Evaluation Group) has emphasised the development of procedures for evaluating models for dense gas dispersion, liquefied pool fire and gas explosions. The department has been responsible for the editorial work of MEG and contributed its chairman.

A large effort has been undertaken within the cooperation with the OECD Halden Reactor Project dealing with the development of overview display systems for control rooms. Use of reliability data in assessing safety and reliability was continued with emphasis on the development of statistical methods suitable for presentation of trends. A post doc study has created valuable results on the feasibility of a Fuzzy Sets approach to treat uncertainties in data and models coherently.

Studies of the reliability of safety systems for wind turbines have been conducted in projects sponsored by the Danish Energy Research Programme and the EU Programme JOULE, establishing procedures for safety assessment, and developing the operational tools for reliability analysis.

In 1995 the Department contributed to specific investigations in Denmark under contract with Danish industries and regional authorities responsible for reviewing safety assessments of industrial plants.

Man/machine interaction

The aim of the Man/machine interaction programme is to develop methods for analysing the interaction between people and advanced technical systems with a view to establishing concepts for safe and efficient treatment of complex work tasks.

Two research projects carried out under the EU Third Framework Programme were finished in 1995: MUSTER (Multi User System for Training and Evaluating Environmental Emergency Response) and COMIC (Computer-based Mechanisms of Interaction in Cooperative Work).

Innovations produced in the MUSTER project are exploited in MEMbrain, a five-year Eureka project in which Risø and a Danish software company cooperate on developing the training and communication modules of a decision-support integration platform for major emergencies.

The COMIC project was an Esprit Basic Research Action devoted to developing the theoretical and technical foundation for the design of computer-based tools that help multiple distributed actors with coordinate their work. Prototypes utilising the conceptual framework established within COMIC were built with support from the Danish Science Research Council and from the department's participation in European Network for Appropriate Cooperation Technology. Through 1995 the department has served the European Commission DG-XII as Coordination Agency of the COST-14 Action on Cooperation Technology.

In a project sponsored by the Danish Research Council for the Humanities field work was carried out in a large manufacturing company to explore the generation, communication and usage of information among the members of industrial design teams.

In the Esprit project MATE (Multi Aircraft Training Environment) human-factors experiments were performed to study the training effect obtainable with flexible, 'soft' control panels. Furthermore, during a continued collaboration with the Man-Machine Research Division of the OECD Halden Reactor Project, assistance has been provided with recording and analysing eye-tracking data in experiments set up to study team performance in simulated diagnostic tasks at the Hammlab nuclear control room facility at Halden in Norway.

Under a collaborative agreement called HELT (Human Elements in Marine Operations) with the Danish Maritime Institute (DMI), a tool for simulating navigator performance is being developed. Other joint undertakings with DMI have included testing and evaluating a workstation for pilots and retrospective human-factors data analysis of simulator training sessions with navigation crews.

System Consequences of Large Scale Utilisation of Wind Power

Large-scale utilisation of wind power imposes new constraints in the electricity and heat supply system, which unless taken care of might generate economic and technical problems. By nature wind power is a fluctuating energy source. Low wind speeds and consequently low power generation may occur at times of peak electricity demand. On the other hand, there might be plenty of wind-produced electricity at times where electricity demand is low.

A situation where wind power production corresponds to 50% of the yearly electricity demand in Denmark is shown in Figure 1. The blue curve shows the varying electricity demand in one-hour time steps during a 3-week period in springtime. The fluctuating wind power production, shown as the red curve, is based on power curves for the average wind capacity in an assumed future system. The assumed wind speeds are based on synchronous measurements at four selected locations in Denmark. The installed wind power capacity is close to the peak power demand in the system. As seen from Figure 1 the wind power production in certain periods exceeds the demand for electricity substantially. Constraints in other parts of the power production system further increases the excess electricity production in this period. Figure 1 furthermore shows that very substantial fluctuations occur in the wind power production. Such fluctuations impose strong requirements on the regulation capability in the rest of the supply system.

Several possibilities exist for solving the problem of excess electricity production. Regulating down the wind power production in periods of high wind speeds is one way of resolving the problem – electricity export may be an other option.

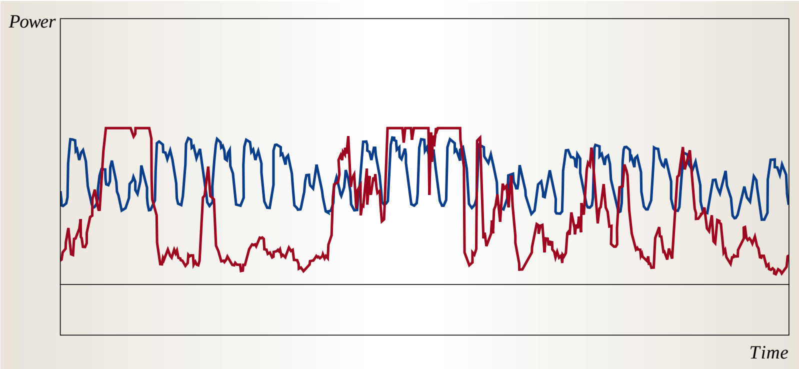
These are some of the issues analysed in a project concerning options for large-scale utilisation of renewable energy for power and heat production in the future Danish energy system. The project is carried out in collaboration with The Test Station for Wind Turbines and the electric utilities ELKRAFT and ELSAM. The project has been supported by the Danish Energy Research programme.

The project addresses technical and system development challenges that arise if regional renewable energy resources are to form the main energy inputs in the future Danish power and heat supply. System development strategies are formed that cover a time scale up to year 2030. The main focus in the analyses are on the long-term aspects. Based mainly on fluctuating inputs from renewable energy technologies such as wind power and photovoltaic and biomass, supply strategies are described capable of providing the same quality of electric service as exists today. CO_2-emission reduction and average production costs of electricity in future systems that integrate large scale renewable energy utilisation are evaluated.

Method and strategies

A scenario approach is used, where verbal descriptions of basic aims

Figure 1. Wind power production and electricity demand in a selected period. (one-hour time steps)



in society at large form the starting point for the analysis. Economic growth, fuel price developments, energy demands, and energy supply strategies are derived in accordance with fundamental aims for society at large.

A main scenario, called "The Green Society", for the development of society at large were assumed that sets up fundamental assumptions for the analysis of large scale utilisation of renewable energy. Defined here, this scenario mainly implies for the energy sector an assumption of a persistent political willingness to promote energy conservation and utilisation of renewable energy resources. An essential goal is to achieve substantial CO_2-emission reductions. Within this scenario strategies for energy conservation and energy supply are developed. The analyses focus on the years 2005 and 2030, medium and long-term, respectively. In the "The Green Society" a main goal is to achieve a renewable energy utilisation covering 75% or more of the expected Danish electricity demand in year 2030. A milestone towards this goal is to reach a 25% coverage of the electricity demand in year 2005 from renewable energy sources equally divided between wind power and biomass.

Three long-term electricity supply strategies for utilising renewable energy sources have been set up. Two strategies (S1: wind 50%, biomass 25% and S2: wind 25%, biomass 50%) put main emphasis on wind power and biomass utilisation, respectively, and each strategy aims to cover 75% of the electricity demand from renewables in year 2030. The third strategy (S3: wind 50%, biomass 35%, solar 15%) combines the three main renewable energy supplies in Denmark and aims to cover the total demand for electricity year 2030.

Four models have been used to carry out the analyses. These are the BRUS model for energy, economic and environmental analysis of the overall system, the supply system simulation models ES3 and SIVAEL and the PSS/E model for Load Flow analysis of the electric grid.

The following description focuses on wind energy integration and the S1-strategy for electricity and heat supply in "The Green Society". Furthermore, some main results on CO_2-emission and economic consequences for year 2030 are described.

Combined heat and power supply

Large-scale introduction of renewables will impose strong requirements on the flexibility in the rest of the energy production system. If at the same time an intensive development of combined heat and power takes place, including a general trend towards technologies with high electricity-generating efficiencies, this will further increase problems with regulation and excess production of electricity. These consequences are illustrated in Figure 2, where yearly overall heat demand is shown on the x-axis and yearly power demand is shown on the y-axis.

The figure illustrates three situations (the slope of the dotted line through the origin is the average ratio of electricity to heat production, called the Cm-value):

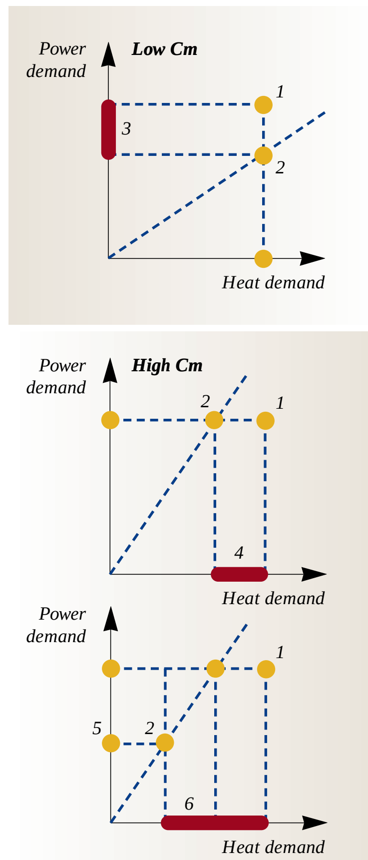


Figure 2. Consequences for combined heat and power production of introducing wind turbines and power plants of high electricity production efficiency.

1. *Heat and power demands*
2. *Combined heat and power production*
3. *Residual power demand (condens) at low Cm*
4. *Residual heat demand (district heat) at high Cm*
5. *Residual electricity demand after wind power*
6. *Residual heat demand (district heat)after wind power at high Cm*

- The upper part of the figure shows the situation today. Having covered the heat demand (along the x-axis) by CHP-production, a remaining electricity demand (interval highlighted on the y-axis) has to be covered by condensing operation of units. Potential (and cheap) heat production accompanying this remaining power generation is not saleable and to some extent one can say that an excess heat production potential exists today.
- The second part of Figure 2 illustrates a future situation where new technologies with higher electricity producing efficiencies are introduced, implying that the ratio of electricity to heat production for the supply system has increased (increased Cm-value). The situation has now reversed. Having covered the electricity demand in the system, a heat demand remains that must be dealt with by other means.
- The lower part of Figure 2 illustrates a situation where, furthermore, 50% of the electricity demand is generated from wind turbines . Wind power substitutes electricity production otherwise produced by CHP-plants, and may thus have reduced the heat production accordingly, and a major heat deficit may arise in the system . If such expected heat deficits were supplied by CHP-production excess electricity production would result.

In "The Green Society" the consequences of a development such as the above-mentioned are analysed. If there is a surplus of electricity and a shortage of heat, the relative cost of heat will increase, and the balance between electricity and heat conservation may be displaced towards an emphasis on heat conservation. Thus the importance of heat conservation in CHP district-heated areas increases along with a change from an excess heat situation to a heat deficit situation. A consequence of the technological development and increased wind power utilisation may be a growing importance of heat conservation measures in the larger urban areas.

In "The Green Society" the solution to the type of effects outlined in Figure 2 is a combination of heat conservation and increased heat production. Heat pumps are introduced to reduce excess electricity production from wind turbines in periods of high wind speeds and to reduce the heat deficit in district heating systems.

The result of detailed assumptions on, e.g. economic growth and energy conservation is a total electricity demand close to today's level during the period up to year 2030. Increasing efficiency in the use of electricity almost compensates for the assumed increase in the demand for electric services in "The Green Society". District heating demands are however assumed to fall substantially during the period . The heat demand in the CHP-system in "The Green Society" is assumed to decrease by 40-50% during the period, due to retrofit insulation and increased insulation standard for new buildings.

Wind power development

An assessment of the development of wind technology has been carried out. Improved design and efficiency are expected to reduce the specific costs of electricity from wind turbines by about 25% during the period. The unit size of typical mass-produced wind turbines is expected to increase from about 0.5 MW as seen today to about 2.5 MW in year 2030, and future wind turbines are expected to operate at maximum efficiency over a wide wind speed range utilising variable speed and active pitch control.

The development of wind power capacity during the period up to year 2030 in "The Green Society" is assumed to follow an almost steady path. It is assumed for the technical analyses of future Danish electricity supply systems that the interaction with the electricity systems of our neighbour countries is kept at today's level. Thus the need for increased regulation capability in the system mainly due to the large capacities of fluctuating wind power must be supplied from within the Danish system during the period up to year 2030.

Wind power and excess power generation

Excess electricity production will increase as the coverage from fluctuating renewable electricity production from wind power increase. Excess generation may increase further due to system constraints and limited regulation capability related to other production capacity in the system. The excess electricity production as a consequence of increasing wind power production is shown for Danish conditions in Figure 3.

When wind power generation exceeds appr. 20% of the total electricity demand excess electricity production starts to emerge. This is shown on the lower curve in Figure 3. Accordingly, when wind-based electricity covers appr. 50% of total electricity demand excess production will be close to 10%, increasing to appr. 40%, when electricity production from wind power corresponds to total demand. The upper curve of Figure 3 shows the percentage of electricity demand that is not covered by wind power, and thus has to be produced by conventional power plants. Even though wind power in energy terms corresponds to 100% of demand, only appr. 60% of the wind-generated electricity can be directly utilised, requiring that appr. 40% of electricity demand be supplied by other means.

Power supply and regulation capability

The desired combination of high regulation capability and high efficiency for the electricity production points in favour of gas-fuelled technologies. Gas technology is assumed to play an important role in the future energy system, where high energy efficiency and system flexibility are essential.

In “The Green Society” the main new technologies introduced on the longer term are biomass gasification, IGCC and fuel cells on natural gas and syngas. Based on these technologies the biomass utilisation in the system can be expected to yield high efficiencies for electricity generation. In the transition period, short-to-medium term, combined-cycle plants on natural gas and CFB-plants or multi-fuel-plants utilising biomass are introduced. Gas turbines supply peak load generating capacity to the system. The consumption patterns for natural gas in the system pose strong requirements as to the flexibility of the gas supply system.

Heat storages (of about one day capacity) are utilised to decrease/eliminate constraints for the combined heat and power production. Furthermore, the heat storage capacities are used in combination with heat pumps. “Excess” electricity production from, e.g. wind turbines is partly recovered by heat pumps to supply the district heating systems. If further heat production is required the heat pump capacity is used and electricity production is raised to supply the heat demand.

What remains of the “excess” electricity production is highly irregular in time and fluctuates strongly in the power. A fraction of this is recovered as resistance heat and what now remains the system is unable to use. Such losses occur in strategies S1 and S3. In practice, however, this potential production will not be generated. The wind turbine capacity in such situations must be able to regulate down the production to maintain the stability on the national grid.

CO_2-emission

The achievable CO_2-emission reductions in the energy system as a whole and in particular in the combined heat and power sector are substantial in the strategies analysed.

In year 2030, CO_2-emissions from the power/CHP sector are reduced by appr. 85% and 88% in strategies S1 and S2, and 100% in S3 relative to the 1992 level. For the energy system as a whole in year 2030 the emissions are reduced by 60-70%, which also includes the effects of energy conservation measures outside the CHP-sector in “The Green Society”.

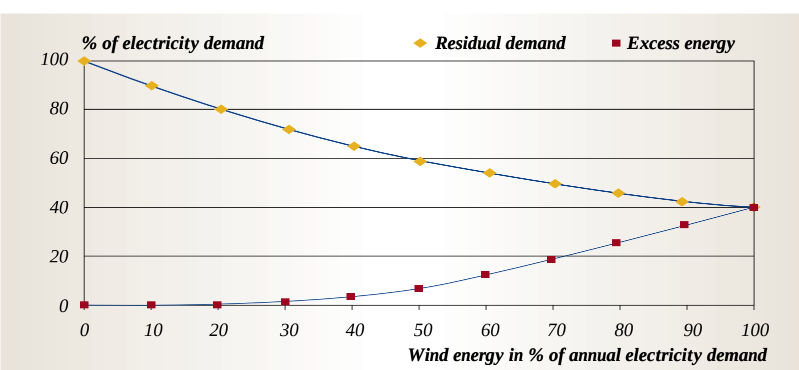


Figure 3. Wind power production in phase with electricity demand on a yearly basis. (Residual supply system not included)

Main conclusions

A main conclusion from the technical analyses carried out is that it is possible over the period up to year 2030 to develop well-functioning power and heat supply systems where 75-100% of the electricity supply is based on Danish renewable energy resources. However, the average production cost of electricity in year 2030 in strategies S1 and S2 is expected to increase about 30%, and for S3 about 65%, relative to the 1992 level. The composition of the average production costs in the strategies year 2030 is changed towards increased investments and a reduced dependence on fuel costs.

This conclusion is based on a number of assumptions, and it must be emphasised, that considerable uncertainty is associated with long-term analyses, e.g. concerning available energy resources, technological development and economy. It should also be mentioned that investments to improve energy efficiency on the demand side (power and heat consumption) are not included in costs on the supply side, and supply technology development costs not reflected in the assumed investment costs are not included. Furthermore, it should be mentioned that the systems analysed in year 2030 are not optimised.

Publications in 1995: 25, 27

POUL ERIK MORTHORST AND
LARS HENRIK NIELSEN

Life Cycle Assessment of Energy Savings in the Industry

During the last years many activities have been initiated to introduce energy-savings in the industry. Nevertheless, many energy-saving proposals that have been made to the industry by energy-advisers have never been carried out. The reason for this lack of enthusiasm is that the introduction of energy-savings in an industrial process often has consequences for the total production process. An example of the consequences resulting from the introduction of an energy-saving is shown in Figure 1.

The introduction of energy-savings in industry could be promoted by developing a methodology to assess all the different consequences for the total production process in the industry. The main purpose of this project has therefore been to develop a methodology to assess energy-savings in the industry. The project was carried out in a collaboration between Risø National Laboratory and Danish Energy Analysis. It was supported financially by the Danish Energy Research Programme.

The methodology that has been developed can be utilised directly by industrial companies to assess the consequences of introducing a new energy-saving technology in the industrial process. The industrial firm itself must prioritise the importance of the different problems that appear by using the methodology.

Methodology structure

The methodology is constructed in two phases: the first phase is a screening of all possible consequences following the introduction of the special energy-saving technology. Based on this screening the important consequences of introducing the technology are pointed out. In the second phase the important consequences are given in a detailed analysis based on a life cycle assessment methodology.

The methodology handles four different consequence areas following the introduction of an energy-saving technology in the industry: energy, environment, work environment and economy.

Delimitation

The methodology has been delimited in different areas in order to make the methodology clear and practically easy to handle.

The energy consumed in producing different energy supplies has been estimated based on a cradle-to-grave analysis. The analysis includes energy consumption in relation to extraction and transport of raw materials, production of the manufactured supply, and disposal at the end of its lifetime.

The materials, that have been analysed in the project in relation to energy-consumption, and thereby giving rise to emissions, are those which seem to be the most important for producing the majority of the energy-saving technologies. The result of the energy-consumption analyses for the different materials is shown in Table 1. The table shows the energy consumed in producing, transporting, and disposing 1 kg material.

Environment includes the most important environmental conditions in the analysed industrial company, while environment connected to all the other different phases of the energy-saving technology has been limited to environmental conditions related to energy consumption.

Emissions have been estimated for 1 kg of the above mentioned materials. The analysis is based on emissions related to energy consumption in different phases: emissions related to material pro-

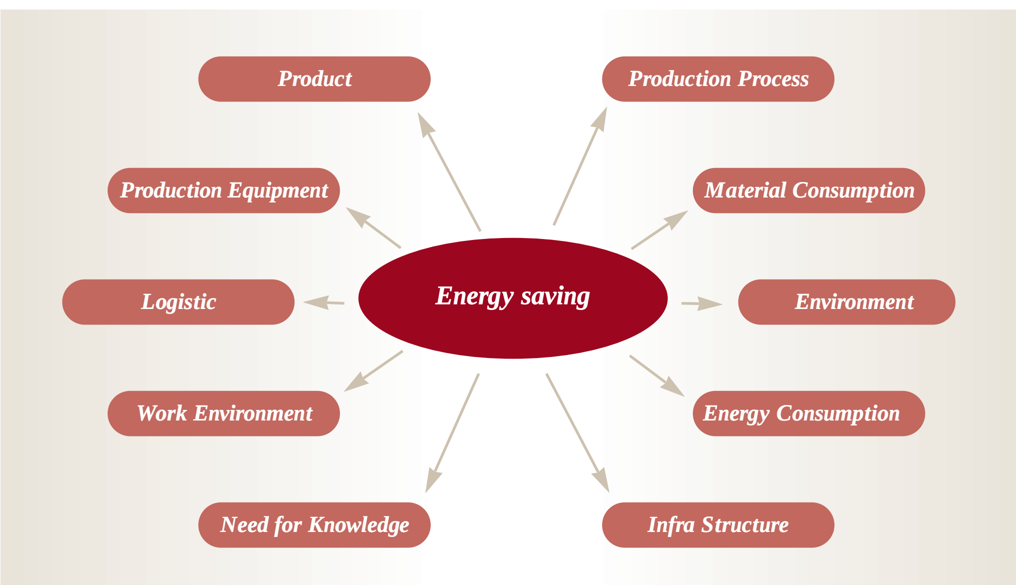


Figure 1. Example of the consequences of introducing an energy-saving technology into an industrial company.

duction, material manufacturing, material transport and material disposal by combustion.

