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Systems Analysis Department annual progress report 1997

Larsen, Hans Hvidtfeldt; Olsson, C.; Petersen, K.E.

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Systems Analysis Department

Annual Progress Report 1997

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

The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1997. The department is undertaking research within Energy Systems Analysis, Integrated Energy, Environment and Development Planning – UNEP Centre, Industrial Safety and Reliability and Man/Machine Interaction. The report includes lists of publications, lectures, committees and staff members.

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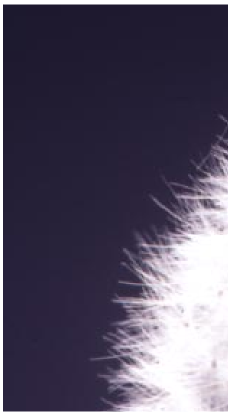

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Introduction

Hans Larsen, Head of Department

In 1997 the department expanded its collaboration with industrial companies, utilities, ministries, governmental agencies and international organisations, both in Denmark and throughout the world. The objective of the research is: development of technical-economic optimisation and risk management methods for complex industrial systems and energy systems, with emphasis on environmental considerations and human factors.

The research activities of the department are undertaken within the following four research programmes:

– *Energy systems analysis*, Frits M. Andersen
– *Integrated energy, environment and development planning, UNEP Centre*, John M. Christensen
– *Industrial safety and reliability*, Kurt E. Petersen
– *Man/machine interaction*, Leif Løvborg

During the year, work was initiated on the establishment of a new fifth research programme Technology Scenarios with the following objective: development of scenarios and prog-noses for future commercial utilisation of technologies, components and materials, including the direct and indirect social consequences. As a start, an internal multidisciplinary working group has formulated an initial framework for future activities, as well as established contacts to relevant industrial companies, universities and governmental authorities. Further, an international scientific advisory panel has been set up with 10 members from respectively Danish industry, and Danish and international universities and research institutes. The panel held its first meeting in September 1997.

In 1995 a major building activity was initiated with the aim of assembling the whole department in one building complex. A new building for the UNEP Centre was inaugurated in 1996 and the whole activity was finalised in the summer of 1997, with the result that the department now has significantly improved premises.
Of the department's activities in 1997, 62 per cent were financed through national and international research contracts or contracts with national agencies and international organisations as well as industrial companies and utilities. The remaining 38 per cent were financed by governmental appropriations. The total turn-over of the department in 1997 amounted to approximately 47 mil. Dkr.

The department has undertaken research and development projects together with international organisations such as the European Union (EU) , UNEP and other UN organisations, 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.
By the end of the year, the total department staff numbered 59 employees, including an academic staff of 53, namely, engineers, natural scientists and economists as well as social and behavioural scientists, of whom 11 were either PhD students at various Danish universities or postdoc fellows, and 6 are secretaries and technical support staff. During the year several guest scientists have visited the department for shorter or longer periods. In 1997 four staff members earned a PhD degree.

Energy systems analysis

The aim of the research programme is to develop methods for assessments of energy, environment and economy in relation to long-term energy-economic development and to the introduction of new energy technologies into complex energy systems, in the long run with the objective of obtaining an improved understanding of energy systems and their interactions with society at large.

The activities in 1997 have included development of energy – environment satellite models to be used in connection with the official Danish macroeconomic model ADAM. Several projects have been undertaken addressing various aspects related to introducing renew-able energy into the Danish electrical power system, including large-scale introduction of wind energy. A project carried out in collaboration with the Wind Energy and Atmospheric Physics Department at Risø aiming at developing a master plan for utilising wind energy in Egypt with a time horizon of 2030 has been finalised. The project was supported by the Danish Development Agency Danida. Further, assessments of externalities from electrical power production based on wind turbines were undertaken based on the methods developed within the EU project ExternE comprising common assessments for 14 countries.

Work has continued on the updating and further development of the so-called INDUS model, which is being used for forecasting energy consumption and emissions from the main industrial sectors in Denmark. The work was sponsored by the Danish electric utilities and the Danish Energy Agency. Finally, two projects have been completed dealing with (1) a study on a possible future Northern European power pool and (2) a study of the benefit to society of underground storage facilities in Denmark for natural gas.

Integrated energy, environment and development planning

The programme on Integrated energy, environment and development planning is hosting the UNEP Collaborating Centre on Energy and Environment which has the overall objectives of promoting the integration of sustainable development concerns in energy policy and planning, especially in developing countries, and supporting the formulation and implementation of UNEP's programmes within the areas of energy and climate change. These objectives are pursued through collaborative activities with institutions at national, regional and international levels where research activities focus on the development and implementation of methodological approaches to energy, environment and development analysis. An underlying objective of the Centre is to support professional and institutional capacity building at national and regional levels in the areas of energy, environment and development planning. The established international scientific advisory panel with representatives from Asia, Africa, Latin America and international organisations held its third meeting in November 1997.

One of the dominant activities in 1997 has been the further development and testing of the methodological framework for climate change mitigation analysis. Various sectors are being addressed including energy, transport, agriculture, forestry and industry. Further, work has been undertaken concerning environmental and social aspects of deregulating the power sector in selected developing countries as well as capacity building in 15 countries in Africa, Asia, Latin America and Eastern Europe. Finally, the UNEP Centre organised a workshop for the Intergovernmental Panel on Climate Change (IPCC) on "Social and Economic Impacts of Climate Change Mitigation" at Risø in June with approximately 100 participants from all over the world.

Industrial safety and reliability

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. The activities include both theoretical and experimental work. To a large extent the latter is undertaken in collaboration with other Risø departments that possess the necessary laboratory facilities.

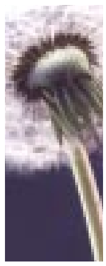
In 1997 the activities have included the development of formalised methods for overview display design for support of error diagnoses, which have been tested at the HAMMLAB simulator at the Halden Reactor project in Norway. A new activity has been initiated in collaboration with the Wind Energy and Atmospheric Physics Department dealing with the development of a particle-tracking technique for an improved description of turbulence and utilisation for measurements of concentration fluctuations. As part of a PhD project a new method using functional modelling for failure analysis of control systems with improved possibilities for identifying hidden failures has been developed and reported. The research concerning the development of new methods for risk assessment has focused on the siting of chemical plants based on risk analysis principles. The activities have been carried out in collaboration with county councils and local communities. Finally, a number of specific risk analysis projects have been carried out for Danish industry and Danish authorities in partial fulfilment of regulation procedures.

Man/machine interaction

The aim of the research 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 execution of complex industrial work tasks. The outcome of the research is primarily directed towards industrial product development, industrial production and transport including sea and air traffic. In 1997 a number of projects were undertaken addressing safety issues related to sea and air traffic. One project was undertaken for Aerospatiale Avions, Toulouse, where experiments in the Airbus-340 flight-simulator have been carried out to investigate pilot behavi-ours during normal and abnormal take-off scenarios. In connection with the EU SAFECO project carried out in collaboration with Det Norske Veritas and the Danish Maritime Institute (DMI) a model has been developed for simulation of tanker steering performance. Further, in collaboration with DMI and University of Texas a questionnaire survey of mariners' perceptions of safety issues has been undertaken.

A project supported by the Danish Social Research Council has been undertaken in collaboration with the Danish industrial company Danfoss dealing with concepts for retrieval and exchange of information via the Internet in industrial development environments.

During the year negotiations have taken place with the Danish National Research Foundation concerning the establishment of a Centre for Human-machine interaction. The Centre is expected to be launched early in 1998 with the participation of the University of Aarhus, the Technical University of Denmark, DMI and Danfoss.



Energy Systems Analysis

EMMA - Energy and Environmental satellite models for ADAM

In energy and environmental policy there is a need for evaluating future developments of energy and environmental variables in line with and consistent with standard economic variables. To facilitate this, satellite models for ADAM for the energy consumption and emissions of CO_2, SO_2 and NO_X are developed and made available to users of ADAM. (ADAM is the model used for official economic planning in Denmark. EMMA is developed in collaboration between The National Environmental Research Institute, Statistics Denmark and Risø National Laboratory.) As ADAM – for a number of energy and environmental analyses – is too aggregated, EMMA contains a disaggregation of relevant economic activities and a linking of emissions to the use of individual fuels. The overall model-structure and linking of ADAM and EMMA is shown in Figure 1.

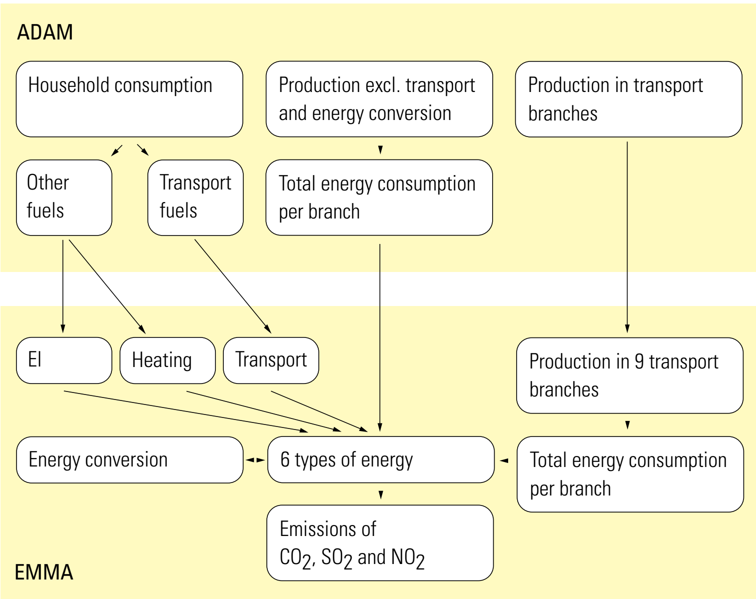


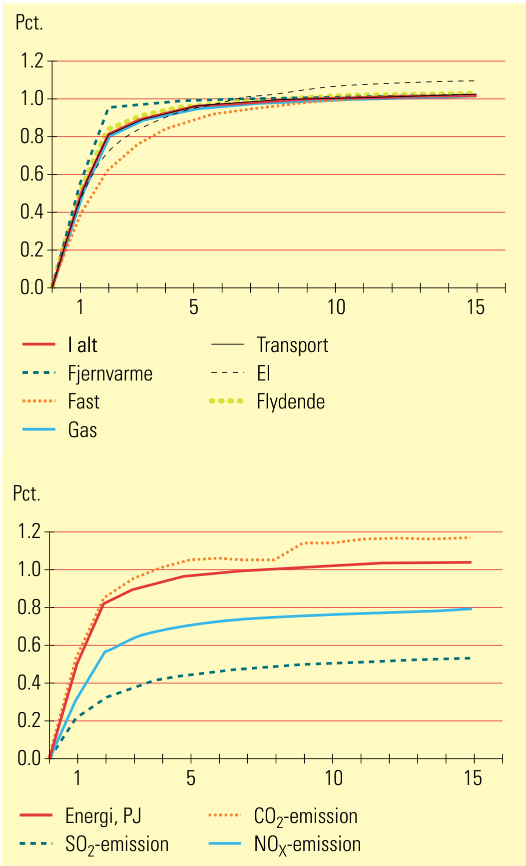
Figure 1 (above)
The overall model-structure and linking of ADAM and EMMA

Figure 2 (right)
Effects of a 1% increase in economic activity

As is seen from the figure, ADAM includes an aggregated description of energy consumption by households and branches. EMMA includes a disaggregation of the transport branch, a further disaggregation of the energy consumption by households, a disaggregation of the total energy consumption into 6 fuels (coal, oil, gas, transport fuel, electricity and district heating) and a rather detailed modelling of the energy conversion branch. Finally, emissions are linked to the individual uses of primary fuels. The modelling of the individual parts of EMMA follows somewhat different approaches.

Households and branches excl. the energy conversion branch are modelled from econometric analyses of past developments in energy consumption and the relevant economic activities, e.g. the production in constant prices, the dwelling area, the stock of vehicles and the price of energy. In general, energy consumption for the different uses follows the development of the relevant activity and has an energy price elasticity between –0.3 and –0.6, that is, when the activity increases 1% the energy consumption increases 1%, and when the energy price increases 1%, the energy consumption decreases between 0.3% and 0.6%.

The energy conversion branch is modelled by a detailed technical description of how primary sources like coal, oil, gas and wind energy are converted to electricity and district heating. The model describes the present production capacity for each of the technologies, installation of new capacities and the choice of fuels depending on the relative prices of the different primary fuels.



Finally, *emissions* are modelled by exogenous technical emission coefficients for the individual uses of primary fuels multiplied by the amount of fuels used. Emission coefficients are defined as technical coefficients depending on the physical content and use of the fuels. CO_2 and SO_2 emission coefficients depend on the carbon and sulphur content of the fuel; NO_X emissions depend on the combustion conditions.

It should further be remarked that SO_2 and NO_X emissions from power plants are regulated by quotas, and that it is assumed that the quotas are just fulfilled. As will be seen, this assumption has considerable consequences for the working of the emission model.

To illustrate some general characteristics of EMMA, Figure 2 shows the effects of a general increase in economic activity and Figure 3 shows the effects of an increase in the price of oil products.

As is seen from Figure 2, except for electricity, in the long term a 1% increase in the general economic activity implies that the energy consumption is increased by 1%. As the long term income elasticity for the electricity consumption of households exceeds 1.0, the total electricity consumption is increased slightly more than 1%. Looking at emissions, figure 2b shows that CO_2 emissions increase somewhat more than energy consumption, while emissions of SO_2 and NO_X increase significantly less than energy consumption. The main reason that changes in emissions differ from the total energy consumption is found within the modelling of the power plants. The marginal increase in the electricity consumption is expected to be produced by a central power plant using coal. As coal has a larger CO_2 emission coefficient than other fuels, (especially seen in relation to wind energy, which do not cause CO_2 emissions) CO_2 emissions increase more than energy consumption. For SO_2 and NO_X, power plants are assumed to comply with the allowed quota, and the increased production implies an increased purification but unchanged emissions from power plants.

Figure 3 shows the effects of increasing the price of oil products by 1%, and may be interpreted as an increase in the world market price of oil not including possible effects on the prices of coal and gas. In the model the important effects are energy savings due to the increased energy price and substitution from oil to other fuels due to the increased relative price of oil.

Figure 3 shows that total energy consumption is reduced, and except for electricity, the consumption of all fuels is reduced, i.e. there is a substitution from other fuels to electricity. Looking at emissions, it is noticed that CO_2 emissions are reduced less than energy consumption, which is due to the increase in coal-based electricity generation. SO_2 emissions are reduced only slightly because the major part of total SO_2 emissions come from the electricity production, and these emissions are due to the quota unchanged. NO_X emissions are reduced considerably due to the reduction in the transport energy consumption, which accounts for about 50% of the total NO_X emissions.

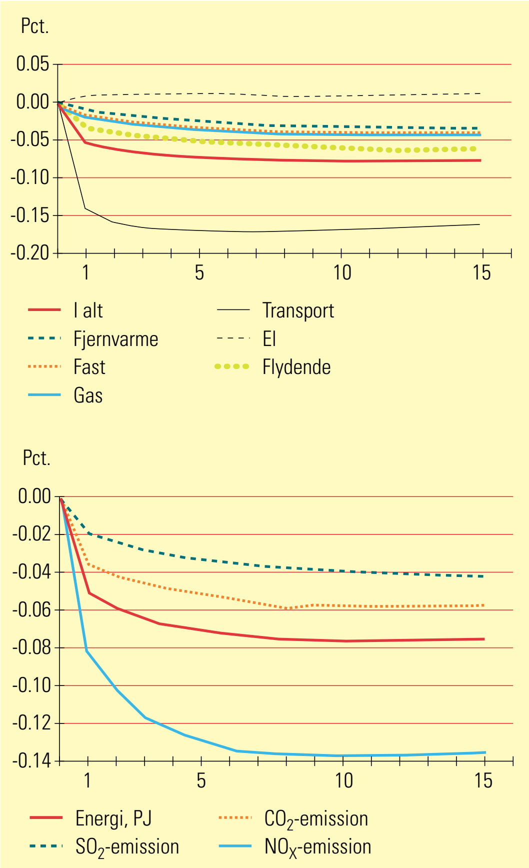


Figure 3
Effects of a 1% increase in the price of oil products

EMMA is distributed to interested subscribers of ADAM and will be used for energy forecasts and policy evaluations by the Ministry of Environment and Energy and for environmental evaluations of the public budget by the Ministry of Finance.

Covering other parts of the economy, for instance the agricultural branch, and additional environmental relevant substances, further satellite models for ADAM are developed within the AMOR centre of the Strategic Environmental Research Programme.

Publication in 1997: 45
Frits Møller Andersen, Henrik Jacobsen, and Poul Erik Morthorst.

Energy Systems Analysis
Development of a liberalised market for electricity

The development towards a liberalised market has been an increasingly important research topic under the programme Energy Systems Analysis with main emphasis on the competitiveness of combined heat and power and renewables.

A northern European Power Exchange

A project with this title was started in 1996 in collaboration with Roskilde University, Department of Social Sciences for the Danish Energy Research Programme. The aim of this project was to describe and analyse the current and alternative proposals for a Norwegian-Swedish, Nordic or northern European power exchange with regard to their consequences for the Danish electricity and heat supply industry and Danish targets and measures for energy and environment policy. The main activities of the project have been:

- Description of existing power exchanges and proposals for multinational power exchanges in northern Europe.
- Analysis of possible strategies for Danish actors and discussion of rules for a power exchange.
- Model analysis of the competitive situation for different producers in northern Europe.
- Requirements for changes in the organisation and regulation of the Danish electricity supply industry and their consequences.
- A seminar on power exchanges "Actors' expectations to a northern European power exchange" was held in March 1997.

An important feature of this project has been to study the ongoing process, and, thus, the detailed contents of the project have been modified accordingly. A final report will be published early in 1998.

Liberalisation in the Nordic countries

Denmark is located at the border between the hydro-power-based systems in the North and the thermal system in the Continent, and there is a long tradition for trade between the two systems.
The pressure for introducing competition in the Danish electricity supply industry during recent years came from Norway and Sweden rather than from the preparation of the EU electricity market directive, which finally was passed in December 1996.

The Norwegian spot market for electricity, which started in 1992, was extended to a common Norwegian-Swedish power exchange from 1996. The power exchange, Nord Pool, has the ambition of being the marketplace for spot and futures trade of electricity also in Finland and Denmark. The Danish utilities, Elsam and Elkraft, are trading at the pool. From 1998 distribution companies and a few large industrial consumers will become eligible for third party access. The expectations of the present and potential actors in the market was the topic for the seminar as well as interviews and study of periodicals on the Nordic and European electricity markets.

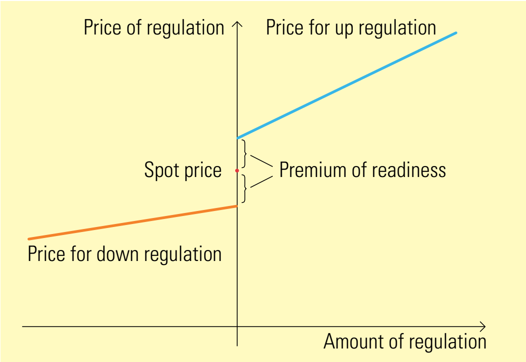
Increasingly, the Danish power suppliers find a common northern European power market attractive. However, they do not consider that a common power exchange is likely to be established, but rather that independent power exchanges will also be able to clear the electricity market. The German market is still considered to be difficult to access.

