Systems Analysis Department annual report 2000

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Systems Analysis Department

Annual Report 2000

Edited by
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Charlotte Olsson and Elin Jensen

Risø National Laboratory
Roskilde · Denmark

May 2001

This report describes the work of the Systems Analysis Department at Risø National Laboratory during 2000. The department is undertaking research within Energy Systems Analysis, Energy, Environment and Development Planning – UNEP Centre, Safety, Reliability and Human Factors, and Technology Scearios. The report includes summary statistics and lists of publications, committees and staff members.

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Contents

Risø-R-1230(EN)

Introduction


Hans larsen

The year 2000 was characterised by a high level of activity in the department and at the same time by consolidation following the organisational changes introduced in 1999.

In 2000 a new strategy for Risø was developed as a basis for negotiating a new performance contract with the Ministry of Information Technology and Research for the period 2002 to 2005. According to the new strategy the research areas for Risø are:

- Energy
- Industrial technology
- Bioproduction, and
- Radiation safety.

In the strategy increased focus is devoted to research on energy technologies and policies for post-Kyoto goals with regard to reducing the environmental impacts of energy consumption.

The department undertakes research within *Systems and Technology Analysis,* which covers all four market areas. The involvement in long-term energy research is particularly strong.

The research in systems and technology analysis develops and applies methods for the technical, economic and environmental analysis of energy systems and industrial systems. The aim is to promote sustainable development in an international knowledge-based economy.
The research activities are undertaken within the following research programmes:


Frits M. Andersen

- Energy Systems Analysis, *Frits M. Andersen*
- Energy, Environment and Development Planning, UNEP Centre, *John M. Christensen*
- Safety, Reliability and Human Factors, *Nijs J. Duijm*
- Technology Scenarios, *Per D. Andersen*.

In 2000, staff members from the department were involved in the strategy process as facilitators in the various panels and as secretariat.

A collaboration agreement has been entered into with the Institute of Economics at the University of Copenhagen and the University of Bath (UK) concerning the establishment of a PhD network in the area of environmental economics.

A number of Scientific Advisory Panels have been established in order to strengthen the contacts and interactions with the Danish and international scientific communities and end users of the results, e.g. industry, governmental authorities and international organisations. Panels have been established for the UNEP Centre, The Technology Scenarios programme, and the Centre for Analysis of Environment, Economy and Society established jointly with the National Environmental Research Institute.

The panels have between 10 and 15 external members and are asked to give strategic advice on the directions for future activities as well as assess the quality and relevance of ongoing and proposed activities. All panels met in the autumn and provided valuable input for the new annual plan 2001 and the strategy.

The department increased its income in 2000, thus maintaining the positive trend of recent years. In 2000, 68 per cent of the department's activities were financed through national and international research contracts, contracts with national agencies and international organisations as well as with industrial companies and utilities. The remaining 32 per cent were financed by governmental appropriations.

The total turnover of the department in 2000 amounted to approximately 52.9 mil. Dkr.

By the end of the year, the total number of employees in the department was 64. This included an academic staff of 59, namely, engineers, natural scientists, and economists as well as social and behavioural scientists of whom 10 were PhD students in co-operation with various universities in Denmark and abroad. There were 5 secretaries and technical support staff. During 2000 three staff members earned a PhD degree.

Hans Larsen,
Head of Department

Energy Systems Analysis

The research programme develops methods for analysing energy, environmental and economic issues, and the interactions between them, as well as new energy technologies and their adaptation to complex energy systems.

Risø and the National Environmental Research Institute (NERI) have established the Centre on Environment, Economy, and Society. The centre is managed jointly by Risø and NERI and comprises the joint activities within the Energy Systems Analysis Programme at Risø and the Department for Policy Analysis at NERI. The research areas covered by the centre are environmental economics, integrated environmental information systems, estimates and forecasts of emissions, and sector analyses within land use, transport, and energy.

In 2000 the major activities within the Energy Systems Analysis Programme were:
Instruments that were analysed in 2000 comprise CO_2 quotas, tradable permits, green certificates, and joint implementation.

Development of methods for analyses and projection of energy consumption and emissions were major activities in 2000. They include work on the harmonisation of emission projections in international models and the development of environmental satellite models for ADAM covering emissions related to the themes climate change, acidification and eutrophication.
Technologies that were analysed in year 2000 include the environmental and energy system consequences of large-scale utilisation of electrical vehicles and the possibilities for introducing hydrogen as an energy carrier in the future Danish energy system.

Frits M. Andersen

Energy, Environment, and Development Planning, UNEP Centre

The UNEP Centre is a collaborative activity established between the United Nations Environment Programme (UNEP), Danida and Risø. The core activities of the centre are funded through two-year contracts.

The centre develops methods for analysing global, regional and national energy and environment issues and supports the development of national planning capacity.

The year 2000 has been characterised by a significantly increased focus on energy for sustainable development. This process is partly prompted by the preparations for the 9th meeting of the Commission for Sustainable Energy, which focuses on this theme in its meeting in April 2001. Also at the 6th meeting of the Conference of Parties (COP) to the UN Framework Convention on Climate Change, there was a strong focus on increasing the efficiency of energy production and utilisation and further developing renewable energy technologies.

The involvement in the work of the Intergovernmental Panel on Climate Change (IPCC) has been significant with four staff members participating as lead authors for the Third Assessment.

John M. Christensen

Safety, Reliability and Human Factors

The research programme develops methods for analysing the safety and reliability of complex technical systems, taking into consideration the strong coupling of technical, organisational and human aspects.

The programme consists of a multi-disciplinary team of scientists, psychologists and information specialists, who co-operate to solve the many problems that ensue with the use of complex technology in a society where safety and reliability have a high priority.

2000 was a year of consolidation of the programme after its initialisation the year before. There was an increase in the diversity of clients and co-operative partners, among them an eCommerce analyst, the Danish Railways (DSB) and the Danish cartographic agency, Kort- og Matrikelstyrelsen, as new users of the Human-Machine Interaction Laboratory. In the area of risk analysis for process industries, we observed an interest from local authorities for support in relation to the implementation of the new European Directive on preventing major accidents involving hazardous substances. Another notable fact was the positive response from the international scientific review of the activities of the Centre for Human-Machine Interaction in co-operation with the University of Aarhus, the Technical University of Denmark, Danish Maritime Institute and Danfoss A/S.

Nijs Jan Duijm

John M. Christensen

Nijs Jan Duijm

Technology Scenarios

The research programme develops methods for analysing commercial, societal and scientific possibilities and consequences in relation to the selection, development and commercial application of new technologies. The programme was established in 1998.

The research is focused on the development of theories and research methodologies for technology analysis based on case studies and empirical problems on the meso-level (the organisational level of the industrial sectors, the firm or the research institution). The research in 2000 centred on two research themes: The first was the development of methodologies for technology foresight studies and other methodologies for prioritising in science and technology. The second research theme was the development of operational theories and methodologies, combining foresight and life cycle assessment (LCA).