In this type of analysis a company will be able to state the different materials in weight used in the energy-saving technology, and obtain the total energy consumption and emissions related to the technology directly.

Work environment has been limited to the actual potential work environmental impacts in the industrial company.

Regarding the economy it is only the economy related directly to the industrial company, which is actually analysed. The economy analysis includes both the direct and indirect economic consequences achieved by introducing the energy-saving technology.

In this way the total analysis focuses on the conditions related directly to the company except for the energy consumption, which is a life cycle assessment.

Demonstration of the methodology

As a part of the project the potential of energy-savings in the Danish industry has been analysed. The energy-saving potential has been divided into branches and end-uses in order to be able to choose an example for demonstrating the methodology, that is relevant to the industry.

In the light of the analysis the case for demonstration of the methodology has been chosen in the graphic industry with the end-use ventilation. The case chosen is a graphic company in a situation having to choose between a traditional ventilating system and a more energy-efficient but more expensive one.

Considering the first phase of the methodology, it was concluded that the company gave economy the highest priority. The simple pay-back time was much larger for the energy-efficient ventilating system than the usual demand of maximum pay-back time given by the company. Therefore, it was of great importance in the second phase of the methodology to analyse other effects to see if these conditions made it worthwhile to choose the energy-efficient system.

In the second phase of the methodology – the life cycle assessment – more costs were added to those of the energy-saving technology as a result of reduced flexibility and increased maintenance. In relation to work conditions improvements were pointed out for the thermal work climate.

In relation to the environment the energy-related emissions were reduced significantly. The CO_2 emissions were cut down by 62% after introducing the energy-efficient ventilation system.

Conclusion and recommendations

The methodology which has been developed in the project has appeared to be useful for an industrial company in order to assess the consequences of introducing an energy-saving technology compared with an ordinary energy technology. It may also be possible to use the methodology for assessing energy and environmentally related consequences by developing new energy-saving products.

The methodology applies to a company with an interest in energy and environment with a basis of decision that is much broader than the one that has been present until now for assessing new energy technologies.

The methodology has in some way been developed as a spread sheet model, but the project is presented and demonstrated only in schemes. Obviously the methodology needs to be developed further as a PC spread-sheet model. In this way the industrial company will be able to insert data indicating the difference between the energy-saving and alternative technologies into the model and calculate the consequences considering energy, environment and economy directly.

Publication in 1995: 34

LOTTE SCHLEISNER

	Petroleum coke MJ/kg	**Coal** MJ/kg	**Oil** MJ/kg	**Natural gas** MJ/kg	**Wood** MJ/kg	**Energy consumption in total** MJ/kg
Steel	*1.6*	*14.1-20.7*	*4.9-8.2*	*0.1*	*0*	*20.7-30.6*
Cast iron	*7.4*	*10.6*	*18.2*	*0.1*	*0*	*36.3*
Aluminium	*0*	*23.1-31.5*	*8-11.4*	*1.4-2.9*	*0*	*32.5-45.8*
Copper	*3.0*	*45.1*	*13.6*	*16.5*	*0*	*78.2*
Lead	*0*	*20.3*	*9.0*	*6.3*	*0*	*35.6*
Zinc	*0*	*61.3*	*9.3*	*2.4*	*0*	*73*
HD-polyethylene	*0*	*30.8*	*9.8*	*5.1*	*0*	*45.7*
PVC	*0*	*19*	*12.6*	*6.6*	*0*	*38.2*
Rubber	*0*	*19.8*	*20.5*	*0*	*0*	*40.3*
Float-glass	*0*	*1.0*	*0.8*	*7.5*	*0*	*9.3*
Packing glass	*0*	*2.0*	*0.8*	*5.3*	*0*	*8.1*
Wood boards	*0*	*0.9-1.4*	*0.5-1.0*	*0*	*0.6-2.2*	*2.0-4.6*
Wood plates	*0*	*2.9*	*1.4*	*0*	*5.7*	*10.0*

Table 1. Total energy consumption related to 1 kg material.

Energy Environment Economic Modelling

Energy, economy and environment are closely linked not only at a local and regional level, but also at the world level. The elaboration of strategies to reduce environmental impacts resulting from the production and utilisation of energy, and ensure sustainable economic development, requires cooperation at a multinational or even world level. A prerequisite to an efficient co-operation is the use of a common language, consistent methodologies, and models to analyse the interrelationships in such complex systems.

The EU EURIO project

Within the framework of the energy research programmes of the European Commission a series of tools and methodologies has been developed and used within the Community for the analysis of strategies. There is obviously a demand by non-EU countries and especially by Eastern European and developing countries for using these tools. Nevertheless, the experience showed that a successful transfer of a model – in the sense that the model will really be operated properly and durably by experts from the concerned country for, e.g., decision-making purposes – is not obvious. Failures often resulted from insufficient training in the operation of a model, its underlying methodology, and the interpretation of its results.

The EURIO project is a part of the JOULE Non-Nuclear Energy Research Programme. The main purpose of the project is to be a support for Research and Technological Development (RTD) strategies in the fields of energy planning and environmental protection. The existing network of experts and institutions in the EU has been expanded to include partners in Central and Eastern Europe with experience in modelling for national decision support purposes and two regional centres in Asia.

Models for the following types of analyses are included in the EURIO project:

* Energy technologies
* Energy demand
* Energy supply
* World energy markets
* Macroeconomic impacts

The main results of the pilot phase, which was completed by the end of 1995, are:

* Overview of modelling experience and needs in the Central and Eastern European countries.
* The EURIO Model Package, where the models EFOM-ENV, MEDEE, MURE and POLES have been selected as initial models for analysis and planning in the overall energy-economy-environment area at various levels.
* The EURIC Tutorials characterised by a modular structure, a stepwise development from basic concepts to the full reference model. The tutorials are exercise driven, and computerised versions of all elements are being developed.
* Model transfer and adaptation in the Central and Eastern European Countries.

The work was organised in workgroups among institutions with special experience in particular models, topical and regional workshops, and bilateral contacts between institutes in Western and Eastern European countries; these are based on visits and an extensive transfer of documents and data by e-mail. The main tasks of Risø have been editing tutorials for energy supply modelling, providing a sectoral model for the electricity sector with combined heat and power (CHP) and collaborating with the partner institutes in Latvia, Lithuania and Ukraine.

Tutorials for energy supply modelling

The main contribution of Risø to the EURIO project has been participation in the development of tutorials for energy supply modelling. These tutorials are exercise driven and follow a formalised stepwise increase of the level of complexity, which is common for all types of models included in the project:

* *Pen and Paper* describes the fundamentals of energy concepts such as efficiency, availability and utilisation, emission factors, technical lifetime, technology costs, interest and discounting.
* *Initiation to modelling* addresses fundamental concepts and assumptions behind the modelling.
* *Coping with complexity* describes levels of aggregation used, energy and material flows, and algorithms for supply-side modelling.
* *Working with a Reference Model* shows, through practical exercises, how to construct national models.

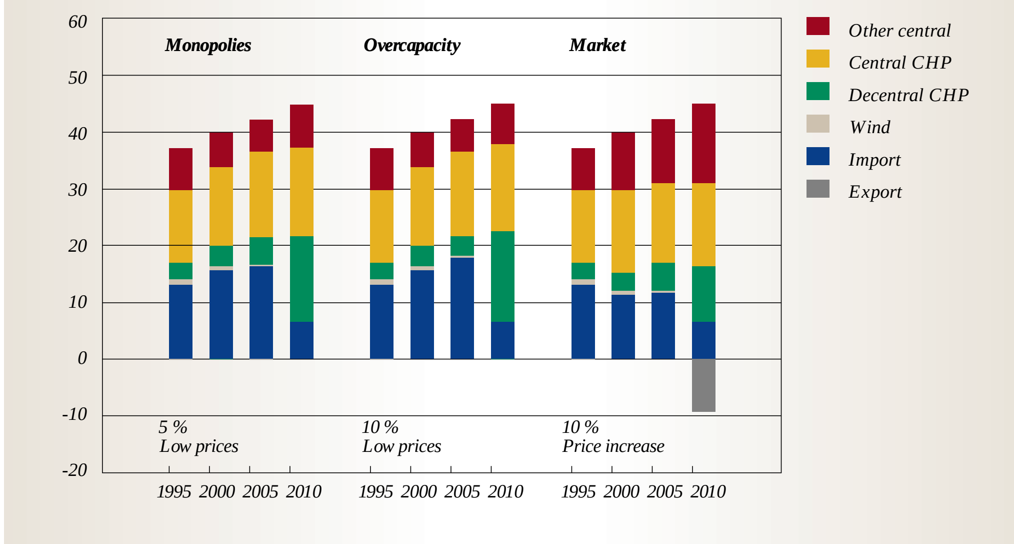


Figure 1.

This structure is used mainly for printed reports and supporting spreadsheets, but more computerised versions using an integration of hypertext and databases are being developed. The report also summarises the experience gained during the collaborative modelling work. Two topics are emphasised:

- The development of a *national model organisation* for implementing and applying the tools and methodologies.
- *Dissemination of models and software* including the legal status of the software for the reference models with a practical example of a licensing and changing practice.

The reference model for energy supply which was used for national case studies in the EURIO project is the EFOM-ENV model describing cost curves for national emission reduction strategies. This model has a long tradition with typically other study objectives such as the penetration of new technologies or impact of fuel price changes. The energy system is described as a network combining the extraction of primary fuels through a number of conversion and transport technologies to the demand for energy services or large energy-consuming materials. Energy demand and prices are exogenous assumptions, which may be determined by macroeconomic models or general equilibrium models. The strengths of the models are endogenous investment in new equipment and endogenous utilisation times during the lifetime of capital-intensive equipment, e.g., power stations.

Applications of the modelling tools for different projects

It is important that models of even a fairly limited complexity be used systematically by different persons for different purposes. This is necessary for model consolidation and understanding – not to mention debugging. Another application of the EFOM model, which is illustrated in Figure 1, was developed mainly within a project "Danish Utilities in a competitive market" for the Danish Energy Research Programme, completed in 1995. The modelling experience gained during the EURIO project modelling is further used for the "Energy tariff project– Latvia" also financed by Danish Energy Research Programme and started in 1995. This project was initiated by the Danish firm Nellemann, Nielsen and Rauschenberger A/S on the basis of their experience with natural gas tariffs in Latvia. The Latvian partners are Rigas Gaze and the Physical Energetics Institute of the Latvian Academy of Sciences. A seminar in Riga is scheduled for May 1996, and the report be published in mid-1996 in English with summaries in Latvian.

Application of a sectoral model for electricity with CHP

Most experience with the optimisation models was gained with the traditional organisation of the electricity supply industry, i.e., vertically integrated regional monopolies. This organisation has been changed in some countries, and it is challenged in many other countries and by proposals from the European Commission on a European electricity market with separation of natural monopolies and activities subject to competition.

The necessary analyses of the consequences and performance of the design and regulation of a competitive market will require the development of different modelling tools. Some of these will benefit from the data and modelling experience of the traditional organisation of the industry.

The optimisation model is used for two types of comparative analyses of the electricity sector that are required for analysing of the consequences of a competitive market:

- Different market conditions for the electricity system in a given region
- The impact of given market conditions on different regions

Both approaches are likely to give results that are conflicting for competing agents. However, this may be a good description of the realworld, which consists of oligopolistic markets, rather than perfect competition. Further tools, i.e., in the tradition of game theory, are needed to analyse the interaction of agents within these types of market.

Figure 1 shows a set of different market conditions used to describe an optimal development of the electricity supply industry in Denmark. The traditional organisation of the industry is illustrated by the model results labelled 'Monopolies'. The market conditions are characterised by low prices for electricity trade and a 5% discount rate. The market is protected, the return on investment in new equipment is safe, and import will occur only at low prices.

Liberalisation will remove this protection. The present situation is characterised by 'Overcapacity'. The return on investment is no longer safe, leading to a higher interest rate, which will discourage investment in new equipment. Prices may be kept too low by competition, threatening the financial survival of the industry.

In a properly organised 'Market', prices are expected to increase to encourage investment in new equipment. The industry must operate on a financial market in competition with other investors, assuming the discount rate at 10%. The Danish electricity supply industry has a competitive advantage because of the availability of potentially cheap electricity from CHP.

Although the volume and type of investment in new equipment may be very sensitive to the model market conditions, the optimal electricity production from both central and decentral CHP is very insensitive to these different market conditions, because the heat market is determined by the district heating infrastructure.

Publication in 1995: 16

POUL ERIK GRONHEIT

MUNICIPAL AND REGIONAL HEAT PLANNING IN THE KATOWICE REGION

The southern part of Poland, Silesia, contains coal fields, which for many years have been exploited intensively. The coal is used for export and for domestic use, especially local purposes. The coal industry has given rise to a number of energy-intensive industries in the region like metallurgical works and electric power plants. Naturally, the coal is also used for room heating purposes, ranging from small stoves to large boiler plants feeding district-heating grids.

Therefore, this region as well as the neighbouring areas in Germany and the Czech republic are heavily polluted with depositions of acid rain, dust, etc., which cause damages to public health as well as to the biosphere in general.

Not all emissions will contribute to local pollution, because parts are "exported" with the wind to other regions. However, corresponding emissions are "imported" from adjacent areas by the wind. The SO_2-emissions are illustrated on the map, which shows that the region around Katowice (indicated in red) is heavily polluted, more than 40 tons per square kilometre per year.

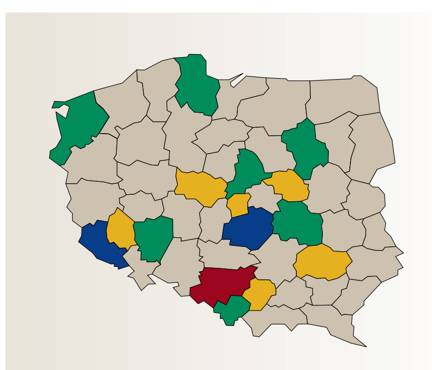


Figure 1. SO_2-emissions in Poland. The most polluted areas marked with red are within the Silesian region .

These facts provided the incentive to concentrate planning efforts at this region and suggest ways in which the emissions could be decreased by pointing out cost-effective methods to decrease the demand for comfort heat and to increase the efficiencies of the combustion devices and flue gas cleaning.

It was decided to establish a co-operation with seven Polish municipalities in the region and to use a Polish engineering company as a link between the Danish and Polish sides. It is supposed that the municipalities will use the master plans as tools in the continuing planning procedures and also for preparing applications for EC support for specific projects concerning emission reduction. The project concentrated on preparing a master plan for the period until year 2015 pointing out improvements to selected buildings and heating plants proposing a campaign aimed at the public, dealing with methods to save energy, e.g. by improving the insulation of buildings and installing regulating valves on the radiators

Therefore, the municipalities played a major role by organising committees which met regularly with the Danish Joint Venture to discuss methods and results of the project.

Organisation

The project – which was supported by the Danish Foreign Ministry – was carried out with several partners: a Danish Joint Venture between Risø, Roskilde University, Rambøll Consult A/S, and the County of Storstrøm, each covering parts of the project in which they have special competence. The seven municipalities studied in the project compiled much of the statistical data. The Polish engineering company Expert Projekt also collected and systematised much information, and, in addition, supported the communication between the Polish and Danish partners.

Objectives

The overall goal for this project is broadly speaking to increase the quality of the environment in the Katowice region by pointing out measures which will decrease the harmful substances originating from the combustion of coal for heating purposes.

There are several avenues of approach which have been proposed in this master plan. Some aim at individuals, e.g., house owners, others aim at public authorities, e.g., the district heating companies. Two main lines may be identified:

- Technical:
  decrease demand, increase energy system efficiencies, and clean flue gases
- Economic:
  consumers shall pay for their individual consumption

The working methods

The master plan considers a number of states of the heating system:

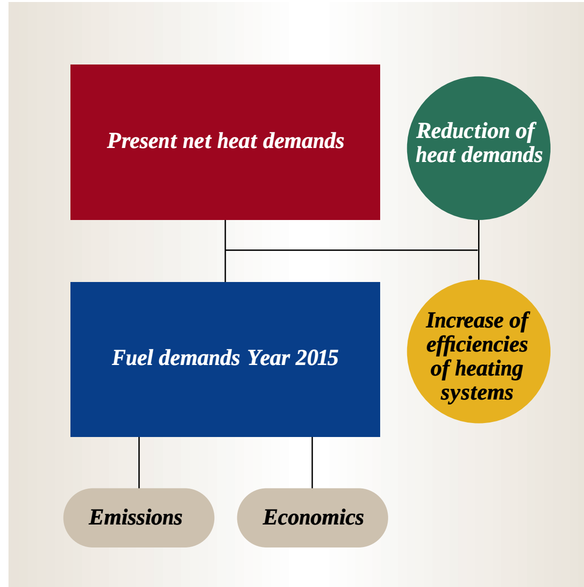
- The present state, as given by available statistics
- The base state in the scenario year – 2015
- Three improving steps – all concerning year 2015 – taken to decrease the pollution

For each of the future states several possible improvements of the heating system have been proposed and included in the calculations: extending the number of connections to the existing district heating grid, introducing district heating in new densely populated areas, and improving the fuel efficiency of the district heating system by a more widespread use of CHP. In the last case, one might provide condensing power plants with heat exchangers for district heating purposes. Also, as small stoves, fired with coal of questionable quality, are relatively high polluters it is proposed that they be replaced by more efficient boilers.

Finally, all large boilers are assumed to be provided with efficient flue gas cleaning devices.

The work has been carried out in collaboration with the partners of the Danish Joint Venture as well as with the Polish counterparts: an engineering firm and the municipalities, which provided the basic statistics and prognosis.

Figure 2. Simulation model.



In order to evaluate the various possibilities within the master plan, Risø prepared a model of the heating system, based on experience gained from similar projects, like one concerning Gliwice, where a single municipality in this region was studied.

The principles of the model are sketched in the figure. The building data including the net heat demands are specified in five building and two age categories. Further, the buildings are grouped according to five heating methods and three fuels. The demands for comfort heat as well as for hot tap water are the primary input, being specific to each building category. From these the fuel demands and emissions of the various categories are calculated – taking into account a possible reduction due to better insulation of buildings and changes of heating methods. The economic calculations comprise the costs of fuels, of operation and maintenance, and of investments into production capacities in order to replace old production capacity like boilers, district heat pipes, and stoves, and to build new capacity if the demand has increased sufficiently.

	Units	Present state	Base scenario	Step 1	Step 2	Step 3
Net heat demand*	TJ/y	5721	6006	6006	6006	5474
Fuel consumption	TJ/y	8901	5968	5870	4834	4417
SO_2 emission	tons	5785	2627	2546	1894	1718
Dust emission	tons	7605	3518	3400	2213	1992
Fuel costs	mill. Zl	-	35.074	34.476	28.419	25.961
Collective costs	mill. Zl	-	42.185	44.097	46.005	43.419
Costs at end-user	mill. Zl	-	4.551	4.592	4.829	14.912
Cost per ton reduced SO_2**	Zl/ton	-	-	16.73	-3.49	2.73

* The heated building area is increased with ~40% in the period until year 2015.
** The values are relative to the Base scenario.

Thus, the Risø part of the work has concentrated upon:

- Specifying the necessary data
- Elaborating the simulation model, utilising a scenario technique
- Evaluating the results

Scenarios

The calculations of possible states of the future (2015) are based on the present state (1994), given by statistics. The way to the scenario-year is not specified, but the scenarios are made in such a way that a continuous change of the energy system from the present to the future state is possible. The following scenarios have been studied, gradually introducing more changes in various parts of the energy system:

- Base scenario:
  The demands and production follow business-as-usual: some reduction of the specific demands is assumed and a large part of the buildings, including most public buildings and service, is connected to the existing district heating grid where possible.
- Step 1:
  As base scenario. In addition new districts relatively near heat plants with excess capacity are furnished with district heating grids.
- Step 2:
  As step 1 – in addition a large part of stoves are substituted by more efficient boilers.
- Step 3:
  As step 2 – with an additional number of energy saving measures carried out in residential and service buildings.

Some results of the simulations

The numbers in the table, which refer to a particular municipality – Dabrowa Gornizca – illustrate the various steps taken to improve the efficiency of the energy system, and consequently of the quality of the environment.

It is assumed that in the period until year 2015 some improvements of building insulation are carried out, resulting in a 10-30% decrease of the specific demand, depending on the building category, with corresponding costs of 0.25-1 Zl/m^2 heated area. In addition, improvements of the heating system are carried out.

For step 3 additional heat saving measures are assumed, reducing the specific demands another 10-20%, but now much more expensive, 2-4 Zl/m^2, because the cheap possibilities have already been used.

It is seen that the fuel consumption and the SO_2 emission are very sensitive to the number of stoves, decreased drastically in step 2. The substitution of these rather inefficient devices with other heating methods really gives rise to an improved air quality. The extra measures concerning increased building insulation, etc., introduced in step 3, are expensive as seen by the end-user costs, but still regarded as worthwhile.

The cost per reduced amount of emission, regarded as a key figure, is very different for the various measures introduced, ranging from ~17 Zl per ton SO_2 if new districts are provided with a costly district heating grid, to a negative value (a gain) when very polluting stoves are substituted.

Final comments

The progress of this project showed that the methods used for many years in Danish energy planning, developed at Risø, can be transferred to Polish conditions. A number of measures have been pointed out in order to reduce pollutions. The economic consequences and the reductions obtained are calculated.