District heating companies are also actors in the electricity market, either as buyers of heat from large-scale CHP plants owned by the power utilities or sellers of power from their own smaller CHP plants. Therefore, the district heating power plants have various attitudes towards the opening of the power market.
Actors' expectations were summarised as follows:

- Large-scale producers and consumers wish to be able to buy outside their own area – an open wholesale market
- Priority power production and minor consumers require joint influence and guarantees against being squeezed in a new market situation – a protected retail market
- The financial sector focuses on liquidity, transparency, security and simplicity as requirements for the power exchange.

Fluctuation renewable energy on the power exchange

At present, Nord Pool consists of two markets for physical trade; a daily spot market and the Regulating Power Market for physical balance. The spot market clears demand and supply and sets a spot price 12-36 hours prior to the actual delivery. Any differences in demand or supply from the market balance on the spot market is later offset on the regulating market just before the actual delivery takes place. Suppliers of regulating services must be able to regulate their supply within short notice in order to meet the requirement of the instant physical balance between supply and demand. As a contribution to the study of large-scale wind power an econometric analysis of the Norwegian regulating market in the winter and spring 1996-1997 was made. It was found that producers with fluctuating power production at Nord Pool need to buy regulation services in order to fulfil their spot market contracts. These producers



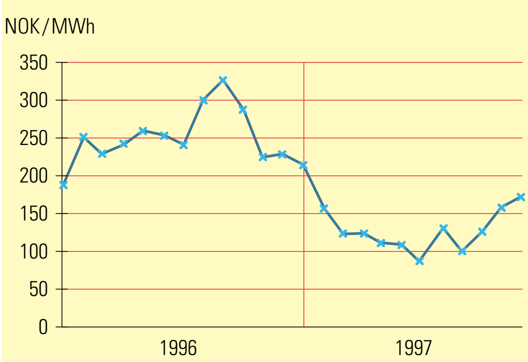


Figure 1 (left)
Asymmetric prices at the regulation power market for physical balance

Figure 2 (right)
Monthly average prices at Nord Pool, 1996 and 1997

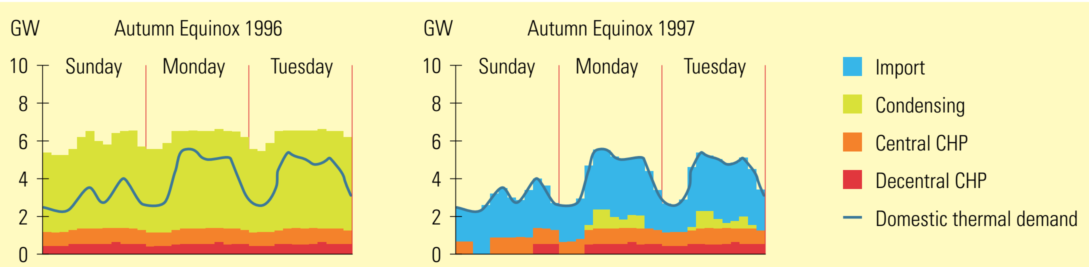


Figure 3
Model result for the Danish electricity production, Autumnal equinoxes 1996 and 1997.

must pay a limited premium of readiness in addition to the spot price. The level of the premium of readiness for down regulation is strongly influenced by the level of the spot price, while that for up regulation is less correlated to the spot price. Also, the slopes of the price curves for regulation differ for up and down regulation. This disclosed pattern might encourage bidders with fluctuating production to move toward a more strategic use of the spot market. By such strategies the cost unpredictable fluctuations due to variations in wind resources may be limited.

Model analysis of the price volatility

The two years in which Nord Pool has been in operation as a common Norwegian-Swedish market has shown great price volatility, because of the natural variation in precipitation. 1996 was a dry year, leading to very high prices, even during the summer. The active participation of the Danish utilities led to a very large export in 1996 (some 50% in addition to national electricity consumption). In 1997 prices have been much lower. In contrast to the Electricity Pool of England and Wales, diurnal price variations have been less important. Thus, price volatility is well displayed by monthly averages, as shown in Figure 2.

Figure 3 shows the results of a calculation using a simple load-dispatch model which was developed for the project on natural gas storage extensions. Electricity import and Danish thermal production are competing at short-term marginal prices. At high prices at the pool the Danish condensing (electricity-only) production will increase to the generating or transmissioncapacities; at low prices most of the time only cogenerated electricity will be competitive with respect to import.

Danish options for the electricity markets

The details of the organisation of the market will be essential for the success of the organisational changes. The countries that have already established organised markets for electricity have chosen very different solutions that were dependent on their traditions and the technology. In mid-1997 the various future options for the Danish electricity industry were described by five models for the Danish participation in a Nordic or northern European power exchange. In addition to the most obvious options, such as the existing pattern of trade at Nord Pool, full participation in a Nordic power exchange, or the prospect for the development of a larger northern European market, two options were added which focus on the special features of the Danish electricity industry:

– A national power exchange designed for the Danish electricity markets, also covering natural gas and cogenerated heat for the large urban district heating systems.
– Emphasising the division in the different synchronised systems with competing underseas HVDC cables, Elsam and Elkraft participate in the continental European and the Nordic markets, respectively.

The new Danish electricity act came into force on 1 January 1998. It is likely to lead to an actor-driven dynamics in the market which may produce quite different solutions.

Publications in 1997: 54, 92, 98
Poul Erik Grohnheit and Klaus Skytte

Energy Systems Analysis

Wind power in an integrated energy system

During the last twenty years renewable energy technologies have developed from being almost non-existent in the Danish energy system to becoming an decisive element in the governmental attempt to stabilise and reduce the emissions of greenhouse gases, as recently shown in the latest energy plan, Energy21. Of all these renewable energy technologies in Denmark today the most important is without doubt wind turbines. At present approximately 1000 MW of wind turbine capacity has been sited in Denmark. According to Energy21 this is targeted to increase to approx. 1700 MW by the year 2005, and to approx. 5400 MW by 2030, including more than 3500 MW off-shore turbines. On the basis of the expected total electricity demand in 2030 from the Energy21 plan, this implies that wind-generated electricity will cover more than 50% of total electricity consumption by that time.

The Systems Analysis Department at Risø has been involved in wind power analysis in a number of projects, ranging from analysis of Off-shore turbines to the impact of large-scale integration of wind power in Egypt.

Off-shore wind turbines

In 1997 Risø finalised the project "National economic costs by reducing greenhouse gas emissions", carried out for the Danish Environmental Agency in collaboration with the Danish Environmental Research Institute. In the project Risø has investigated the cost of reducing the emissions of CO_2-equivalents using a number of different technological options, among these off-shore wind power. Off-shore turbines are getting an increasingly important role in the development of wind power. Without doubt the main reason is that on-land sitings are limited in number and that the utilisation of these sites to a certain extent is exposed to opposition from the local population. Today two off-shore wind farms have been sited in Denmark: Vindeby wind farm established in 1991 and Tunø Knob wind farm established in 1995. The last-mentioned has specially operated successfully. Investment costs has turned out to be lower than expected, while total electricity production has been higher.

The analysis carried out by The Systems Analysis Department shows, that compared to land-based turbines the main differences in investment costs are related to two issues: foundation and sea transmission cables, which are considerably more expensive than for on-land sitings. If the construction of foundations are optimised while at the same time the capacity of the off-shore turbines is increased, then the cost per kWh produced is expected to decrease from approx. 7.5 US cent (Tunø Knob 500-kW turbine) to approx. 4.7 US cent for a 1500-kW turbine.

The costs of sea transmission cables are very sensitive to the distance to the coast. As shown in Figure 1 the production cost rises from 4.9 to 6.9 US cent, when the distance to the coast goes out from 5 to 30 kilometres. Increasing the capacity of the wind farm lowers the cost per unit of electricity produced significantly. When the distance to the coast increases from 5 to 30 kilometres the electricity production cost for a 200-MW wind farm increases from only 4.1 to 4.4 US cent per kWh mainly due to the higher cable cost. Compared to a conventional coal-fired power plant this corresponds to a cost of approx. 5 US$ per tonne CO_2 reduced.

Wind power in a free market

The electricity market in northern Europe is in a transition phase. Norway and Sweden together have established an Electricity Exchange market and on a small scale Danish utility companies have engaged in pool trading. The development within this area might significantly influence the future perspectives for wind turbines in the Danish energy system.

These issues are addressed in a project Risø at present carries out in collaboration with the Danish Utility companies, "Systems integration of fluctuating electricity production from renewables under free market conditions". Considering the Danish electricity system as part of a northern European electricity exchange, the project aims at identifying optimal strategies for large-scale utilisation of renewables, especially wind power. Among other national regulatory measures and technologies, the possibilities for Danish electricity export and import are central in the analysis.

Wind energy possesses some special characteristics, which might be of utmost importance to address in a free market context: Wind-generated electricity is subject to seasonal as well as daily variations, making it difficult to predict the supply of wind power to the market. At the same time fixed costs (levelised investment costs) amount to a high share of total production costs of the turbines, leaving limited degrees of freedom to adjust expenses in the short run. Among others these topics are analysed in the project, which is expected to be finalised at the beginning of 1998.

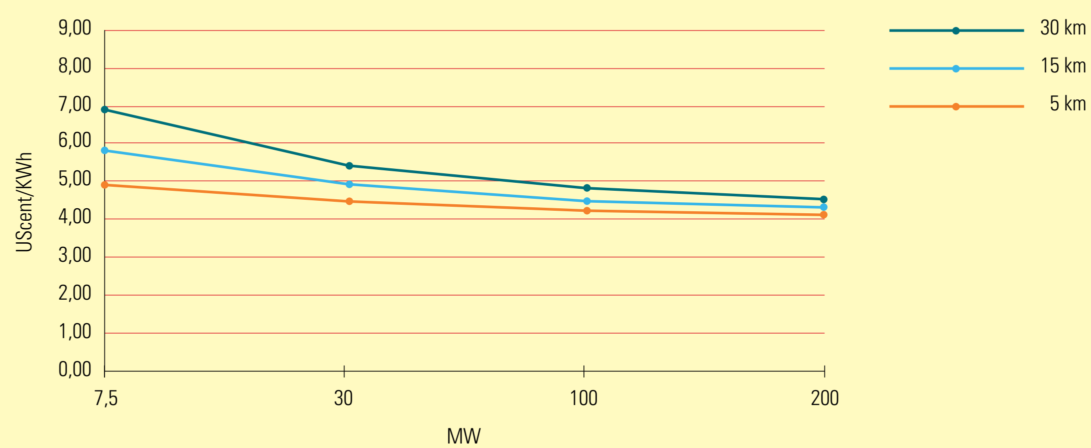


Figure 1
The cost of electricity produced by off-shore wind-turbines as a function of distance to the coast and the capacity of the wind farm

Externalities in relation to wind

One way to improve the competitiveness of wind turbines is to introduce externality adders. Denmark has been one of 15 countries involved in the National Implementation of the ExternE methodology. The aim is to quantify the environmental costs imposed on society that are not included in the market price (effects of air pollution on health, buildings, crops, forests and global warming, emissions of noise etc.).

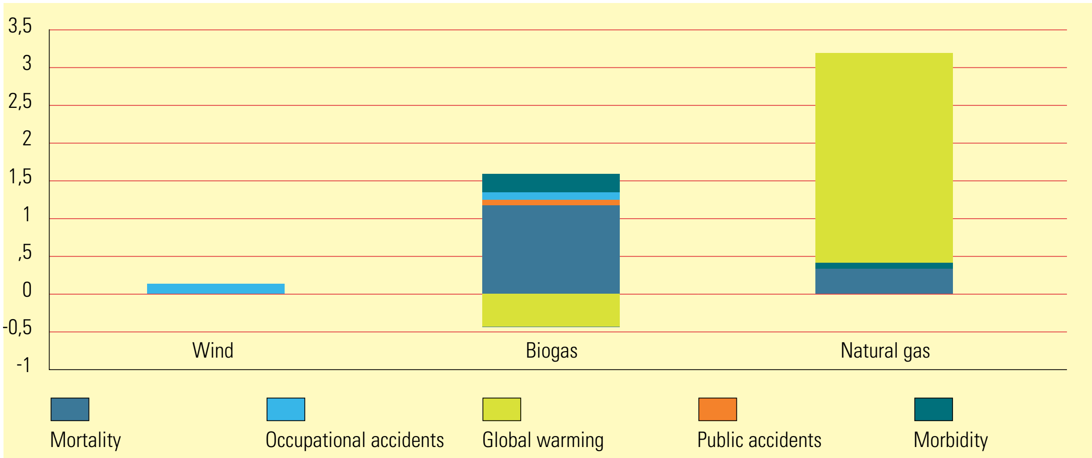
Being a country with large resources of wind energy Denmark in this study has focused on the fuel cycle for an off-shore wind farm and for an ordinary wind farm. Also, a decentralised natural gas-fired CHP plant and decentralised CHP plant based on biogas have been analysed in the study. In 1997 the impacts for the different fuel cycles were assessed and the damages were monetised. The analysis of the wind fuel cycle is based on a life cycle assessment, including impacts from material extraction and manufacturing. The impacts have been divided into those due to the use of fossil fuels for the material manufacturing and those due to the presence and operation of the turbine. Nearly all the damages from an off-shore wind farm are related to the production of the materials for the wind farm. The damages are mostly related to the emissions of CO_2 and to some extent NO_x and SO_2.

For the off-shore wind farm the following impacts have been assessed as externalities for the full life cycle of the wind turbines: noise, visual amenity, atmospheric emissions related to material production, accidents, impacts on birds, impacts on fish, interference with electromagnetic communication systems.

Figure 2 shows the most important of the damages related to fuel cycles for wind, biogas and natural gas estimated by the Systems Analysis Department using a monetised estimate for global warming damage of 51 US$ per tonne CO_2. The figure shows only externalities related to electricity production.

As seen from the figure the externalities for wind are 0.1 UScent/kWh being around 2% of the production costs. Biogas has a positive effect on global warming through the reduced emission of CH_4 from agriculture, meaning that the total externalities amount to just above 1.1 UScent/kWh electricity being around one-fourth of the electricity production price. In the case of natural gas the externalities are as much as 80% of the production costs (global warming accounts for about 3/4 of the externalities). The atmospheric emissions are the dominant damage for all the fuel cycles.

Figure 2
Most important damages related to wind, biogas and natural gas



Publications in 1997: 34, 44, 52, 53, 86, 93, 98
P. E. Morthorst, L. H. Nielsen, P. Skjerk Christensen and L.Schleisner

Wind energy in Egypt

Not only in a national but even in a global perspective is wind power being developed rapidly. Within the past 6 years the global installed capacity has increased almost threefold, from approx. 2.3 GW in 1991 to approx. 6.2 GW in 1996, an annual growth of more than 20%. During several years the Systems Analysis Department has participated in a Danida-financed project aiming at transferring methods and tools necessary to formulate a longterm strategy for implementing wind-produced electricity in the Egyptian national power system. Egypt has excellent wind resources, e.g., in the Red Sea area, with high yearly average wind speeds, implying high electricity production from wind turbines in this region. A number of energy system models have been adapted to Egyptian data; scenarios have been constructed according to targets for utilisation of renewable energy in Egyptian national plans and, finally, consequences have been analysed regarding fuel savings, avoided emissions, economy, and social impacts.

The study has been carried out in collaboration with the Egyptian administration according to suggestions made by the Systems Analysis Department; the members are specialists and decision-makers from authorities and industries that are involved in national planning and possible manufacturing of wind turbines.

During 1997 the Systems Analysis Department has supported the preparation of a wind energy master plan report by carrying out the following tasks: analysing and commenting on results obtained with the transferred tools, suggesting particular items to be studied in further detail, commmenting on reports made by various committees and elaboration of the final report in cooperation with the responsible Egyptian authority.

Energy Systems Analysis
Natural gas storage extensions – assessment of national economic gains

Overall national economic gains, achievable by extending underground storage capacity for natural gas in Denmark, are analysed in a project carried out in collaboration with the consulting firm Rambøll. The project is supported by the Danish Energy Research Programme.

The prime focus of the analysis is the evaluation of achievable gains, related to load levelling on a seasonal basis, during normal operation over the lifetime of a gas storage. Detailed optimisation of gas storage operation, in response to annual demand and price profiles in short time steps, is carried out for a number of scenarios. Consequences of size and year of commissioning of a gas storage extension are analysed based on different assumptions concerning, e.g. future demands for natural gas in different sectors in the Danish energy system, fuel price forecasts on natural gas and alternative fuels and natural gas supply and grid extensions in northern Europe.

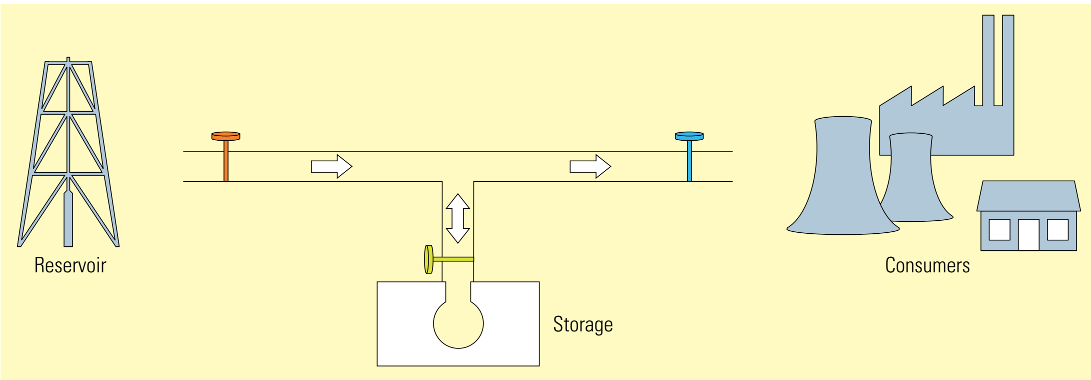


Figure 1
Basic elements and dynamics of the system.

The system

Figure 1 shows a schematic overview of the main elements in the system considered. As illustrated, the overall underground natural gas storage capacity (on shore) in Denmark is part of a nationally integrated single-pipeline gas supply system.

Two larger natural gas storage facilities are part of the present Danish gas supply system. In northern Jutland seven underground caverns in a salt dome at Ll. Torup are in operation. In Zealand a larger aquifer type natural gas storage facility is located at Stenlille. The Danish storage capacity today at these facilities is approx. 600 mio. normal cubic meters natural gas (600 MNm^3NG). The natural gas is presently supplied from fields in the Danish sector of the North Sea, and the gas is fed into the grid at Nybro in western Jutland. A part of the production is exported to Sweden and Germany. Aspects concerning the geographic location of the system elements have not been taken into account in the analysis.