The last months of 1999 marked a breakthrough on external funded tasks and by the end of 2000 the programme has a satisfying project portfolio. The projects comprise Danish as well as EU funded projects and the projects are carried out in co-operation with Danish and European universities, research organisations and firms.

One of the main events in 2000 was a PhD-course in "Management of research and innovation" developed and carried out in collaboration with Copenhagen Business School within the framework of the REMAP joint research project.

Per Dannemand Andersen

Per D. Andersen

Bottom-up modelling for macroeconomic analysis

The results of bottom-up models, which employ a traditional optimisation model approach to study the long-term penetration of new and environmentally benign technologies, are also important sources for assumptions in macroeconomic models.

This approach was applied using the EFOM-CHP model. This model describes a set of standard regions or electricity generators with heat markets suitable for combined heat and power (CHP) for space heating or industrial processes. The results of the model were developed originally for the EU Shared Analysis Project. The CHP regions were characterised by the existence of initial CHP capacities and the size of the heat market (large-scale urban district heating network vs. small heat distribution networks). In 2000 the results of this model were used for making analyses of the impact of tradable CO_2 permits in different European countries, focusing on technology choice and fuel switching, in particular the substitution of gas for coal.

The electricity and heat markets in western European countries in 1995 were described using the standard CHP regions as 'building blocks', and forecasts of the development was made using the optimisation results for the 'building blocks' for the years 2000, 2010, and 2020.

The results of the optimisation are very sensitive to the assumptions made on the future prices of coal and gas. The forecast of fuel prices used for the Shared Analysis Project would lead to a switch from coal to gas in the short-term, because gas-based technologies are very competitive, when gas prices are relatively low. However, by the end of the last period the optimisation shows a substitution back to coal, because of increasing gas prices. This leads to an increase in CO_2 emissions in that period.

In particular, the bottom-up model was used to study the impact of the availability of new technologies such as micro-scale CHP on the household level. This technology will have little impact on the fuel switching, because the small-scale CHP generation will replace gas-fired electricity-only generation in very efficient large-scale combined-cycle gas turbines.

These results were also used as input to the European macroeconomic model for energy demand forecasts, E3ME, covering the 15 EU Member States plus Norway and Switzerland. The bottom-up results concerning technology choice were translated into macroeconomic terms, which show a significant switch in the economic activity between sectors. There will be less activity in the utility sector and more in the manufacturing of consumer durables, because a significant part of electricity generation will take place in households, the tertiary sector and small industries.

In the combination of models described above, the electricity demand and electricity trade in the regional optimisation model were exogenous. Thus, the results of the analysis can be improved by using other combinations of models with the same data. A new partial equilibrium model for the electricity and heat markets in the Baltic Sea Region, Balmorel, has been developed in co-operation with institutes in the Baltic countries, Russia and Poland under the Danish Energy Research Programme. In contrast to the traditional optimisation models, this model has elastic demand for electricity, and electricity trade among the electricity regions is endogenous. The first version of Balmorel was finished by the end of 2000.

The main contribution by Risø to this model development has been a spreadsheet model to create sets of consistent technology data for electricity and heat generation technologies with parameter variations for fuel supply, scales of generating units and technology vintages. This set of technology data is useful for various types of models that include data for identifiable technologies.

Publications in 2000: 71, 81, 82

Poul Erik Grohnheit.

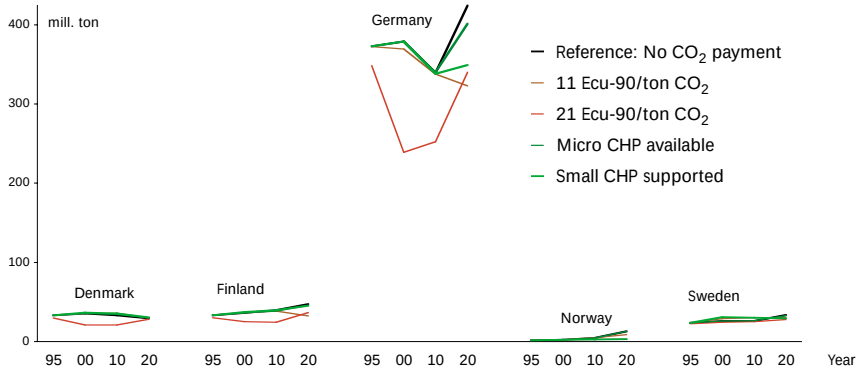


Figure 1.
Absolute values of CO_2 emissions in five countries. A reference forecast is compared with forecasts of the impact of CO_2 payments and the availability of micro-scale CHP with and without support in the form of a public service obligation. The results show that there could be a potential for significant emission reduction from CO_2 payments in the short-term, because of fuel switching, while the reduction potential from new technologies is negligible except for Germany.

Hydrogen and battery electric vehicles: System integration and CO_2 emission.

Large-scale integration of Battery Electric Vehicles (BEV) and Hydrogen-based Fuel Cell Vehicles (HFCV) in the transport sector may significantly reduce the emission of pollutants, and improve air quality in local and urban areas. Such vehicles may offer high energy efficiency and very low environmental impact compared to the conventional Internal Combustion Engine Vehicles (ICEV). Emissions to the environment are essentially zero when operating these alternative vehicles. Furthermore, such vehicles can provide a flexible energy path for integrating a fluctuating electricity supply, such as wind power, to serve transport energy needs.

Energy system consequences of large-scale utilisation of electric vehicles have been analysed in a project carried out by the Systems Analysis Department. The project has received support from the Danish Energy Research Programme. The overall aim of this study has been to analyse the potential advantages of the alternative vehicles relative to Danish long-term aims in energy- and environmental planning, where air pollution reduction and CO_2 emission reduction are central issues.

Electric vehicles supplied from the Danish grid

For an average vehicle in the Danish fleet of passenger cars and small delivery vans, key numbers from the analysis are shown in Table 1 on the potential development for the specific energy consumption and CO_2 emission of the BEV and HFCV drive trains. This development is compared with an expected development for the conventional gasoline ICEV of corresponding size and use.

Table 1.
Vehicle energy efficiency and specific CO_2 emission. Comparisons for an average fleet vehicle of type ICEV, BEV, and HFCV. Power supply according to Energy21, The Plan scenario.

Type of vehicle Size: Average fleet	1997-2000	2005-2010	2025-2030
ICEV Reference			
kWhgasoline/km	0.66	0.55	0.55
gCO2/km	176	150	150
ICEV '3litre aim'			
kWhgasoline/km	0.27	0.27	0.27
gCO2/km	72	72	72
BEV			
kWhelectricity/km	0.24	0.13	0.10
gCO2/km	156	63	19
HFCV			
kWhhydrogen/km	-	0.32	0.24
gCO2/km	-	181	53

The BEV and HFCV energy supplies are based on electricity from the Danish grid, and it is assumed that the Danish electricity supply system develops over time in accordance with the *Energy21, The Plan* scenario. Hydrogen to operate the direct hydrogen fuel cell vehicle is produced via electrolysis. The emission of CO_2 involved in the overall energy system is shown in the table. Local emissions of pollutants to the air from BEVs and HFCVs are negligible.