Further, the elapse of the project showed that the co-operation between Danish private and public enterprises and between the Danish and Polish participants has been fruitful and resulted in a master plan for each of the seven Polish municipalities.

Helge V. Larsen and
Peter Skjerk Christensen

Emission Inventories

The European Environment Agency (EEA) in Copenhagen has established a small number of European Topic Centres. Risø is a member of the international consortium forming the European Topic Centre on Air Emissions (ETC/AEM). The framework in EEA for inventories of emissions to the air in European countries is called CORINAIR. Until now 31 countries, all of Europe including Russia to the Urals, have participated in the task. Risø was the project leader for the extension to the three Baltic countries: Estonia, Latvia and Lithuania. The main tasks of the Topic Centre in 1995 were validating the CORINAIR 1990 inventories and preparing the CORINAIR 1994 inventory.

The CORINAIR databases for nine European countries were verified by Risø under a special contract with EEA including assistance to Maltese experts in developing the first inventory for Malta. Other countries were verified by other members of the ETC. The new CORINAIR 1994 inventory must fulfil the conflicting demands for both more pollutants (e.g., metals and persistent organic pollutants) and more rapid preparation, delivery and availability of emission estimates. One instrument for achieving this goal was the development by the ETC of a new userfriendly windows-based software. This enables both aggregation of detailed area sources data and large point sources data into national aggregated data and making comparisons with national energy balances.

Several international organisations require regular reportings of emission inventories for different pollutants and in different formats. One important improvement in the new CORINAIR software is the ability to extract the results in accordance with these requirements. Reporting to the EU and IPCC as well as to the Convention on Transboundary Air Pollution (UNECE/EMEP) and the North Sea and Baltic Sea conventions (PARCOM and HELCOM) will be included.

The joint EMEP/CORINAIR Atmospheric Emission Inventory Guidebook will be published by EEA in early spring 1996 both as hard copy and CD-ROM. In 1995 Risø prepared the chapters covering marine activities and air traffic. It is the responsibility of ETC to maintain and develop this Guidebook.

The EEA has established National Focal Points (NFPS), one for each European country. The NFPS are responsible for national information collection. ETC/AEM maintains close coordination with all NFPS. Risø has the responsibility to assist the NFPS in the five Nordic countries and Greece. The National Environment Research Institute (DMU) is the Danish NFP. The Danish Energy Agency and Risø as National Reference Centres (NRCS) are responsible for supplying the Danish NFP with relevant energy data. One important task in 1995 for Risø was the updating and validating of the 1972-1994 energy balances in such a way as to facilitate emission calculations.

Risø participated in the preparation of Transportstatistik 1995 issued by Statistics Denmark. The Danish emissions from road traffic for 1990-1993 were calculated by the COPERT model. Other traffic emissions were also updated.

In connection with the Danish signature in 1995 of the UNECE VOC Protocol Risø updated the projection of Non-Methane VOC emissions for the Danish Environmental Agency showing that a 30% reduction in 1999 compared to the 1985 level was possible if the conditional agreement between the Industry and the Agency was implemented.

Publications in 1995: 1, 2, 3, 15

Niels Kilde
and Jørgen Fenhann

Support to UNEP Energy Programme

Two major UNEP energy-environment studies, in India and China, were completed during 1995. These studies represent two of the key activities in UNEP's energy programme in recent years. Both projects aimed specifically to strengthen national and regional institutional capacity in the area of energy environmental analysis and to promote policies that would reduce energy-related environmental emissions. The detailed studies of the two countries addressed all aspects of energy and environment policy and planning, with substantial participation of local teams.

The India and China projects were funded by the UNEP Energy Programme, and initiated and supported by the Centre, although organisationally and substantively the projects exhibit a number of differences.

Also completed in 1995 was a two-year collaborative project to develop a facility for analysing the environmental loadings of complete fuel chains. Specifically, the work involved the enhancement of the LEAP/EDB computer analysis tool and was a collaborative effort between the UNEP Centre and the Stockholm Environment Institute's Boston Centre.

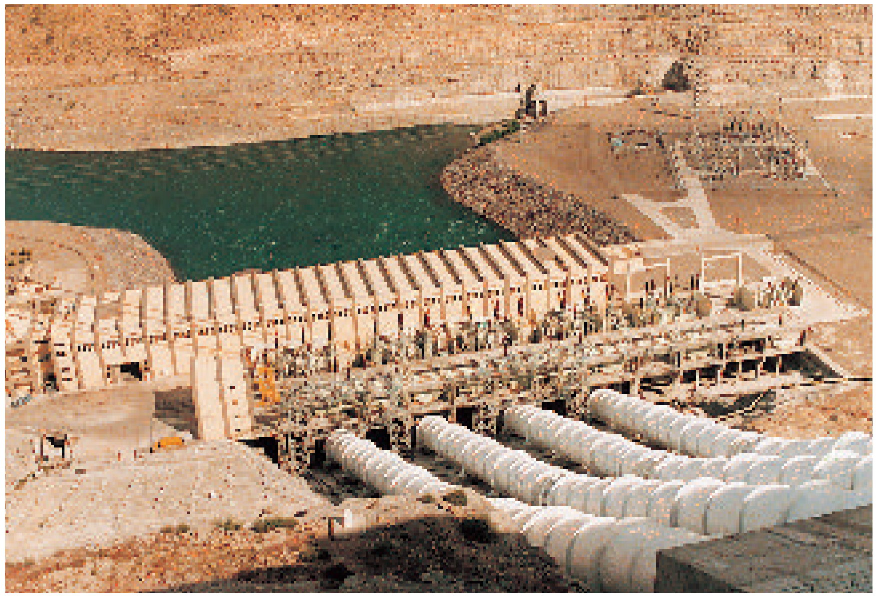
Environmentally sound energy policy and strategies for India

The India study was implemented by the Tata Energy Research Institute (TERI) of New Delhi under the guidance of a national Steering Committee chaired by the Ministry of Environment and Forests, and including other key ministries, industrial bodies and research institutes.

On the basis of detailed sectoral studies the project team established a business-as-usual (BAU) energy scenario for India over the next 20 years, describing how energy demand and supply would be expected to develop, and in particular, detailed analyses of the environmental effects. The BAU scenario projected large increases in energy demand: coal supply would have to be increased three fold; petroleum product consumption would more than double; electricity generating capacity would have to be increased by a factor of three; and firewood demand, assuming that supply is not a constraint, would increase from the present estimated levels of 200-250 million tonnes to about 350 million tonnes.

These increases in energy demand would place heavy loads on the local, regional and global environment. The study went on to define alternative energy development paths whereby the growing demands for energy services could be met in a sustainable way.

India has a large number of options from which to choose, including increased energy efficiency, accelerated renewable energy development, introduction of clean coal technologies, increased share of hydro resources and provision of alternative environmentally friendly energy options for the rural areas. If all of these options were to be adopted successfully, emissions of pollutants could be reduced significantly without affecting the annualised energy system costs.



Hydro power plant in Argentina.

On the basis of the study of alternative energy-environment scenarios and an analysis of the present economic and institutional situation in India, the study made a number of observations and has put forward recommendations for achieving the desired more sustainable energy path.

One of the key institutional findings of the study is the importance of the fragmented structure of the energy planning process in determining the energy situation. This has resulted in a sub-optimal allocation of resources, which unfortunately are geared more towards meeting short-term requirements than planning for a longer-term strategy for the sector as a whole. The more detailed recommendations and a timebound action plan resulting from the project are under discussion with the Indian Government with the aim of identifying specific implementation possibilities and follow-up activities.

Incorporation of Environmental Considerations in Energy Planning in the People's Republic of China

The China project was started in June 1993 with the signing of an agreement between UNEP and the National Environmental Protection Agency (NEPA) of the People's Republic of China. The project was similar in scope to the Indian study described above, but in contrast, analysed the national situation at a regionally disaggregated level, rather than in terms of national sectors. The project had several aims: to provide a broad overview of the national energy development situation, develop an alternative national energy scenario, and identify economic and technological factors that might constrain the implementation of energy systems which would be able to minimise environmental impacts. The project also included detailed regional studies for Beijing and Guanxi provinces.

The project aimed specifically to explore the economic and environmental impacts of a range of integrated energy policy measures, and to examine a number of different environmental indicators, such as loadings of SO_x, NO_x, CO, CO_2 and particulates. The study describes what could happen under assumptions of particular packages of policies and technologies. The analytical tool used in the study, the LEAP/EDB accounting framework, was well-suited to this task. The use of the accounting framework contrasts with the optimisation approach used in the India study. In the LEAP/EDB case a simple approach based on physical simulation of energy flows was used, providing the analyst with a set of tools for checking the energy, economic and environmental consequences of different scenarios.

The UNEP Centre was involved closely in the substantive work of the project, through training and close collaboration on the use of energy-environment modelling tools. In this connection, a number of members of the Chinese team had extended stays at the Centre during 1994.

The UNEP/NEPA project study team arrived at a number of key policy recommendations for changing the present pattern of energy production and consumption, and establishing an energy system which is more compatible with sustainable development. Although there are clear similarities between the recommendations of the China and India studies described above, there are major differences in their implementation strategies, reflecting the political, social and economic conditions of the two countries. A major achievement of the China study is that the analysis identifies relevant decision levels and actors, and specifies conflicting objectives and strategies. All these factors are

Caracas street scene.

likely to play a decisive role in the formulation of a long-term energy base for China.

Development and use of a tool for Fuel Chain Analysis

The Stockholm Environment Institute's Boston Centre (SEI-B) and the UNEP Centre have recently completed a two-year project to develop and apply a tool for fuel-chain analysis in developing countries. The tool was an extension of the LEAP/EDB model developed by SEI-B, and the work was carried out in close collaboration with counterparts in Venezuela and Sri Lanka where the tool was tested through case studies.

Fuel Chain Analysis is an analytical technique in which energy requirements are tracked through chains of conversion processes on the basis of the efficiencies and process energy requirements of each process. Coefficients (e.g., emissions per unit of fuel used) yield an estimate of the impacts associated with each process. Since each process can potentially require many different inputs, an analysis can quickly become quite complex.

The justification for carrying out Fuel Chain Analysis on alternative energy options is that substantial environmental impacts often occur in conjunction with stages of the energy process other than combustion. Many renewable energy technologies are highly intensive in material input, and the associated environmental impacts may weigh heavily. Fossil fuel processes on the other hand embody environmental impacts at the mining or fuel extraction stage, as well as in the disposal of waste. A realistic comparison of alternative means of supplying energy thus requires that the whole chain of processes, and the associated environmental effects, be taken into account.

The UNEP/SEI Fuel Chain Analysis project represents one of the first applications of this technique in developing country settings. Case studies were selected to give broad coverage of four important fuel chains: oil and gas (Venezuela), and coal and biomass (Sri Lanka). In each case, the new tool was used to study the impacts of fuel and technology choices including the greenhouse gas emissions of each fuel chain.

The project demonstrated that fuel chain analysis can be a useful tool for evaluating the environmental consequences of fuel choice decisions in a developing country context. Fuel chain analysis forces the analyst to draw explicit boundaries around systems and allocate impacts within and between co- and by-products of the energy system. These tasks are not necessarily simple or obvious, but are nonetheless important in forming rational energy policies.

The results of the project were recently presented and the tool demonstrated at the International Symposium on Electricity, Health and the Environment, organised by a group of international agencies, including UNEP, and hosted by IAEA in Vienna. The tool and the case studies are fully described by Lazarus et al. (1995)

Publications in 1995: 20, 28, 29, 30

GORDON A. MACKENZIE AND PRAMOD DEO

The energy agenda has been dominated in recent years by global environmental issues, in particular the threat of rapid climate change. Local and regional environmental effects associated with energy production and utilisation have received comparatively little international attention, with the exception of the acid rain problem. Local and regional energy-related environmental effects, such as air pollution and land degradation are already presenting serious problems, both in developing and industrialised countries. With the projected large growth in energy consumption in the developing world these effects are bound to cause increasing damage to ecosystems, agricultural land and crops and human health.

Local, regional and global environmental effects cannot be considered in isolation. Often the same root causes contribute to environmental degradation at the different levels. Thus, if the local environmental threat is addressed it helps alleviate the global problem.

The World Energy Council (WEC) established Working Group 4C in the 1993-95 studies programme to address energy-related local and regional environmental issues related to energy, and in particular to provide real practical experience in dealing with these kinds of environmental impacts and their causes. The focus was on developing countries and countries with economies in transition. The group was chaired by Hans Larsen, Head of the Department of Systems Analysis, and John Christensen and Gordon Mackenzie of the UNEP Centre acted as secretariat. The participation of developing country members in working group meetings was supported financially by Danida.

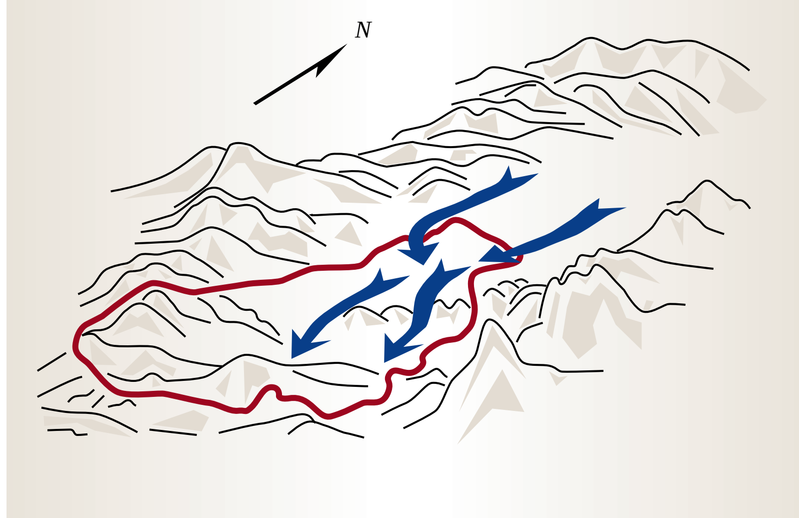
The working group brought together a wide range of experts from different national, institutional and professional settings. Members contributed case studies to the working group and these case studies, along with a review of the underlying environmental issues, established the basis for the report of the group, "Local and Regional Energy-related Environmental Issues" which was published by WEC in connection with the Tokyo Congress in October 1995.

The review of local and regional energy-related environmental issues focused on some of the major environmental problem areas such as urban air pollution, indoor air pollution, disturbance and use of land, and electromagnetic fields from, for example, overhanging power lines. The review concentrated mainly on specific environmental impacts, but also presented information on key energy areas with multiple environmental effects, such as coal, oil and transport. The themes of the fourteen individual case studies are listed in the box. Three selected areas are discussed below.

- Environmental issues of power production from fossil fuels
  - Germany
  - Poland
  - Russia
- Environmental issues related to hydropower
  - The Serra da Mesa hydropower plant, Brazil
  - The Saguling hydropower plant, Indonesia
- Environmental consequences of windpower
- Electrification in rural areas, grid expansion and transmission lines
- Urban air pollution:
  - The Mexico City Metropolitan Area
  - Motor vehicle exhaust in Greater Cairo
- Biomass energy
  - Environmental implications of small-scale use of biomass
  - Large-scale biomass utilisation; the pulp and paper industry in Portugal
- Impacts of energy scenarios on regional acidification
- Environmental impacts of the oil and gas sector in Nigeria
- Spontaneous combustion in Chinese coal mines and its environmental impact.

Indoor Air Pollution and Biomass Energy

Indoor air pollution in urban and rural households associated with the combustion of fuel for cooking is a serious health problem in many developing countries. It has been estimated that 400 million people, primarily women and chil-



Mexico and the direction
of prevailing winds.

dren are subjected to dangerous levels of smoke in the home, with serious health impacts such as respiratory diseases and cancer.

The combustion of biofuels contributes to a large part of the indoor air pollution problem. The smoke produced when biofuels are burned contains a very large number of carbon-containing chemicals, many of which are damaging to health. The indoor air-pollution problem is widespread and deeply ingrained in energy-use habits in much of the developing world, and far-reaching changes will be required to alleviate it significantly.

Partial solutions of the problems exist, for example, through increased ventilation, improvement of stoves, or changing cooking patterns. One of the case studies described by the working group showed how improved charcoal cooking stoves in Kenya could provide such a solution. This stove has better combustion and heat transfer efficiencies, resulting in reduced fuel consumption for the same cooking use.

Urban Air Pollution

Air pollution in urban areas causes a variety of different types of damage, but the impact on human health is probably the most disturbing. Human beings are affected by air pollution both directly, through inhalation of polluted air, and indirectly, through contamination of drinking water and food, and through skin transfer.

Often meteorological and topographical factors aggravate the situation, concentrating pollutants in cities and preventing their dispersion. Surrounding hills can trap pollution, as can thermal inversion layers in temperate and cold climates. A classic example of this occurs in Mexico City, the subject of one of the case studies covered in this work (see Figure 1).

In the Mexico City Metropolitan Area (MCMA) the urban air pollution problem has evolved from that of a typical "developing country" city, dominated by SO_2, CO, lead and particulate matter, to that of a "modern" city, dominated by ozone formation and photochemical smog. The case study describes how air quality monitoring, modelling of pollutant dispersion and analyses of traffic patterns have provided a comprehensive picture of the air pollution situation in the MCMA. This has enabled possible solutions to be examined in detail, such as large-scale mass-transit systems, traffic management, improvement of the vehicle fleet and rearrangement of the traffic pattern through staggered work times.

The other urban case study dealt with Cairo, where the characteristics remain those of a "developing country" city. Air pollution is dominated by particles and lead from vehicle emissions. Impacts on human health are a serious concern.

The studies illustrate the importance of tackling air pollution in the rapidly growing urban areas of the world. Early action is recommended as urban development and increasing use of motor vehicles can rapidly lead to a situation which is virtually out of control, necessitating the imposition of difficult measures at a later stage. Many sessions at the WEC Congress highlighted this problem, and transport will be an important issue in the new studies programme.

Hydropower

The exploitation of hydropower can lead to a wide variety of environmental impacts, particularly when it involves the inundation of land for a reservoir. These issues were addressed in two separate case studies, from Brazil and Indonesia, each of which examines one particular hydropower project. The two studies complement each other through the different settings, environmental impacts and different approaches. For example, the Brazilian case is in an area of relatively sparse population where only a small number of settlements were affected, while the Indonesian one involved a major resettlement and compensation activity.

The 1200 MW Serra da Mesa power plant is under construction in the centre of Brazil and although the area of the reservoir is planned to be very large (1784 km^2) only 4000 people will need to be relocated. For this reason the environmental impact assessment focuses mainly on ecological issues.

The Saguling hydropower plant in Indonesia is one of three connected hydropower plants near Bandung. Work on the Saguling plant was initiated in 1981 and it came into service in 1986. Since the plant is situated in a densely populated area with good soil and developed agricultural systems, the main issues of the environmental impacts are land compensation, resettlement and loss/creation of jobs. Other issues are erosion, public health and the problems of aquatic weeds.

Conclusions

The working group provided an opportunity to present a review of relevant environmental effects with a selection of case studies illustrating both successful treatment and problematic examples of the environmental effects associated with energy. The case studies in particular provide a broad body of experience on energy-related environmental issues on which to base recommendations.

The importance of considering local and regional environmental issues alongside the global ones is not new, but this multi-level view is being increasingly re-emphasised. It emerged clearly from the WEC Tokyo Congress that the immediate policy priorities focus on local and regional issues, especially for developing countries and countries in transition. There is a general willingness to see problems in a more integrated manner and expand interaction and collaboration aimed at transferring technological and financial resources.

Publications in 1995: 17, 18, 19

Gordon Mackenzie

Cross-sectoral Climate Change Mitigation Assessment for Developing Countries

The UNEP Greenhouse Gas Abatement Costing Study like the majority of mitigation studies in the first and second phases, finished in 1994, focused on CO_2 reduction studies for the energy sector. Climate change mitigation is, however, developing more and more from being a specific energy sector issue to becoming a comprehensive economic and natural resource development issue. This process is supported by recent international negotiations and by experience gained in ongoing studies for developing countries.

The UNEP Collaborating Centre on Energy and Environment has conducted a combined methodological and country study project for UNEP in Phase Three, focusing on a cross-sectoral climate change mitigation assessment. Cross-sectoral studies aim at assessing emission reduction potentials for all major greenhouse gases emitted by the energy sector, industry, agriculture, forestry and waste management.

A main methodological development area in the third phase of the UNEP Greenhouse Gas Abatement Costing Study has been the establishment of a methodological framework and set of assumptions for integrating sectoral studies.

The United Nations Framework Convention on Climate Change (FCCC) is setting agenda for international collaboration in climate change activities. One important tool in establishing this international collaboration process is a methodological framework defined for a national climate change assessment to be used as a background for national strategy development and reporting requirements according to the convention. The UNEP methodological framework for national climate change mitigation studies aims at being part of such background material.

International research efforts

The UNEP framework is closely related to current international research efforts on mitigating climate change. A number of co-ordinated international country study efforts have developed and tested mitigation assessment methodologies. Two of the main programmes are the US Country Study Programme and the UNEP GHG Abatement Costing Study. These studies have developed guideline documents including common analytical structure, assumptions and scenario concepts. The methodological frameworks and national study results have been covered extensively in the Second Assessment Report of the Intergovernmental Panel on Climate Change where the Centre has participated as lead authors.