Approach

The optimal operation strategy during one year, for the overall gas storage capacity in the Danish system, is determined by using discrete dynamic programming. The maximum net annual yield/gain of the overall gas supply system is the criterion used for the optimum solution. This optimisation is carried out both for the existing storage capacity and for the total storage capacity including the extension of the storage capacity.

Constraints and assumptions concerning the natural gas supply to the Danish on shore grid and assumptions concerning gas consumption in Denmark are equal in these two calculations. This allows for calculating the annual overall additional benefit related to the gas storage capacity extension considered.

The above calculation is repeated for the next year and so on. This is done in order to calculate potential annual benefits from the storage extension during the expected/chosen lifetime of the new storage facility. Based on the annual optimal benefits, a present value is calculated with the year of commissioning chosen as base year. The analysis proceeds further by repeating the above calculations for a new base year etc.. A present value related to the gas storage extension is thus determined, as a function of the year of commissioning.

The basic assumptions, e.g. concerning the future consumption and supply of natural gas in the Danish energy system, during the period analysed (years 2000-2030), are in accordance with the latest Danish energy plan: Energy21. The analysis focuses mainly on consequences of two paths for the future development described in Energy21. These are called "Plan" and "Reference". Two further scenarios for the future Danish natural gas consumption have been analysed. They are based on the European Commission Dir. Gen. for Energy (DGVII) analysis European Energy To 2020. The scenarios are termed "Conventional Wisdom" and "Hyper Market".

The Danish natural gas consumption is split into five sectors. Considerable differences in the seasonal variation occur between these sectors, where sectors in particular with heat constrained gas consumption show large seasonal variations. Due to uneven development among these sectors over the period analysed, the overall seasonal variation will change.

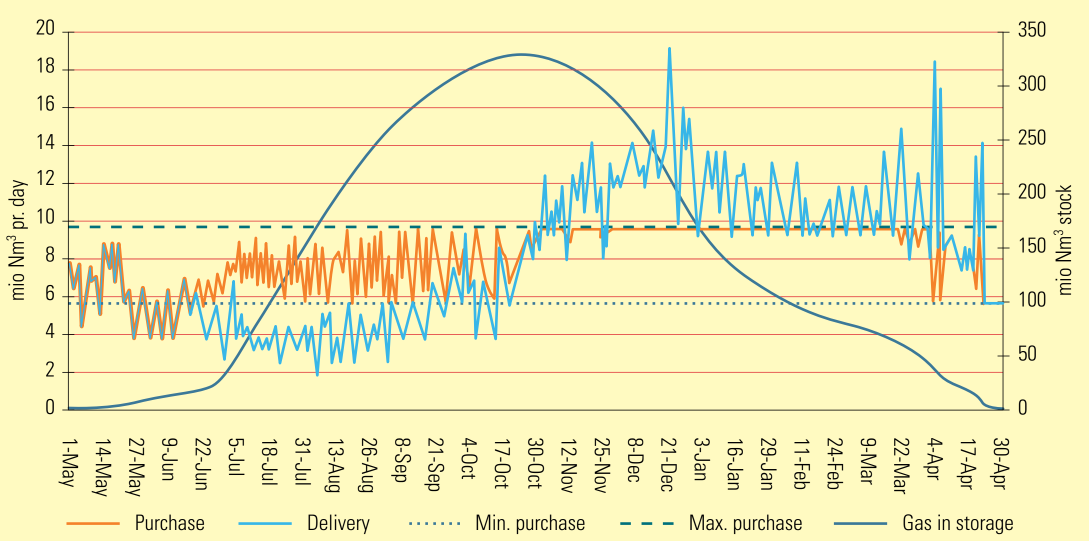
In this analysis, gas prices on the Danish market are assumed to be based on the costs of the alternative fuels available for each sector. Short-term substitution prices have been assumed. Gas substitution prices on the residual gas market (to large power plants) can be determined on the basis of electricity prices at the northern European market. Thus, gas sales prices differ among sectors in accordance with the fuel alternatives, conversion efficiencies etc. In particular, withdrawal from the gas storage achieve the substitution prices. In situations of supply shortage, customer groups having the high substitution prices are first supplied.

The flexibility and constraints in the gas supply are essential for the benefits gained from the storage capacity in the system during normal operation. Different aspects concerning gas supply contracts have been considered. Besides the costs, the annual take and load factor (LF: mean daily take / peak daily take) are often the main parameters focused on in gas supply contracts. Gas purchased under high load factor conditions is generally favourable, due to the reduced transmission costs and other supplier benefits in consequence of a low seasonal variation on the production side. On the consumption side, however, high load factors may impose severe constraints and increase the need for storage capacity. In this analysis different supply contracts, characterised by different load factors, have been taken into account. Furthermore, some future pipeline alternatives have been reflected in the study through sensitivity analyses.

Figure 2 presents an example of optimal solutions for gas flows and the profile for gas stored during one year of operation.

The initial demand profile and supply constraints related to a 0.7 load factor are shown. Furthermore, the figure shows the resulting optimal natural gas purchase form the supply, to storage injection and to customers directly.

Figure 2
Example: Optimal natural gas purchase and storage level. The amount of working gas in the overall storage system is shown on the right axis.



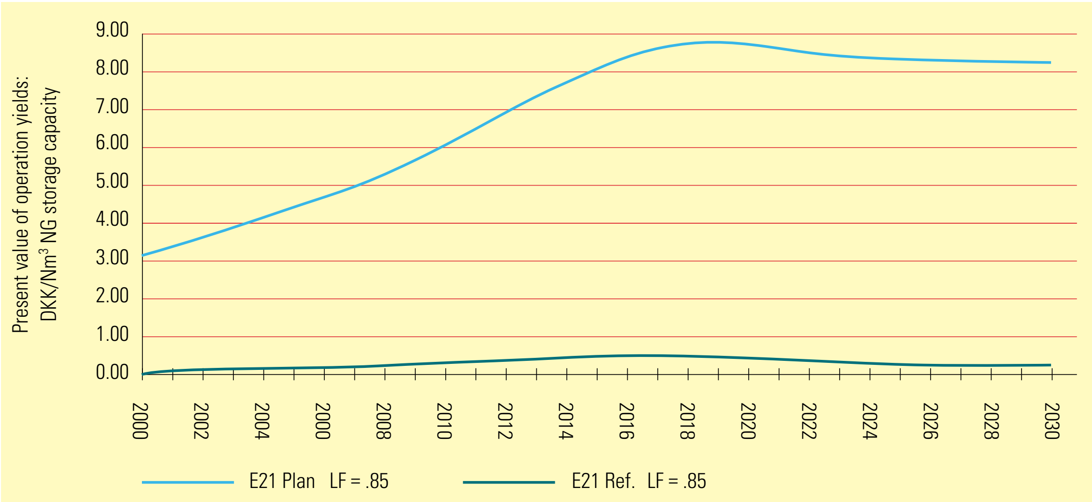


Figure 3
Present value of yields/gains during 30 years of operation. Base year as x-axis. Rate of interest: 5 % p.a. Price level: 1995 DKK. Storage extension: 100 MNm^3. Unit: DKK/Nm^3 NG storage capacity.

Figure 3 shows, as an example, the present value of gains related to a natural gas storage extension in the Danish energy system, as a function of the year of commissioning of the extension. The basic assumptions concerning natural gas demands are in accordance with Energy21. Gains of a storage extension are shown, based on the assumptions laid down in the “Plan” and in the “Reference”. It is seen from the figure that the present value of the achievable gains, during the assumed lifetime of the storage extension, very much depends on the assumed path for the future development, here expressed as the “Plan” and the “Reference”. The substantial difference seen in Figure 3 is not a consequence of significant differences in the Danish annual natural gas consumption in the two situations. The main reason is the difference in seasonal variation in the consumption in the two situations. Relative to the “Reference” development path, the “Plan” includes a considerable shift in the future gas consumption among sectors, towards increased gas-based combined heat and power production. A result of the shift among sectors is an increased seasonal variation in the overall gas consumption that builds up during the period analysed.

General remark

The achievable benefits of a natural gas storage extension is highly sensitive to a number of the parameters entering the analysis, and large uncertainties are often associated with these parameters. A decision concerning gas storage extensions, therefore, very much depends on the decision makers expectations to the development in these parameters. The approach used has shown to be appropriate to form an overview of the various interacting factors in the system.

Publications in 1997: 39, 40, 41, 42, 97
Lars Henrik Nielsen

Integrated Energy, Environment and Development Planning

UNEP Support Activities

The programme on Integrated Energy, Environment and Development Planning is hosting the UNEP Collaborating Centre on Energy and Environment (UCCEE) which is a collaborative activity between the UN Environment Programme, Danida and Risø. The Centre started in 1990 and enters its fourth biannual project phase in 1998. Under the Centre heading, the programme has gradually expanded its external activities and this tendency was continued in 1997 with a number of new projects directly with UNEP and Danida, but increasingly also with other multi- and bilateral agencies.

These projects all conform with UNEP's general mandate and the strategy for the UNEP energy programme and in this way they contribute to and expand the UNEP work programme both in energy and climate change.

One of the core Centre functions remains to be to provide direct substantive support to UNEP programme activities on energy as well as on climate change, and in relation to UNEP's role as implementing agency of the Global Environment Facility. These support activities vary considerably in format from preparing scientific input to official UNEP management presentations at conferences to working closely with programme staff on strategy, programme and project development, and in being responsible for the implemen-tation of major projects like the UNEP/GEF project on "Economics of GHG Limitations".

A few examples are presented below to illustrate the various functions and to highlight some of the events in 1997.

Work programme on methodologies for mitigation assessment

The Subsidiary Body for Scientific and Technological Advise (SBSTA) has been preparing a work programme on methodological issues relevant to the implementation of the Climate Convention (FCCC). This work programme was discussed and approved at the SBSTA meeting in July.

The UNEP Industry and Environment Office (UNEP IE) had jointly with the Centre prepared a proposal for a sub-programme on methodologies for mitigation assessment. This sub-programme builds upon the present Centre activities, especially the GEF project on "Economics of GHG Limitations", and proposes further development, dissemination and training activities for the coming biennium. The proposed subprogramme was accepted by the Climate Change Secretariat and included in the proposed programme of work under the heading of "Assessing mitigation measures and policies".

The proposed subprogramme was adopted with the following text:

> *(c) ''Noted and strongly supported the work programmes..., in particular the work undertaken by the United Nations Environment Programme Collaborating Centre on Environment and Energy at Risø (UNEP/RISØ) in Denmark on assessing mitigation measures and policies.''*

Through its activities with the IPCC and the UNEP/GEF project the Centre has begun the implementation of the work programme and will continue activities in 1998/99 in accordance with the SBSTA decision.

Sustainable Energy Development

The UN General Assembly Special Session (UNGASS) held in June undertook an "Overall Review and Appraisal of the Rio Commitments on Sustainable Energy" and as one of the outcomes it was decided to have the meeting in the Commission on Sustainable Development (CSD) in 2001 focus on Sustainable Energy. Along with other key UN agencies, UNEP will naturally play an active part in the preparations for this CSD meeting when they formally commence. It is, however, important to utilise the time before the CSD meeting and the formal preparation process to expand activities in the area of sustainable energy development so there will be a strong substantive basis for common decisions.

A first informal meeting to follow-up on the recommendations from UNGASS was convened in October by the Austrian Government in collaboration with the UN Department of Economic and Social Affairs (UN-DESA) and UNDP. UNEP was represented by both IE and Centre staff and will in the further process play an active role in close collaboration with UN-DESA and UNDP. The special report on Wind Power (described in a later section) for UN-DESA is one example of this active involvement.

With its strong involvement in environmental and especially renewable energy activities, Danida has acquired a strong interest in sustainable energy and Denmark was one of the countries promoting the special energy session of the CSD at UNGASS. Combining these interests UNEP IE and the Centre have prepared a new initiative on "Implementation of Renewable Energy

Technology (RET) Projects" in collaboration with UNDP and Danida. This initiative has been established late 97 and will begin implementation in 98. It will focus on identification and promotion of practical RETs projects in a small number of developing countries and will include an analysis of barriers to their implementation and action that can reduce these barriers and ensure implementation.

Activities Implemented Jointly under the FCCC

The concept of joint implementation (JI) of climate change projects was introduced in the Convention text and the first Conference of Parties (COP I) in 1995 decided to establish a pilot phase for JI type projects under the name Activities Implemented Jointly (AIJ).

As part of its climate change activities, UNEP has undertaken a number of awareness building activities related to AIJ/JI in order to enhance the international understanding of the concept and its possibilities and risks.

UNEP IE in September convened a workshop together with the International Energy Agency that focused on the issue of incentives during the AIJ phase where no formal crediting of emission reductions can take place.

Centre staff helped prepare the workshop and took part in the deliberations and the subsequent preparation of the workshop report, which was presented at the meeting of the Convention bodies in October. IE has also prepared a "Primer" on JI/AIJ issues which was widely distributed at the COP III in Kyoto in December.

Finally, the Centre and IE jointly prepared a concept for a regional awareness and capacity building programme in the African region. This programme is planned together with other Nordic institutions and if agreed it will start mid-98. In order to proceed on a practical level with the aim of providing input to the regional programme, a national level study in Zimbabwe has been prepared by IE and the Centre together with the Zimbabwean Government and the Southern Centre on Energy and Environment. This project will examine the problems and opportunities associated with possible acceptance of AIJ/JI projects for the country and establish a basis for deciding if such a financing mechanism is attractive for the implementation of the national climate change policy.
The project, which is financed by Danida, will commence at the beginning of 1998.

As mentioned in the introduction, a large number of support tasks are of a more ad-hoc character like reviewing papers and reports. A very special support task was to assist the IE office in preparing a booth for the COP III at Kyoto in December. In view of the importance of this meeting UNEP had a very strong presence and the booth became a focal point for information dissemination on the climate change activities of the UNEP and the Centre.

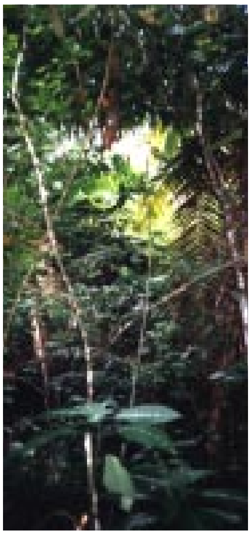
Publications in 1997: 6, 8, 102
John M. Christensen

Integrated Energy, Environment and Development Planning

Methodologies for climate change mitigation assessment

In 1997 staff from the UNEP Collaborating Centre on Energy and Environment (UCCEE) continued to develop the mitigation assessment methodology guidelines for the multi-country greenhouse gas (GHG) mitigation study, being funded by the Global Environmental Facility (GEF). The purpose of these guidelines is to provide the country study teams in the participating developing countries with a common methodological framework for assessing the effectiveness and costs of different measures to reduce greenhouse gas emissions.

The guidelines are tested in country studies for Argentina, Ecuador, Senegal, Mauritius, Indonesia, Vietnam, Hungary and Estonia. UCCEE will convene regional workshops in Asia, Latin America and Africa in 1998 to promote the wider use of these guidelines in other developing countries to assist them in preparing GHG mitigation plans for their national communications under the Framework Convention on Climate Change.



The rain forest is a major carbon sink

The major thrust of UCCEE's work on the mitigation guidelines in 1997 has been to expand the sectoral coverage and to extend the cost concepts applied to assess a broader range of social and environmental impacts in addition to the costs and benefits traditionally assessed in economic studies. Additionally the guidelines have been expanded with new chapters covering the use of policy instruments to stimulate GHG mitigation activities and the estimation of implementation costs in order to remove barriers that can slow down the adoption and diffusion of new technologies in developing countries.

Broader social and economic impact assessment

Climate change mitigation studies until now predominantly have focused on CO_2 reduction options for the energy sector. This perspective, however, should be widened in the light of the significant contributions from land use greenhouse gas emission sources including forestry as well as agricultural activities. The Kyoto climate protocol adopted in December 1997 in line with this also addresses multiple emission sources and sectors.

In the most recent 1997 version the sectoral coverage in the GEF project guidelines has been expanded to include the forestry, agricultural, transportation and waste sectors, thus making the guidelines comprehensive in terms of its treatment of sectoral opportunities for abating GHG emissions.

Each chapter includes a discussion of:

– delineation of system boundaries for assessing mitigation options
– technical discussion of the mitigation options that can be used in each sector in the short-, medium- and long-term,
– the analysis steps required to conduct a GHG mitigation assessment
– the methods that can be used to calculate the emission reductions and costs associated with each of the mitigation options.

Where previous methodological guidelines for conducting mitigation assessments have tended to emphasise the importance of technological factors in mitigating GHG emissions, the UCCEE guidelines are unique in the emphasis they place on the correct accounting of the costs of these activities in a rigorous way. The guidelines show that focusing on the "off the shelf" costs of different technologies is insufficient because it obscures many other types of indirect costs that occur when the mitigation measure affects resource use in a sector or affects the goods and purchases from other sectors. The guidelines also emphasise the importance of accounting for market distortions and governmental practices in developing countries which affect the cost of capital, labour and other inputs associated with the purchase, operation and maintenance of different mitigation technologies and practices.

Implementation policies

Previous work in this area has shown that there are a number of GHG mitigation measures that can be implemented at zero cost, or with a positive rate of return to developers. However, these measures are often not implemented because of various barriers that exist in developing countries. The barriers include a large number of institutional aspects and policy issues. The new version of the guidelines develops a framework for the assessment of implementation costs in a way where these activities are integrated in the project evaluation alongside more traditional resource components like technologies, labour, land and fuels.

It is emphasised that a successfull implementation strategy should be based on identification of barriers and an outline of policies required to overcome them. In this way it is the idea to develop a number of barrier removal policies that can enhance the ability of the market actors to implement climate change mitigation actions.

Some developing countries are especially vulnerable to climate change damages, e.g., in the case of flooding or sea level rise

These policies will include traditional market liberalisation policies and price reforms as well as more specific capacity building efforts.

The UCCEE guidelines also include a broad evaluation of the alternative types of domestic and international policy instruments that can be used to provide incentives to undertake GHG mitigation activities. These instruments include regulation of emissions, building practice and energy conservation standards, land use regulations and practice laws, carbon taxes, emissions trading and offset systems, and joint implementation. The guidelines describe how these policy instruments work in practice and provide guidance regarding the evaluation and implementation of these policies in developing countries.

Experiences with application of the methodological framework

The country studies of the GEF project have now finalised the first part of their work and a number of experiences with practical application of the guidelines therefore emerge from the national reports. The mid-term reports received from the studies suggest the following preliminary methodological conclusions:

- Most countries have conduced a broad assessment of the relationship between general national social and economic development goals and trends and climate change mitigation.
- Mitigation policies are defined as a broad concept, where technical options are considered in the context of national policy instruments and implementation aspects.
- Most studies, in addition to those in the energy sector, have included one or two new sectors. In particular transportation and forestry have been assessed. This also implies that the three main GHGs (CO_2, CH_4 and N_2O) are considered.
- Macroeconomic assessment and implementation issues are – so far at best – analysed in only a very preliminary way. It is expected that most of the countries in the final phase of the project will focus of these issues in more details.
- It appears that the most familiar step of the methodology (baseline, mitigation and project cost assessment) present least problems, while the assessment of macroeconomic impacts and implementation policies, as more unfamiliar issues, have raised more difficulties.