Only a moderate reduction in gasoline consumption per average km driven is expected for the ICEV during the period. The expected fleet average vehicle is seen to require about twice the fuel of the so-called '3litre' ICEV (33km/litre) vehicle.

Compared to the conventional ICEV, the battery electric vehicle (BEV) is very attractive from both an energy efficiency and CO_2 emission point of view. The CO_2 emission may be reduced to less than half of the ICEV for new BEVs entering the fleet in the period 2005 to 2010. BEVs entering the fleet late in the period, 2025 to 2030, have considerably lower CO_2 emission than the ICEV. This is due partly to the expected technical development of the BEV and partly to power system developments.

As for the BEV, the HFCV is very attractive with respect to the removal of air pollutants from road traffic. However, the HFCV that can match the ICEV in fast refill and range per refill, cannot be expected to match the ICEV before 2010 from the viewpoint of CO_2 reduction, when the hydrogen is produced by electrolysis via the Danish power system on average. The long-term Danish power system development and expected HFCV drive train development, however, will change this beyond 2010.

BEV and HFCV vehicles, which have entered the fleet, improve their CO_2 characteristics over time, as the power supply system develops towards lower CO_2 emission per kWh delivered, according to the developments of Energy21, the Plan.

Electric vehicles supplied from Danish offshore wind power.

If electricity fueling the BEV and HFCV is based on renewables, of course there is no CO_2 emission associated with operating the vehicles. With an average amount of driving of about 20000 km/year, the energy resources needed to operate the average vehicle in the Danish fleet are expected to develop as indicated in Table 2. In the table it is assumed that offshore wind turbines supply the energy.

From Table 2 it is seen that an average BEV vehicle in the fleet year 2030 can be expected to consume annually the electricity equivalent to the production from approxi-

Table 2 Offshore wind power capacity capable of generating the electric energy that corresponds to the annual demand of an average, electricity-based vehicle.

Wind power capacity able to support one (fleet average) vehicle		
Technical stage	***BEV***	***HFCV***
Year	*KW/car*	*kW/car*
2005	*1.44*	*-*
2015	*0.90*	*2.26*
2030	*0.66*	*1.77*

mately 0.66 kW installed wind power capacity offshore. Hydrogen to serve the corresponding HFCV vehicle could be produced from the electricity generated by approximately 1.8 kW of installed capacity wind power under Danish offshore wind conditions.

Lars Henrik Nielsen
Publication in 2000: 63

Greenhouse Gas Emissions from Danish Agriculture

In 2000 the Danish Ministry of Environment and Energy published the report "Climate 2012, Status and Perspectives for Danish Climate Policy". The projections of the future emissions of greenhouse gases from Danish sources used in this report were made at Risø. At the moment the Danish Energy Agency is financing an update of these calculations at Risø as a background to the coming Danish ratification of the Kyoto-Protocol. The emission projections, covering the period until the end of the first commitment period 2008-2012, take into account the latest action plans of the Danish Government in the sectors with relevance to greenhouse gas emissions: energy, industrial greenhouse gases, waste, forests and the agricultural sector.

One of the main objectives of the work on emission inventories at Risø is to create a scientifically based consensus among the stakeholders for each sector concerning the emission factors and size of the emitting activities. This has now also been created for the agricultural sector. In a working group together with the agricultural research institutions, Risø projected each of the emitting activities in Table 1 in a detailed manner. For some activities new emission factors were calculated.

Table 1 shows the result for 1999. The emissions of methane (CH_4) and nitrous oxide (N_2O) have been converted to CO_2 equivalents. These emissions from agriculture in 1999 amount to about 17% of the total emission of greenhouse gases from Denmark (about 73,000 kt CO_2 eq.). The projection shows that this total declines in 2010 to about 11,000 kt CO_2 eq. Compared with the old calculations the share of CH_4 is smaller, due to more recent and better estimates of the emissions from cow manure. However, the total emission has not changed much.

In addition, the working group made the initial calculations of the cost of greenhouse gas emission reduction for agriculture. The emission from the digestion in cows can be reduced 30% by adding more vegetable fats to the fodder. Four different options for reducing the evaporation of ammonia were investigated. Finally, the cultivation of elephant grass as a multi-annual energy crop was analysed; this option has the interesting characteristic of being relatively less costly, reducing the N_2O emission, storing carbon in the soil, saving fuel for the tractors and replacing fossil fuels.

Jørgen Fenhann

Table 1. Emission of methane and nitrous oxide from Danish agriculture in 1999

Compound -source	Emission (CO_2 eq.) kt/year	(%)
Methane+Nitrous Oxide	12,160	100%
Methane	3,599	30%
-animal digestion	2,828	23%
-manure handling	770	6%
Nitrous oxide	8,562	70%
-manure handling	730	6%
-mineral fertilisers	1,530	13%
-applied animal manure	1,095	9%
-nitrogen fixation	248	2%
-crop residues	1,924	16%
-industry and urban waste	53	0%
-cultivation of organic soils	45	0%
-animal grazing	284	2%
-NH^3 volatilisation	376	3%
-nitrogen leaching	2,277	19%

Interactions of a tradable green certificate market with a tradable permits market.

The reduction of greenhouse gas (GHG) emissions is an important goal in the energy and environmental policies of the European Union and its member states. According to a recent directive-proposal from the EU commission, the inclusion of renewable technologies is one of the important ways to achieve this emission reduction. More policy instruments are on hand to pursue this objective. Within the past few years green certificate markets have gained an extensive interest in Europe and elsewhere, and markets seem to be appearing in a number of countries, among which are Denmark, Italy, Belgium (Flanders), England and Australia. In Denmark targets for deploying renewable energy resources have existed for quite a long time and the establishing of a green certificate market to be functioning by 2002 is agreed by Parliament. In parallel with this, the possibilities of establishing a market for tradable permits for CO_2-emissions in the power industry are frequently discussed.

If these two instruments are set into play at the same time, two separate markets with two individual targets are going to co-exist in a number of countries. How these two markets may interact with each other in international trade and how they may interact with the physical spot market for electricity are analysed at Risø in a number of on-going projects. Among these are: *The use of policy instruments in the long-term implementation of renewable energy technologies under free market conditions.* This implementation is carried out within the Strategic Environmental Research Program and the *InTraCert project,* the latter within the EU 5th framework programme in collaboration with ECN, Warwick University and others. The two projects are to be finalised in 2001.