Until now climate change mitigation studies for developing countries have been inspired primarily by established models and concepts in energy sector, agriculture and forestry studies. This means that CO_2 reduction studies have used existing energy system models with specific details on technical and economic constraints in energy demand and supply. In most cases forestry studies have been carried out as detailed site specific studies of carbon se-

	Reduction option	Sector	Greenhouse gas	Zim$/ton CO_2
1.	*New ethanol plant*	*Transportation*	CO_2	-1,232.6
2.	*Tillage*	*Agriculture*	CO_2	-1,046.3
3.	*Efficient lighting*	*Energy*	CO_2	-543.0
4.	*Geyser time switches*	*Energy*	CO_2	-171.9
5.	*Coal bed ammonia*	*Mining*	CH_4	-159.9
6.	*Methane from sewage*	*Waste water*	CH_4	-135.9
7.	*Prepayment meters*	*Energy*	CO_2	-107.3
8.	*Coke oven gas for Hwange*	*Mining*	CO_2	-104.5
9.	*Efficient motors*	*Energy*	CO_2	-99.3
10.	*Efficient boilers*	*Energy*	CO_2	-23.0
11.	*Savings in industry*	*Energy*	CO_2	-14.0
12.	*Efficient tobacco barns*	*Energy*	CO_2	0.1
13.	*Pine afforestation*	*Forestry*	CO_2	9.9
14.	*Biogas from landfills*	*Waste management*	CH_4	24.4
15.	*Efficient furnaces*	*Energy*	CO_2	47.5
16.	*Biogas for rural households*	*Energy*	CO_2	48.0
17.	*Hydro power*	*Energy*	CO_2	65.1
18.	*Solar geysers*	*Energy*	CO_2	161.9
19.	*Central PV electricity*	*Energy*	CO_2	564.4
20.	*Power factor correction*	*Energy*	CO_2	6,687.0
21.	*Solar PV water pumps*	*Energy*	CO_2	27,566.3

Note: US$ 1 = ZIM$ 8.2. CH_4 emissions have been transformed to CO_2 equivalents using a Global Warming Potential factor of 24.5.

Table 1. Marginal reduction costs for GHG emission reductions in Zimbabwe in 2030 (Zim$ per ton CO_2 equivalent).

questration for different forestry projects. Agricultural studies have been more limited but as in the case of forestry studies, have focused primarily on a detailed assessment of greenhouse gas emission connected to specific crops or livestock.

The comparability of these different sectoral modelling results have been limited and the IPCC Second Assessment Report has therefore recommended that one of the future priority research areas should be to develop a framework for cross-sectoral comparability.

Specific methodological issues connected to the case studies for Venezuela and Zimbabwe

The case studies of Venezuela and Zimbabwe are further developments of the CO_2 mitigation studies for the energy sector conducted as part of the Phase Two of the UNEP Greenhouse Gas Abatement Costing Study. The two country studies have aimed at improved macroeconomic assessment and expansion with new sectors and greenhouse gases.

Macroeconomic assessment

Mitigation assessments typically address a long time horizon covering at least 20 years. Such a period is preferred in order to reflect the long capital stock lifetime in main greenhouse gas emitting sectors and the long term nature of the climate effect. The long time horizon, however contrasts with existing national economic and social development plans which typically address five- to ten-year periods. The availability and quality of statistical data is at the same time poor in many developing countries and in this way provides a very limited background for constructing long-term baseline scenarios.

The macroeconomic assessment in the case studies of Venezuela and Zimbabwe has therefore focused on short term projections and development constraints which could be important to future trends in major greenhouse gas emissions and for the implementation of mitigation options. Some of the main issues addressed are:

- Relationship between main economic sectors and emissions.
- Assessment of how investments in improved production efficiency in the main economic sectors can be combined with mitigation strategies.
- Foreign exchange and capital constraints.

Greenhouse gas mitigation options will in many cases be “win-win options” where the mitigation cost is less than the value of saved energy or the increased production in industry or other sectors. This simply reflects the present old and inefficient state of production plants in the countries. These “win-win options” can, however, be difficult to implement because they will face the same “general barriers” as investment in new production plants already does in the countries. Examples of such win-win projects for Zimbabwe are assessed to exist in leading growth sectors like manufacture and construction. These sectors currently use outdated production equipment, and large investment projects are likely to be undertaken in the coming five to ten years. The challenge is to exploit the possibilities for combined mitigation projects and general investment activities.

In Venezuela and Zimbabwe agriculture and forestry are key economic sectors as well as greenhouse gas emission sources. Main sources in these sectors are CO_2 emissions from land clearing and degradation and CH_4 emissions from livestock. For these sources mitigation options will be integrated with efficiency improvements in the sectors connected to increased mechanisation, fertilisers, efficient breeding and land distribution. Despite price and market conditions, these efficiency factors are difficult to relate directly to macroeconomic development.

A general equilibrium model has been developed for Venezuela to study alternative policy schemes including carbon taxes and investments in energy efficiency improvements. A new sector included in the Venezuela study is forestry, and in the Zimbabwe study new sectors are waste management, agriculture and forestry. As already stated, the construction of baseline and mitigation scenarios for forestry and agriculture is complicated because future development trends will be closely integrated with a large number of social and distribution aspects of land use management.

The Phase Three study for Zimbabwe has more specifically included two new CO_2 reduction options for the energy sector, namely efficient lighting and ethanol production for transportation fuels in addition to the methane options coal bed ammonia and sewage methane. These options are shown in order of merit together with the options already included in the Phase Two country study shown in Table 1. The introduction of these options expands the negative/low cost area of the emission reduction potential.

Forestry assessment

Traditional forestry analysis has often been a very detailed technical analysis of management practices, species or crops. Such analyses provide important technical background information but do not fully address all import issues connected to the economic and social development context, opportunity cost and implementation areas.

The Venezuela study includes a detailed assessment of forestry projects for the two project categories: (1) management of existing forests to avoid or reduce carbon emission; and (2) management for expanding forest cover in the country.

The methodology of the forestry study for Venezuela focuses on site-specific assessment. The project cost is measured according to the Endowment Method. The total net cost of carbon stored includes the net opportunity cost of the land used for the project and an endowment sufficient to cover the establishment of the project and the expenses and incentives for its ongoing operation, including maintenance, management and monitoring, sufficient to assure the sustainability of the project and its carbon storage. The carbon savings are calculated as the total accumulated storage.

For Zimbabwe the assessment of forestry options has been a broader discussion of opportunity cost and implementation barriers in the context of the official plans of the Zimbabwean Forestry Commission. It is concluded that the cost assessment for forestry projects in addition to the direct land and maintenance cost should include an assessment of long term development trends in opportunity cost as a reflection of the economic sustainability of the projects. Forestry projects should at least supply a surplus larger or equal to other competing land use activities, and this surplus needs to be shared with the local indigenous population that could use the land resources for other activities.

Methodological conclusions

The studies for Venezuela and Zimbabwe have highlighted some important methodological complexities in cross-sectoral assessment including:

- Limited statistical background and appropriate macroeconomic models for constructing consistent baseline scenarios.
- Integration between a broad number of economic and social development issues and the implementation of mitigation options. Energy efficiency improvements will in many cases meet the same barriers as general economic development in the countries, and options related to land use activities will be even more difficult to implement due to unsolved land allocation problems. This means that the measurement of direct project costs addresses only part of the project requirements.
- Carbon savings obtained in forestry projects have different time horizons than energy sector options which means that assumptions need to be made about the time value of carbon if project costs are to be directly compared.

Publications in 1995: 9, 11, 14

Kirsten Halsnæs

The UNEP Centre (UCC) has been involved in a number of collaborative project activities in Latin America in 1995. These have been at local, national and regional levels, as described below. In 1996 a number of new national and subregional activities will be initiated in the region with focus on capacity building in support of the implementation of the Climate Convention.

Joint Seminar with OLADE

Several international activities and bilateral programmes have been established to support national climate change mitigation and vulnerability studies in the Latin American and Caribbean countries. Through the UNEP GHG abatement costing study the Centre has been collaborating with country teams in Brazil and Venezuela on national mitigation analysis, and new collaborative projects are under preparation with Argentina, Ecuador and Peru.

Despite the large number of countries involved in analyses related to climate, limited regional interaction between country teams has taken place. Apart from the regional workshops organised in the context of the US country studies programme, national studies have been carried out very individually with no major intercountry contacts on data and methodological experiences.

The Centre convened jointly with the Latin American Energy Organisation (OLADE), a Latin American and Caribbean Seminar on Energy and Environment, with the aim of providing national teams with an appropriate forum for exchanging experience, highlighting methodological questions, and identifying gaps for further research and development The seminar was hosted by the Ministry for Energy and Mines of Colombia from 28 to 30 November 1995. Over 60 participants from 15 countries of the region attended the event. The seminar was supported by the state oil companies from Colombia (ECOPETROL), Mexico (PEMEX) and Venezuela (PDVSA).

The first part of the seminar included the presentation of national inventory and mitigation studies. A presentation from the Centre on methodological issues and on the result of the UNEP Greenhouse Gas Abatement Costing Study supplemented the country presentations.

The experience from accomplished and ongoing national studies are that many conceptual and methodological questions still need to be answered. These include the design of reference energy systems, a methodological framework for cross-sectoral analysis, macroeconomic impact assessment, implementation aspects and the broader policy evaluation.

It was also concluded that more attention in the future should be given to the assessment of joint regional mitigation activities because many options identified in national studies will have interregional links.

The seminar stressed the need for close co-operation among the national teams and recommended this to be structured in relation to OLADE's activities and programmes. The participants agreed that national studies, especially in the areas of GHG inventories and mitigation analysis, should take more advantage of the methodological developments in energy planning already carried out by OLADE. These will include more extensive use of the Energy-Environmental-Economic Information System, the energy balance concepts, and specific energy demand forecasting tools in combination with the methodological guidelines developed by the Centre in the UNEP Greenhouse Gas Abatement Costing Study.

The second part of the seminar focused on the presentation of specific programmes and actions undertaken by national oil companies in Colombia, Ecuador, Mexico and Venezuela on preventing or repairing damages associated with oil-related activities in their countries. The legal frame and institutional setup adopted by these countries were also presented at the seminar.

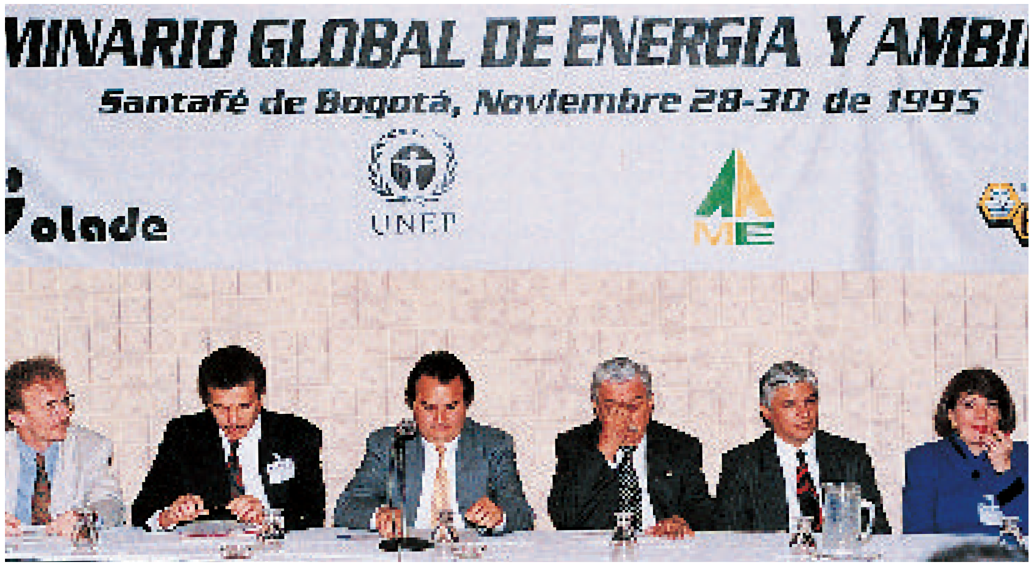
The major recommendation from the seminar was on the strong need for establishing collaborative linkages between the national teams to promote regional co-operation, where OLADE is called on to play a catalytic role. A second regional seminar convened by OLADE will take place in La Havana later 1996. The Centre expects through its planned regional activities to enhance and strengthen Latin American and Caribbean collaboration. These activities will also include sub-regional assessments, and co-ordination and dissemination of national experiences.

Mitigation Assessment for Venezuela

A cross-sectoral assessment of mitigation options for Venezuela has been undertaken by the Directorate of Energy Planning at the Ministry for Energy and Mines with financial support from UNEP and advisory and technical back-up from both the UNEP Centre and the Lawrence Berkeley Laboratory. The study, conducted in the context of the UNEP GHG Abatement Costing Study, aimed at a further development of the methodological guidelines developed under Phase II of the UNEP project.

The study includes a detailed assessment of three abatement options: forest management, the reduction of flaring and venting of associated natural gas, and efficiency improvement of industrial boilers. In Venezuela, forest clearing plays a very important role in the carbon budget, accounting for more than 40% of national CO_2 emissions. The analysis shows that forest protection and management of the native forest represent the two options with the highest carbon conservation potential and the lowest carbon unit cost.

The reduction of flaring and venting of associated natural gas represents an attractive solution not only because of the high potential for CO_2 reduction, but also because of the economic benefit accrued to the oil extraction and processing industry. However, various factors including the spatial distribution of both the resource and the potential markets, the physical conditions of oil exploitation, and the mismatch between natural gas demand and supply have prevented more extensive use of natural gas. Three different alternatives have been considered as technical options to overcome these constraints: multiphase pumping, pipeline constructing, and injecting gas into closed wells.



The study includes a detailed assessment of three possible measures to control GHG emissions from industrial boilers. The options are improvement of preventive maintenance, recovery of residual heat, and fuel switching to natural gas. A highly disaggregated industrial survey has been carried out by the Ministry of Energy on operating efficiencies, age distribution, capacity ranges and type of boilers.

A multi-sector general equilibrium model has been implemented to assess macro-aggregates like sectoral outputs, balance of payments, employment, energy demand, and CO_2 emissions resulting from the adoption of specific policies. Alternative policy changes analysed in the study are: i) an energy price increase brought about by increasing indirect taxes on oil products; ii) new investments in energy efficiency in the industrial sector; and iii) tax increases on oil products combined with an increase in energy-efficiency investments.

Although the study represents a step further in the complex issue of climate change mitigation analysis, the experience shows that a large-scale effort is still required in order to develop and implement both a comprehensive cross-sectoral methodological framework for national GHG abatement studies and a flexible approach for a broader assessment of mitigation policies. The UNEP-GEF project on Economics of GHG Limitations, expected to start early 1996, will focus on such issues.

Training Manual For Integrated Resource Planning

The existing literature on demand-side management (DSM) and integrated resource planning (IRP) is considerable, but most material has a clear focus on applications in industrialised countries. There are no teaching/training materials available designed especially for interested workers in developing countries. Over the past years information has become available on end-use analysis in some developing countries. Energy conservation programmes have been implemented with varying degrees of success in others. UCC found that it would be useful to organize this material in a format suitable for use as an introductory workbook to academic and professional audiences in developing countries.

A collaborative activity to develop a workbook "Improving efficiency of energy services in developing countries: Tools and Methods for Integrated Resource Planning" was therefore established with one of the leading experts in the area, Prof. Gilberto Jannuzzi from the University of Campinas in Brazil. This book is targeted to students of post-graduate courses in energy planning and to people working in electricity utilities in Brazil and other developing countries.

The workbook, which will be finalised in 1996, takes a hands-on approach to understanding and using the tools of end-use energy analysis in the context of Integrated Resource Planning in developing countries. It reviews the theoretical framework for end-use energy analysis, the basic methodologies currently being used in designing strategies to integrate supply options with demand-side options, and tools to account for the economic, environmental and other social costs of energy conversion and use.

The book will highlight realistic examples and case studies, providing a practical, hands-on approach to solving problems related to energy planning in developing countries. Examples and exercises, suitable for computer spreadsheet solution and drawn from the authors' experience in developing countries, will accompany each analytic section of the book.

The UNEP Centre will support the publication of the first English-language edition in 1996 while Procel, the conservation subsidiary of the Brazilian national utility Eletrobras, has agreed to help fund the Spanish and Portuguese editions.

Publications in 1995: 13, 37, 38

Arturo Villavicencio, Jørgen Fenhann and Kirsten Halsnæs

Capacity Building for Climate Change-related Activities in Africa

Climate change mitigation options for Tanzania

A collaborative activity between the UNEP Centre and the Centre for Energy, Environment, Science and Technology (CEEST) has been finalised during 1995. The collaboration was aimed at providing CEEST with advisory and technical back-up under the National Study on Climate Change Mitigation Analysis. The study was undertaken by the Ministry of Tourism, Natural Resources and Environment with financial support from the German Agency for Technical Cooperation (GTZ).

The UNEP Centre involvement in the study was focused on providing the CEEST team with methodological guidance, and analytical approaches and concepts along with recent relevant literature on the key issues of mitigation analysis. The methodological guidelines on abatement costing developed by the Centre, provided both the background elements for outlining the main components of the study and a comprehensive framework to gain insights and a better understanding of the implications of different mitigation strategies on the country's social and economic development.

The analytical and strategic aspects of the mitigation assessment were the main topics addressed along with the informal training sessions and discussions held with the study team. Special emphasis was put on the question of selection of technologies and mitigation options and their integration in both the national development objectives and the decision-making process.

The collaboration between the UNEP Centre and CEEST was undertaken as a joint responsibility in which the local knowledge and experience at CEEST was considered an equally important input. The collaboration has operated in a very satisfactory way through an intensive exchange of information and several working missions from both sides providing an example for future activities.

National studies and regional collaboration in Southern Africa

Phase 1 of the Danida-funded study "Climate Change Mitigation in the SADC, national studies and regional collaboration" was finalised in 1995. The aim of the project was to extend the collaborative experience with both the Southern Centre for Energy and Environment in Zimbabwe and CEEST in Tanzania to the SADC region. The Centres for Energy and Environment in Botswana and Zambia were the other institutions involved in the project.

In addition to the strengthening of collaboration and networking among the national centres, the focus of the project was to examine the subregional interaction and possible joint mitigation activities. Technical options identified at both national and regional levels for the energy, agriculture, transport and forestry sectors are summarised together with regional and individual country overviews in the Phase I report. Two regional seminars with the participation of representatives from relevant ministries in the

four countries were hosted by the Southern Centre in Harare.

The next phase of this activity will concentrate on the assessment of the regional and national economic consequences of implementing abatement options, such as:

- Effects related to larger regional investments in power supply and transmission systems and in the transportation sector; and
- Effects at a more general economic level that may have implications on the relative comparative strengths of production sectors and countries, as a consequence of implementing abatement options and regulation policies.

The regional analysis will be integrated in the UNEP-GEF project on Economics of GHG Limitations which is expected to start early 1996, and additional support for national capacity building and training activities is expected from DANIDA.

U.N. Climate Change Convention Reporting for Burkina Faso

The Centre is responsible for a DANIDA-supported national capacity building programme in Burkina Faso. This project was started in February 1995 and will continue into 1996. The project aims to assist the Burkina Faso Government in building sufficient indigenous capability to establish the initial reporting to the UN Framework Convention on Climate Change.

Main activities have so far concentrated on collecting the necessary information for developing a reliable database on anthropogenic sources and sinks of GHG emissions. A preliminary inventory of GHG emissions has been established for 1990. Figure 1 presents the main findings of the inventory which show the overwhelming contribution of land use and forestry, and agricultural activities to GHG emissions. The persistent destruction of the forest resources and land degradation are the major environmental and economic threats Burkina Faso is confronting today. Therefore, responses to climate change issues can generate a wide range of benefits at both national and local levels which may be even more important to local development than their effects on GHG reduction.

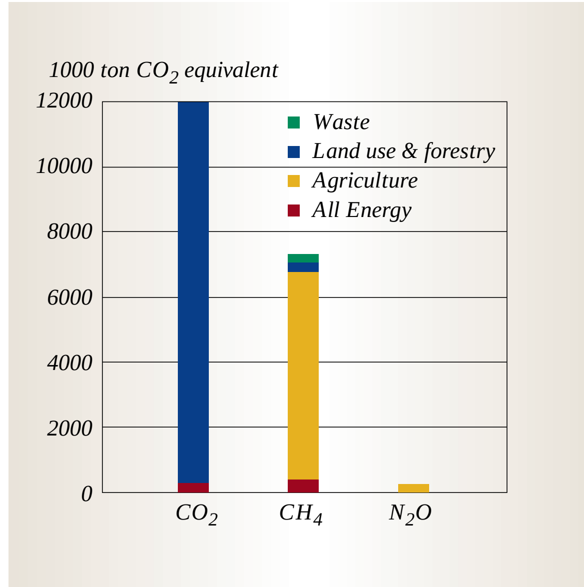


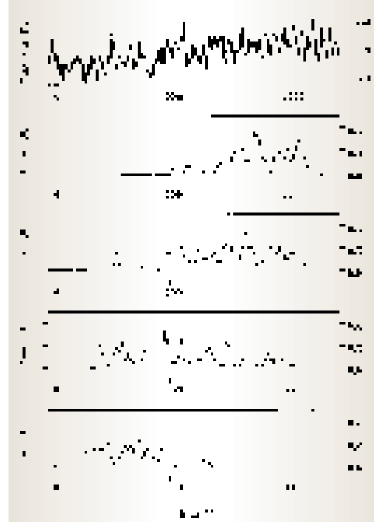
Figure 1. Burkina Faso GHG inventory for 1990.