The overall experience with the methodological framework so far is that the guidelines have been applied in general in the country case studies, although some, not unexpected, difficulties have emerged with the more advanced parts of the guidelines.

Development of a cost concepts paper

The recently finalised Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) included an examination of the economic and social dimensions of climate change. This assessment concluded that there is a need for further clarification and coordination of the economic concepts applied in relation to different dimensions of climate change studies and policy development. UCCEE was therefore together with the Lawrence Berkeley National Laboratory in the United States asked by the IPCC to organise a workshop and develop a concept paper on these costing issues.

The workshop was held in June 1997 at Risø National Laboratory with the title: Mitigation and Adaptation Cost Assessment: Concepts, Methods, and Appropriate Use. The 80 invited experts and policy makers from all parts of the world had an extensive and very constructive discussion of the concept paper, and it was agreed that the paper should be sent out for expert and government review to a total of more than 1000 reviewers from the IPCC expert roster. A new updated version of the paper will then be developed in the first part of 1998.

Publications in 1997: 8, 9, 36, 67, 84
Kirsten Halsnæs

Integrated Energy, Environment and Development Planning

Climate Change Mitigation Studies: National Studies, Capacity Building and Regional Perspectives

The UNEP Centre is currently involved in a number of country studies related to greenhouse gas emissions and climate change. These activities should be seen in the context of the United Nations Framework Convention on Climate Change (UNFCCC) under which all developing country parties are committed to submitting national communications on greenhouse gas emission (GHG) inventories and, optionally, their vulnerability to climate change, adaptation measures and mitigation potentials. Countries are assisted in preparing their national communications through so-called "enabling activities" funded by the Global Environment Facility, and in addition bilateral sources such as Danida are providing resources to promote the build-up of capacity in selected countries.

Although at present under the UN Framework Convention on Climate Change developing countries have no commitment to undertake climate change mitigation by reducing greenhouse gas emissions or increasing carbon sinks, it is important for countries to be aware of the potentials and costs of national mitigation measures.

Of the sixteen country studies currently being supported by the UNEP Centre, eight are being carried out within the UNEP/GEF project "Economics of GHG Limitations". These national studies are in developing countries in Latin America, Africa and Asia, as well as in former centrally planned countries in Eastern Europe. In addition, Danida funds three countries in southern Africa (Botswana, Tanzania and Zambia), and a project in Egypt is funded through UNDP/GEF. These latter four country studies are running parallel to the UNEP/GEF project and follow the same methodological guidelines. Four further countries are involved in somewhat broader activities, supported by Danida (Burkina Faso and Peru) and UNDP/GEF (Jordan and Lebanon).

Country teams, UNEP Centre staff and colleagues from Lawrence Berkeley Laboratory met for a mid-way workshop in May 1997 in Mauritius. Here teams presented mid-term reports describing the baseline or reference scenario against which greenhouse gas emission reduction actions can be assessed. In the second half of the project countries are selecting and evaluating climate change mitigation options, following the methodological guidelines. A particular characteristic of the UNEP methodology developed at the Centre is the model-independent nature. Thus, a number of different planning and analysis tools are being employed by the country study teams to define the baseline and assess the mitigation scenarios, while the general analytical approach and assumptions follow a uniform pattern. Some examples of the range of approaches and settings are indicated below:

Staff at the new Energy Agency, Burkina Faso

Argentina

In the Argentinean study, carried out by the Instituto de Economía Energetica for the Argentinean government, a significant amount of effort has been spent in defining the baseline development for the country. This is justified by the considerable reforms in Argentina since the early 1990s, essentially privatising the entire energy industry. Mitigation options being considered involve both the demand side (such as transport modal shifts and new fuels such as CNG and fuel cells), and the supply side (where the main option is hydropower although wind and small-scale solar have some potential.) The analysis is being carried out with a combination of the LEAP and EFOM-ENV tools.

Botswana

As one of the three Danida-supported southern African country studies, the Botswana team led by Energy, Environment, Computer and Geophysical Applications (EECG) Consultants Ltd., on behalf of the Botswana government, is carrying out the assessment using both the LEAP integrated energy model and the Risø GACMO spreadsheet model. This combination of analysis tools (also used in Zambia) allows both an integrated picture of the energy system to be established as well as a detailed cost analysis of the individual mitigation options to be carried out. Major options in Botswana are energy savings and fuel switching in industry, transport and household sectors, with important links to agriculture and forestry.

Burkina Faso

The UNEP Centre has been involved since April 1995 in a collaboration with the government of Burkina Faso, funded by Danida, in an activity aimed at building capacity to

– establish the initial reporting to the UNFCCC
– periodically carry out GHG inventories
– pursue policies that could mitigate climate change

The first phase of the project was completed and published in 1997 and a new phase has been submitted to Danida for funding.

Estonia

Given Estonia's reliance on highly polluting oil shale as its primary energy source, Estonia's mitigation options concentrate primarily on improving the combustion of oil shale within a cleaner process (such as pressurised fluidised bed), as well as other cleaner fossil fuel technologies including coal and gas. Nuclear, wind and hydro are the other supply side options being considered. The study is carried out on behalf of the Estonian government by the Stockholm Environment Institute's Talinn Centre and employs the MARKAL-MACRO model for the analysis.

Peru

A Danida-funded project to build capacity for energy-environment analysis and planning is being carried out in Peru as a collaboration between the UNEP Centre, the Technical University of Denmark, the Peruvian National Council for the Environment and the National University of Engineering. The Peruvian activity follows the general mitigation analysis to some extent, but also focuses on the use of different tools for strategic planning. As part of the project, a special seminar on Strategic Planning was held in Lima in November 1997.

Vietnam

The study for Vietnam, coordinated by the country's Institute of Meteorology and Hydrology, builds on existing work, particularly on the UNDP/GEF ALGAS programme. Of particular interest in the current study is the adjustment of the baseline scenario for Vietnam to take into account the slowdown in the economies of South East Asian countries and recent national trends. In view of the significant uncertainty, the team plans to use multiple baselines in the assessment. Mitigation options being considered include electricity efficiency improvements in transmission, distribution and consumption, as well as options in the forestry and agricultural sectors.

Regional studies in Southern Africa and South America

The UNEP/GEF project also considers the potential that exists for regional groupings to undertake mitigation measures. Two regions were selected for study: the Andean Group in South America and the SADC (the Southern African Development Community) countries in Southern Africa. Both groupings are well developed with regard to sectoral cooperation, in particular with regard to electrical power, but so far neither has a defined common stance on climate change. One of the ultimate aims of the regional studies is to contribute to sensitising regional decision-makers to the opportunities and potential for such cooperation.

The Andean Group study is a collaboration between the UNEP Centre, IDEE Argentina and the Latin American Energy Organisation (OLADE). The study focuses entirely on power sector cooperation for CO_2 reduction. Much of the year's work on the Andean Group study has concentrated on a detailed specification of the baseline scenario for the subregion in which no regional action is implemented to mitigate climate change.

The SADC regional study is carried out as a collaboration among the Southern Centre for Energy and Environment (SCEE), based in Harare, Zimbabwe; the Centre for Energy, Environment, Science and Technology (CEEST) in Dar es Salaam, Tanzania; EECG Consultants in Gaborone, Botswana; and the UNEP Centre. In addition to looking at cooperation in the power sector, the study considers regional transport arrangements. The UNEP Centre, as study coordinator, is responsible for the synthesis of the studies carried out by the regional centres, as well as research into the institutional and political issues involved in regional cooperation related to climate change. During the past year the regional baseline has been established and a number of mitigation options for the SADC area have been assessed. The results of the SADC study along with deliberations on regional cooperation in Southern Africa will be published in book form in 1998.

The studies as a whole are scheduled for completion by mid-1998. Results of the national and regional studies, as well as the methodological framework, will be presented and discussed in regional conferences to be held in Africa, Asia, Latin America and Eastern Europe.

Publications in 1997: 5, 28, 65
Gordon A. Mackenzie

Bakers using a traditional woodfuel oven in Burkina Faso

Integrated Energy, Environment and Development Planning
Environmentally Sustainable Electric Power Development

The electric power industry today is changing throughout the world. Deregulation and privatisation are introducing competitive forces into a hitherto largely monopolistic structure and altering utility planning processes; rapid technological development is making new technologies increasingly competitive against conventional options; and environmental concerns like global climate change could radically alter the entire energy landscape.

To help ensure that the various forces affecting the electricity industry are compatible with environmentally and socially sustainable development, the UNEP Collaborating Centre on Energy and Environment is investigating sustainable electric power development from three separate but related angles: 1.) industry restructuring, 2.) planning methods, and 3.) technology development. Activities and recent results in these three areas are described below.

Power Sector Reform

Though the electric power sector is being reformed and restructured throughout the world, the nature of reform varies significantly between countries. In some cases, state-owned utilities are being corporatised or privatised outright; in other cases vertically integrated monopolies are being unbundled into separate generation, transmission, and distribution companies. Competition in the generation market is being introduced either through private independent power producers (IPPs) selling power to the monopoly utility or by allowing consumers to purchase electricity directly from separate generators through negotiated contracts and spot markets. In some countries, aspects of all of the above may be occurring.

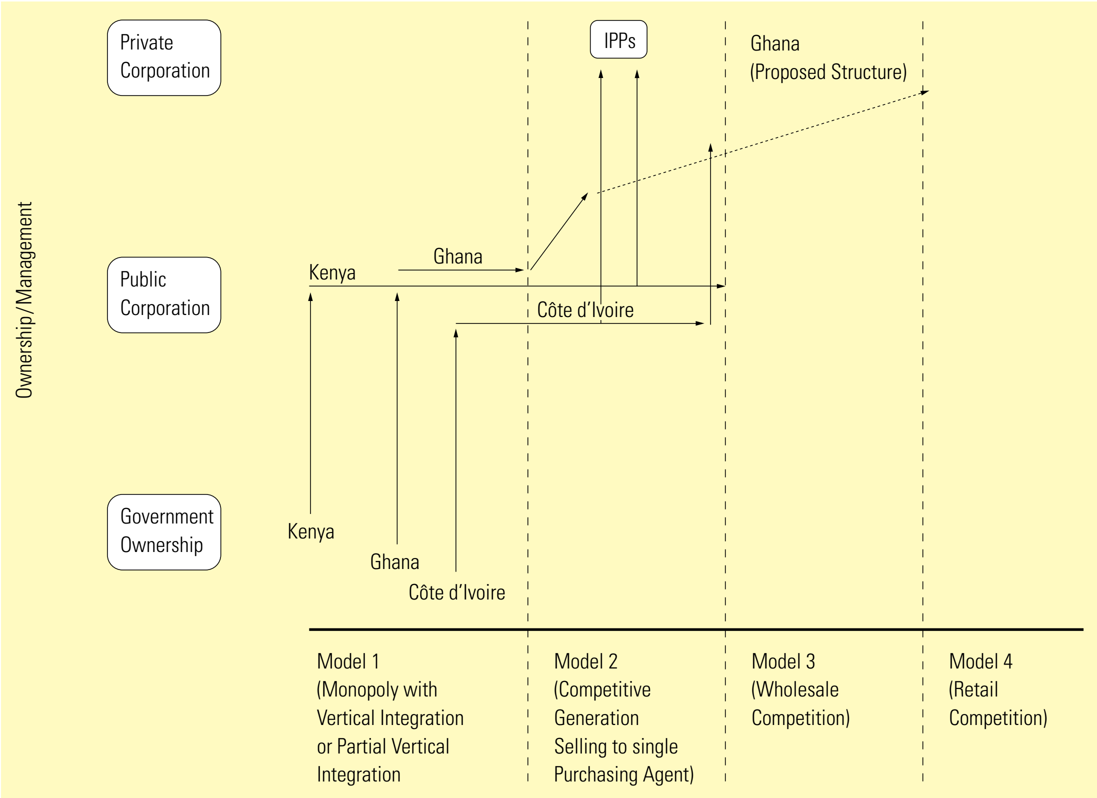
The environmental and social impact of such reforms is unclear. In some countries, competition may reduce electricity prices, thus stimulating higher consumption and greater pollution; in other countries, removal of energy subsidies will result in higher prices and stimulate improved energy efficiency but will also have severe financial impacts on the poor. Short-term competitive pressures may favour fossil-fuelled power plants with low capital costs and hamper renewable energy, but on the other hand, with greater customer choice, customers may increasingly choose to purchase "green" electricity from suppliers selling electricity generated sustainably. In developing countries, rural electrification programs in poor and sparsely populated areas could be significantly impacted.

To investigate some of these factors, the UNEP Centre has two ongoing projects related to power sector reform. In Ghana, the UNEP Centre and the African Energy Policy Research Network co-organised and hosted a workshop in November entitled Power Sector Reform: Process and Implementation Experiences in Sub-Saharan Africa. The workshop brought together participants to share their experiences from six sub-Saharan African countries currently restructuring their electricity industries: Côte d'Ivoire, Ghana, Kenya, Mauritius, Uganda, and Zimbabwe.

The workshop demonstrated that reform was largely being driven by a common theme: the need to improve utility financial performance, and the need to harness private capital to finance sufficient investment to meet burgeoning electricity demand. Yet, wide differences also exist between countries. The following figure illustrates the directions of reform in three countries. The vertical axis represents utility ownership and management structure, varying between complete government ownership, public (government-owned) corporation, and private ownership. The horizontal axis represents the industry's competitive structure, varying between vertically integrated monopoly and retail competition.

As can be seen in the figure, Kenya and Côte d'Ivoire have followed broadly similar paths. In both countries, government-owned vertically integrated monopolies were converted into corporations with varying degrees of mixed private and public ownership; competition was then introduced at the generation level with all generators (including IPPs) selling to the utility which maintains a monopoly on transmission and distribution and serves as a common purchasing agent for all generated power. Ghana, on the other hand, is dispensing with the common purchasing agent and is introducing wholesale competition in which generators compete to sell power to large consumers and distribution concession monopolies through negotiated bilateral contracts and a spot market.

In addition to those illustrated above, further differences between countries can be characterised by the reform process itself. For example, Ghana's process has been characterised by step-by-step reform, creating an independent regulatory commission, and gradually privatising the utility and introducing competition. In next-door Côte d'Ivoire, on the other hand, reform occurred virtually overnight through a "big-bang" approach in which the state vertically integrated monopoly was rapidly broken up into a private operating and management company, which operates the entire system under a monopoly concession, and a state-owned company, which continues to own all assets and is responsible for system planning and expansion. Côte d'Ivoire has followed an approach of



Adapted from: Hunt and Shuttleworth (1996), Competition and Choice in Electricity.

privatising the utility first, and then gradually defining and refining the regulatory structure as the need arises. Other contrasts include Zimbabwe's reform being driven primarily by an internal utilityled process of performance improvement, while Kenya's reform has been significantly pushed by external pressure from donors such as the International Monetary Fund.

The workshop demonstrated that there is no single successful path for reform, and that a wide variety of strategies can be successful. Nevertheless, some common lessons emerged. These include the need for a strong independent regulatory authority and for clear and transparent rules and responsibilities. The need to explicitly address social goals such as rural electrification was also high-lighted as a key challenge of restructuring. The full results of the workshop and in-depth analysis will be published in 1998.

In Argentina, the UNEP Centre is investigating implementation issues relating to climate change mitigation options within the context of Argentina's highly competitive restructured electricity industry. Argentina's electricity market contains a number of features with potentially large impacts on the environment. First, the generation market is characterised by great uncertainty, which favours construction of gas-fired power plants with low capital costs rather than hydropower plants with higher capital costs but lower operating costs. As a result, climate change mitigation through hydroelectric power becomes difficult despite Argentina's vast hydro resource. Secondly, all actors in the energy market have a strong incentive to sell as much energy as possible, making utility-led energy efficiency programmes difficult to implement. Given such factors, the UNEP Centre is working with the Instituto de Economía Energética (IDEE) to identify how measures to reduce greenhouse gas emissions can be implemented through appropriate incentive schemes which are compatible with the competitive market. The study is part of a larger study on the economics of greenhouse gas limitations, funded by the Global Environment Facility. Results will be published in 1998.

Integrated Resource Planning

The above discussion highlights some of the many changes occurring in the electricity industry world-wide. In some countries, the planning process is being largely replaced by reliance on market forces and competition to dictate the timing and size of investments in power system expansion, particularly for generation. However, planning continues to retain an important function in most countries and particularly in developing countries, where economies and electricity systems have not developed to the point where market forces alone will mobilise sufficient and cost-effective investment in electricity system expansion.

In many countries, especially those with rapidly growing electricity demand, it can be more cost effective to meet some of the demand for energy services by improving the efficiency of end-use consumption on the demand side rather than relying solely on increasing electricity supply capacity. Integrated Resource Planning (IRP) is a planning methodology which allows equal consideration of a wide variety of means to meet energy service demand, including end-use energy efficiency, cogeneration, and renewables. The goal of IRP is to meet energy service needs at minimum overall cost, including environmental and social costs. While IRP has been widely practised in North America and Europe, no single source of material has existed for providing training to utility planners or university students on integrated planning methods. This lack of training materials is a particular impediment to IRP in developing countries. Recognising this need, the UNEP Centre has produced a textbook entitled Tools and Methods for Integrated Resource Planning: Improving Energy Efficiency and Protecting the Environment. The book provides detailed explanations of IRP concepts as well as numerical examples and problems to be worked out by students. The textbook is expected to be particularly useful in developing countries as well as in Eastern European countries with economies in transition.

Wind Energy

Wind energy is one of the most promising renewable energy technologies available today. With costs falling continually and drastically over the last 15 years, wind energy has advanced to the point where it is roughly economically competitive against several conventional fossil fuel technologies. In a number of countries such as Denmark, Germany, India, UK, and USA, innovative policy mechanisms have been successful in stimulating thousands of megawatts of wind energy development, and such countries' experience offers valuable lessons for other countries considering increasing their use of wind energy.

The UNEP Centre was commissioned by the United Nations Committee on New and Renewable Sources of Energy and on Energy for Development to produce a report outlining the technological, economic, environmental, social, and policy status of wind energy as well as perspectives for future development. The report provides the most up-to-date summary of wind energy information available and was co-written by Risø staff from the UNEP Centre and Energy Systems Group, both in the Systems Analysis Department, and in the Wind Energy and Atmospheric Physics Department.

A short version of the report was delivered to the United Nations in New York in September 1997 and will be published by the UN as a report of the United Nations Secretary-General in early 1998. A longer full version of the report, entitled Wind Energy: Status and Perspectives for the 21st Century, will be published in mid-1998. The two reports should prove highly useful to policy makers pursuing wind energy development options.

Publications in 1997: 31, 32, 101
R. Redlinger and J. Turkson

Industrial Safety and Reliability

Functional models as a basis for failure diagnosis

The development of more and more powerful computers has opened the way for the introduction of robots in a number of fields. The most advanced of these robots are being designed for autonomous operation and, therefore, comprise an extensive software-based operations management system. An important part of this will be a diagnosis program to identify those system states which may prevent the execution of the system mission.