Important features of the two above-mentioned markets – the green certificate market (TGC) and the tradable permits market (TEP) - are the possibilities for opening up international trading in certificates and permits. With regard to the TGC-approach, international trade will secure a cost-effective siting of renewables and their development. The renewable technologies will be established in those countries which have the highest production potentials and where renewable energy can be produced at the least cost. Problems in fulfilling the national quotas will be handled by importing TGCs, while the surplus of certificates may be exported to countries with a shortage. This secures that the national targets for developing renewable energy technologies are reached in the most cost-efficient way. And similarly, an international TEP-market will secure that CO_2-reduction options in the power industry are implemented in those countries where these are most cost-efficient. But until now the analyses carried out in the two projects point out a number of shortcomings in the simultaneous use of these two instruments:

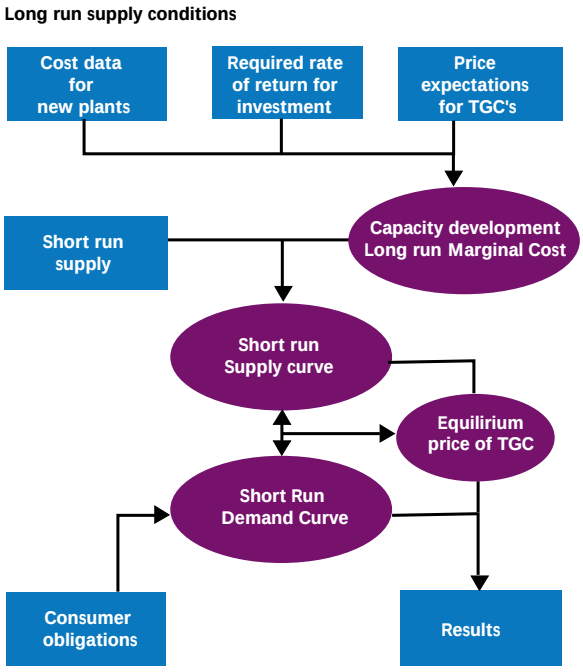


Figure 1.
Modelling the price-determination at a national TGC-market.

- Normally no GHG-credits are attached to the green certificates. This implies that international trade in TGCs in a liberalised electricity market will not by itself contribute toward fulfilling the national GHG-reduction target of the Kyoto-protocol. This means that an international TGC-market will merely be an efficient instrument in fulfilling the renewable development target, not in fulfilling the GHG-reduction target.
- In a liberalised electricity market, there will from time to time be export or import of electricity across borders and therefore it might be difficult to figure out what is actually substituted by an increased electricity production from renewable energy technologies. Thus, if the two instruments – TGC- and TEP-markets – given liberalised market conditions are to be used as part of a national GHG-reduction strategy, it is important that they are used in a co-ordinated manner. With regard to national GHG-reduction an optimal utilisation of the TGC-regulated renewable production will take place only if a co-ordinated adjustment of the TEP-regulated conventional power production is undertaken. Thus, an increase in the TGC-quota has to be matched with a corresponding decrease in the TEP-quota to fully utilise the renewable production in a national GHG-reduction strategy.
- Finally, it is important that the price of a green certificate in international trade reflects the value of the product. If the value does not correspond to the price this will bias the incentives for an international trade in

certificates. Only by using a tradable permit system based on the bidding (auction) procedure will the costs of CO_2-reduction be fully reflected in the spot market price of electricity; and only by introducing this kind of TEP-system will international trade in green certificates be equivalent to a domestic development of renewables.

Publications in 2000: 32, 33, 94, 95
Poul Erik Morthorst

Hydrogen and renewable energy in the Danish Energy System

This project evaluates the use of hydrogen as a means for large-scale introduction of renewable energy within a 30-50 year timeframe, focusing on two main aspects: as a transportation fuel and as a storage option for fluctuating renewable energy supplies in the power and heating supply system. The project is carried out by Roskilde University Centre (project management), two energy companies, Elkraft (electrical power), and DONG (natural gas and oil), as well as Risø, and is funded by the Danish National Energy Agency's Hydrogen Programme. It is to be finalised by early 2001.

Four scenarios are studied: two, analysed by Risø, with 2030 as timeframe and illustrating hydrogen's role within the present energy planning context (and thus linked to the energy plan of the Danish government, Energy 21); and two with a longer view, towards the year 2050. One of the scenarios analysed by Risø, focusing on the conversion of Danish transport energy to hydrogen, based on renewable energy, is outlined here. This scenario mirrors the planning scenario of Energy 21, except for the conversion of transport energy to hydrogen and the establishment of sufficient renewable energy capacity to cover the hydrogen generation (on an annual basis).

In the scenario, just under 80% of the transport energy of 2030 is to be converted to hydrogen - leading to a similar cut in CO^2 emissions. The remainder is envisaged to be converted beyond 2030 except for a small fraction (about 5% of the total) driven by electricity. With the exception of aircraft power, it is expected that all drive systems will be based on fuel cells following the implementation of the conversion. This is done either in the form of so-called "direct-hydrogen fuel cell systems", driven by hydrogen stored onboard as compressed gas, or as "indirect-methanol fuel cell systems", in which the fuel is converted on-board to hydrogen with methanol. The latter option facilitates onboard energy storage, but has the disadvantage of poorer energy efficiency. For aircraft propulsion hydrogen jet turbines are applied with on-board storage of the hydrogen in liquid form.

Hydrogen and methanol are generated by electrolysis and biomass gasification. The energy input is fully renewable - as wind power (about two-thirds), biomass (one quarter) and photo-voltaics (5%). It is based entirely on energy recources mapped in the planning process of Energy 21, but not utilised in its planning scenario. The calculated costs per tonne CO^2 saved are in the same range as other CO^2 reduction options in the transport sector.

Publication in 2000: 87
Kaj Jørgensen

Table 1. Transport sector fuels and energy supplies in the year 2030 according to the hydrogen scenario investigated

PJ/annum	Hydrogen drive	Methanol drive	Remaining transport sector	Total transport sector
Biomass	5	32	0	37
Wind	94	0	0	94
Photovoltaics etc.	7	0	0	7
Oil, natural gas	0	0	46	46
Total	106	32	46	184

International activities and UNEP support

The Energy, Environment and Development Planning Programme is the institutional framework for the UNEP Collaborating Centre on Energy and Environment. The core Centre functions are to provide technical and analytical support to UNEP's Energy Programme and more broadly contribute to UNEP's activities in the areas of climate change, and environmental and development economics. The Centre also provides support to UNEP in its function as implementing agency of the Global Environment Facility (GEF).

Overall the year 2000 has been characterised by a significantly increased focus on energy for sustainable development. This process is partly prompted by the preparations for the 9th meeting of the Commission for Sustainable Energy which focuses on this theme in its meeting in April 2001, and also at the 6th meeting of the Conference of Parties (COP) to the UN Framework Convention on Climate Change there was a strong focus on energy efficiency and renewable energy technologies. The focus is not driven only by environmental issues and significant increases in oil prices in 2000 has naturally increased the commercial interest in other energy sources.

Internally in UNEP the energy programme activities are given increased prominence and will be a central theme in the meeting of the UNEP Governing Council in early 2001.