Planned activities under the project will emphasise on the vulnerability analysis of the regional and local ecosystem, and the adaptation measures needed to cope with the climate change impacts that may follow from increasing concentrations of GHGs in the atmosphere. In this context, a collaborative effort with the Institute of Geography at the University of Copenhagen has been established under the Sahel-Sudan Environmental Research Initiative (SEREIN) of the Danish Environmental Research Programme. The collaboration aims to make use of remote sensing techniques for assessing GHG emissions from savannah fires and land-use changes.

Publication in 1995: 6

Jørgen Fenhann and Arturo Villavicencio

Review and Dissemination of Physical Effect Models



Atmospheric dispersion is one of the aspects to consider when assessing the possible consequences to people and the environment in case of an accidental release of toxic or flammable gases. During the last two or three decades models have been developed to predict the dispersion of hazardous gases and experiments were carried out to validate these models.

Over the past few years the European Commission has come to emphasis the importance of model quality and validation, e.g., through establishing special expert groups and guidelines for model development and evaluation. The REDIPHEM project (Review and Dissemination of Physical Effect Models) has been contributing to this aspect by making available several sets of experimental data and by reviewing newly developed models in the area of dense gas dispersion.

REDIPHEM, finalized in December 1995, was a CEC-sponsored project jointly carried out by TNO (Netherlands) and Risø. Risø's task has been to collect the experimental data on dispersion of toxic or flammable gases in the atmosphere, to review this data and to make them easily accessible for, e.g., model validation purposes. The experimental data originated from a large number of field test campaigns as well as from various wind tunnel simulations of the atmospheric dispersion, specifically of gases denser than air.

Figure 1 shows an example of data as included in the REDIPHEM database: data from FLADIS trial no 009. The graph on top displays the output of a wind-direction vane, the graphs below display the ground level concentration at a crosswind array 70 m downwind of the source. The 4 sensors are 10 m apart: as the wind direction slowly changes from 280° to 310°, the plume moves from left (sensor displayed at the bottom) to right (sensor displayed on top).

The REDIPHEM database is organized in PC-files containing different kinds of information:

- The description of experiments is divided into quantitative release specifications, meteorological conditions and comments in text files;
- The instrumentation is described by lists of sensor positions and text files describing the signal types and sensor characteristics;
- The actual measurements are represented by time series.

Figure 1.

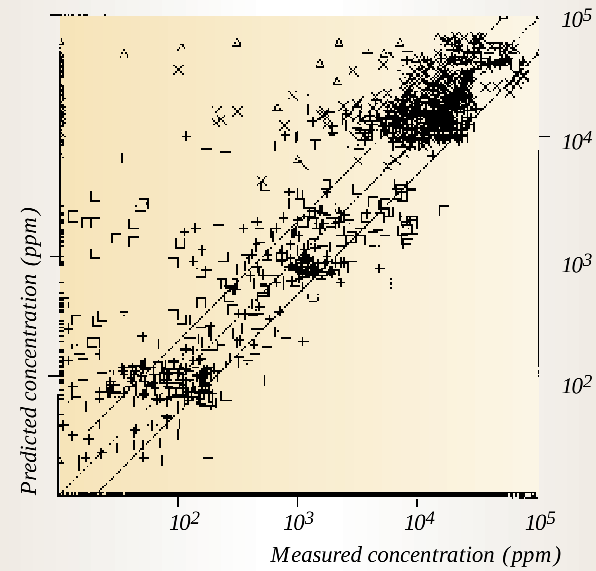


Figure 2.

The value of experimental information is a combination of the general usefulness of the data and the measurement quality.

The usefulness is an aspect which can be judged only in relation to theory or specific model predictions, and it is left to the data user to decide whether or not the experiments contain the necessary information for his analysis. However, the quality of the measurements has been considered, and most data with obvious severe problems have been omitted from the database. Data with less severe deficiencies is included without corrections, but the general measurements quality and typical errors of the sensor are described.

The REDIPHEM database has been used to compare the measured data with predictions from a few simple models that predict the dispersion of continuously released gas in the atmosphere in case of an accident. The main aim of this exercise has been to find the best method to rank the performance of these types of models.

Two options for such an evaluation exercise were investigated. The first is based on using all available data paired in time and space, leading to almost 12000 30-s averaged data pairs for the field data and 16000 data pairs for the wind-tunnel data. Figure 2 shows the comparison of the predictions made by one of the models (the model proposed by Britter and McQuaid) with the experimental data from field trials. Each data point in Figure 2 represents a 30-s averaged concentration signal at a specific position downwind from the source. The dashed lines indicate a factor of 2 deviation from perfect agreement.

For the second option, prior to the comparison with the model predictions, the maximum concentration at a certain downwind distance together with the plume width is derived from the data. These maximum concentrations are then compared with the model predictions for the plume centre line. Although the ranking of the models is the same irrespective of the option, it is concluded that for these simple models, which cannot reproduce all features of the experiments such as release height and the misalignment between jet direction and wind direction, the second option based on the maximum concentrations leads to the most consistent results, provided one takes also into account a comparison of the plume width.

Publications in 1995: 69,98, 99

Søren Ott and
Nijs Jan Duijm

Project	***Type***	***Substance***	***Number of time series***
Burro	*Field test*	*LNG*	*1419*
Coyote	*Field test*	*LNG*	*857*
Tortoise	*Field test*	*Ammonia*	*366*
Eagle	*Field test*	N_2O_4	*423*
Lathen	*Field test*	*Propane*	*1780*
FLADIS	*Field test*	*Ammonia*	*2564*
TNO	*Wind tunnel*	*SF6*	*404*
Hamburg	*Wind tunnel*	*SF6*	*4256*
WSL	*Wind tunnel*	*Argon, BCF*	*8092*
All data			*20161*

Overview of the experimental data contained in the REDIPHEM database.

Release of Toxic Gases from Fires in Chemical Stores

In many countries a large number of chemical plants are in operation involving the storage of substantial amounts of hazardous substances in warehouses. This implies risks, and the consequences of chemical fires seem to be one of the most important hazards in that context. A number of fires have actually occurred at chemical warehouses, e.g., the fire at Sandoz, Basel (Switzerland) in 1986. Chemical fires might generate very toxic combustion products which are dispersed with the fire plume and might be harmful to the humans exposed and the environment.

To analyse fire risks the CEC Environment program is funding some projects. One of them is entitled “TOXFIRE-Guidelines for Management of Fires in Chemical Warehouses”. The project was initiated in 1993 for a three-year period. The participants are South Bank University (Great Britain), VTT – The Technical Research Centre of Finland (Finland), SP – Swedish National Testing and Research Institute (Sweden), Lund University (Sweden) and FOA – Swedish Defence Research Establishment (Sweden), National Environmental Research Institute (Denmark) and Risø (Denmark).

The objective of the project is to develop the basis for two sets of guidelines in relation to fires in chemical warehouses. The first set is guidelines for the safety engineers to be used in accident prevention and the second set is guidelines for the fire brigades to be used if an accident nevertheless occurs. Both guideline sets will be the outcome of a detailed and systematic study of chemical fires supplemented by experiments based on model compounds to determine important properties of the substances involved and source characteristics and assessment of parameters of importance for fire scenarios. Also included will be the consequences to humans and the environment of the chemical fire.

Simulating chemical fires at Risø

Risø simulates chemical fires on a small scale in the laboratory. The experiments are carried out in a DIN 53436 furnace and the combustion products are analyzed by means of Fourier Transform Infrared Spectroscopy. In Figure 1 an example for a recorded IR spectrum is shown. It shows the combustion products of CNBA and how the concentration of the products is changing during the combustion experiment.

During the last two years, a number of different substances, e.g., polymers and pesticides have been investigated. In 1995, experiments were made using 4-chloro-3-nitro-benzoic acid (CNBA) and Tetramethylthiuram monosulphide (TMTM). The former is an aromatic compound containing chlorine and nitrogen. The latter contains sulfur and nitrogen. CNBA is used in the chemical industry as an intermediate in dye production and TMTM is used in the rubber industry as a vulcanizer. The simulation of the fire course was established by using six different scenarios for each substance, varying from full to poor ventilation and using different temperatures.

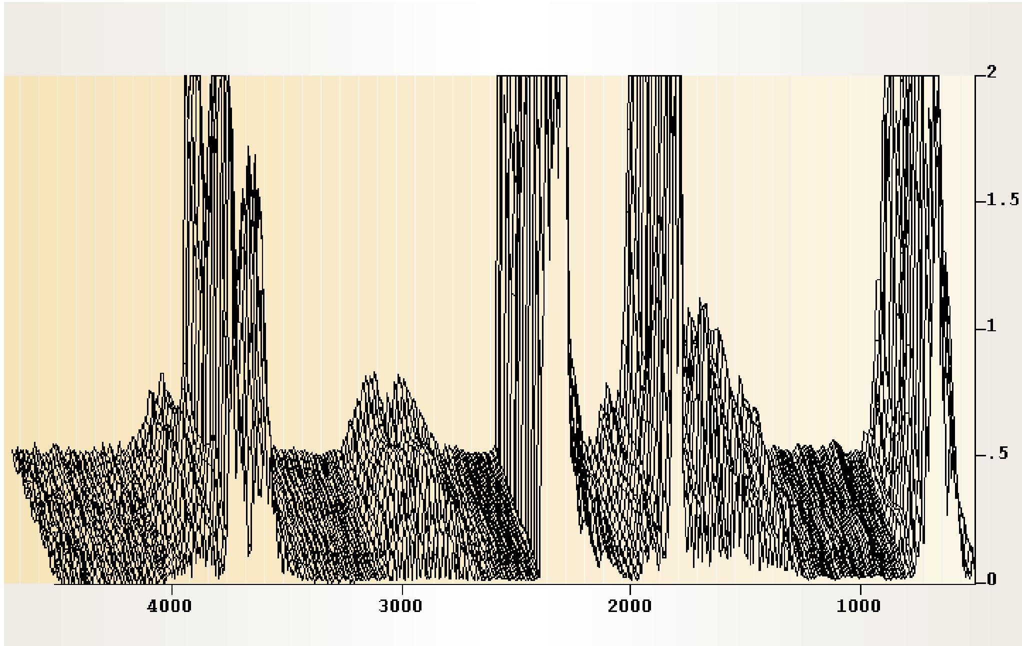
An example of the findings is that at high temperature CNBA burns generating a thick black soot, and small flames flash up in intervals. Under fully ventilated conditions the combustion gases contain high concentrations of hydrogen chloride and different nitrogen oxides. But also the very toxic hydrogen cyanide is observed. At a low temperature of about 500°C CNBA does not burn and evaporates unchanged. Parts of CNBA might therefore survive a fire. CNBA was also tested by our partner from The Swedish National Testing and Research Institute in a large-scale test. Here CNBA gave some problems: it was very difficult to ignite, and after burning normally for a while and generating a lot of soot it suddenly flashed up. The situation apparently got under control, however after a short while the fire flashed up again. The cause of this flash up has not been clarified at the moment, but the substance and conditions will be investigated carefully to find an explanation.

TMTM on the other hand is decomposed under both high and low temperatures and all ventilation conditions. Apart from other compounds the combustion gas contains high concentrations of sulfur dioxide.

The findings are in agreement with the following pattern: at high temperatures (at about 900°C) the investigated chemicals are almost completely burned, producing inorganic gases, as e.g., carbon dioxide, hydrogen chloride and sulfur dioxide. At lower temperatures (at about 500°C) the substances might partly survive a fire, and depending on the fire conditions, partly be converted into other organic products, which might be very toxic.

Importance for fire safety

The two examples illustrate the importance of the fire simulations. The simulations provide information on the burning characteristics of the substances and the composition of the fire products.



Such findings are essential for fire brigades, as it will improve their possibilities for controlling chemical fires, and provide assistance in order to select appropriate fire protection measures. These guidelines will be established during 1996 and a final report will be completed at the end of that year.

Publications in 1995: 71, 72, 87, 119, 123, 124

Frank Markert

Figure 1.
The FT-IR spectra for a combustion experiment of CNBA at 900°C and reduced ventilation. The experiment takes about 1 hour and about 350 spectras are recorded.

The work within the field of reliability analysis comprised research and development as well as practical applications of reliability analysis methods.

The research and development work was concentrated on non-probabilistic analysis methods and functional modelling.

Two projects concerned the practical application of methods for improving wind turbine safety: One of these, under a Danish energy research programme – a EFP-94 project - deals with establishing a methodology for analysing the reliability of the safety systems of wind turbines and a database with reliability data for wind turbine components and equipment. The other is an EU project, JOULE IIA, which provides recommendations for assessing wind turbine safety.

Non-probabilistic Methods

Non-probabilistic methods of reliability, safety and uncertainty analysis were investigated. They are considered as perspective directions of research. The main argument is that the conventional mathematical tool based on probability, is too restrictive, enabling only a part of the useful information over reliability and safety of objects to be formalised, while the rest of the information like fuzzy, subjective, non-specific is unused or used in an incorrect way. Also, an uncertainty analysis within the frame of the conventional theory handles only one type of uncertainty without considering the others and leads us to be sceptical of numerical reliability and safety characteristics.

The works carried out in this direction are the following:

- The fuzzy approach and possibility theory were implemented for reliability analysis of robots operating in hazardous or disordered nuclear environments
- The usefulness of the Dempster-Shafer theory of evidence for reliability analysis in the case where the data are non-specific was demonstrated
- In the light of the Dempster-Shafer theory the concept of risk was reconsidered
- An approach was developed to analyse reliability on the basis of generic data and built on the concepts of “analogy” and belief functions.

Functional Modelling

The idea behind Functional Modelling is that there exists an intention behind the design, construction and use of any human-made system. The intention can be expressed in terms of the system’s goals, the systemís functions to attain those goals and the system’s components to realise those functions. The prime objective of the Functional Modelling techniques is to describe a human-made system by identifying its goals and its functions. This objective differs from that of traditional modelling methodologies, which focus on the components of a human-made system.

The activities involving Functional Modelling have concentrated on two projects:

1) Identification and prediction of failures in process control systems, which due to their dynamic nature and their control action often are able to hide failures. The results of this project will be presented as a Ph.D. thesis.

2) Identification of hazards in process plants by considering such plants as socio-technical systems, and hence to include technical, human and organisational aspects in the task of hazard identification. The working title of this project is TOMHID.

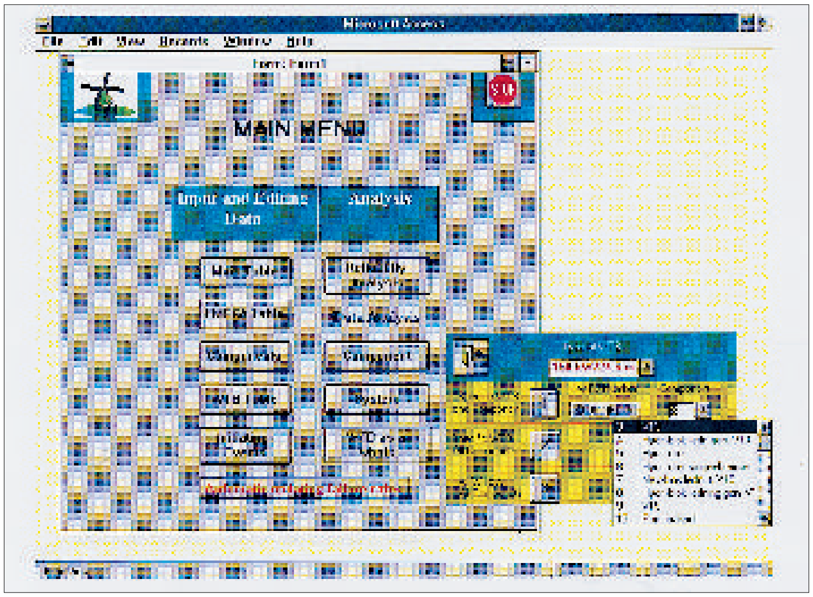
The EFP-94 Project on the Safety Systems of Wind Turbines

The EFP-94 project is carried out in a cooperative effort between Risø National Laboratory (Systems Analysis and Meteorology Research Departments), BONUS Energy A/S, NORDTANK A/S and ELSAMPROJEKT A/S.

The primary purpose of the project is to establish a practical tool to be used by the manufacturers and authorities for analysing the safety systems and identifying possible weak points in them, thereby effectively facilitating an improvement of the safety of the wind turbines.

The methodology for the analysis of the reliability of the safety systems of wind turbines was based on a series of Risø’s reliability

Figure 1.



computer programs, calculating the reliability characteristics of the safety systems.

A fault tree data file is prepared on the basis of a Cause-Consequence diagram. Such a diagram depicts the event sequences leading to a selected unwanted condition, the so-called top event of the analysis, in this case overspeed of the wind turbine rotor. This diagram is constructed on the basis of the documentation for the safety systems.

The basic event data file contains a list of all component failure modes included in the fault tree. The database automatically takes the relevant empirical data characterising failures of the respective components, calculates the appropriate failure data and inserts them into the basic event data file.

A preliminary version of the database has been established. Its characteristics take advantage of the graphical features of the windows software with simple ways to view and process information. It also provides extensive querying and connective facilities, and it is possible to use one query for work on data stored in different formats and locations. Further, it enables the automating of most tasks easily without the need for programming.

The software associated with the database consists of two parts: the first is the database itself with tables, queries, results, macros and calculation routines for simple data analyses and the second are the reliability computer programs.

A series of possibilities are presented to the user in order to provide required information and for asking questions on the number of failures which have occurred within a certain subsystem or in a specified component, failure causes and consequences.

In addition, a series of choices between calculations are presented to the user like the evaluation of the probability of overspeed of the rotor or of the failure of a given subsystem. Further, a list can be provided of the failure modes dominating the occurrence of the top event or the failure of specified subsystems in order of their probability. Furthermore, specified reliability characteristics can be calculated like frequency, consequence or duration of specified events.

Figure 1 shows the main menu. By means of this the user can choose between data editing and various kinds of analyses. Figure 2 shows an example of a presentation of results: The repair time and number of failures experienced over a certain period of time are presented in a table and in column diagrams for two different sections of the wind turbine safety system.

The database will be continually updated with data concerning the component failures experienced on the basis of the work sheets completed by the repair crew. For each work report a record will be entered into the database containing the respective codes for component, failure mode, subsystem, failure cause and date of occurrence.

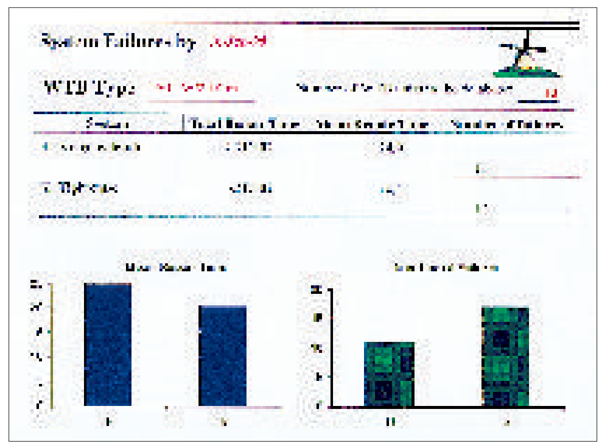


Figure 2.

During the work, project areas were identified where further research is required, for instance on the completeness of event sequence models and the calculation of the probability of occurrence of event sequences containing high probability events, based on cut sets.

Publication in 1995: 89

IGOR KOZIN AND
HANS E. KONGSØ

A Multi User Information System Concerning Aging and Maintenance Assessment

When process plants get older, the equipment reaches an age where the observed failure rate may deviate from those predicted, since the equipment may experience aging problems. Consequently the planning should be reviewed with the purpose of re-optimization keeping safety and productivity.

Risø participates in a research programme in this area. The work is a part of the Nordic Nuclear Safety research programme NKS and the project is done in collaboration with Sydkraft, Barsebäck, Swedish Nuclear Inspectorate (SKI), the data base office (TUD) and Delft Technical University.

Nuclear equipment, e.g., safety systems, are complex, high technology systems that must operate for long periods without serious failure and with a very long total life. A great amount of redundancy and diversity is used in nuclear facilities to ensure the safety of the plant. Repairs, inspections and overhauls of equipment are usually done at specific time intervals, when the plant is down for refuelling. These processes generally follow a pattern of increasing complexity, depending on the operating times accumulated by the system.

The physical environment in which the equipment operates may have serious detrimental effects on the complex mechanical and electronic components of the equipment. High temperatures, high vibration, high humidity and the presence of radiation all take their toll.

The nuclear power plants in the Nordic countries have established a common database to which all repairs on components are reported. Fourteen nuclear power blocks in Sweden and Finland contribute to this common database. A database containing reports from safety-related failures, the so called Licensee event reports, is also established as a common database. These databases are used mainly for calculating the reliability of the components involved in safety studies in order to increase the overall safety of the plant.

The aim of the present work is to develop methods based on the use of the database for aging and maintenance assessments of the components, since obviously maintenance is a requirement for safety and efficiency.

To extract the relevant information some issues need to be discussed:

- How to define high quality maintenance
- How to measure high quality maintenance
- Which data are available for the purpose
- How should the results be presented to the different users.

In nuclear power plants safety plays an important role so one strategy used for maintenance planning is to keep the maintenance cost as low as possible consistent with the highest level of safety.

To accomplish this a combination of high quality components and excellent repair work is required, with preventive repairs carried out at the optimal time.