For designers there is a duality in the way the diagnosis is considered, stated as identifying which components are working properly or which functionality is available. For the construction of a knowledge-based diagnostic system it will normally be advantageous to apply a function-oriented analysis. A major part of the development of such a system was carried out in 1997 under a project concerning an autonomous underwater vehicle (AUV). The development, furthermore, constituted one part of a Post Doc project.

Functional modelling methods

The choice of modelling method normally will be between the only two well-developed alternatives, i.e. The Multilevel Flow Model (MFM) and the Goal Tree-Success Tree (GTST) method. MFM is better suited for closed process systems, while GTST is a fairly general hierarchical diagram model relating the different functionalities to each other. In the AUV-project the relations between functionalities were of interest and, therefore, GTST was chosen as the modelling method.

As illustrated in figure 1, GTST features a hierarchical breakdown of goals into subgoals, subgoals into functions (Goal Tree), and finally connects functions to components and software with the capabilities needed to establish the lowest levels of the functional hierarchy (Success Tree). The Success Tree in some cases is best visualised as one where the single components are connected to the lowest level of functions they implement, and the higher levels of the hierarchy proceed downwards. In other cases, where there is a need to visualise explicitly the dependence of each low-level function on the components realising it, the Master Plan Logic Diagram (MPLD) method may be used for drawing the Success Tree. This is illustrated in figure 1 where the components are placed vertically, and a matrix showing the connections is directly visible.

Automatic diagnosis – approaches

Three different approaches have been identified for automatic real-time diagnosis: local diagnosis, model-based diagnosis and a main, centralised diagnosis. The Local Diagnosis is expected to locate single sensor failures, motor and servo failures, software failures, etc. Each module is designed as an "agent", performing an intelligent validation of all input received from other modules or hardware, regarding both sensor data and commands. Furthermore, the module will test its output before submitting it and perform self-tests in the internal algorithms where applicable. The module diagnosis thus is carried out mainly by the module itself, which allows for rather thorough diagnosis algorithms, since both the internal structures and intermediate results are available. However, connected modules also carry out a check on the performance of the module. This is a crude check compared to the internal one to detect situations where the internal diagnosis has stopped working.

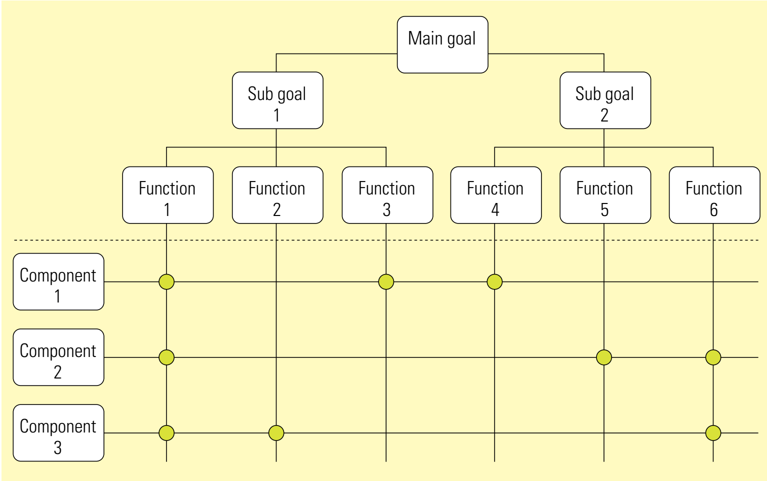
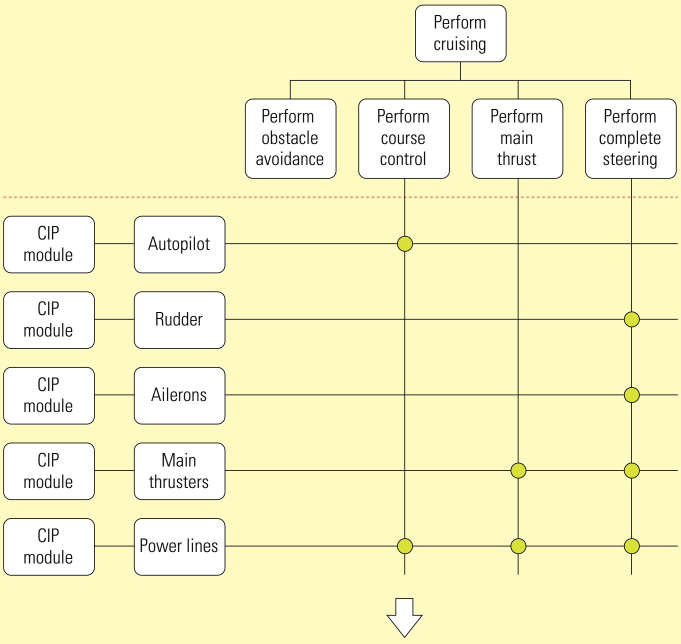


Figure 1
An illustration of the principles of the GTST method

When a problem in a module or hardware is detected, other modules may not be able to carry out commands correctly. Therefore, this approach has to be accompanied by a system to resolve such subsequent reported errors. In the submarine, this is done using a Main Diagnosis System, too.

The Model-based Diagnosis System compares the actual performance of the system with a model running in real-time. The model is given the actual system parameters and status as input. A discrepancy between the model and the physical system indicates a failure. In the submarine, it is used to detect malfunctions in the vehicle hydrodynamic behaviour. The hydrodynamic model of the vehicle uses as input the current state of the vehicle hardware, e.g. thruster speed and fin angles. The outputs are, among others, the vehicle position and speed, which are compared to the corresponding data from sensors. Large discrepancies will be interpreted as failures, whereas small discrepancies will be used to update the

Figure 2 (next page)
An illustration of the transition from the traditional MPLD representation to the Excel representation and further on to the diagnostic rules generated



			Perform_course_control	Perform_main_thrust	Perform_complete_steering
BB-address	BB-value	Autopilot_software	1		
BB-address	BB-value	Rudder_port_side			1
BB-address	BB-value	Rudder_starboard_side			1
BB-address	BB-value	Aileron_port_side			1
BB-address	BB-value	Aileron_starboard_side			1
BB-address	BB-value	Main_thruster_port_side		1	1
BB-address	BB-value	Main_thruster_starboard		1	1
BB-address	BB-value	Power_lines	1	1	1

```
(defrule Perform_main_thrust
      (logical (object (is-a Main_thruster_port_side) (BB-address BB-value)))
      (logical (object (is-a Main_thruster_starboard) (BB-address BB-value)))
      (logical (object (is-a Power_lines) (BB-address BB-value)))
=>
      (assert (Perform_main_thrust))
)
```

model. The detected failures include wave interference, hull damage, and entanglement with wires, seaweed, fishing net, etc.

A centralised Main Diagnosis is a combination of the above two approaches, where all fault detection is gathered in a single module. This facilitates the fault handling, but complicates the detection and requires more data traffic, as the Main Diagnosis needs detailed information.

In the submarine, a combination of all three diagnostic systems will be used. The Local Diagnosis and the Model-based Diagnosis are used as described above. The Main Diagnosis will then use a knowledge-based scheme derived from a functional model of the vehicle to compile the data into a single status representation for the vehicle, thereby extracting the reason for failures.

Elicitation of diagnostic rules from a functional model

The Main Diagnosis System, mentioned above, which deducts reasons for and consequences of malfunctions registered by the local diagnostic functions, is being built on the basis of the functional model by means of an expert system tool CLIPS developed by NASA. The Master Plan Logic Diagram (MPLD) was chosen as the most appropriate tool for presenting the transition between the Goal Tree (GT) part and the Success Tree (ST) part of the model. Unfortunately, the diagrams quickly become very large so that the practical printing and reading turns out to be difficult. In order to circumvent these problems a modular approach was chosen, and the MPLD was implemented by means of Excel spreadsheets.

The process of going from the GTST model to diagnostic rules is illustrated in figure 2. The GT was subdivided into a number of smaller GTs, each representing a subgoal at a certain level. The subgoals at the bottom level of each of these GTs were transferred as column headings to an Excel sheet. The leftmost three columns in the sheet represent the vertical left-hand side of an MPLD for the system, comprising the software and physical components necessary for fulfilling the goal and subgoals of the GT. The traditional MPLD would have horizontal lines from these components and vertical lines from the bottom level of the GT with markings in those crossings where a connection exists, as shown in the figure. Instead of drawing the MPLD in this way we produced it in the form of matrices in Excel spreadsheets, one for each of the GT-diagrams, and the connections are marked by "1"s in the relevant cells. An excerpt of such an Excel sheet is shown in the figure.

The two first columns in the sheet hold names and values of input signals from the local diagnosis system informing about the state of the resource in question.

The matrices written as Excel sheets offer the possibility of an automatic transfer of information from the modelling task to the task of setting up a diagnosis system. A macro has been set up in Excel which can go through a matrix column-wise, testing whether a cell is empty or not. If the cell is not empty (i.e. contains a "1") the macro writes a rule which can be implemented in a CLIPS diagnosis program. The rule concerning column c will be composed of information taken from the column heading and the headings of the rows with non-empty cells in column c. The example shown in the figure is a rule saying that in order for main thrust to be available, the two thrusters in starboard and port side must be available in addition to the two power lines.

Results

In 1997 the modelling of the functions of the AUV with the aim of establishing a logical structure for the reasoning in the knowledge-based diagnosis has been almost completed by means of a Master Plan Logic Diagram model. This model establishes the static relationships between functionalities and system resources.

The diagnosis system has been defined as three separate entities: The Local Diagnosis, the Model-based Diagnosis and the Main Diagnosis, where the latter handles the outputs from the former two. This division is expected to provide a high efficiency in the diagnostic.

A tool for automatic generation of diagnostic rules for the knowledge-based tool CLIPS has been developed as a Microsoft Excel application. The automatic generation of rules gives a much better overview of the MPLD data and facilitates the correct implementation of changes as a consequence of design changes, since the text has to be written only once, namely in the model. So far, it has been implemented only for the interface between the Goal- and the Success-parts of the MPLD; but the method must be further developed to comprise the whole model.

Publications in 1997: 61, 62
Kurt Lauridsen, Palle Christensen
and Henrik Ø. Madsen

Industrial Safety and Reliability
Land Use Planning and Accident Scenarios

Any choice we make: choosing a technology, making design decisions, or setting the course, has consequences for safety. Aiming for a safe society one must be mindful of the most sensitive decisions affecting safety, and this includes the issue of land use planning. Here technical installations are situated geographically in such a way that not only restrictions on safety and environmental impacts are fulfilled, but also practical and economic consequences are emphasised. One therefore has to have an overview of different risk factors and accident scenarios and be able to operate in a risk-benefit space, when options are compared and evaluated. The land use planning decision always has a double base in that it draws on both technical and political facts, so the decision output reflects risk knowledge as well as societal trends and political preferences.

The development of a methodology for land use planning involving chemical sites is the issue for the LUPACS project, being run under EU's Environment and Climate programme. Decisions on land use are typical multicriteria decisions and the method developed shall be practical for planners in local and regional administrations. The project is coordinated by Risø and the team pairs different European academic groups with Danish and Swedish planners.

On a European scale the Seveso case served as the demonstration reminding us that a chemical plant may suddenly change into a source of pollution and human suffering, indeed we are still installing processing plants and gas tanks within reach of residential areas. Being cognisant of this requires thorough risk analyses and careful planning, where the collective knowledge of accidents and risk control is put at the disposition of planners, who are generally not risk experts.

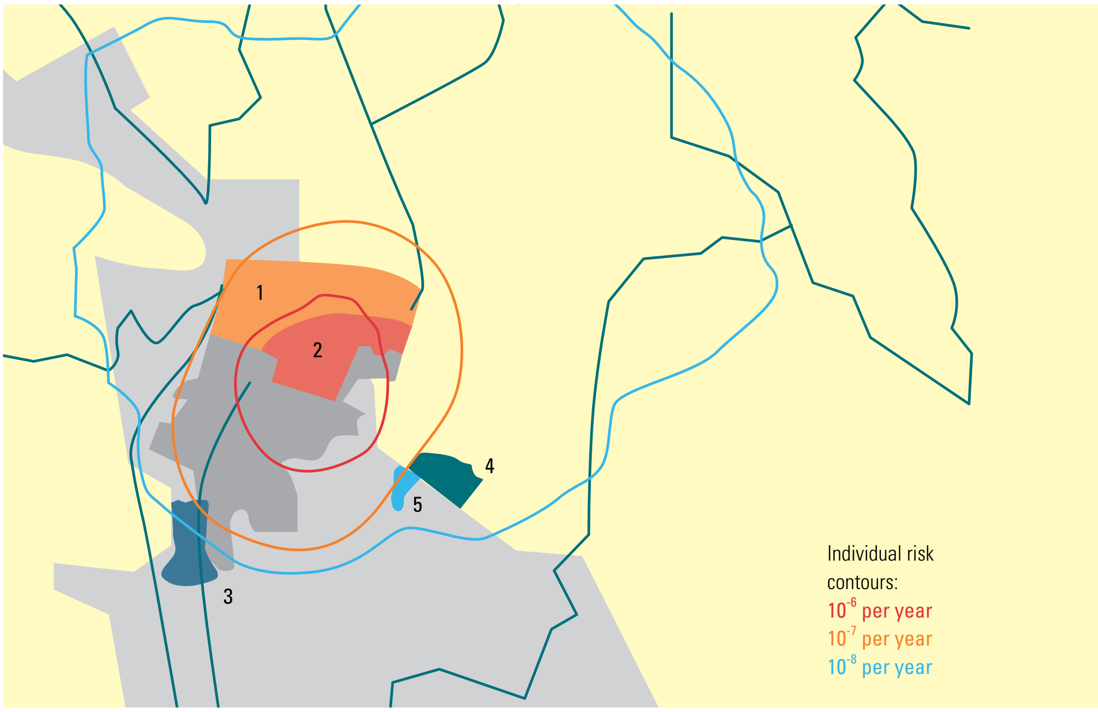
The MEMbrain project treated a parallel problem, namely how risk knowledge and accident experience can be made available in an overview form for emergency managers. A frame for presenting and overviewing accidents was developed together with an accident model and a model for emergency actions. A main issue was simplicity and ease of use in a dynamic environment, where focus is put on specific events and their possible developments and consequences. In the planner´s office, time stress has a different quality, but like the risk analyst the planner shall operate on the set of risk sources, accident scenarios and environment representations: buildings, humans, traffic systems, recipients etc. The planning process focuses on gathering the integral consequences in terms of both benefits and costs from choosing whatever planning solution, and judging these consequences on society's scales.

The LUPACS methodology structures the planning decision process as a sequence of seven steps, which one can loop through as many times as required in order to narrow down on a preferred solution:

– formulation of the decision situation
– description of the case
– specification of objectives
– development of alternatives
– assessment of benefits, costs and consequences
– evaluation, choice
– presentation, communication.

To support this process, the planner will receive suggestions for objectives and corresponding indices, and mappings like GIS-images and suitable risk curves should be made available to the planner for viewing and manipulation. Two planning cases – one in Denmark, one in Sweden – are used as testing gear for finding whether the proposed decision frame, scheme of objectives etc. makes sense to planners. The Greek partner, NCSR-Demokritos, has developed software for some of the calculations and presentations applicable to multicriteria decisions, and the Scandinavian cases were treated with the Greek system to produce the "efficient frontiers". The ability to present accident effects and environmental impacts on geographical maps together with optional land uses will support discussions and decisions, and is a step forward in risk communication as well. Land use planning requires planners to communicate safety aspects and environment aspects with politicians, and in some cases public hearings take place. For these purposes it is practical to demonstrate geographically the consequences of each alternative and the options available.

This first experience shows that concepts from risk engineering may not be immediately taken over by the physical planner, but the potential for interacting with the risk mappings is an obvious quality that can first be appreciated, after these functions have been made available on the planner´s desk for trials and experiments. Running the two cases required considerable support to the planners from risk specialists in making calculations and organising data to establish the required input. Results from these runs have been instrumental both for discussions of the concepts involved and for specifying user needs, which is the next program topic in LUPACS.



Risk contours on a map with planning options. Risk is represented as the probability that an individual may die as a result of a plant accident.

1 Additional residential area
2 Expansion of the plant
3 Additional residential area
4 Additional residential area
5 Extension of school
dark grey: town centre/residential area
light grey: municipality boundary

A basic reference for risk reviews and risk calculations is the set of possible accidents selected to be appropriate for a case under consideration. Both the MEMbrain and the LUPACS projects have acknowledged the dominant role played by accident scenarios as a basic language for dealing with risk. The qualities and limitations of the accident scenario as a bearer of essential risk information need to be thoroughly investigated in order to point out possible flaws, with which one ought to be aware, when assessing risk.

Publications in 1997: 25, 48
Carsten D.Grønberg, Birgitte Rasmussen and Nijs J.Duijm

Industrial Safety and Reliability

Establishment of a particle tracking experimental facility

The dispersion of contaminants in the atmosphere is of major concern in many Risk studies. Over the years Risø has conducted a large number of field tests using up-to-date equipment. Today experiments tend to focus on plume structure. The fluctuating nature of concentrations is a common feature of dispersion experiments. The signal from a concentration sensor detecting gas some distance from a release is usually profoundly intermittent with periods of large peaks alternating with 'quiet' periods where no gas is detected. The relevance of this observation for e.g. explosivity of clouds of flammable gas is obvious, yet at the moment relatively little can be done in order to quantify concentration fluctuations.

Turbulent diffusion results from the advection by the turbulent velocity field, while 'ordinary' diffusion, such as the diffusion of ink on a wet piece of paper, is a result of Brownian motion. The Brownian motion acts independently for individual ink particles making them follow independent paths. In turbulent diffusion the situation is different because nearby particles tend to follow similar paths. As a result particles tend to arrive in clusters, and the concentration signal becomes intermittent. The Particle Tracking project initiated in 1997 aims at studying this effect by means of controlled experiments. The Particle Tracking project is a joint project between the Systems Analysis and Wind Energy and Atmospheric Physics Departments (both at Risø), sponsored by the Danish Technical Research Council.

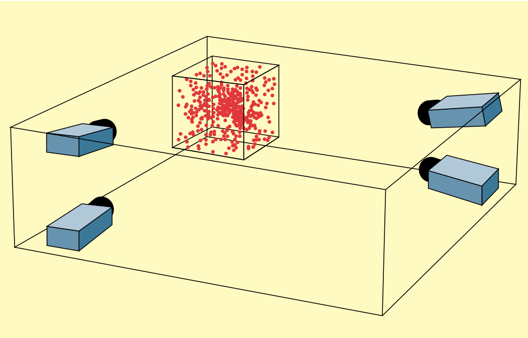
Particle tracking is an experimental technique that consists of measuring individual trajectories of small neutrally buoyant particles added to the flow. This is done by digital image processing and stereoscopic methods. In recent years the improved performance of commercially available standard processing hardware (frame grabbers, on-line compression cards, harddisks) has made the method a serious possibility. So far particle tracking has been confined to two-dimensional flows. The project aims at extending the technique to three dimensions.