The Energy programme activities have continued to expand in 2001 with a number of very interesting developments, which are all implemented jointly by the Energy Unit in Paris and the Centre:

With support from the Danish Ministry of Foreign Affairs a new Sustainable Energy Advisory Facility (SEAF) was established with the objective of assisting developing countries move towards a sustainable development path through small targeted interventions either in the form of technical assistance or institutional support e.g. in areas such as sector planning studies, project assessments etc. The SEAF programme is established as a pilot activity in support of the CSD 9 process and the initial activities, which are being implemented in Africa, Central America and the Caribbean will be presented during CSD 9. With a documented positive outcome it is expected that the SEAF will continue and be expanded.

The GEF funded project implemented jointly by the Energy Unit and the Centre running an "investment advisory facility" for renewable energy and energy efficiency projects in developing countries and countries with economies in transition has continued with a number of studies for different development finance institutions.

The "African Rural Energy Enterprise Development" (AREED) programme aimed at increasing the capacity of the private sector in selected African countries to offer energy services using clean, efficient, and renewable energy technologies was launched in January and is at the end of the year fully operational in 5 pilot countries . The project couples enterprise development services with modest amounts of start-up financing. The project is funded by the UN Foundation and is implemented jointly by the Energy Unit and the Centre together with E & Co, a US based non-profit venture finance NGO, and a number of African NGOs.

School in rural area of South Africa electrified with solar energy (PV) system

General preparations for the meeting of the CSD 9 has continued with UNEP and Centre involvement in several ways. The most significant is the organisation of the African High-level Regional meeting on Energy and Sustainable Development jointly with the UN Department on Economic and Social Affairs. The meeting takes place during the first weeks of 2001 but organisation and preparation of the substantive papers have been a significant activity in the latter part of 2000.

Other activities within the energy programme include the finalisation of the African regional project on promoting implementation of RETs, launching of a new project for the Pacific Islands on "Capacity building on technological and economic integration of wind energy and other renewable energy technologies into the electricity systems of Pacific Island Countries" and continuation of the col-

laboration with the Latin American Energy Organisation (OLADE) on the Caribbean Energy Action Programme.

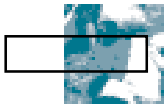
Climate Change Activities have mainly focused on analytical and capacity building activities partly in connection with the National Communications Support Programme and partly in relation to the Clean Development Mechanism where the Centre works on analytical issues related to sustainable development indicators and decision making frameworks, approaches to project baselines and criteria for project screening and selection.

The regional programme in Africa on "Sustainable development and climate change finance" has continued with the three national pilot studies and preliminary findings were presented in a side event during COP6 chaired by the UNEP Executive Director Dr. Töpfer.

The Centre at the COP 6 also hosted another side event which provided a forum for non-annex I countries work on baseline approaches to CDM. This work has since continued in collaboration with OECD, covering the annex I countries, and a joint workshop on these issues will be held at Riso in 2001.

Finally the centre worked closely with the Asian Development Bank (ADB) and UNEP's regional office in Bangkok on a series on national and regional workshops focusing mainly on the CDM. The key papers were published by the ADB in a book launched at COP 6 where ADB and UNEP also presented the results in a joint side event.

The involvement in the work of the Intergovernmental Panel on Climate Change (IPCC) has been significant with four Centre staff members participating as lead authors for the Third Assessment, one as convenor, and two staff members being lead authors for special reports on respectively scenarios and technology transfer.



Publications in 2000: 8, 13, 14, 15, 27, 35, 44, 51, 52
John M. Christensen

Climate Change

Sustainable Development and Climate Change Finance in Africa

The UCCEE is currently collaborating with the governments of The Gambia, Ghana, and Uganda to develop the capacity of these countries to participate in the Clean Development Mechanism (CDM). This project is being conducted for UNEP, with funding from Danida.

The project has two main objectives:

- To develop the analytical capacity of various groups in the three countries to develop, assess and implement future CDM projects.
- To increase the institutional and organisational capacity of the governments in these countries to attract future investments in CDM projects and to implement policies and procedures to administer the CDM.

This project began operation in February 2000 and is slated for completion in late March 2001. To date, each of the countries have held national workshops to introduce the project to stakeholders and increase participation in the project by groups in government and the private sector. Working groups in each country have identified a number of potential CDM projects. These projects have been screened using criteria developed by UCCEE and the Southern Centre of Zimbabwe, and a small number of candidate projects have been selected for technical and financial assessments, based on the principles of CDM. Dr. Peter Zhou, Botswana, provided training to the working groups in each country, using UCCEE Guidelines, to estimate project emissions reductions and financial benefits and costs. A joint workshop was held in Uganda to review each other's work and to share their experiences. In addition, each country is currently working on proposals to establish an institutional framework for administering CDM. UCCEE is the project co-ordinator and is also providing training and technical assistance in key areas. The final country workshops will be held in March 2001 to announce the results of the projects and lay further groundwork for the active involvement of these countries in the CDM.

Publication in 2000: 42
John Callaway

Regional collaboration in Asia

The Asian region is due to large population and high economic growth a major present and future Greenhouse Gas (GHG) emitter. It is therefore important to consider how global climate change policies can be integrated in sustainable development policies for this region. Over the last two years UCCEE has collaborated with the Asian Development Bank about how the Kyoto Mechanisms of the Climate Convention can be implemented in Asia with a particular focus on the Clean Development mechanism (CDM). The work has included the development of technical background papers on the issues and sub-regional and national workshops and capacity building activities. UCCEE has specifically been leading the discussion on estimating the size of the CDM markets and other Kyoto Mechanism markets. The market estimates have included an assessment of the total potential financial transfers from industrialised countries with GHG emission reduction commitments to Asian countries and other parts of the world. It has been concluded that Asian countries can supply a number of low-cost GHG emission reduction options that include energy efficiency improvements, electricity savings, and renewable energy options to international CDM markets. They conclude also that it might be economically attractive for industrialised countries as well as Asian countries to collaborate on how to implement these options.

Urban use of rural fuel: women waiting for a lift to town with bags of charcoal to be sold. Lusaka, Zambia.

Publication in 2000: 12
Kirsten Halsnæs

Evaluation of proposed "liability" provisions for the Kyoto Mechanisms

With the support of the California-based EPRI, Erik Haites (Margaree Consultants) and the Centre(UCCEE) tested liability provisions that have been put forward to foster the compliance of the Kyoto Protocol to the climate change convention in a three-month project. The Kyoto Protocol allows for measures that can be applied outside of a country's border, including international emissions trading. Some governments are concerned that these mechanisms will encourage countries to sell emission quotas, which they will subsequently need for compliance purposes (overselling). A number of governments and non-governmental organisations have proposed liability rules that include over a dozen liability proposals. A model was constructed for the period 2008-2012 to compare the liability proposals in terms of the quantity of emission quota available over time and the cost of compliance to legal entities. The model produced a ranking of liability options. The option that came out on top, a commitment period reserve, was subsequently taken up in the negotiating text for the implementation of the Kyoto Protocol. An abbreviated version of the report is published in the first issue of 'Climate Change' (2001).