The following is a list of possible indicators for high quality maintenance:

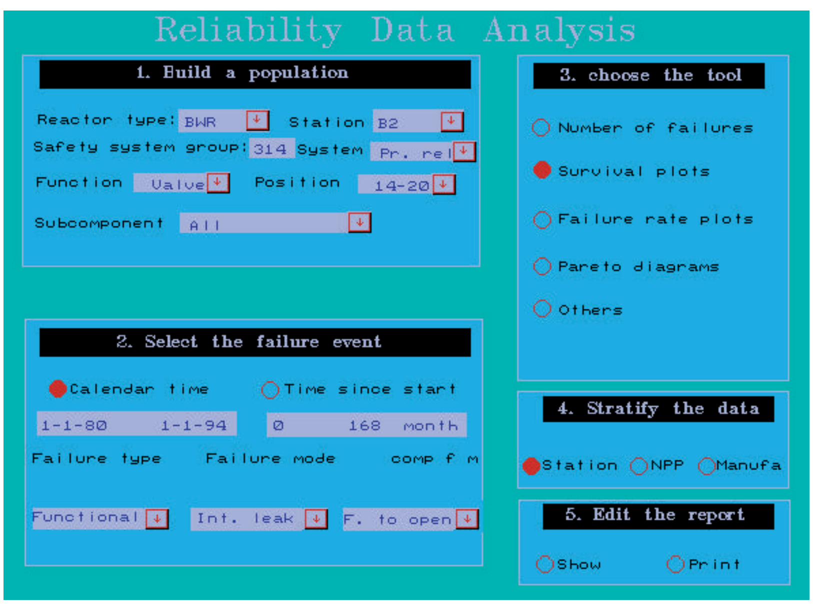


Figure 1.

- The repair rate is comparable with other identical components from other manufacturers
- The repair rate is comparable with identical components on other nuclear plants
- The number of early failures following repairs is low
- The number of unplanned repairs is low
- The relation between preventive and corrective repairs is reasonable
- The failure rate is not increasing
- The time used for maintenance is not increasing
- The unavailability due to repairs is low

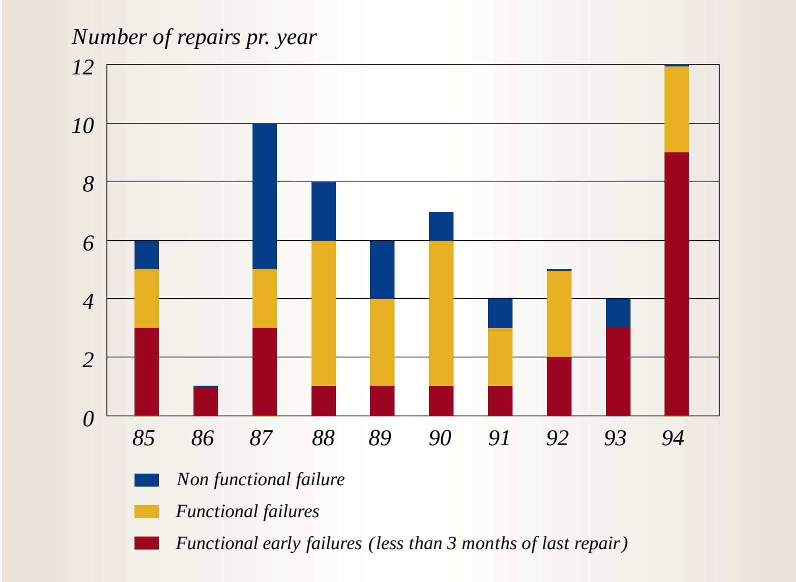


Figure 2.

One important issue is the discrepancy between the userís needs and the information available. A failure report contains information about the failure and the repair, as well as a classification of the failure type. The classification describes how the failure was detected, the failure effect, what has been done during repair and the failure type.

To treat the information in the reports a computer program is developed. The program does all the necessary statistical work. The interface of the program is shown in Figure 1.

The main idea behind the design of the program is the possibility of pooling data from selected process plants, from selected components, selected failure modes and selected time intervals. This possibility enables the user to select the plant in question, pool data from several plants and compare the results. A large number of graphs can be retrieved to be able to elicit a problem. The system of graphs can be used as a hierarchical system where the user starts with an overview graph and then dives deeper and deeper into an indicated problem.

The graph in Figure 2 shows for one plant the number of failures per year for a system of three pumps. It also shows the number of these failures which appear less than 3 months after the last repair. This is one of the graphs where the number of early failures can be seen. The interval for detecting early failures can be selected too. The graph in Figure 3 present so-called subsurvival functions. The curves are two survival plots, where one shows components ending their operating period in a preventive repair and the other the components ending the period in a corrective repair. This means that the graphs show the probability for the next repair to be detected either as a corrective repair or a preventive one. The steepness at the beginning of the curves tells about the number of early failures occurring after repair.

In this pump system the corrective repairs are dominant, so that there is a high probability that a given repair will be a corrective one. The interpretation of the results and the question about changing components or changing maintenance plans require a knowledge of the systems that the users are expected to have.

Publications in 1995: 100, 101

Jette Lundtang Paulsen
and Joan Dorrepaal

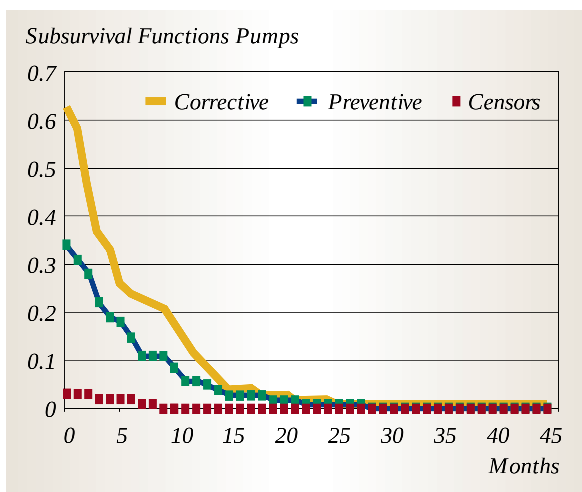


Figure 3.

An accident raises questions like: how did it happen, was it equipment failure or human error, or was it avoidable? In addition to caring about losses and other consequences, it is essential to draw knowledge out of it, formulate experience for use by hardware designers, system designers and risk managers. The area dealt more specifically with in this work is the extraction and eventual use of accident knowledge for emergency preparedness.

MEMbrain is an EUREKA project running 1993-1998 with nine European partners. The aim of the project is to define and implement a standard European software and hardware platform for Major Emergency Management. The present work, which is a part of the MEMbrain project, covers the following activities:

- systematically extracting and presenting accident knowledge from a large selection (totally 20-25 cases) of accidents, representing the main accident types
- developing models to support both the case work and the later structuring of the extracted knowledge for training purposes
- devise a formulation of the general accident knowledge collected that can function in a *scenario generator* or other type of accident bank for training use.

In 1995, the case study part with 19 cases has been finished and the accident models have been formulated including a set of generic accidents; in addition a training scenario for use by the Norwegian Radiation Protection Authority (Statens Strålevern) has been prepared.

Emergency managers and emergency personnel generally gather accident knowledge from three sources:

- personal experience
- education and training
- contingency plans and procedures,

and the prevailing forms for representing accident knowledge are the *scenario* and *case story*. When pilots or nuclear reactor operators are trained with training simulators, these can reproduce malfunctions and critical conditions in order to train responses to selected accident scenarios. Training of emergency managers can be conceived as an expansion in two directions compared to traditional simulator training: both the system dimension and the accident dimension are stretched considerably.

Alternatively, emergency manager training can be conducted with emphasis on *rehearsing the plans*, where the reactor or aeroplane is substituted by "an emergency".

To collect accident knowledge for later transfer to a *training scenario generator*, the first step was to sketch a set of generic accidents: a transport accident, a power plant accident, a processing plant accident, etc. An example would be transport of dangerous substances – the same substances are also met in processing and storage, but characteristic for transport emergencies, the volumes handled can be smaller. However, transport accidents can happen anywhere on route, and correspondingly affect several emergency teams.

As the second step, these generic accident descriptions were structured and the resulting schemes have been applied to 19 accident cases, among which are the Seveso, Chernobyl and Bhopal accidents, the Scandinavian Star ferry fire and the Herald of Free Enterprise capsize. By the end of the year, experience from this case

Tor Arne Dalnes, Scan-Foto

Scandinavian Star ferry fire.

*Figure 1. Accident model with **u**ncontrolled **f**low **o**f **e**nergy*

work is being formulated, leading to several minor adjustments of the schemes. But a more general result of the case work at this point is that it has formed the background for making an accident model. Adequate tools will be needed for structuring and governing the transfer of accident knowledge between the sphere of risk analysis and case studies on one side, and the scenario-and-training setup on the other.

Modelling the emergency situation

An accident model has been developed to describe the emergency situation. A key concept of this model is *u*ncontrolled *f*low *o*f *e*nergy (UFOE), essential elements are the state, location and movement of the energy (and mass). A UFOE can be considered as the driving force of an accident, e.g., an explosion, a fire, a release of heavy gases. As long as the energy is confined, i.e., the location and movement of the energy are under control, the situation is safe, but loss of confinement will create a hazardous situation that may develop into an accident.

The accident model is explained as follows:

- A confined amount of energy can constitute a *hazard source.* If sufficient energy is present, the prerequisites for an accident are present.
- Central factors of the accident model are *confinement* and *loss of confinement*. Confinements involve containing systems and control systems.
- The combination of sufficient energy and inadequate confinement results in *uncontrolled flow of energy* (UFOE).
- If a *vulnerable object is exposed* to an energy flow without sufficient barriers, then the accidental consequence becomes a fact. Vulnerable objects can be human beings, environment and property.

The development of an accident does not depend entirely on the properties and quantities of the substances involved. Structural, operational and managerial factors have also a large impact on the transfer of energy. These are pictured as "socio-technical conditions" in the accident model, which comprises all elements having an influence on the accident course. Another part represents the control efforts established, which can be divided into hazard control and emergency support. The reason is that the control efforts have a different character before and after the loss of confinement. As long as the confinement is maintained the control effort can be characterised as hazard control implying that safety functions and responsibilities have been specified. If there is a loss of confinement, creating an UFOE, the emergency organisations and measures are activated.

Centered around the triad of hazard source, UFOE and vulnerable objects, a set of universal emergency measures has also been formulated. The six basic ways of controlling or fighting UFOES towards vulnerable objects are: move these objects away from UFOE; modify the energy; redirect the flow; control the source; encapsulate the moving energy; establish a negative source. Examples of negative sources are: leading spills to the sewer – thus exporting the problem to a different place – or adding chemical agents that react immediately with a dangerous substance, producing substances easier to handle.

Domain model

A domain model has been chosen to provide a general framework for representing the different accident and emergency scenarios occurring in society. A domain can be characterised as a group of activities with allied goals and elements, e.g., transportation, chemical process plants. The domain model consists of three main categories:

- The *status* contains the background information for developing accident and training scenarios. Key elements are: territory characteristics, resources, process conditions, systems control, organisation, sources of information and analysis methods.
- *Context* contains the safety and emergency characteristics of the domain.
- Objectives and principles for *training* are handled in the tird category, which covers training objectives and training process.

Birgitte Rasmussen and
Carsten D. Grønberg

Emergency Management Training Using Virtual Reality

During 1995 Risø has been responsible for an EU project – inside the area of Environment – concerning guidelines for a training system: MUSTER – Multi User System for Training and Evaluating environmental emergency Response. The training performed by MUSTER is especially dedicated to improving the co-ordination of efforts of decision making in emergency management. It was initiated in 1993 and concluded summer 1995, and during the last six months had emphasized in particular the presentation of the emergency situation to the trainees.

Fortunately, major emergency situations are so rare that coping with them will never be ordinary routine. Therefore, training decision makers and developing their co-operative efforts is of utmost importance to secure the availability of an efficient level of preparedness should a real emergency situation occur.

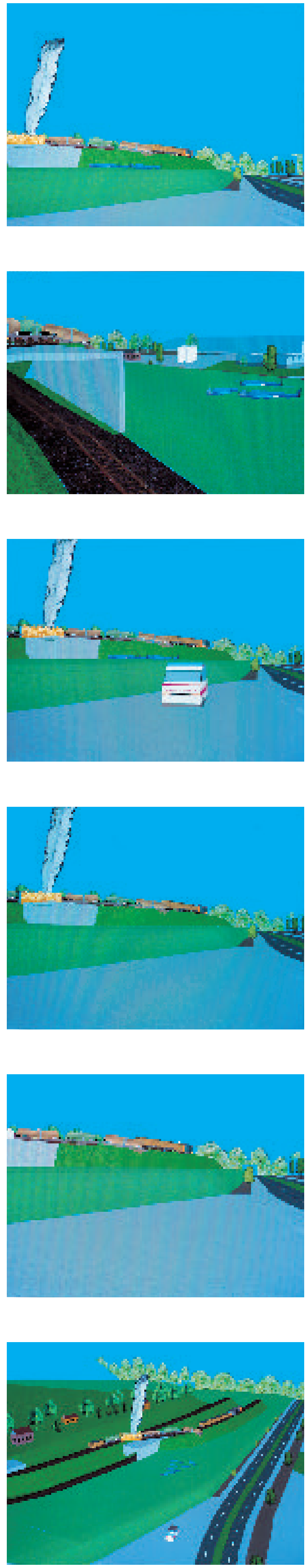
The entire emergency management organisation designed to cope with large emergency situations is normally built up of various units such as fire brigades, police forces, civil defence personnel and hospitals. The skills to be trained exist mainly on three different levels: the skill of the individuals in each of these units, the efficiency of each unit per se, and finally, the co-ordinated performance of the units. All of these are essential for attaining the optimal efficiency in emergency management.

The individual skill as well as the separate efficiency of each organisational unit are effectively trained within each unit by frequent exercises and drills, and their optimising is not the goal of the training supported by MUSTER.

The goal of MUSTER is rather to develop advanced and efficient means of supporting the co-operative training among the various units forming the complete emergency management organisation, i.e., to train the co-operative efforts among the decision makers who are in charge of these units.

Even though the MUSTER project was defined as a paper project that merely specifies an efficient training system, these specifications were supported by the development of two illustrative prototypes: one for a Danish demo covering a railway accident with release of toxic material, and the other for an Italian demo covering a burning oil tanker in the oil port of Genoa. By use of these prototypes, functionalities and user interfaces of the system could be tested and commented upon by the end-users.

In the MUSTER system the presentation to the trainees is – as in the real world - divided into the on-field area and the remote area, each of which has its own decision makers. The on-field presentation shows the actual situation for the trainees situated at the location of the accident and is meant for trainees such as the commander in charge of, e.g., the fire brigade, the police, and the paramedics normally working on site. The remote presentation shows the surroundings for remote control rooms, e.g., the headquarters located at the fire- or the police-station, and is meant for trainees who are normally present in these



The set of figures illustrates a possible evolution of a virtual accident scenario.

locations and acting as back-ups for the on-site emergency managers. All trainees must have the same equipment available, e.g., radio communication, as in a real situation.

In order to make the on-field presentation as realistic as possible, we approached a new and efficient way of training: simulation of emergencies using virtual reality, VR. In VR all kind of situations may be experienced in extensive detail, and mistakes are allowed to occur - which is often a very beneficial way of learning – without the loss of human lives or properties, and with no influence on the real environments.

The training environment for the Danish prototype, a railway area in Fredericia, was modelled using a CAD-like tool, and in co-operation with DIVISION in England this model was converted into a virtual reality system. Using this system the trainees may interactively walk around in the area and inspect the scenery from various points of view in the same way that the commander in charge would carry out his inspection in a real emergency situation. Moreover, the VR environment will reflect the changes performed interactively during the training session, e.g., the appearance after ambulances are called and the disappearance after casualties are removed.

The VR presentation used in MUSTER is non-immersive as the intention in a MUSTER training session is to train the co-ordinated performance of the decision makers. Therefore, we have chosen a form of virtual reality in which the trainees can discuss the critical situation based on a common visual presentation displayed on the screen of a workstation.

The visual impression of the scenario given to the trainee is supplied with a presentation of the heat radiation from a potential fire or the smell, indicating the concentration of release of toxic materials at the location of the trainee. These indications are shown by meters on a PC monitor. Furthermore, the relevant sound effects which have proven to be very effective as a stressing factor may easily be added; so, the only sense missing is that of taste. The heat radiation and calculations of the concentration of toxic materials are based on heat radiation models and dispersion models including the direction and strength of the wind in the actual scenario.

The attached pictures – taken from the Danish prototype – show a virtual reality accident scenario related to the transport sector. A hypothetical railway accident took place in the vicinity of Fredericia, which is a junction of railway traffic. A train carrying dangerous goods – LPG gases and acrylonitril – has been derailed, and one of the wagons is on fire, thereby heating a nearby LPG wagon. If this wagon is not cooled within a given time, its high temperature will cause it to explode. Another tank wagon is leaking the very toxic acrylonitril that evaporates and creates a toxic plume, which is driven towards Fredericia by the wind. The toxic plume divides the area into two, as only specially equipped rescuers are able to work in the contaminated area. Only a specialised group of the fire brigade possesses the necessary equipment, so that neither the police nor paramedics are able to work in the polluted area. Furthermore, a number of injured persons are located in or near this area and need help. When the commander in charge arrives at the site of the accident, he will be given the view shown in the first picture. The remaining pictures illustrate a possible evolution of the scenario: searching for casualties under the bridge, call of ambulances, removal of the casualties, extinction of the fire, and finally, an example of a birds eye view of the scenery.

The VR presentation in the MUSTER demo was handled by Silicon Graphics workstations; however, a simple version may be operated using ordinary PCs if the continuous interactive inspection of the site using virtual reality is replaced with a discrete inspection presented by a set of still pictures covering the site from different points of view and in different situations. The details in the presentation are given by the number of pictures selected from the database. Also this kind of system has been implemented and tested in the MUSTER set up.

Publications in 1995: 41, 42, 48, 49, 50, 51, 52, 53, 54, 55, 80, 81

VERNER ANDERSEN

Training of Train Control Operators' Handling of Recoveries

Train control operators in the Danish State Railways face an immensely complex task during the recovery of an accident. Though recoveries are presently handled at a level acceptable to the railway authorities, it is generally agreed that the performance of the operators could be improved. Training is seen as an effective way to improve performance, since it enables the operator to practice the seldomly used emergency procedures. To create an effective training design the difficulties confronting the operators during recoveries must be disclosed. If the difficulties are not clarified, the risk of creating a training design directed at skills which the operators master in advance is high.

The purpose of the Ph.D. project described here is to create a foundation on which a training design directed at operators' handling of recoveries can be based. The project was initiated in 1993. It is performed in cooperation with the Danish State Railways under supervision from the Department of Psychology at the University of Copenhagen.

To clarify the operators' difficulties it is necessary to conduct a systematic analysis of their tasks. In this project the method *hierarchical task* analysis was used. Broadly speaking this method implies that the tasks of the operators are gradually broken down into part-tasks until the difficulties related to task performance have been clarified.

The task analysis was performed in close contact with railway personnel, in particular train control operators but also people knowledgeable in other ways about the operators' tasks. This was done to ensure that the conclusions reached would be acceptable to members in the organisation. Because the effectiveness of training to a large extent depends on the motivation of the trainees, the close contact should also support design of scenarios pertaining to and interesting to the operators.

Part of the project involved examining the implications of a separation of the operators' tasks into two major categories: Emergency Management (EM) tasks and Traffic Management (TM) tasks. The tasks in the two categories differ in their characteristics. EM-tasks relate to the direct recovery of an accident. They are performed only in cases of emergencies and involve co-operation with members from outside the railway organisation. TM-tasks relate to the indirect consequences (disturbances) which an accident imposes on the traffic flow. They involve only co-operation of people within the railways. Thus, TM-tasks are identical to those performed by the operator on a daily basis, except that the traffic situation generally is much more complex during a recovery. Seen from a training perspective the distinction indicates that dissimilar training needs exist in relation to the two types of tasks.

The training of EM-tasks should focus on the development of strategies relating to three aspects of the operator's performance:

- for obtaining information - necessary to decide if conditions for performing the individual EM-tasks prevail;
- for prioritising the EM-tasks; and
- for deciding when the different notifications can be considered complete.

Thus, to effectively train EM-tasks it is reasonable to incorporate a set of procedural guidelines to support performance. The establishment of guidelines is possible, since the way problems present themselves to the operators can be considered as fundamentally identical from one recovery to the next.

The training of TM-tasks on the other hand should be conducted differently. TM-tasks are not described in any form – except in the task analysis. The traffic situation confronting the operators performing TM-tasks during recoveries is generally very complex. Often the elements they must attend to (engines, wagons, engine drivers, train staff, etc.) far exceed the capacity of human short-term memory. For this reason the operators' main difficulty is to decompose the TM-task into part-tasks which they can grasp. The decomposition of TM-tasks, though, can only at a very high level be considered to be a task which is identical from one recovery to the next. This implies that focusing strongly on procedures is not an effective strategy when training TM-tasks. Instead, it seems reasonable to establish a set of prototypical situations relating to the specific part of the railway system for which the trainees are responsible on a daily basis. The operators may use these situations to support their general understanding of possibilities for action in different types of situations.