The goal for 1997 has been to design, build and test a particle tracking experimental facility. It consists of a water tank measuring 32x32x45cm^3, a turbulence generator, 4 synchronized CCD cameras, a powerful synchronized xenon flash light and two computers. The idea is to have a water tank with a (statistically) stationary turbulence. The turbulence is generated by two oscillating grids placed at the top and at the bottom of the tank. Using two grids (instead of one, which has been done more often) has two major advantages: it produces a fairly large region at the tank centre with nearly homogeneous and isotropic turbulence, and there is practically no mean flow. Truly homogeneous isotropic turbulence is an abstraction, but it still plays a dominant role in turbulence theory, because symmetry makes the cumbersome mathematics easier to work with, and because real turbulence has a tendency to approach isotropy as it develops to smaller scales (those scales that are responsible for in-plume mixing). The lack of mean flow means that eddies 'sit still' making it possible to study directly the dynamics of eddy interactions and also how particle paths diverge. This would be extremely difficult to do for turbulence produced in a boundary layer or by a grid in a windtunnel, since here a large mean flow removes eddies so quickly that it effectively prevents the detection (by means of a stationary sensor) of any time evolution. As a result relatively few experiments have been made to study the temporal evolution of turbulence phenomena.

The motion of the particles is recorded by four CCD cameras as illustrated in figure 1. The camera output is fed to two computers each equipped with a frame grabber, which digitizes and compresses the information and stores it directly on the hard disk. This enables the taking of long sequences of high quality.The cameras, flash light and computers are all synchronized.

The mechanics, synchronization electronics and light source have been designed and built by Risø, but otherwise commercially available standard equipment has been used. Standard video uses interlacing (alternating between odd and even lines) so that only half of the lines are exposed at a time. This considerably reduces the resolution of pictures along vertical directions, but the problem is circumvented by firing the flash light while both half-pictures are open for exposure. The frame grabber subsequently processes the pictures as interlaced, and eventually they can be combined into full images.

The outputs from the four cameras are analysed and transformed into particle tracks in space. A stereoscopic image can be made from just two cameras (or two eyes), but certain ambiguous particle configurations exist. With four cameras this problem is essentially eliminated. The transformation, made by software developed by Risø, is done in a series of steps. The individual images are made up of pixels corresponding to tiny square light-sensitive elements on the CCD chip. Since the pixels have a finite size light hitting one particular pixel will belong to a narrow bundle of rays inside the tank with a cross section of about 0.25mm. This would normally mean that the spatial resolution is 0.25mm, but actually it is possible increase this accuracy by almost an order of magnitude.



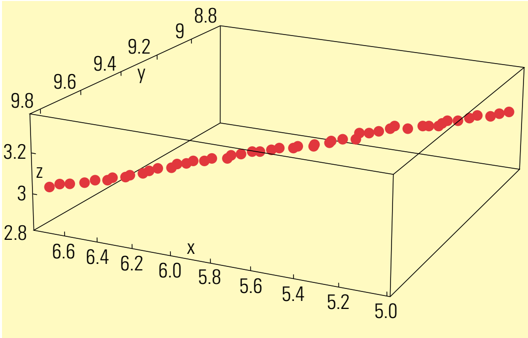


Figure 1 (left)
Particles are tracked by means of stereoscopy using four CCD cameras.

Figure 2 (right)
Reconstructed three-dimensional trajectory of a slowly moving particle. The dots show the particle centre while the actual particle is much larger than the dots. Numbers on the axes are in mm.

Clearly, if the image of a particle is focused within one pixel the information about the exact location within that pixel is lost. The trick is therefore not to focus, but instead deliberately make large images (covering 9 pixels, say). The intensity at nine pixels essentially gives nine equations to determine the centre of the image, which is more than sufficient. After having localized particle centres on the images these are transformed into rays in space and the particle positions are found where rays from all cameras intersect. The final step is to make tracks by identifying particles from one instant in time to the next. The system is capable of tracking about 1000 particles simultaneously.

Figure 2 shows an example of a particle track made during testing. The flow is very slow, and the particle moves only 3mm in ten seconds. In this laminar flow the particle trajectory is in reality smooth and the observed jitter is due to the inaccuracy of measurement. The volume overlooked by the cameras is much larger than shown (about 140mm across) indicating a spatial resolution beyond that obtainable from direct numerical simulations using any existing supercomputer.

The plans for the near future are to make a thorough characterization of the turbulent flow in the tank measuring the full Eulerian spatio-temporal velocity correlation tensor and to proceed investigating Lagrangian statistics of particle pairs and clusters of particles. The experimental results will be used in the CONFLUX project and other Risø projects concerning concentration fluctuation modelling. Such models typically rely on a number of simplifying assumptions of a statistical nature that are difficult to bring to direct tests, except by means of particle tracking. The hope is that the facility will be used in this way to test models of practical applicability as well as to investigate turbulence problems in general.

Søren Ott

Industrial Safety and Reliability
Uncertainty in Risk Analysis

All risk analysis studies are subject to considerable uncertainties. These studies contain a series of steps like hazard identification, identification of accident scenarios, determination of failure rates of components and systems, and consequence analysis. Uncertainties are introduced at all steps in the analysis and originate from different sources such as the failure statistics that are used to determine the accident frequencies and the consequence models that are applied to determine the impacts on the environment.

The risk analysis may have important implications for society. In order to be able to make correct decisions on, e.g., the acceptability of a facility, the analyst should provide information about the uncertainty of his/her analysis. In practice, this information is often lacking or incomplete. Risø has been involved in a number of activities that aim to shed light on the uncertainties related to different steps in the risk analysis process.

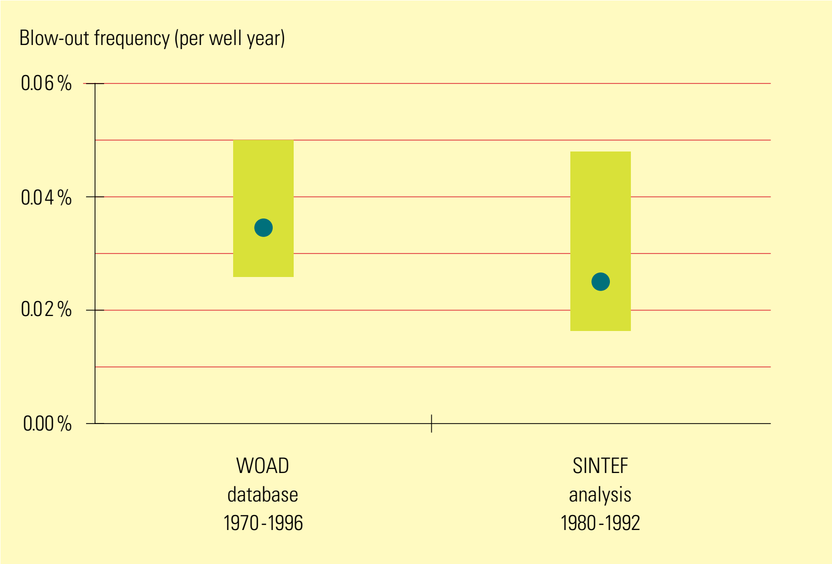
With respect to consequence modelling, Risø has been involved in improving the quality of dense gas dispersion models through a variety of activities. These activities included the FLADIS field experiments with releases of pressurised ammonia, a collection of experimental data on dense gas dispersion in an easily accessible format (REDIPHEM) and also the membership of the Heavy Gas Dispersion Expert Group. The Heavy Gas Dispersion Expert Group produced lists over available heavy gas dispersion models and experimental data sets as well as an evaluation protocol for heavy gas dispersion models, which was tested by means of a small, publicly accessible evaluation exercise. The Group finished reporting these activities in 1997.

These type of activities continued in 1997 within the EU project "SMEDIS - Scientific Model Evaluation of Dense gas Dispersion Models", co-ordinated by HSE, UK. About 15 European organisations cooperate in this project. Each partner puts forward one or more of its dense gas dispersion models, which subsequently will be evaluated, both with respect to the scientific basis of the models as well as by means of comparing model results with experimental data. Following recent progress in describing dense gas dispersion in more realistic, complex situations, such as terrain with obstacles and phase transitions, these complex effects are evaluated within the project. Risø contributes to this project by bringing in two different dispersion models. The first one is Risø's one-dimensional model GReAT, the principles of which have been developed some 10 years ago. The model is in use at several institutes and consultant firms in Scandinavia. The second one is the recently developed two-dimensional shallow-layer model SLAM, which can handle flow over sloping terrain. The SMEDIS project makes also extensively use of Risø's collection of experimental data REDIPHEM. Following the experiences from, e.g. the FLADIS experiments, Risø's activities in connection to SMEDIS in 1997 have been focused on the correct method to describe instantaneous clouds, a method that now is included in the GReAT model.

Also in other areas of consequence modelling attention is paid to the problem of uncertainty. In 1997, this was focused on fires involving hazardous chemicals. This work considered the interdependency of the subsequent steps in a risk analysis study. In particular, this work showed the importance of the proper definition of scenarios for fire development with respect to the physical boundary conditions, and how laboratory experimental data on the combustion of chemicals can be transferred to the different phases in these scenarios.

The work in the EU-supported Model Evaluation Group (MEG), chaired by Risø, was continued in 1997. The emphasis was laid on dissemination of the results from the work on models for heavy gas dispersion and vapour cloud explosion and on launching new activities on models for human errors and momentum fires. The activities of MEG were presented at a meeting in Austria for the competent authorities from the EU member countries, who are among the major users of the results of the MEG activities.

Risø is frequently asked to review and comment on risk analyses submitted to Danish authorities. In 1997 two of these cases dealt with new concepts in offshore installations. In one case a review was performed on the data used to determine the probability of a blow-out in the Danish sector of the North Sea. Fortunately, blow-outs are rather rare on the North Sea, but this also means that the blow-out frequency obtained from the statistical material available from off-shore operations in the North Sea is rather uncertain. By using the larger amount of data available from operations world-wide, the uncertainty in the derived blow-out frequency becomes less, but it prevents one from distinguishing between different types of equipment or differences in the geophysical conditions. A similar problem arises when one wants to exclude "old" technology by limiting the data to recent years only. By reducing the size of the data set, the uncertainty in the derived blow-out frequency becomes larger. In such a case it can be very hard to show significant trends in blow-out frequencies as in Figure 1. If one considers mean values only without taking into account the



Blow-out frequencies at off-shore production platforms derived from two different datasets covering different periods. The red area indicates the 90%-reliability interval.

uncertainty, and this is done very often, one concludes that the blow-out frequency in the period 1980-1992 is lower than in the period including the decade before. But if one does consider the statistical uncertainty, this conclusion is no longer so certain. These aspects need to be considered when selecting the "right" data for a risk analysis.

Finally, it is not solved how the decision maker can handle uncertainty in risk analysis. Modern legislation might require that the risk analyst provides information on the uncertainty, but it does not give guidance as to how this uncertainty might affect the decision on whether a new operation should be accepted. Next to continuing research to improve the knowledge on the various elements that contribute to the overall uncertainty of risk analysis, Risø will also address the implications of uncertainty on decision making in the coming years.

Publications in 1997: 4, 18
Nijs Jan Duijm and Kurt Petersen

Man/Machine Interaction

An information system architecture for engineering designers

Engineering design is a cross-disciplinary activity in which people with different areas of expertise often collaborate. Rapid advances in technology, decreasing product life-cycles, and globalization of enterprises with the attendant need for information concerning legal, regulatory, and environmental concerns necessitate the exploration of many different information sources concurrently. During 1997 we have developed an architecture for an information system to assist designers using the Internet, based on an empirical, cognitive field study of designers´ work, system requirements and information needs. Secondly, we have investigated and implemented current software required for this architecture that is available on the Internet.

The computational architecture is based on integrating relevant tools to provide a transparent interface to a variety of information sources. The architecture describes the components of the system and how they interact. Different functionalities are encapsulated inside software 'agents' that interact with one another, and with users. Scripting languages, web and interface development tools are used extensively, to enable typical users to adapt to the 'system', without having to learn special-purpose, lower level, computational tools and languages.

In addition to providing access to information sources, the information system architecture facilitates the collection of information from designers online, so that individual designers can input data that will become part of the overall system. Appropriate agents organise and integrate the data collected from designers. Regular updates and means for data collection online ensure that the information is current and relevant.

The system functions in a passive mode presenting information when requested, or in an active mode offering suggestions and presenting options, in addition to providing the requested information. Provisions are available to develop individual, personalized, databases.

Important functionalities of the information system include data-base - and classification systems to gather, organise, store, retrieve, and present relevant information, including data on expertise, needs, design histories, bibliographic sources, standards, rules, regulations, hand-books, images and audio and video information, possibly live, cross-indexed for projects within an enterprise. Other important functionalities include visualisation of the classification schemes that represent the boundaries of the information space for each of the work domains, and customizable interfaces that are compatible across a large number of work domains and their heteregeneous information sources in databases. It is also important to provide the ability to handle a variety of file formats, and to 'translate' between different subject matter domains, using appropriate thesauri. Finally, means for handling inputs from designers and merging with existing databases will be required.

Development of the structures for organising these basic information clusters and the design of the protocols for interaction among the various blocks are active research areas. The software infrastructure is being built around a core comprised of the operating system, around which there is a layer with software such as Perl, Java and web clients. On the outer layer are CGI scripts, GUI tools, and database programs. We plan to adopt the HLA architecture for integrating the various pieces of software.

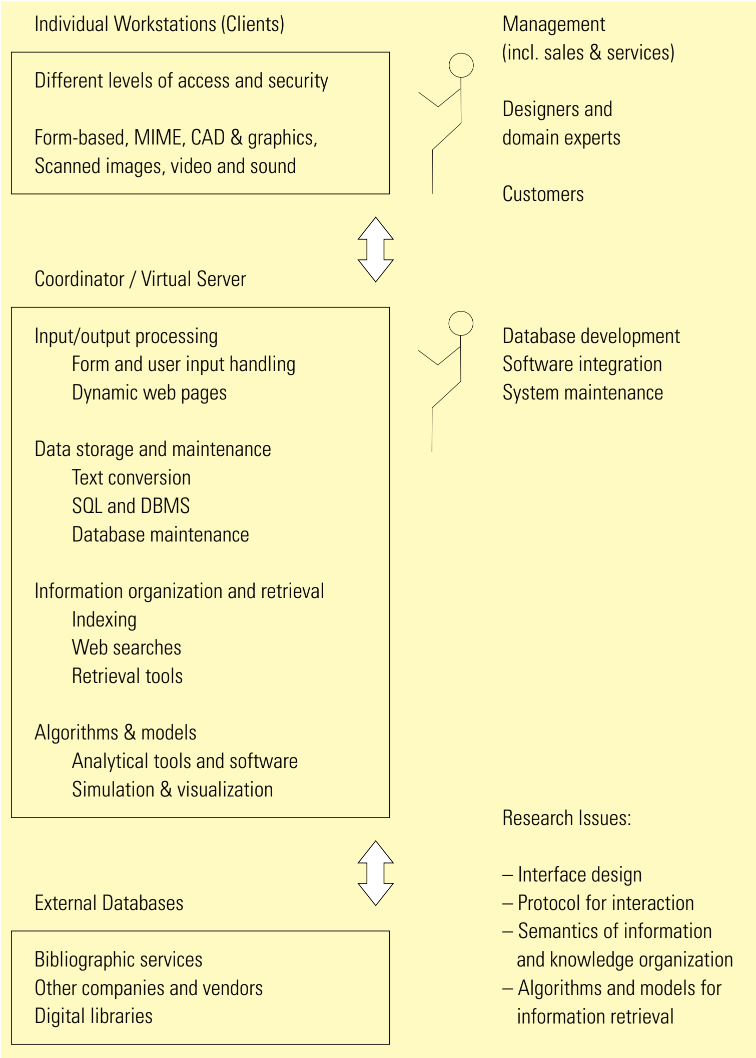
The specified software system functions in a distributed environment, with a main server, several mirrors, major subsystems for specific databases and individual workstations, which primarily are web clients to be used by designers. The operator interface is comprised of a combination of web tools, Java applets and applications and CGI scripts.

Listed next are some of the software tools, by functionality, that are appropriate for developing the information system for design support.

1. Search and retrieval programs that index and provide information by linking to the sources. For instance, Perl modules that provide low - level functionality, such as opening remote files and text manipulation routines, can be used to identify sources of information on a given topic. Using keywords chosen by the user, relevant information can be shown on a web browser linked to other components.

2. Database systems with form-based web interfaces can help organise information generated by users. For instance, data about possible vendors of a specific technology can be conveniently organised using mSQL, a database system integrated with Perl or Java modules that form the 'front-end' to mSQL.

3. Web software to link the databases to spreadsheets can be adapted, e.g., using Apple Computer's WebObjects, or written in a scripting language such as Perl.



The system architecture and the key functionalities desired.

Components of the system architecture have been implemented. These include a simple database for expertise, indexing and retrieval, and a filter for bibliographic information. The interface is provided through web clients. Additional components are being tested and added to build the system incrementally. Future work includes the implementation of the system in actual design environments followed by an evaluation of the effectiveness of such a system architecture using the Internet tools to improve engineers' information seeking possibilities for new approaches during design.

Publications in 1997: 21, 22, 23, 58, 59, 66, 91

Annelise Mark Pejtersen

Man/Machine Interaction

Simulation of helmsman steering performance

Modern large sea carriers are designed for autopilot-controlled fast and fuel-saving ocean crossing. Their large moments of inertia and generally sub-optimal steering characteristics at low speeds make it difficult to steer such a vessel with the precision required during harbour approaches and movements through narrow straits and inland waterways. Course shifts involved in keeping a large ship on a safe track within a sea traffic lane or other restricted waters are planned by the navigator on the ship bridge (usually the captain or a pilot hired for the navigation task). Major course shifts necessary to follow an angled or bended track are typically effectuated via rudder commands from the navigator to the helmsman (usually a mate). In waypoints where only a minor course correction is required the navigator will normally command the helmsman to enter the vessel on its new course without specifiying a rudder angle. The helmsman is then charged with the task of acting as an autonomous controller of the ship's heading. A helmsman complies with a course command by setting the ship into rotation around its vertical axis and by stopping the turn when his compass repeater indicates that the vessel is on the commanded course.

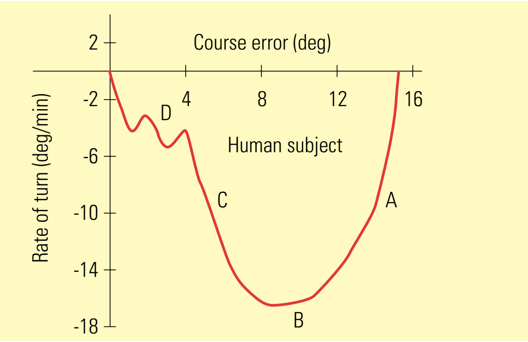
In the EU project SAFECO (Safety of Shipping in Coastal Waters) Risø and the Danish Maritime Institute (DMI) have cooperated on the development of a helmsman model which can be used to simulate ship tracks in turns performed by helmsmen of varying rudder manipulation skills and preferences. The DMI has implemented the model as a component of a desk-top simulation system that simulates navigator track planning as well as track following in which the course shifts are effectuated by the helmsman. The purpose of this extended system is to present a simulation methodology for the assessment of maritime collision and grounding risks and the design of passageways for large ships.