Publication in 2000: 11
Fanny Missfeldt

Technical Support To UNFCCC National Communications

The National Communications Support Programme (NCSP) provides assistance to non-Annex I Parties in preparing their National Communications to the UNFCCC. The UCCEE is responsible for technical backstopping on the organisation and presentation of workshops, and for direct technical assistance to countries.

During 2000 the Centre provided technical backstopping to UNEP and UNDP in the design and presentation of thematic workshops on abatement (Kenya, March and Uruguay, June). In addition the UCCEE made financial agreements with UNDP Country Offices to support four regional exchange workshops: Malaysia (September), Armenia (October), Egypt (November) and Paraguay (December).

The Centre also reviewed different components of draft national communications for Bhutan, Cambodia, Croatia, Ghana, Guyana, Jamaica, Nicaragua, Sri Lanka and Trinidad and Tobago.

Juan Zak

CDM analytical issues

The Centre has established an analytical workprogramme in relation the development and possible implementation of the CDM. The programme builds on the Centre's long-term experiences with analytical and capacity building activities, work on climate change mitigation strategies and project analysis and focuses on the issues most critical to the interests of the developing countries:

Sustainability

The Kyoto mechanisms of the Climate Convention states in Article 12 that countries with a GHG reduction commitment can offset this by implementing so-called CDM projects in countries without such a commitment. It is a condition here that CDM projects should assist sustainable development in the project host countries. Inspired by the sustainability clause of the Kyoto Protocol UCCEE has initiated the development of a methodological framework for the assessment of GHG emission reduction policies in the context of sustainable development. The work includes general technical background work that addresses how climate change policy objectives can be integrated into a broader policy agenda for developing countries that include economic, social and environmental development dimensions. The framework suggests a number of indicators, which reflects these dimensions, and some of these indicators have been assessed in relation to national case studies. The financial costs and broader development implications were based on this framework assessed for 22 case projects in Zimbabwe, Botswana, Mauritius, and Thailand. This study extended a more traditional assessment of the costs of the various projects with development indicators that reflect local air pollution impacts, employment generation, health impacts and income distribution impacts. A number of the projects considered had significant positive local side-impacts, implying that GHG emission reduction and improvement of local air quality or increased employment could be achieved simultaneously. The results thereby indicate that the accounting framework applied to project evaluation has major implications on the cost effectiveness ranking of GHG emission reduction projects.

CDM Project Baseline Activities

When undertaking project-based activities such as under the Clean Development Mechanism, the evaluation of emissions reductions that are generated requires the estimation of a project baseline. In 2000 UCCEE pursued its programme, which focuses on developing and strengthening analytical and methodological capacity on baselines in developing countries. UCCEE builds on its prior mitigation studies that have focussed on identifying project possibilities at the national level. The programme offers technical advice, internet access to documentation and data to developing country experts in order to enable an independent formulation to be made of views on baselines from a Non-Annex I perspective. In 2000 UCCEE cooperated in this context with the Peruvian environmental agency CONAM and the South African energy research institute EDRC. In order to make more information available on recent methodological developments, UCCEE has set up a searchable and open-ended database on baseline literature on its website under www.uccee.org. As part of this programme, UCCEE has also reviewed the existing literature on baselines and has conducted a survey among a limited number of baseline practitioners and 'experts'.

Publications in 2000: 29, 30, 48, 49, 83
Kirsten Halsnæs, Fanny Missfeldt.

Energy for Sustainable Development

Implementation of Renewable Energy Technologies (RETs) – Opportunities & Barriers

In February 1999, UCCEE launched a Danida-sponsored UNEP project aiming to identify barriers to the implementation of renewable energy technologies (RETs) and explore measures to overcome the identified barriers. The project included three country case studies (Egypt, Ghana and Zimbabwe) that were prepared by national institutions in these countries. The New and Renewable Energy Authority at the Ministry of Electricity and Energy in Egypt, the Kumasi Institute of Technology and Environment (KITE) in Ghana, and the Southern Centre For Energy and Environment in Zimbabwe were responsible for the country case studies.

After preliminary identification of relevant RETs for the country concerned, national workshops involving various stakeholders were held between July and September 1999. Based on the discussions, a few RETs were identified for more detailed study. Barriers and opportunities for disseminating solar water heaters, PV systems for rural electrification and large-scale biogas systems were analysed for Egypt. Biomass, solar and small hydropower were explored for Ghana.

Final national workshops were held in June in Egypt and Ghana, and in August 2000 in Zimbabwe to discuss the findings of the study. The lessons learned from the studies point to key concerns on RETs and to the need for stakeholders to promote RETs. For example, in the case of Egypt, financial schemes, market incentives, and measures to assure quality of products have been proposed to overcome important barriers. Final reports are now being prepared by the participating teams of the countries.

The experiences from the case studies are now being generalised for the dissemination and use in promoting RETs. The national studies will be presented at the Re-

gional African workshop on Energy and Sustainable Development planned to be held in January, 2001. The regional workshop, sponsored by Danida, the United Nations Department of Economic and Social Affairs (UNDESA) and UNEP, will provide input to the Ninth Session of the Commission on Sustainable Development (CSD 9) to be held in 2001.

Publications in 2000: 44, 45, 46
Jyoti Painuly

Faster Market Penetration for Renewables in South Africa

The Government of South Africa is in the process of formulating specific policies on renewable energy. In March 2000, ECN, CSIR, RMA and the Centre (on behalf of Risø) launched a project to contribute to this process, financed by the SYNERGY Programme of the European Commission and the consortium members. The identification and evaluation of project opportunities for renewables in South Africa has been completed. The consortium is currently identifying the potential EU contribution to such projects and preparing an action programme to enhance the South African – European collaboration on renewables.

Juan Zak

African Rural Energy Enterprise Development (AREED) Initiative

The AREED initiative seeks to create and support energy companies that use renewable energy technologies to meet the energy needs of the poor, thereby reducing the environmental and health consequences of existing energy use patterns. AREED involves UNEP's Energy sub-programme and Regional Office for Africa, the Centre and E&Co, a non-profit organisation. Two regional representatives were appointed to deal with the Southern/Eastern, and West African regions. Country representatives were also appointed for Botswana, Zambia, Senegal, Mali, and Ghana. The project kicked off with introductory and project identification missions to each of the five countries, which resulted in a large number of prospective businesses and opportunities being identified. The first round of training of prospective entrepreneurs in business plan development took place in Zambia and Mali towards the end of the year.

Anton-Louis Olivier

Installing a 2.5 kW windturbine for remote area power supply in Africa

Sustainable Energy Advisory Facility

Recognising energy as one of the key areas for achieving sustainable development and strengthening coherence between energy development strategies and sustainability, the Ninth Session of the UN Commission on Sustainable Development (CSD-9) will be focused on energy issues. A substantial number of initiatives are taking place as part of the preparatory process led by governments, NGOs, industry associations and international organisations. As part of this process, the United Nations Environment Programme (UNEP) and Danish Development Agency (DANIDA) have launched the Sustainable Energy Advisory Facility (SEAF) project to meet very specific country needs regarding a broad range of sustainable energy topics. The project is being implemented by the UNEP Centre in close collaboration with the UNEP Division of Technology, Industry and Economics.