The results from this part of the project consequently indicate that training of recoveries could be made more efficient if the session is divided into two parts: The first part should be directed at the difficulties experienced by the trainees when performing their "normal" tasks during the altered conditions a recovery causes. The second part should address the difficulties experienced by the trainees when performing the tasks unique to a recovery. Such a division seems to be useful for two reasons:

- it will be possible to adapt the most effective training strategy related to each type of task, which can be expected to improve the effectiveness of the session; and
- the often very expensive training time required whenever participants from multiple organisations take part in the session can be reduced.

This reduction is possible since the trainees in the second part of a session can be expected to master their "normal" task. Thus, the session involving a full emergency team would not have to deal with difficulties within a given organization, but only with tasks involving or affecting members from other organizations.

Publications in 1995: 65, 96, 97

Ann Britt Miberg

A remote control operator.
(DSB fotoarkiv/Lars Lindskov)

Obtaining a detailed understanding of the mental information processing performed by operators of complex technical systems is essential for the design of efficient human/machine interfaces and decision support tools. It is furthermore needed for evaluating the effectiveness of simulator training and for including the human element in probabilistic assessments of industrial risks. Experimental techniques which are employed for identifying search strategies and decision heuristics used by human subjects to control a simulated or real dynamic work environment include: verbal "think-aloud" protocols, the use of sound and video to record the subjects' communication acts and interactions with instruments and control panels, and making use of eye tracking to catch visual orientation behaviours and allocation of attention.

Operator equipped with eye mark recorder.

Location of the operator's attention.

In 1993 the department entered into a collaborative effort with the Department of Electronics and Mechanics to build a transportable system that permits experimenters to make recordings like these in synchronism with each other. With this system – MULTIMO – the output from several video cameras and eye trackers is presented jointly on a single large monitor. Event markers and transcripts of the verbal protocols make it possible to perform cross correlations and other types of experimental data analyses in a very effective manner.

In 1995 the MULTIMO system served as the main tool in several human factors experiments. Three of these were:

Team performance in control rooms. This experiment was planned and organised by the Man-Machine Research Division of the OECD Halden Reactor Project, Norway. It was effectuated as a pilot study under the Halden Human Error Project which aims at understanding the diagnostic errors that may be committed by nuclear control room operators during reactor malfunctions and emergencies. In the experiment two operators collaborated on diagnosing an incident simulated at the Halden Hammlab control room facility. It was important to detect how the operators performed the visual information search involved in the task, and therefore both operators were equipped with eye-tracking goggles. This was the first application of dual eye tracking performed with MULTIMO.

Alarm handling in operating rooms. In this experiment MULTIMO was used to disclose how anaesthesiologists react to cascade alarms. It is an open human factors issue whether any monitoring signal that exceeds a preset threshold should trigger an alarm independently of the context, or whether it is better to filter out redundant alarm information so that cascade alarms are avoided. The experiment was carried out using an anaesthesia simulation facility available at a hospital in Copenhagen. It showed that, once a critical alarm has been received from the patient monitoring equipment, anaesthesiologists act as an effective human alarm filter by ignoring additionally triggered alarm events.

Test of drivers' use of traffic signs. This experiment proved that it is possible to make recordings with MULTIMO under severe space limitations. The system was installed in an ordinary passenger car, and eye tracking and video was used to detect to what extent drivers pay attention to the sign information along a road route. These data were collected for the Danish road authorities in a project that aims at establishing guidelines for the design of driver-friendly traffic signs.

Publication in 1995: 44

JOHN PAULIN HANSEN AND LEIF LØVBORG

Comparing Conventional Control Panels with Re-configurable Panels

Touchscreen technology has improved significantly in recent years enabling users to operate touchscreen-based controls with much greater precision and reliability. In turn, this development has led to an interest in applying this technique to replace conventional control panels for certain applications.

Conventional control panels contain "hard" controls, e.g., switches, dials or handles which give operators tactile feedback. In contrast, a touchscreen-based control panel contains "soft" controls – that is, graphic pictures of controls shown on a computer-generated display. Users may then operate soft controls by sliding their fingers across a transparent touch-sensitive surface on top of the computer display. As the user "moves" the control, the picture of the control will change and this change will normally be accompanied by appropriate sounds ('clicks' and 'tocks') which correspond to auditive feedback emitted by real controls.

The chief drawback of touchscreen-based control panels is, of course, that they fail to give users tactile feedback – a user cannot "feel" the position of a control, nor feel the resistance when he or she changes its state. So, for most safety critical applications – such as control panels in airplane cockpits, ship bridges or control rooms – hard controls are nearly always preferable. On the other hand, soft controls have a significant advantage by being extremely easy to re-configure: it is quick and inexpensive to re-configure the layout, position and even type of control on a touchscreen-based panel.

In areas such as simulator training and interface design, re-configurability of control panels has a great attraction. Yet, the adoption of soft controls in these areas has been slow, since there have been doubts about the training effectiveness of soft controls. Thus, there has been concern that users who have been trained in a simulator on "soft" control panels and who are then transferred to an operational environment with conventional control panels might produce more errors or perform more slowly than trainees taught in a conventional environment.

An experiment conducted by the department suggests, however, that training effectiveness *need not* be reduced when users are trained on a soft control panel. The experiment was the first in a series of experiments carried out within Esprit project MATE (Multi-User Aircraft Training Environment), in which Risø is responsible for Human Factors evaluation of a new type of re-configurable cockpit simulators. In the experiment, subjects who were volunteers belonging to Risø's staff, were trained and subsequently tested in carrying out a short checklist contained in the pre-start procedure conducted by pilots flying a common turboprop airliner. The subjects were randomly allocated to one of two groups. One group was trained on a real or conventional panel, viz., a physical replica of a subsection of the overhead panel of this aircraft, while the other

Subjects who were tested in the control panel experiment were trained either on the conventional panel (right) or on the touchscreen-based panel (left). Their performance was then evaluated on the conventional panel alone.

was trained on a touchscreen-based simulation of the panel (see accompanying pictures). Having been trained to attain the same level of skill, *all* subjects were then tested one day later on the *real panel*. If the hypothesis were true that training on soft controls leads to a reduction in performance, subjects trained on the touchscreen-based panel would display more errors or would perform more slowly. But it turned out that there was no significant difference: the number of errors were the same across the two groups and there was a negligible (i.e., non-significant) tendency of subjects trained on the soft panel to function at a slightly slower pace than those trained on the real panel.

Experiments on the training effectiveness of re-configurable control panels will be continued in the department in order to investigate if pilots will achieve the same level of training using the two types of panels involving very different types of controls, and further studies will focus on optimizing soft controls and identifying the extent to which "motoric" memory contributes to the memorizing of procedures.

Publications in 1995: 43, 45, 46

H.B. ANDERSEN

SIMULATION OF

A large proportion of the collision and grounding accidents occurring with ships can be ascribed to navigation error caused by insufficient alertness on the bridge or limited insight shown by the navigation crew into the manoeuvring characteristics of the vessel. The safety of shipping, particularly in confined waters, may be enhanced by providing ships with advanced radar equipment, setting up vessel traffic control systems and employing full-mission nautical simulators to train navigation crews in the execution of difficult ship-handling tasks. Together with the Danish Maritime Institute (DMI) work has begun to develop a computer tool that will make it possible, in principle, to assist nautical authorities and ship owners in predicting the risk-reducing effects of such measures. The work is carried out under the HELT collaboration agreement between DMI and Risø.

The idea behind the tool is to estimate the probability that a ship is accidentally navigated into waters outside its permitted lane, and to do this from repeated simulations performed with a mathematical ship model. This approach involves the development of methodology for simulating human variability associated with executing the rudder and engine adjustments required to maintain a ship on the segments of an angular course line.

Collision or grounding resulting from, for example, having an inexperienced crew on the ship bridge, can often be attributed to timing errors in performing a critical manoeuvre in the fairway.

Timing is therefore a good indicator of the effects of crew training and other risk-reducing measures. For this reason the simulation tool should be provided with capacity to generate ship trajectories that reflect the influences of timing errors on course and speed changes.

The mathematical ship model developed for an experimental prototype of the tool is installed on a server PC which displays the current position of the ship on a digital sea chart. Rudder angle and engine thrust are controlled by a client PC equipped with software routines for interrogating the ship about its position, heading, speed, rate of turn, depth under keel and drift caused by current and wind. These quantities are displayed on a simulated bridge console and will be used as input to task networks designed to simulate the control actions performed by ship navigators during course adjustments and turns.

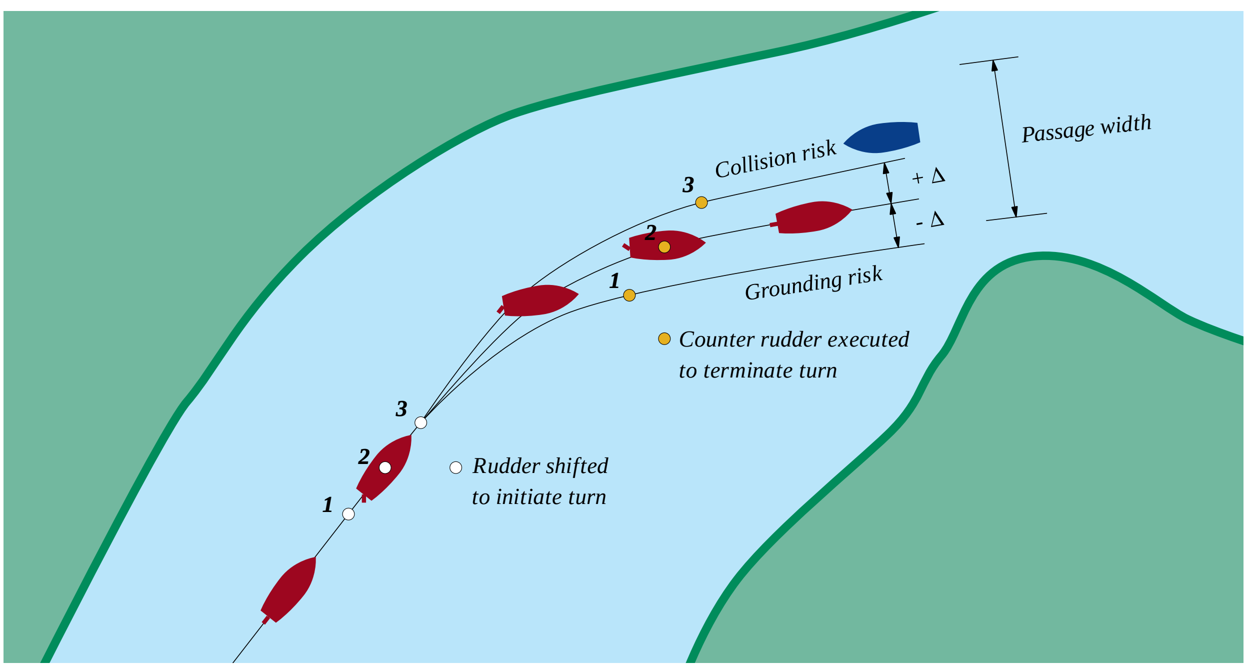
Applying networks to simulate human control tasks is an empirical methodology involving the observation of human action sequences and recording of the time used to accomplish each step of such a sequence. For example, to construct a task network that simulates the actions on a ship bridge while approaching a waypoint where a course change must be effectuated, it is necessary to determine minimum and maximum limits for the time a captain (or his co-navigator) will need to take a bearing or estimate the distance to a buoy.

Task execution data for the continued design of the prototype tool are compiled with support from the MULTIMO system in experiments with professional crew trainees at full-mission simulator facilities available at DMI. A comprehensive series of experiments will be carried out in a new EU project called SAFECO (Safety of Shipping in Coastal Waters).

Publications in 1995: 78, 86

Leif Løvborg and
Finn R. Nielsen

Imprecise timing in performing the rudder adjustments used to turn a ship onto a new course line is a potential source of colision og grounding risk in narrow fairways.



Computer Support for Coordination of Embedded Software Testing

The manufacturing industry is confronted by increasing demands for improved quality products, shorter lead-times, higher flexibility, etc. One way to respond to this has been to apply the concept of concurrent engineering, i.e., bringing knowledge of all stages of the product life-cycle – design, development, production, use and destruction – into the early phases. This requires, however, the involvement of many people having different competences in the design work. The need for coordination increases, and it becomes obvious to consider computer support. How to use computer technology to support people in coordinating their work is the core issue within the field of Computer-Supported Cooperative Work (CSCW). Development of prototypes is part of a research effort at Risø to formulate a frame of concepts for how computer technology can support the coordination of work. The core of Risø's work within CSCW has been to develop of the theory of coordination mechanisms.

> ✶ A coordination mechanism reduces the complexity of the coordination to be conducted by stipulating the flow of the distributed activities, and by mediating relevant information among the actors involved in the work.

The prototype introduced here is an example of a computer-based coordination mechanism. A field study was conducted in order to establish an empirical basis. This was a joint effort between Risø and Institute of Manufacturing Engineering, Technical University of Denmark. The prototype development was closely related to, and partially funded by, the Esprit BRA project 6225 COMIC, and the KOMEK project sponsored by the Danish Research Science Council.

Requirements for computer support

A detailed field study was conducted at Foss Electric A/S, Hillerød in order to establish a basis for understanding coordination in manufacturing. Foss produces equipment for measuring quality parameters of agricultural products. Designing a new instrument thus involves people of many areas of expertise, such as: mechanical design, electronics, software engineering, chemistry, draughting and process planning. The coordination aspects of a large development project were studied. In this 2-year project more than 50 people were involved.

One of the areas addressed explicitly was the coordination of the testing and correction of the more than 200,000 lines of software code embedded in a new instrument. This was a complex task involving more than 20 testers and software designers. For each identified problem the tester filled out a form classifying and describing it. The form was then sent to a diagnostic group which diagnosed the problem and decided when it should be corrected and by whom. When the problem had been dealt with, the correction was verified by the designer responsible for the monthly integration processes. Treating each reported problem involved several people, e.g., a tester, the diagnostic group, a designer, a plan manager and an integration manager. Furthermore treating the different problems needed coordination.

From a detailed analysis of the coordination of the problem handling work, a set of requirements for computer support of software testing was established, and based on these, and the basic ideas in the theory of coordination mechanisms, a prototype was designed called BRaHS (Bug Reporting and Handling System).

> ✶ The basic idea in the design of BRaHS was to provide a system supporting distributed registration and classification of software errors and the automatic routing of information among the involved actors.

Central design considerations

What was unique in the design approach was an attempt to combine an active stipulation of the work flow with a high degree of flexibility, and in addition provide support to the users so they can be aware of each others work. Keywords for the design are: distribution, i.e., all users have a version of the system running on their own PC connected in a network; flexibility allowing the users to use the system which they found most useful; malleability, so the stipu-

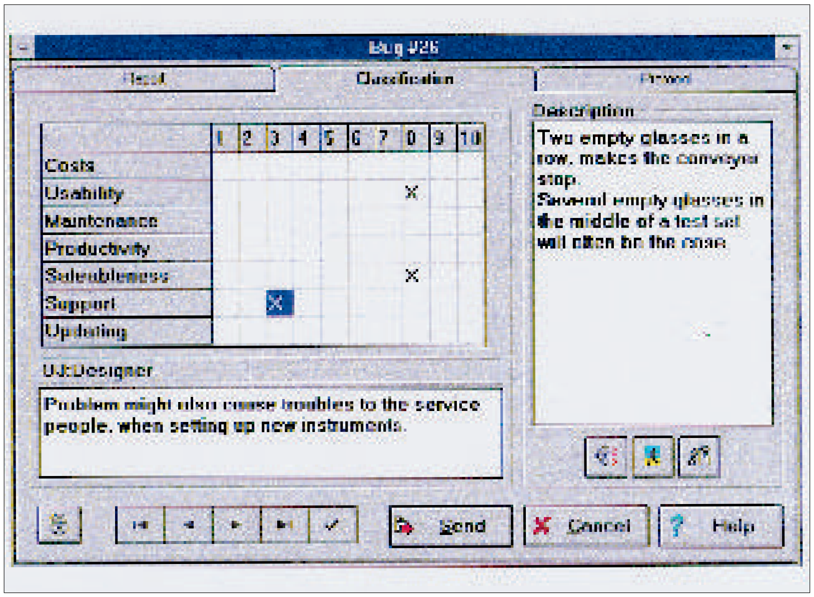


Figure 1. The system reduces the need for negotiation on how to treat a problem by providing an advanced classification structure. A lot of ad hoc-based negotiation is avoided. The coordination is, furthermore, supported by automatic routing of classification information on software problems among the testers, diagnostic team and designers.

lated work-flow and embedded classification structures can be refined and tuned to fit the current situation; local control implying that the users have the control of the execution of the system, i.e., they can decide themselves whether the pre-specified work flow should be obeyed or overruled; and visibility to the participants of the work-flow protocols embedded in the system.

BRaHS provides all the facilities required for registering information about errors and ensures that all registered errors are treated. The overall functionality includes facilities for describing a specific problem, classifying problems, passing on information on a registered error to the diagnosis team or the software designer responsible for correcting the problem, and searching and browsing in aggregated information containing registered problems. Apart from these types of facilities BRaHS also include access to respecify the protocol stipulating the flow of the forms, re-specify the classification structures used for classifying errors and their importance, or re-specify which participants are involved or which roles they have.

The treatment of a software problem will affect a number of actors all using BRaHS. The first user is the tester involved in testing of the software. He uses BRaHS to inform the diagnostic team of a specific problem. The diagnostic team forwards the problem description to the designer responsible for fixing the problem by means of the system. When the designer has dealt with the problem, he or she registers the correction information in BRaHS, and sends a notification to the integration manager who is responsible for verifying the corrections. When a correction is verified, the integration manager classifies the problem as dealt with in the system.

Future work

The BRaHS prototype is an example of how certain aspects of complex coordination activities can be supported by means of computer systems. In concurrent engineering projects coordination plays a key role. If computer-based coordination mechanisms are designed thoroughly, and well-integrated with other applications used, they can reduce the need for time consuming *ad hoc* based face-to-face coordination. Through the process of a field study, an analysis, a requirement specification, and a design of a first prototype of such a system has been established.

The research results have served as an important input to the effort of establishing a theoretical framework for computer-based coordination mechanisms, and the work is continued through detailed evaluations of the field study findings, prototype and concepts.

Publications in 1995: 56, 57, 58, 59, 62, 63, 64, 116

Peter Carstensen

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Industrial Safety

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Sørensen, C.,
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Sørensen, C.,
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Committees

Danish

Research committee, Energy and Society (Min. of Environment and Energy).
Hans Larsen.

Steering committee, Danish Society for Risk Assessment.
Palle Christensen.

Advisory Group, Energy Centre Denmark.
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Quality Assurance Group (Globorama).
Lotte Schleisner.

Research Council (Ministry of Culture).
Annelise Mark Pejtersen.

Advisory Group on Sustainable Exploitation of the Natural Resources in Developing Countries. (The Danish Environmental Research Programme).
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Working group on The Future need for Energy Research (Min. of Research).
Hans Larsen (chairman).

Committee on Future Role of Information Service Organisations. Danish Library Service Center.
Annelise Mark Pejtersen.

Committee, The Human Aspect of Information Technology in the Information Society. (Min. of Research).
Annelise Mark Pejtersen.

Committee for Renewable Energy Systems. (Danish Council for Renewable Energy)
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Committee for Energy Conservation in the Public Sector (Danish Energy Agency).
Lotte Schleisner, Poul Erik Morthorst.

Board of Danish Society for Simulator Training and Safety in Transport Industries (Sim Trans).
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International

Member of IFIP working group 13.2 on User Centered Design.
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Editoral board, Journal of Loss Prevention in the Process Industries.
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Committee for European Standards on Nuclear Electronics (E.C).
Palle Christensen.

Executive committee: European Foundation for Coorporation in Energy Economics.
Hans Larsen.

World Energy Council, Studies Committee, Project 4. Environment, Work Group C: Local and regional related environmental issues.
John M. Christensen, Jørgen Fenhann, Gordon Mackenzie and Hans Larsen (chairman).

Management and Policy Committee for UNEP Collaborating Centre on Energy and Environment.
Hans Larsen (chairman), John M. Christensen.

Halden Programme Group (OECD).
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Editoral Board, Reliability Engineering & System Safety.
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TELEMAN User Group (E.U.).
Kurt E. Petersen.

Halden Ad Hoc Scientific Advisory Group on Human Error Analysis.
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Editoral Board, Stand Points: The Electronic Journal of Information Contexts.
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Board of Management, Halden Reactor Project (OECD).
Hans Larsen.

Member of Program Committee and Proceedings Chair for the Fourth European Conference on Computer Supported Cooperative Work, Stockholm, 11-15 September 1995.
Kjeld Schmidt.

Model Evaluation Group (E.U.).
Kurt E. Petersen (Chairman).

World Energy Council Programme Committee on Energy Issues of Developing Countries.
John M. Christensen.

IFIP Technical Committee TC.13 on Human-Computer Interaction.
Leif Løvborg.

Papers Committee for Interact 95, IFIP TCB Fifth International Conference on Human-Computer Interaction.
Peter Carstensen.

Member of the Board of the Foundation of Co-operative Work Technology.
Kjeld Schmidt.

ENFLO Advisory Board (University of Surrey).
Kurt E. Petersen.

Coordinating Editor for CSCW, An International Journal of Computer Supported Cooperative Work (Kluwer Academic Publishers).
Kjeld Schmidt.

Expert group of ECO-Labelling of Insulation Products. (E.U.).
Lars Henrik Nielsen.

Programme Committee for International Symposium on Electricity, Health and the Environment, Vienna 16-19 October, 1995.
John M. Christensen.