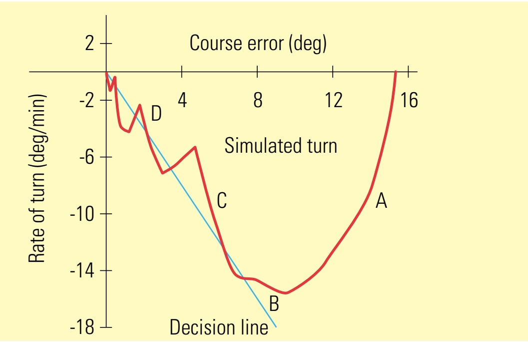
In the helmsman modelling work carried out at Risø an advanced mathematical model of a 70,000-tonne container vessel was used to represent the steering characteristics of a large modern sea carrier. The mathematical ship model is based on PMM (Planar Motion Mechanism) model tests in the laboratory facilities available at DMI. These tests provided a series of non-dimensional coefficients representing the hydrodynamic forces and moments acting on the vessel. A simulation program whose time steps generate a numerical solution of the associated equations of motion for the vessel was written and installed on a separate computer interfaced to the computer which accommodates the helmsman model. The latter interacts with the simulated ship from a simulated helmsman console which displays a compass repeater and a rate-of-turn indicator. A scroll bar indicates the rudder setting and makes it possible to steer the ship model manually in experiments with human subjects.

Data for defining the structure and parameters of the helmsman model were recorded in an experiment in which three DMI staff members with professional knowledge of ship steering served as subjects in an experiment in which they performed a large number of turns with the simulated vessel. In these turns the ship model was adjusted to simulate a speed of 12 knots (6.2 ms^{-1}). This is half the maximum speed for this type of vessel and a reasonable choice for simulating the manoeuvring of a large carrier in restricted waters.

The helmsman model consists of three parts: (1) a model of the sequential rudder actions used by experienced helmsmen to turn a ship into a new heading, (2) a feedforward control model of the rudder settings a helmsman uses to start and halt a turn and (3) a dynamic control model of the gradual rudder adjustments which are necessary to finish a turn gracefully. Together these three model components represent a helmsman's control strategies and knowledge of the ship's response to the rudder. The two diagrams shown are phase plots in which the turn rate of the ship is plotted

Phase plots of an anticlockwise turn of 15 degrees (turn to port) performed by a human subject (left) and a corresponding simulated turn (right). The capital letters refer to rudder settings (see text).





against its course error in a course shift of 15 degrees to port performed by a human subject (left) and course shift of the same characteristics simulated with the helmsman model. The principal rudder control actions involved in this example are: (A) setting a rudder angle which provides the ship with an anticlockwise angular acceleration, (B) returning to midship rudder to prevent the turn rate from becoming too large, (C) switching to counter rudder to decelerate the rotation of the ship and (D) alternating between midship rudder and decreasing counter rudder angles to terminate the turn with little course overshoot or undershoot.

In the model a helmsman's decision to switch to counter rudder is represented by a parameter α which is measured in time units and portrayed by a decision line through (0,0) in the phase plane defined by course error and turn rate. A helmsman who prefers to terminate his turns by gradually reducing the counter rudder angle, as in the above example, is simulated by an α value of 20-30 seconds. A smaller α value of 10-15 seconds produces a simulation of a helmsman who favours a fast overshoot strategy with resulting heading oscillations of decreasing amplitudes.

The three subjects' choice of acceleration rudder and counter rudder settings in the helmsman experiment were characterised by large coefficients of variation of 40 to 50%. This observation suggests that a helmsman's individual skills and preferences may have a significant influence on the cross-track deviation in course shifts performed with large ships. The variability exhibited by the subjects' rudder settings has been included in the model as fluctuations simulated by a Normal distribution. A truncated exponential distribution appeared to be a reasonable choice for simulating the variability of the α parameter and the time intervals between a helmsman's readings of the heading and turn rate of the ship.

The prototype version of the helmsman model was implemented as a Smalltalk object embedded in a Digitalk Smalltalk/V development environment to which classes have been added to bring about an interactive communication link to the ship model. This design made it easy to re-implement and install the model in the C^{++} desk-top simulation system at DMI.

Leif Løvborg

REGINA MÆRSK, the world's largest container vessel with a capacity of 6,000 TEU, is the first in a series of 12 currently being delivered from Odense Steel Shipyard. Photo: Maerskline.

Man/Machine Interaction

Pilot´s behaviour during critical take-off scenarios

It would be misleading to characterise the take-off phase of modern airliners as a critical phase - yet, about 10-15% of all civil aviation accidents happen during take-off. While accident rates of all types are, in general, very low in airlines in the developed world, large efforts are being made to reduce their number, not least because of a forecasted doubling of departures within the next 15-20 years. Due to the relatively critical nature of pilot behaviour during take-offs, it is of considerable interest to determine to what extent a pilot's attention and visual orientation patterns are changed when, for instance, symptoms of degraded performance of the aircraft appear.

Figure 1
The Airbus simulator at Aerospatiale, Toulouse, where each of the pilots is wearing an eye tracker during the experiment described in the article

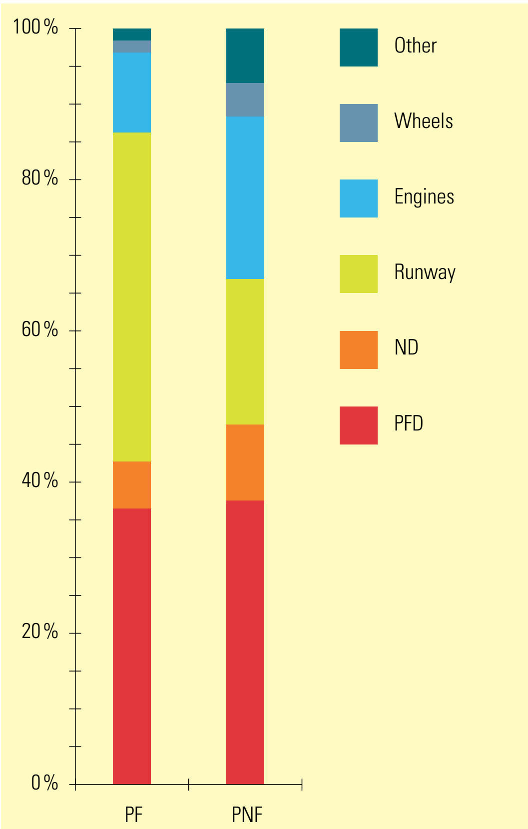


Figure 2
The diagram illustrates the distribution of visual attention of all Pilots Flying and all Pilots Not Flying across several take-off scenarios

During take-off pilots have well-defined tasks to carry out. The Pilot Flying (PF) takes care of steering the plane on the runway. The Pilot Not Flying (PNF) scans the instruments, announces specific speeds, i.e., 100 knots, (for example) V1, and Vr. The decision speed, V1, is calculated in advance of the take-off and lies around 120-140 knots for modern jets. Before V1, the captain may decide to reject the take-off. If the take-off is rejected after V1 has been reached, there may be too little runway left to enable the aircraft to come to a safe halt. If the captain does initiate a rejection of the take-off (an RTO) - and it is always the captain's decision to do so - the earlier this is initiated, the safer. It should be noted that when a take-off is rejected, the entire kinetic energy of the aircraft has to be dissipated as frictio-nal energy to the brakes. Finally, at Vr, the rotation speed (around 140-160 knots), the PF "rotates" the plane and it lifts off from the runway.

The French aerospace company Aerospatiale SA (main Airbus partner) has contracted Risø to carry out an experimental investigation of pilot behaviour during critical take-off scenarios. The experiment, which has been carried out as a collaborative project between Aerospatiale and Risø, was conducted in a fixed based ("no motion") simulator in Toulouse, simulating the heaviest aircraft in the Airbus family, the A340, Figure 1. It was of special interest in the study to determine the visual cues the pilots uses during so-called abnormal take-offs. The study involved the use of two eye trackers and Risø's analysis tool (Multimo) in combination with Risø's expertise in using eye tracking as a source of information gathering in real time, technical environments.

For the main experiment of the study, Aerospatiale had recruited 10 Airbus crews (20 pilots) and each crew went through six take-off scenarios twice in random order. The scenarios were not known to the pilots in advance. Altogether, 120 take-off trials were recorded, each trial yielding eye tracking data from both the Pilot Flying, PF, and the Pilot Not Flying, PNF. The video recordings along with the log from the simulator were synchronised using techniques developed at Risø.

The study confirmed that there is a significant and entirely expected difference between the PF and the PNF, i.e., the former looks much more at the runway and the latter much more at the instruments, Figure 2, which illustrates the distribution of visual attention of the pilots between 80 knots and V1 at 140 knots. But the study also showed that the visual attention of each of the pilots does not differ systematically across a range of normal and abnormal scenarios. In fact, pilots' distribution of visual attention

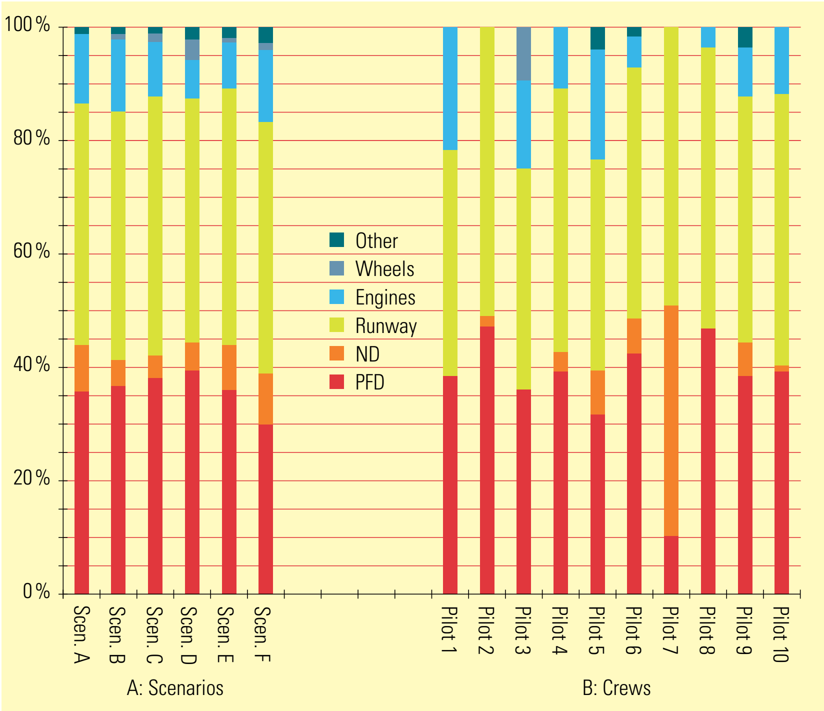


Figure 3
Distribution of averaged visual attention of ten Pilots Flying across six scenarios in terms of frequency of focus, speed above 80 knots and below V1 or rejection. The left-hand side (A) shows pilots' distribution of focus for each of six different scenarios. The right-hand side (B) shows each of the ten pilots' distribution of focus across the six scenarios

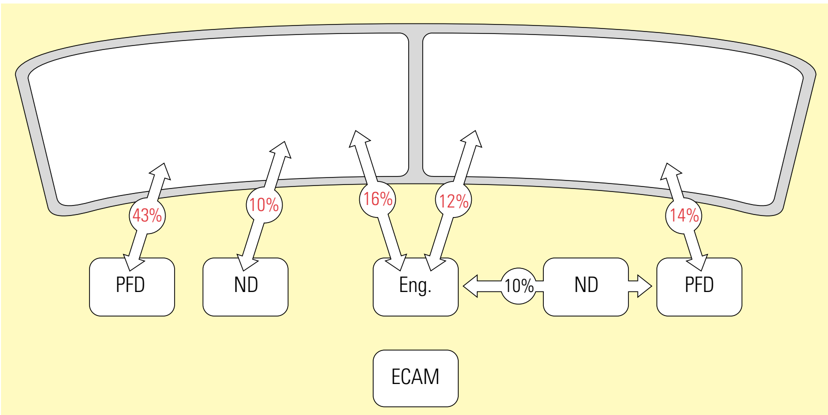


Figure 4
The three most frequent eye fixation transitions for the PF (left) and the PNF (right) overlaid on instruments and runway for speed above 80 knots and below V1 or RTO. The figures on the arrows indicate the percentage of total transitions

to specific instruments and runway across widely differing scenarios is surprisingly uniform, Figure 3A. In contrast, for any given selection of scenarios, there are rather great differences among pilots flying and among pilots not flying, Figure 3B. The study also analysed the eye scan patterns of the PF and PNF between 80 knots and V1 or RTO. The scan patterns are defined in terms of transition of pilots' focus to and from a given instrument or the runway. It was demonstrated that there was no significant difference between scan patterns of normal and abnormal scenarios before rejection of take-off, Figure 4.

Steen Weber and Henning Boje Andersen

Man/Machine Interaction

Assessment of mariners' perception of safety issues

A questionnaire survey has been carried out among seafaring personnel in five shipping companies focusing on factors which have an impact on safety at sea. The survey was based on the Ship Management Attitudes Questionnaire, developed as a joint project by Risø, the Danish Maritime Institute (DMI) and the University of Texas (NASA/FAA) Aerospace Crew Research Project. The Ship Management Attitudes Questionnaire was distributed to seafaring personnel in five shipping companies during 1997 (four Danish companies and one Asian company).

awareness of human factors issues. In aviation, the data are used to determine what actions, if any, are needed to enhance the organisational structure and safety system and to define training needs for personnel training. Findings from the survey are presented in confidential reports to individual companies, but published reports will describe results in anonymous form, de-identifying the participating companies.

A	B	C	D	E
disagree strongly	disagree slightly	neutral	agree slightly	agree strongly

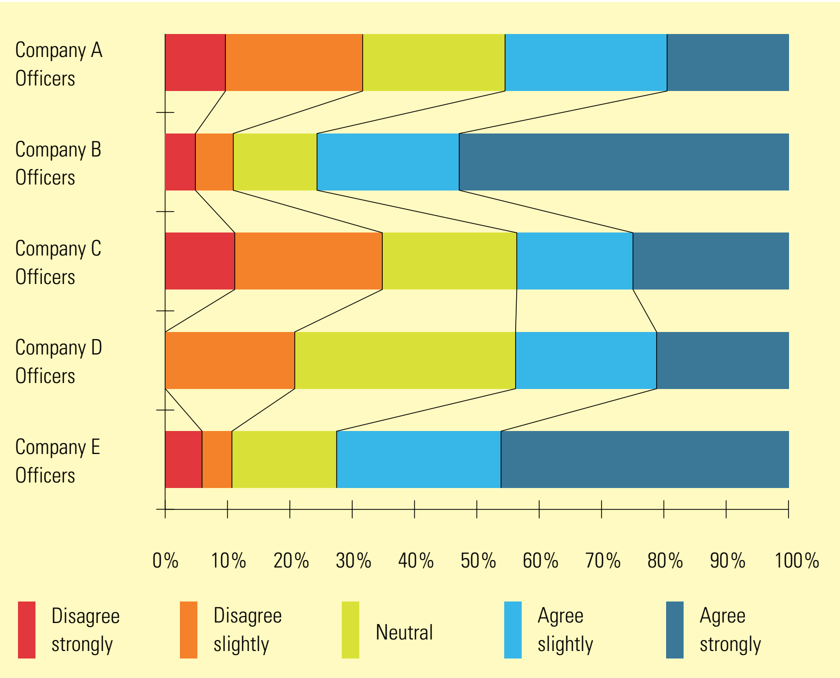
In total, 1462 questionnaires (out of 4100 distributed) have been returned to Risø, where data input and processing have been carried out. Since excess questionnaires were placed aboard ships, the response rate cannot be determined precisely; however, the rate of response is almost certainly above 30%, and it appears to be well above 40% for deck and engine officers.

Organisations can use survey results to assess their organisational culture, in particular the perception by employee groups of their organisation's safety values and system and their attitudes to and

The survey shows that the practices and attitudes reported on by mariners are, in general, sound. However, there are notable differences among companies, and there is room for improvement on several points in each of the companies surveyed.

Most of the questionnaire items were formulated as statements to which respondents were asked to indicate their agreement – "Please answer by writing beside each item the letter from the scale below": It is a well known that questionnaire answers have a tendency to group around the middle answer (C). The interpretation of results has to take this tendency into account.

Figure 1
Distribution across five companies of mariners' responses to the statement: "I know the proper channels through which questions regarding safety procedures should be routed"



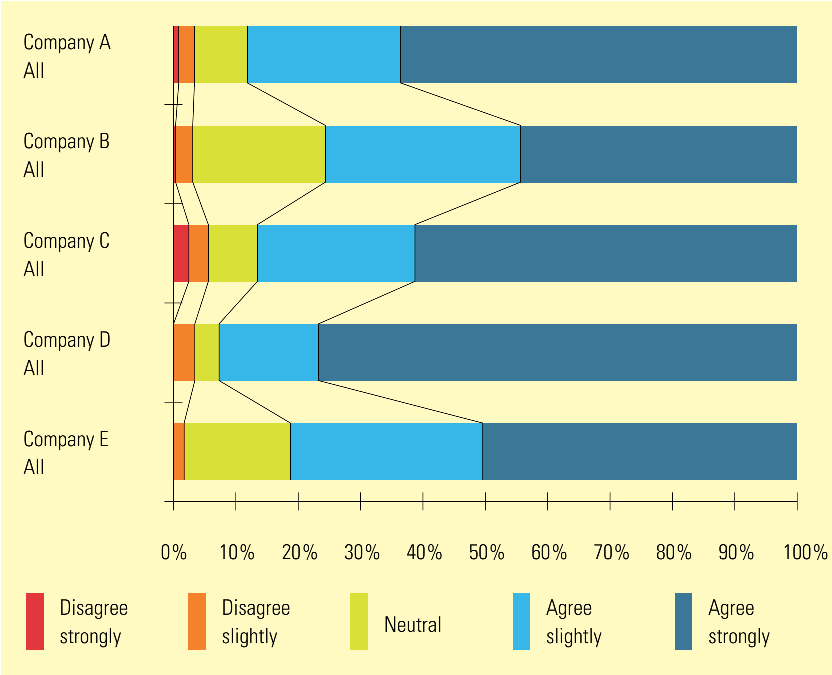


Figure 2
Distribution across five companies of mariners' responses to the statement: "Accidents and near-misses are always reported according to company orders"

Some of the questions asked respondents about their knowledge about ways of reporting critical safety issues. In general, a very large majority of mariners reported that they are well aware of how to report safety critical issues. Thus, when asked to indicate agreement or disagreement with the statement "I know the proper channels through which questions regarding safety procedures should be routed", a large majority of respondents expressed (slight or strong) agreement, while a very small minority expressed disagreement (see figure 1 which shows the relative distribution of responses for the five companies surveyed).