The Facility aims at strengthening the capability of institutions to analyse and implement sustainable energy approaches, and assist organisations and institutions to quantify and disseminate the results of their sustainable energy activities. These objectives are expected to be achieved by undertaking practical bottom-up type interventions oriented to: (i) reinforce integration between energy programmes and projects and sustainable development strategies; (ii) promote synergistic effects among projects; (iii) strengthen local capabilities on technology assessment and selection; and (iv) support both the completion and continuity of sustainable energy projects.

Sustainable energy objectives require undertaking actions in a mutually reinforcing manner avoiding duplication. Experience shows that there is a great deal of overlap at the level of both sectoral energy policies and individual projects, and their effectiveness can substantially be increased by fostering synergistic effects among them. The SEAF intends to demonstrate that harnessing these synergies does not require starting new programmes or projects, but rather implementing small-scale interventions focused on information exchange, working toward

convergence of strategies, and seeking a consensus on policy frameworks. This is precisely the focus of SEAF interventions. They are intended to be additional activities that draw on other works and catalyses other resources. For ongoing sustainable energy projects, SEAF would help strengthen their outputs or improve their results.

The pilot phase of SEAF has started with a limited number of countries. Botswana, Jamaica, Mali, Namibia and Uganda are those where SEAF interventions are being implemented. It is expected that the Facility will be expanded and extended in the future.

Arturo Villavicencio

Institutional Capacity Building in Burkina Faso

Since 1997 the centre has been involved, in collaboration with the Danish Energy Agency, in a Danida sponsored capacity building activity in the new Energy Agency in Ouagadougou in Burkina Faso. The second phase of the project has just been finalised. Besides a general lift in the capacity of the Agency a major result is a set of new laws for the electricity sector. One is the law which liberalises the electricity supply and has been approved by the parliament. Additional regulation has been prepared to set up a Regulator for the electricity supply, a Rural Electrification Agency and a Rural Electrification Fund where the latter shall support electrification projects for rural villages in the future. The money in the Fund shall come from a small fee on the electricity sold from the electricity grid.

Another important result is an electrification plan for the 386 capitals of all departments in the provinces in Burkina Faso. An electrification model for the country was built at Risø. The model projects the electricity consumption until 2016 in all the 386 villages based on specific indicators. The user has to decide whether and when the village shall be connected to the main grid, a nearby village, an auto producer, or have its own diesel generator or be supplied by solar PVs. A sub-model can calculate which of the supply options is economically optimal for a given village.

Jørgen Fenhann

Sustainable Energy Development in Small Island Developing States

The particular situation of Small Island Developing States (SIDS), namely heavy dependency on imported fossil fuels and high vulnerability to the effects of climate change, is addressed by the UCCEE in two different world regions.

During 2000 the Centre has collaborated with OLADE and GTZ in assisting decision-makers in the Caribbean to formulate and evaluate energy policies, with the aim of achieving sustainable development. Two case studies were undertaken in Jamaica and Barbados, in order to demonstrate the application of methodological guidelines prepared within the broader regional OLADE-GTZ-ECLAC project on energy and sustainable development

Another initiative being developed in the Pacific Island Countries is capacity building on integration of wind energy into the electricity systems. UCCEE staff assisted by Risoe's wind experts visited Fiji last March to develop a work plan with the regional partners USP and SOPAC. Later political developments in Fiji brought the project to a stall. Activities are being gradually restarted including arranging siting for the experimental wind turbine, specifying the postgraduate course and collecting information for the regional wind development plan.

Arturo Villavicencio and Juan Zak

Safe and Environmental Friendly Recovery, and Disposal of Explosive Wastes

All over the world large stocks of old ammunitions are awaiting destruction. The EU-Life program and Danish Environmental Protection Agency supported a multinational project to develop safe and environmentally friendly alternatives to the usual methods of destruction, viz. burning or detonation in the open air. The approach was twofold. It combined laboratory and large-scale tests to find the combustion properties and emission yields for specific wastes. This was supported by theoretical assessments using the methods of functional modelling and mufti-criteria-analysis to evaluate and compare the different technologies to establish the Best Available Technology Not Exceeding Excessive Costs (BATNEEC)

The co-ordinator was DEMEX Consulting Engineers A/S (Denmark) and apart from Risø National Laboratory the participants were Ammunitionsarsenalet, Kommunekemi A/S (both Denmark) and TNO (The Netherlands). The project was begun in 1996 and was finalised during spring 2000.

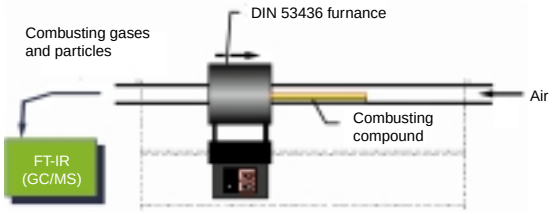


Figure 1. Illustration of the DIN 53436 furnace used for burning and pyrolysing desensitised wastes

Laboratory scale tests

Risø National Laboratory reviewed the degradation mechanisms of the energetic materials used and performed a number of combustion tests on desensitised wastes containing trinitro-toluene (TNT) or nitro-cellulose. This was done in a tubular furnace built following the specifications in DIN 53436.

The equipment enables the simulation of different combustion temperatures as well as pyrolytic conditions. The combustion emissions were analysed using on-line Fourier Transform Infra-Red (FTIR) spectroscopy for the gaseous emissions and sampling combined with GC/MS detection for the liquid/solid residues.

The FTIR was also used to measure the emission yields resulting from closed detonation chamber tests performed by Ammunitionsarsenalet.

The tests gave valuable information on emissions under different combustion, pyrolysis and detonation conditions.

Selecting the environmentally best solution

The project included a multi-criteria analysis in order to select the "best" disposal technique from the environmental point of view. Six different techniques were considered, including the currently applied techniques of Open Burning and Open Detonation. The criteria were: the air pollutant emissions, the total mass of controlled and uncontrolled deposited waste, the total area under occupation, and acute hazards for human life and health hazards. By quantifying the performance of a technique relative to an ideal solution, a single number, the score, can be derived. An "objective" score is obtained when all criteria are considered equally important. Alternatively, a score is constructed considering expert opinions on the relative importance of the criteria. The experts considered safety aspects to be more important than environmental ones. Because safety impacts differ less than environmental performance, scores based on expert judgements are rather close. The ranking isn't changed, however.

Table 1.
Comparison of disposal techniques for ammunition based on pollutant emissions to air and soil, area occupation, safeguarding life, and preventing health damage. The ideal score is 1.