IPCC Working Group III, Principal lead author on the Socio-Economics of Climate Change.
Kirsten Halsnæs.

IPCC Working Group II, Lead author on Methods for Assessment of Mitigation Options.
John M. Christensen.

IPCC Working Group III, Danish focal point on Emission scenarios and the Socio-Economics of Climate Change.
Kirsten Halsnæs.

Programme committee for TIEMEC '95, The International Emergency Management and Engineering Society Conference, Nice (F), May 9-12 1995.
Verner Andersen.

Programme committee for the International Aspects of Emergency Management and Environmental Technology Conference, Oslo (N), June 19-21 1995.
Verner Andersen.

Programme Committee for ACM SIGIR '95. 18th International Conference on Research and Development in Information Retrieval, Seattle, USA, July 9-13, 1995.
Annelise Mark Pejtersen.

UN/ECE task force on Emission Inventories. Panel on Maritime Emissions.
Niels Kilde.

Technical Programme Committee for ESREL '95, June 1995. UK.
Kurt E. Petersen.

Programme Committee for ESREL '96/PSAM-III, June 1996, Greece.
Kurt E. Petersen.

CEN-TC310/WG4, Ergonomics and Human Factors in Advanced Manufacturing Techniques.
Palle Christensen.

Programme Committee for ECAME-95, European Conference and Workshop on Human Factors and Ergonomics in Advanced Manufacturing Technology (AMT), June 1995.
Palle Christensen.

Cigré TF38.03.13. Sequentiel Probabilistic Methods.
Hans Ravn.

Board of Directors for TIEMES, The International Emergency Management and Engineering Society.
Verner Andersen.

Organising Committee for COLIS2: Second International Conference on Conceptions of Library and Information Science. Copenhagen (DK), 1996.
Annelise Mark Pejtersen.

Programme Committee for 19th International Conference on Information Retrieval. Zurich (CH), 1996.
Annelise Mark Pejtersen.

Programme Committee for Information Systems Research Seminar in Scandinavia - IRIS18, Gjern (DK), 11-13 August 1995.
Carsten Sørensen.

Programme Advisory Board, Fifth International Conference on Human Aspects of Advanced Manufacturing and Hybrid Automation, Maui, Hawaii, 7-10 August 1996.
Kjeld Schmidt.

Programme Committee, IAEE Conference on Transport, Energy and Environment, Elsinore (DK), 3-4 October 1996.
Hans Larsen (Chairman).

Organising committee for MIE'96 Congress, Copenhagen (DK) 18-22 August 1996.
Steen Weber.

Hans Larsen, *M.Sc. (Elec. Eng.), Ph.D.* The Technical University of Denmark 1972. From 1973 to 1976 at Dragon project at AEE Winfrith, U.K. Risø from 1976. Energy Technology Department 1976-80, working with systems reliability. Head of Energy Systems Group 1980-84. Head of Systems Analysis Department from 1985. Member of the Danish Academy of Technical Sciences 1993.

Charlotte Olsson, *M.Econ.* University of Copenhagen. Børsinformation Telecom 1990-92. IFX Scandinavia 1992-1994. Administrative officer at Risø from March 1995.

Man/Machine Interaction

Leif Løvborg, *M.Sc. (Elec.Eng.).* Risø from 1962. Radioisotope techniques (1962-66), nuclear geophysics and mineral exploration (1967-86). Group Leader (Electronics Dept.) 1965-86. Human factors research from 1986. Acting head of Cognitive Systems Group 1990-92. Head of Cognitive Systems Group 1992-94. Head of the Man/Machine Interaction programme from January 1995. Main research interest: Simulation of safety-critical MMI systems.

Henning Boje Andersen, *M.A. (Philos.),* Senior Scientist. Copenhagen University and Oxford University (logic, philosophy of language) 1976-79. Medical Faculty, Copenhagen University and Roskilde University (philosophy of science) 1980-83. Risø from 1984, Systems Analysis Department from 1990. Main activities: Human-computer interaction, support of emergency management and multi-user training, evaluation of training transfer.

Verner Andersen, *M.Sc. (Elec.Eng.), Ph.D.,* Senior Scientist. Risø from 1966. Nuclear physics (1966-76), plasma physics (1976-86). Leader of programme on plasma-physics technology 1983-86. Information technology from 1986. Systems Analysis Department from February 1990. Main activity: Project management, systems development.

Peter H. Carstensen, *M.Sc. (Com. Sc.).* Dansk Datamatik Center 1984-1988, Labour Unions' Centre for Informatics 1989-1991. Systems Analysis Department from February 1992. Main activities: Human-computer interaction, Evaluation of complex user interfaces, Computer Supported Cooperative Work, Methodologies for analysis of work in complex settings, System development methodologies.

John Paulin Hansen, *Ph.D. (Psychol.).* Risø from 1988, Systems Analysis Department from February 1990. Major subject: Simulation, visual perception, recording of eye movements, evaluation of interfaces, MMI analysis and modelling.

Steffen Routh Herskind, *M. Sc. (Com. Sc. with Math.)* Roskilde Edb-school 1994-1995, Ph. D. student at Risø from June 1995. Subject: Efficiency in trucking. Applying CSCW to the transport sector to reduce the environmental adverse effect of truck driving.

Monica Divitini, *M.Sc. (Computer Science)* at the University of Milano in 1991. Milano University, Department of Computer Science 1992 - September 1995. Visiting researcher at Risø, Systems Analysis Department from October 1995. Main Activities: Computer Supported Cooperative Work, user modelling in cooperative environment, agent-based software.

Ann Britt Miberg, *M.A. (Psychol.).* Major subjects: Training, decision making, reactions of humans in critical situations. Ph.D.-student at Risø (1993). Subject: Design of simulator training directed at train control operators' handling of emergencies/recoveries.

Finn R. Nielsen, *M.Sc. (Appl. Math. & Phys.).* Technical College of Copenhagen 1968-74. Risø from 1974. Systems Analysis Department from February 1990. Main activities: MMI simulation, implementation of software concepts.

Annelise Mark Pejtersen, *M.A. (Sci. of Lit.),* Senior Scientist. University of Copenhagen 1971-73, Associate Professor at the Royal School of Librarianship 1971-82, Acting Professor 1983-85. Visiting Senior Research Scientist at Georgia Institute of Technology 1982-83. Risø from 1986. On leave as manager of the Labour Unions' Centre for Informatics 1989-90. Systems Analysis Department from February 1990. Main activities: Cognitive work analysis, Theories and methods for interface design, Multimedia interfaces, Information retrieval and support systems for product development.

Kjeld Schmidt, *M.Sc. (Sociol.),* Senior Scientist. Roskilde University 1972-85, Dansk Datamatik Center 1985-88, Labour Unions' Centre for Informatics 1989-90. Systems Analysis Department from March 1990. Main activities: Theory and methodology for analysis of cooperative work in complex settings, Computer-Supported Cooperative Work, taxonomy of work domains.

Diane H. Sonnenwald, *M.Sc. (Com. Sc.), Ph.D.* School of Communication, Information and Library Studies, Rutgers, the State University of New Jersey, Bell Labs 1980-1985, Bell Communications Research 1985-1993. U.S.A. National Science Foundation International Postdoctoral Fellow 1993, Risø from 1993 until August 1995, NATO Post doc. Fellow, 1994. Main Activities: The exploration and integration of knowledge from different domains during the design process.

Carsten Sørensen, *M.Sc. (Com. Sc. with Math.), Ph.D.,* Senior Scientist. Department of Mathematics and Computer Science, Aalborg University 1989-1992. Systems Analysis Department from September 1992. Main activities: Computer Supported Cooperative Work, computer support for integration of design and process-planning in manufacturing, analysis of MMI systems.

Tuomo Tuikka, *M.Sc. (Com.Sc.)* University of Oulu, Finland 1992. Research Assistant 1993-1995, Post doc. at Risø from May 1995. Main Activities: Computer supported Cooperative Work, Software Processes, Testing, Prototypes of CSCW systems.

Steen Weber, *M.Sc. (Elec.Eng.), Ph.D.,* Senior Scientist. Risø from 1972. Computer codes for nuclear fuel management (1974-75). Risk Analysis Group (Dept. of Energy Technology) 1975-84, Acting Group Leader 1982-83. Systems Analysis Department from February 1990. Main activities: Human computer interaction, Emergency management, Prototype development.

Simulation and Optimisation of Energy Systems

Hans Ravn, *M.Sc. (Eng.), Ph.D.* México 1978-1979 and 1987. Danish Energy Agency 1980-1983. Technical University of Denmark 1983-1995. Consultant. Risø from April 1995. Head of research programme. Main research activities: Operations Research, Optimization, Energy systems.

Peter Skjerk Christensen, *M.Sc. (Elec.Eng.),* Senior Scientist. Risø from 1958. Nuclear research and education (1958-69), reactor engineering and thermohydraulics including simulation models (1969-76), Systems Analysis Department from 1977. Stationed in Cape Verde Islands as energy advisor to the government (1991). Main activities: Energy systems modelling, renewable energy technologies, energy planning in Eastern Europe and Egypt.

Jørgen Fenhann, *M.Sc. (Physics with mathematics and chemistry),* Senior Scientist. Niels Bohr Institute 1977. Risø from 1978. Main activities: Development of energy planning models, new and renewable energy technologies, calculation of emissions from energy systems, and energy-environmental planning for Eastern European and developing countries.

Poul Erik Grohnheit, *M.Econ.,* Senior Scientist. Danish Building Research Institute 1969-71, town planning consultant 1971-72 and 1979-80, economic planning and budgetting in local government 1973-79. Risø from 1980. Main activities: economics of electricity generating systems, electricity markets and energy environment economic modelling.

Christina Ingerslev, *M.Sc. (Technological and Socio-Economic Planning)* Ph.D. student at Risø from February 1993. Subject: Strategies for reducing the CO_2 emission from the manufacturing industry, in particular dairies and papermills.

Henrik Klinge Jacobsen, *M.Econ.* Alm. Brand 1989-1991. Greenland Home Rule 1992-1993. Risø from December 1993. Main activities: Macro-economic modelling and the integration of macro models and energy models, input-output analysis, energy planning models.

Niels A. Kilde, *M.Sc. (Chem.Eng.),* Senior Scientist. The Danish Steelworks Ltd. 1962-81. Research and quality control (1962), planning and administration (1967), casting department manager (1972), development and energy manager (1977). Risø from 1981. Main activities: Energy use in industry and transport, emission inventories.

Helge V. Larsen, *M.Sc. (Elec.Eng.), Ph.D.,* Senior Scientist. Technical University of Denmark 1974. Storno A/S from 1975. Risø from 1976. Department of Reactor Technology 1976-77. Systems Analysis Department from 1977. Main activities: CHP production, modelling of energy systems, economic models for the oil and gas sector, development of planning models for wind energy, energy planning in Eastern Europe.

Poul Erik Morthorst, *M.Econ.,* Senior Scientist. Risø from 1978. Head of Energy Systems Group 1985-89. Main activities: General energy planning and modelling with emphasis on electricity demand forecasting, economics of renewable energy technologies, especially wind turbines.

Lars Henrik Nielsen, *M.Sc. (Phys.,Math.),* Senior Scientist. Risø from 1981. Main activities: Probabilistic methods and model development, technical-economic modelling, energy system simulation and assessment of energy technologies, especially renewable energy.

Lise Nielsen, *M.Econ.* Ministry of Finance 1986-1988 and 1993-1995. Institute of Economics, University of Copenhagen 1988-1993. Risø from August 1995. Main activities: Environmental economics and macroeconomic modelling.

Lotte Schleisner, *M.Sc. (Mech.Eng.),* Senior Scientist. Risø from 1984, Research Section of the Engineering Department. Energy Systems Group from 1989. Main activities: Assessment of energy technologies (including renewables and hydrogen technologies), life cycle analysis and environmental effects of energy technologies, and externalities from energy systems.

Peter Stephensen, *M.Econ.* Ph.D. Student at Institute of Economics, University of Copenhagen 1989-91. Risø from 1991 until May 1995. Main activities: Environmental economics and macroeconomic modelling.

Lene Sørensen, *M.Sc. (Eng.), Ph.D.* Risø from 1990 as Ph.D. student. Major subject: environmental planning and uncertainty. International Institute for Applied Systems Analysis in 1991 and Lawrence Berkely National Laboratory in 1994. Post doc from 1993 until December 1995. Main activities: integrated energy/environmental models, evaluation of models, uncertainty in planning, methodologies for multi criteria assessments.

Integrated Environmental and Risk Management

Kurt Erling Petersen, *M.Sc., Ph.D.* Risø from 1977. Department of Energy Technology. Risk Analysis Group from 1977-1984. Systems Analysis Department from 1985. Head of Research Programme on Integrated Environmental and Risk Management from 1990. Deputy head of Systems Analysis Department. Main activities: Risk and reliability analysis and treatment of reliability data.

Palle Christensen, *M.Sc. (Elec.Eng.),* Senior Scientist. Risø from 1962. Electronics Department 1962-86. Department of Information Technology 1986-88. Secretary of Risø's patent council 1973-88. Systems Analysis Department from 1988. Main activity: Risk and reliability analysis and development of computer codes for reliability and safety analysis.

Nijs Jan Duijm, *M.Sc.* from Technical University of Delft, Holland, Senior Scientist. TNO from 1983- 1995 (Fluid Dynamics Department). Risø from 1995. Main activities: Atmospheric dispersion of hazardous gases, turbulent flows.

Carsten D. Grønberg, *M.Sc. (Elec.Eng.).* Risø, Electronics Department 1967-78. Safety Department 1978-84. Systems Analysis Department from 1985. Main activities: Human factors, emergency management, risk communication, risk management.

Atoosa Jalashgar, *M.Sc. (Elec.Eng.)* from Institute of Electronic Systems, Aalborg University (1992). Ph.D. student at Risø and Technical University of Denmark from 1994. Activities: Failure analysis of process control systems, functional modelling, safety and reliability analysis of wind turbines.

Hans E. Kongsø, *M.Sc. (Mech.Eng.),* Senior Scientist. Risø from 1957. Research reactor DR2 1957-63, Department of Energy Technology 1963-84. Systems Analysis Department from 1985. Main activities: Computer codes for reliability and consequence assessment, and reliability and safety assessment of nuclear plants and windturbines.

Igor O. Kozin, *Ph.D.,* Obninsk Institute of Nuclear Power Engineering, Obninsk. Risø from August 1994. Main activities: development of reliability data bases, analysis of failure and maintenance data, reliability and uncertainty analysis.

Kurt Lauridsen, *M.Sc. (Elec.Eng.), Ph.D. (Nuclear engineering),* Senior Scientist. Risø since 1974. Department of Energy Technology 1974-87. Department of Informatics 1987-90. Systems Analysis Department from March 1990. Main activities: Reliability analysis, risk management.

Frank Markert, *M.Sc. (Chemistry), Ph.D.,* Scientist. Systems Analysis Department from August 1995. Main activities: Risk assessment of chemical plants, toxic effects from releases and assessment of chemical warehouse fire consequences.

Lars Nyborg, *M.Sc. (Chem.Eng.).* Ph.D. student at Risø from 1994 until August 1995. Subject: socio-technical approach to risk management. The impact of socio-technical factors on the overall safety performance of industrial organisations.

Søren Ott, *M.Sc. (physics), Ph.D.* (Turbulence theory), Senior Scientist. Risø from 1985. Main activities: Models and computer codes for consequence assessment; dense gas dispersion and flame experiments.

Jette Lundtang Paulsen, *M.Sc. (Mech. Eng.),* Senior Scientist. DTH 1972. Research reactor DR3, 1972-1980. Uranium Extraction project, 1980-1986. Department of Informatics, 1986-1990. Department of Systems Analysis from 1990. Main activities: Maintenance and Safety assessment, Displays for control rooms.

Birgitte Rasmussen, *M.Sc. (Chem.Eng.), Ph.D.,* Senior Scientist. The Technical University of Denmark from 1981-84. Risø from 1984. Main activities: Risk assessment of industrial activities, hazard identification, risk management, risk communication.

Lene Smith-Hansen, *M.Sc. (Chemistry).* Risø from 1986 until February 1995. Main activities: Risk assessment of chemical plants, toxic effects from releases and assessment of chemical warehouse fire consequences.

UNEP Collaborating Centre on Energy and Environment

John Møbjerg Christensen, *M.Sc. (Eng.) Ph.D.* Danish National Agency of Technology 1980-83. Oilconsult, Consulting Engineers and Planners 1983-84. Risø from 1984. Energy Systems Group 1984-88. Programme Officer, Energy Unit, United Nations Environment Programme 1988-90. Head of the Centre from October 1990. Main activities: energy-environment planning in developing countries, project initiation, UN contacts and coordination.

Pramod Deo, *M.Sc. (Physics) Ph.D.* (Infrastructure Economics). Founder Director of state and national level energy institutions, Maharashtra Energy Development Agency (1986-88) and Energy Management Centre (1989-93). Asian Institute of Technology, Bangkok 1985-86 and Energy Policy Consultant at World Bank 1993. From July 1993 with the Centre as Senior Energy Economist. Main activities: energy-environment planning in developing countries, project development and management, technical support to UNEP.

Kirsten Halsnæs, *M.Econ.,* Senior Economist. Danish Ministry of Housing and Building, 1983. Risø from 1987. Energy Systems Group until end of 1992 with the main activities: Methodologies for energy and environmental modelling. From January 1993 with the Centre. Main activities: The Economics climate change mitigation studies, methodologies for climate change assessment in developing countries, environmental economies.

Gordon A. Mackenzie, *B.Sc. Ph.D. (Physics),* Senior Scientist. Guest researcher at Risø 1974-78. Lecturer at Edinburgh University 1978-79. Energy Systems Group from 1980. 1984 to 1987 Energy Adviser/Deputy Director at Department of Energy, Zambia. From February 1988 until February 1990 leader of Environmental Modelling Group. From October 1990 with the Centre as senior energy planner. Main activities: integrated energy/environmental models, energy and environment in developing countries, environmental database.

Henrik Jacob Meyer, *M. Econ.* Rockwool Foundation Research Unit 1990-93. Technical University of Denmark 1993. Risø from December 1993. Main activities: Environmental economics, macro-economic consequenses of greenhouse gas abatement, externalities in the production of energy, valuation of environmental benefits and damages.

Steffen Rønsholdt Nielsen, *M.Sc. (techn. soc.),* Ph.D. student. Risø from February 1995. Main interest: climate change mitigation focussing on the impact of alternative land-use patterns in developing countries with a case studie in Ecuador.

Joel N. Swisher, *M.S. (Mech. Eng.), Ph.D. (Env. Eng.).* Solar Energy Research Institute (U.S.) 1980-83, consultant to New Zealand Ministry of Energy 1984-85, research engineer with Architectural Energy Corp., Colo., U.S.A. 1986-88. Private engineering consulting practice 1988-1992. Visiting Research Engineer at Lund University, Sweden 1991-93. Risø from July 1993 until December 1995 with the Centre.

Arturo Villavicencio, *M.Sc. (Math.).* National Energy Institute (Ecuador) 1979-85. Energy Planning Consultant for the Latin American Energy Organisation, CEC and World Bank 1985-88. Energy Adviser at OLADE 1988-90. From May 1991 with the Centre. Main activities: Energy/environmental models, integrated energy-environment planning in Latin America.

Short Term Guest Researchers

Gilberto de Martino Jannuzzi, *Professor* in the Energy Department, University of Campinas, Brazil. Training manual for Integrated Resource Planning.

Hubert Meena, Centre for Energy, Science and Technology, Dar es Salaam, Tanzania. Climate change mitigation study for Tanzania.

Lugard Majoro*, research assistant* at African Energy Policy and Research Network, Nairobi, Kenya. Transport energy in East Africa.

Peter Zhou, *director of Energy, Environment, Computer and Geophysical Applications,* Gaborone, Botswana. Transport energy in Southern Africa and climate change mitigation study for Botswana.

Jan Scherfig, *Professor of Environmental Engineering,* University of California Irvine. Waste Water Treatment Modelling.

Zbigniew Nahorski, Systems Research Institute, Polish Academy of Sciences, Warsaw, Poland. Water Quality problems, mathematical modelling.

Programmer

Søren Præstegaard, *datanom.* Regnecentralen 1973-79. Risø from 1979. Datanom with special subject: Optimization completed 1985 at EDP-school, Copenhagen. Working on simulation models, graphics and general user support.

Secretaries

Maria M. Andreasen
Gytha Egelund
Vivi Nymark Hansen
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Irma Strandvad

Research Technician

Erling Johannsen

Temporary Staff

Morten Nielsen *(M.Sc. student),* 1 March - 31 December. Software documentation; development of facilities for human factors experiments.

Joan Dorrepaal *(M.Sc.),* from 1 January to 31 December. Development of methods for reliability and maintenance assessment under the Nordic Nuclear Safety Research Programme.

Erwin Dan Nielsen *(M.Sc.),* 15 February - 31 December. Statistical analysis of experimental human factors data.

Therese Ib Andersen *(student),* from April - June 1995. Assistance with life cycle assessment project.

Søren Mensal Kristensen *(graduate student),* from October 1995. Energy Tariff project.

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The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1995. The department is undertaking research within Simulation and optimisation of energy systems, Energy and environment in developing countries – UNEP Centre, Integrated environmental and risk management and Man/machine interaction. The report includes lists of publications, lectures, committees and staff members.

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