On the other hand, in some of the companies about a third of the officers responding reported that checklists and briefings are omitted or handovers not carried out properly in at least 40% of the cases. While in other companies only a very small minority of officers reported such a relatively high rate of omissions.

Similarly, in some companies a somewhat high proportion of officer respondents (senior deck officers included) expressed slight or strong disagreement with the statement that accidents and near-misses are being reported according to the procedures of their company (see fig. 2). The response to this item is significant. First, it is important to a company management to gather knowledge about the factors involved in near misses to improve procedures and practices so as to gain better protection against accidents.

Second, it is known from aviation that a range of organisational changes are required before a "no-blame" voluntary reporting system can be established. This is a point where it is likely that maritime companies could profit from the experience of successful airlines that actively support incident reporting schemes.

Henning Boje Andersen and Steen Weber

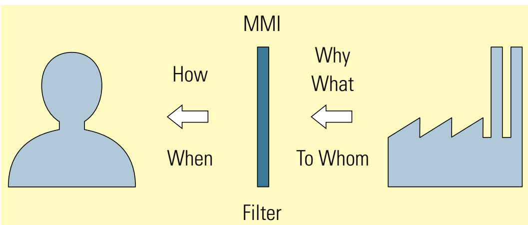
Man/Machine Interaction

Design of an Overview Display for a Waste Incineration Plant

In complex process plants the role of the operator for the most part concerns supervising the behaviour of the plant. The automatic control systems have taken over the operator's manual work, such as opening and closing valves, starting and stopping pumps and controlling water levels. For the supervision role, it is important to select the right information to give to the operator, both to ensure that he gets the essential information, and that he is not overloaded with unnecessary information. The operator has to supervise that the control system controls the plant and in the case of deviations, he must be able to apply control manually and find the failure. An operator information system can be viewed as a filter where the designer of the displays decides which information should be on the displays and how to display it. The designer of operator information systems needs a strategy for this design task. The general strategy is illustrated in Fig.1. The method is developed in collaboration with the OECD Halden Reactor project, where it has been used to develop overview displays for nuclear power plants.

In waste incineration plants one very interesting problem arises compared to other energy producing plants. Namely that the operators do not know the burning value and moisture content of the waste. This leads to an incineration process which cannot be controlled solely by the automatic control system, but must also be based on the operator's visual inspection of the process and his correcting actions.

An overview display was developed for the waste incineration plant and installed at the plant. The operator must be considered as a part of the control system, but without a specific transfer function. The information to the operator about plant status must be correct enabling him to take the right decisions about actions to be done manually. This constrains the selection of information to the operator and the way that is presented.



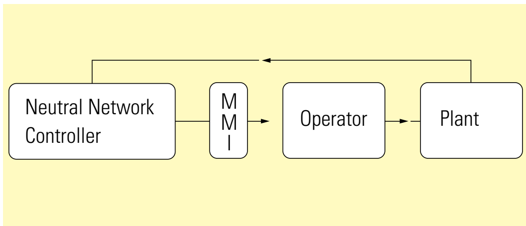


Figure 1 (left) Man-Machine interface seen as a filter between plant and operator

Figure 2 (right) The display (MMI) has been tested in the above configuration at the Waste Incineration Plant in Darmstadt

The CLEAN project

This project concerns the optimisation of the waste incineration process with regard to minimising the environmental load from exhaust gases. To achieve this the project seeks to optimise the control system. For the optimisation of the control system a neural net controller has been developed based on experience from the plant. The work was carried out in collaboration with Risø's Optics and Fluid Dynamics Department, which had the task to develop methods to classify the waste, Forshungszentrum Karlsruhe Germany responsible for the NN-controller and Technishe Hochschule Darmstadt Germany responsible for making measurements at the incineration plant.

For the initial implementation of the neural network controller the operator is regarded as a part of the controller. He has to perform those actions manually, which the controller will execute in the final implementation. The initial implementation is therefore a test of the neural network controller. Apart from providing information about plant conditions the display must advice the operator about manual adjustment of set points. Figure 2 shows the set-up for the test of the display and NN-controller.

Analysis of the information required for design of the display

A major problem in waste incineration plants is how to cope with the emission of unwanted elements in the crude gas, for example, CO level and dioxin content that are too high. Problems such as these can be avoided by maintaining a sufficiently high temperature in the incineration chamber and a sufficient airflow to the incineration process. Due to unknown variations of humidity and heating value of the waste it is difficult to estimate the airflow. The optimal way of running the process is to keep the energy output constant corresponding to a constant steam flow. The problem is the amount of input waste to the process. The general strategy as shown on fig.1, has been used to analyse the problem of deviation from normal energy output.

The general strategy applied to the waste incineration process

Strategy		Example
What is the goal?	→	Minimise release products
What is the problem?	→	Incomplete burnout of waste
Why does it occur?	→	Unknown characteristics of input waste
How is it observed?	→	Unstable steam production, CO and O2 levels
How should it be controlled	→	Change amount of input waste, primary air, secondary air, grid speed and preheating
How should it be presented	→	Mixture of trend curves, profiles of process variables and video of the drying and burning zones

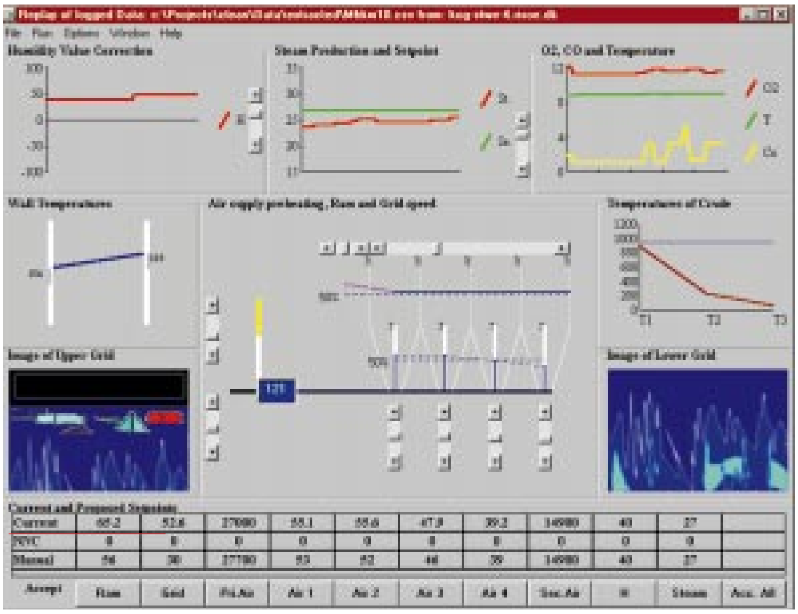


Figure 3
Display as developed in the project

As seen on the display developed (Fig. 3), the variables are presented in a graphical form from which the operator can confirm whether or not the operation of the plant is normal or if any deviation occurs.

Test of the display

A formal test has not been carried out, but the neural network controller has been tested against the target incineration plant in Darmstadt using the display developed. The new display gave the information required on a single screen. On the current display system navigation through several windows was required to get the same information. During the development the display has been tested against logged data from the incineration plant and against a simulation model of the plant.

Publication in 1997: 90
Jette L. Paulsen and Steen Weber

Conference
TIEMS '97

In June 1997 Risø arranged the Fourth International Conference on Emergency Management in the framework of TIEMS, "The International Emergency Management Society", in which Risø for now holds the presidential role.

TIEMS was founded in 1993 as a non-profit organisation in order to combine all aspects of emergency management and discuss how the use of methods and technologies may improve efficiency in emergency management.

Until now three international conferences have been held within the framework of TIEMS under the themes:

– Bridging the Gap Between Theory and Practice,
– Globalisation of Emergency Management,
– International Issues Concerning Research and
– Application in Emergency Management.

The conferences emphasise the major goal of TIEMS: to bring together people with very diverse backgrounds dedicated to emergency management. Participants from six continents have joined the conferences. This year the conference took place near Copenhagen, June 10-13, 1997.

The conference topics were very broad in their scope and include Natural Disasters, Technological Disasters, Application Areas and Techniques.

TIEMS solicits papers, demonstrations, workshops and case studies in all relevant areas. Besides the aspects normally covered in the TIEMS conferences, e.g. decision support, modelling, handling of man-made or natural disasters and training, this conference was enhanced by including aspects involving medical care and economic constraints.

Moreover, the conference was dedicated to the tremendous advancements in information and communication technologies that have been experienced in recent years, which has consequently increased the possibilities of coping with emergency situations. However, at the same time emergency management tasks have increased in complexity to an unprecedented magnitude. This has been the result of the increased complexity in industrial plant activities, which not only have led to manmade catastrophes, but which have increased the vulnerability of society if such plants are damaged by natural catastrophes.

The conference was sponsored by the Ministry of the Interior, Emergency Management Agency, and by the Danish Rescuing Company, Falck.

The conference proceedings have been published in 1997.

Verner Andersen

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International

IFIP Working Group 13.2 on User Centered Design
Annelise Mark Pejtersen

Editorial Board, Journal of Hazardous Materials
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Editorial Board, Intergovernmental Panel of Climate Change, Working Group III
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Programme Committee for TIEMEC'98. The International Emergency Management Society Conference, Washington (US), May 19-22 1998
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NUPEC, Group of International Experts
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Technical Programme Committee for ESREL'98, June 1998, Norway
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Scientific Programme Committee for 2nd IPCC workshop on Integrated Assessment in Africa, August 1998, Zimbabwe
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Programme Committee for Fifth International ISKO Conference, August 1998
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Editoral Board, Reliability Engineering & System Safety
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Halden Ad Hoc Scientific Advisory Group on Human Error Analysis
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Papers Committee for Interact 97, IFIP TCB Sixth International Conference on Human-Computer Interaction
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IPCC Working Group III, Danish focal point on Emission scenarios and the Socio-Economics of Climate Change
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UN/ECE task force on Emission Inventories. Panel on Traffic Emissions
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CEN-TC310/WG4, Ergonomics and Human Factors in Advanced Manufacturing Techniques
Palle Christensen

Cigré TF38.03.13. Sequentiel Probabilistic Methods
Hans Ravn

Board of Directors for TIEMS, The International Emergency Management Society
Verner Andersen

Working group on Socio-economic Research on Fusion (E.U.)
Poul Erik Morthorst.

Management Committee, European Topic Centre on Air Emissions (EEA)
Niels Kilde.

International programme committee. International conference on transition to advanced market institutions and economics. Systems and operations research challenges. Transition '97. Warsaw (PL), 18-21 June 1997
Hans Ravn

Programme committee. Nordic operations research conference. NOAS'97. Copenhagen (DK), 15-16 Aug. 1997
Hans Ravn

Associate editor. Energy Economics
Poul Erik Grohnheit

Council, International Association for Energy Economics (IAEE)
Hans Larsen

Programme Committee. IPCC Workshop. Mitigation and Adaptation Costs and their Policy Implications, Risø (DK) June 16-18 1997
Kirsten Halsnæs

IPCC Writing Team for discussion paper Mitigation and Adaptation Cost Assessment – Concepts, Methods and Appropriate Use
John M. Christensen, Kirsten Halsnæs, John M. Callaway

Informal consultative forum for the exchange of experiences on climate change project development, implementation and follow-up - CC: FORUM (Climate Change Secretariat, Bonn)
John M. Christensen, Kirsten Halsnæs

Programme Committee for TIEMS '97. The International Emergency Management Society Conference, Copenhagen (DK) June 10-13 1997
Verner Andersen, Steen Weber

Coordinating Editor of Computer Supported Cooperative Work. The Journal of Collaborative Computing (Kluwer Academic Publishers)
Kjeld Schmidt

Scientific and Programme Advisory Board for the First International Conference on Allocation of Functions, ALLFN '97, Galway, Ireland, October 1-3 1997
Kjeld Schmidt

Programme Chair (Social/Behavioural Track) for the ACM Conference on Supporting Group Work (GROUP '97), Phoenix, Arizona, 16-19 November 1997
Kjeld Schmidt

Programme Committee and Proceedings Chair for the Fifth European Conference on Computer Supported Cooperative Work, Lancaster, UK 7-11 September 1997
Kjeld Schmidt

Technical Programme Committee for ESREL '97, June 1997, Portugal
Kurt E. Petersen

Programme Committee for ACM SIGIR 97. 20th International Conference on Research and Development in Information Retrieval. Philadelphia, USA, July 27-31, 1997
Annelise Mark Pejtersen

Danish

Research committee, Energy and Society (Min. of Environment and Energy)
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Danish Research Council (Ministry of Research)
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Working Group on Soft IT Research (Danish Research Council for the Humanities and Danish Research Council for the Social Sciences)
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Advisory Group on Sustainable Exploitation of the Natural Resources in Developing Countries. (The Danish Environmental Research Programme)
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Committee on Energy Statistics for Transport (Min. of Environment and Energy)
Jørgen Fenhann

Steering committee on maritime emissions in Danish waters (Danish Environmental Protection Agency)
Niels Kilde

Steering committee on Emissions from Danish road traffic (Danish Environmental Protection Agency)
Niels Kilde

Advisory Board (Danish Board of Technology)
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Environmental Appeal Board (Min. of Environment and Energy)
Kurt E. Petersen, Birgitte Rasmussen

Committee for the Future of Libraries in the Information Society, UBIS udvalget (Ministry of Culture)
Annelise Mark Pejtersen

Systems Analysis Department

- *Hans Larsen*
  M.Sc. (Elec. Eng.), Ph.D. Head of Dept.
- *Charlotte Olsson*
  M.Econ., HD Administrative officer

Energy Systems Analysis

- *Frits Møller Andersen*
  M.Econ., Head of Research Programme
- *Peter Skjerk Christensen*
  M.Sc. (Elec. Eng.), Senior Scientist
- *Jørgen Fenhann*
  M.Sc. (Phys. with Math. and Chem.)
  Senior Scientist
- *Poul Erik Grohnheit*
  M.Econ., Senior Scientist
- *Henrik Klinge Jacobsen, M.Econ.*
  Ph.D. student
- *Niels A. Kilde, M.Sc. (Chem. Eng.)*
  Senior Scientist
- *Karin Kousgaard, M.Sc. (Eng.)*
  Ph.D. student
- *Helge V. Larsen*
  M.Sc. (Elec. Eng), Ph.D., Senior Scientist
- *Poul Erik Morthorst*
  M.Econ., Senior Scientist
- *Lars Henrik Nielsen*
  M.Sc. (Phys. & Math.), Senior Scientist
- *Lise Nielsen*
  M.Econ. Scientist
- *Halldòr Pálsson*
  M.Sc. (Mech. Eng.), Ph.D. student
- *Hans Ravn*
  M.Sc. (Eng.), Ph.D, Senior Scientist – until September 1997
- *Lotte Schleisner*
  M.Sc. (Mech. Eng.), Senior Scientist
- *Klaus Skytte*
  M.Sc. (Math. Econ.), Scientist

Integrated Energy Environment and Development Planning

- *John Møbjerg Christensen*
  M.Sc. (Eng.), Ph.D.
  Head of Research Programme
- *Cassandra Brooke*
  B.Sc. (Econ.), MA, Environmental Planner
- *John M. Callaway*
  MS (Agri. and Res. Econ.), MA
  Senior Economist
- *Pramod Deo*
  M.Sc. (Phys.), Ph.D., Senior Energy Economist
- *Maria J. Figueroa*
  M.Sc. (Env. Energy), Energy Scientist
- *Kirsten Halsnæs*
  M.Econ., Ph.D., Senior Economist
- *Gordon A. Mackenzie*
  B.Sc. (Phys.), Ph.D. Senior Scientist
- *Henrik Jacob Meyer*
  M.Sc. (Econ.), Scientist
- *Steffen Rønsholdt Nielsen*
  M.Sc. (Techn. Soc.), Ph.D. student
- *Anne Olhoff*
  M.Econ., Ph.D. student
- *yoti P. Painuly*
  B.E. (Mech.), Fellow IIMB,
  Senior Energy Planner
- *Robert Redlinger*
  M.Sc. (Env. Eng.), Senior Energy Scientist
- *Ian Rowlands*
  B.A.Sc. (Chem. Eng.), Ph.D.
  Energy Planner - until November 1997
- *Christopher F. Saarnak*
  M. (Geo.), Ph.D. student
- *John K. Turkson*
  MBA, Ph.D., Post. doc.
- *Arturo Villavicencio*
  M.Sc. (Math.) Senior Energy Planner – until December 1997

Industrial Safety and Reliability

- *Kurt Erling Petersen*
  M.Sc. (Comp. Sc.), Ph.D.
  Head of Research Programme
- *Palle Christensen*
  M.Sc. (Elec. Eng.), Senior Scientist
- *Nijs Jan Duijm*
  M.Sc. (Eng.), Senior Scientist
- *Carsten D. Grønberg*
  M.Sc. (Elec. Eng.), Researcher
- *Atoosa Jalashgar*
  M.Sc. (Elec. Eng.), Ph.D.
  Post. doc. - until December 1997
- *Kurt Lauridsen*
  M.Sc. (Elec. Eng.), Ph.D., Senior Scientist
- *Henrik Østergaard Madsen*
  M.Sc. (Eng.), Ph.D., Post. doc. – until November 1997
- *Frank Markert*
  M.Sc. (Chem.), Ph.D., Scientist
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  M.Sc. (Eng.), Ph.D. student
- *Søren Ott*
  M.Sc. (Phys.), Ph.D., Senior Scientist
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  Senior Scientist
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  M. Sc. (Chem. Eng.), Ph.D.,
  Senior Scientist

Man/Machine Interaction

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  M.Sc. (Elec. Eng.), Head of Research Programme
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  M.A. (Philos.), Senior Scientist
- *Verner Andersen*
  M.Sc. (Elec. Eng.), Senior Scientist
- *Peter H. Carstensen*
  Ph.D. (Comp. Sc.), Senior Scientist – until September 1997
- *Steffen Routh Herskind*
  M.Sc. (Comp. Sc. with Math.)
  Ph.D. student
- *Finn R. Nielsen*
  M.Sc. (Appl. Math. & Phys.), Researcher
- *Morten Nielsen*
  M.Sc. (Com. Sc.), Ph.D. student
- *Annelise Mark Pejtersen*
  M.A. (Sci. of Lit.), Senior Scientist
- *Kjeld Schmidt*
  M.Sc. (Sociol.) Senior Scientist – until December 1997
- *Steen Weber*
  M.Sc. (Elec. Eng.), Ph.D.,
  Senior Scientist

Short Term Guest Researchers

- *Gunnar Hauland*, M.Sc., Norway
- *Mariana Sanderson*, M.Sc., UK
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- *Martin Bawa Amadu*, M.Sc., Ghana
- *Ogunlade R. Davidson*, Prof., Sierra Leone
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Biographic Data Sheet

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The report describes the work of the Systems Analysis Department at Risø National Laboratory during 1997. The department is undertaking research within Energy Systems Analysis, Integrated Energy, Environment and Development Planning – UNEP Centre, Industrial Safety and Reliability and Man/Machine Interaction. The report includes lists of publications, lectures, committees and staff members

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Information Service Department,
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(Risø Bibliotek, Forskningscenter Risø),
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P.O.Box 49
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ext 4004/4005
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