	Score using equal weights for criteria	*Score using expert judgements*
Open Burning	*0.18*	*0.88*
Open Detonation	*0.40*	*0.91*
Closed Detonation	*0.37*	*0.87*
Fluidised Bed Oven (FBO)	*0.87*	*0.99*
FBO with urea injection	*0.95*	*0.99*
Rotary Kiln	*0.93*	*0.99*

Publications in 2000: 6, 28
Frank Markert, Nijs Jan Duijm

Importance of concentration fluctuations for toxic gas releases

The determination of safety distances around facilities that process or store toxic substances requires knowledge of the concentration at which people suffer from the toxic effects. At present, this information is gathered from tests

on animals exposed to the substance for at least 10 minutes. Experiments with toxic gas clouds drifting with the wind show that concentrations inside these clouds change rapidly, i.e. there are large concentration fluctuations (the dark blue curve in figure 1). In order to investigate how important these fluctuations are for the toxic effects, Risø developed a model describing the time-dependent uptake of gases in the airways of humans and test animals. The model uses a representation of the geometry and branching of the almost 40 elements in the airway from the nose, throat and trachea down to the microscopic alveoli in the lungs. The airflow and penetration and diffusion of the toxic substance is then calculated during a series of respiration cycles. The model shows that the tissue in the human airways responds to variations of concentration within a few seconds (the purple and yellow curves in the graph). Thus, for highly reactive gases (like ammonia and chlorine) concentration fluctuations are important to consider for their toxic effects. At present, most dispersion models in use for predicting the extent of toxic gas clouds present concentrations averaged over, say, 100 s only (the light blue curve). These models need to be improved in order to incorporate concentration fluctuations. Similar improvement is needed as information is gained on the toxic effect of extremely short duration exposures.

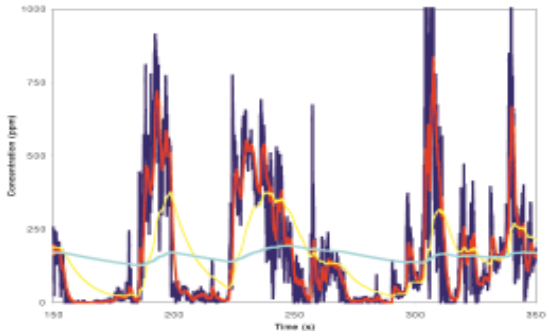


Figure 1. Concentration fluctuations in a toxic gas cloud. The graph shows measurements without processing (dark blue) and after averaging over 1s, 10s, and 100s (purple, yellow, and light blue, respectively). Concentration in the lungs (1s to 10s averaged) can be much higher than predicted by dispersion models (100s averaged).

The work was performed in the framework of a 2-year CEC-supported project in co-operation with TNO, The Netherlands, and the Royal Danish School of Pharmacy, and concluded in 2000. Work in 2000 addressed validation of the model and assessment of the relevant time scales in the airways.

Publication in 2000: 54
Nijs Jan Duijm, Søren Ott

Factors contributing to uncertainties in risk analyses

Quantitative Risk Assessment is an important part of the decision-making process concerning land use planning and the acceptability of industrial facilities in given locations. In order to improve the understanding of the uncertainties associated with Risk Analysis of major industrial hazards, a European project on the ASSessment of Uncertainty in Risk ANalysis of Chemical Establishments (ASSURANCE) was launched in May 1998.

A key element in the project is the use of a Benchmark Exercise, i.e. studies of the same facility carried out by different teams independently of each other. Seven research teams from different countries performed risk analyses of the same ammonia storage plant. The Systems Analysis Department's role (jointly with the EC's Joint Research Centre) was to co-ordinate the exercise, compare the results, and identify the sources of uncertainty and their magnitude.

The project was divided into three phases: (i) the qualitative analysis phase, where hazards were identified, assessed qualitatively, characterised and screened, (ii) the quantitative analysis phase, resulting in the assessment of individual and societal risk, and (iii) the performance of a number of case studies, to get a greater insight into specific issues arising within the risk analysis procedure.

One way to present the results of a quantitative risk analysis is by means of iso-risk curves, i.e. curves on a map where the risk is the same for all points on the curve. An example of iso-risk curves for the individual risk is shown below. The individual risk is the probability that a person staying unprotected in the same location around the clock during one year will die as a consequence of an accident in the facility considered. The two curves shown are the maximum and minimum distances found by the partners in the project for an annual fatality risk of 10^{-5}.

Figure 1. Iso-risk curves for annual individual risk of 10^{-5}

The work during 2000 concentrated on the uncertainty assessment for the quantitative analysis phase. It was carried out separately for the frequency assessments and consequence modelling of hazardous scenarios. This separation allowed the identification of the very root causes of the deviation in risk assessments and their range among the research teams.

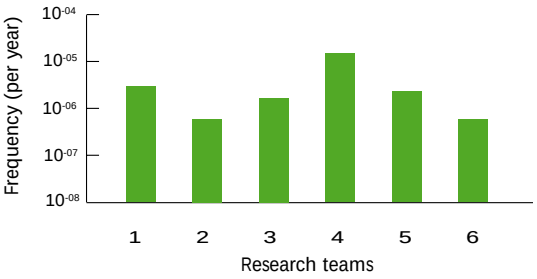


Figure 2. Frequencies of the rupture of a pressurised ammonia tank

Figure 2 is an example demonstrating the deviation in frequencies for one scenario by six research teams. As can be seen, there are deviations of more than one order of magnitude between some teams in this case. An investigation into the root causes of the deviations reveals differences in data sources, in the use of data from the same source and in the interpretation of plant data.

Although the project will not be terminated until mid-2001, the findings made so far show that substantial differences may exist between the results from different risk analysts. The following types of uncertainty have been found to influence the results:

* Misunderstandings or lack of knowledge about plant layout and operation
* Completeness of hazard identification
* Modelling uncertainty (failure modelling and consequence modelling)
* Data uncertainty

Publications in 2000: 78, 93

Igor Kozine, Kurt Lauridsen, Frank Markert

Availability of offshore wind farms

*For a single system the **availability** is defined as the fraction of time for which the system may operate. The concept availability assumes two possible states for the system, either operable or not operable. For a group of identical units, e.g. a wind farm, the availability definition will have to be modified into an average value, because the group will have many states of operability. The sum of operable time for all units divided by the sum of calendar time of all systems, is called **the group availability factor**.*

The Departments of Wind Energy and Systems Analysis with the support of the Danish Energy Agency have established a collaboration with the power distributing company SEAS to evaluate the special maintenance conditions for offshore wind farms and how these will influence the productivity. The maintenance situation for offshore farms is heavily influenced by the climate.

There will be two situations when a turbine will be unavailable:

The first will be when it is undergoing preventive maintenance. Preventive maintenance can be planned in advance. The farms will contain equipment for remote monitoring in order to identify incipient faults. Repair of such faults may require only a brief planning period.

The second will be due to unforeseen faults. These may cause the turbine to stop immediately. The possibility to repair the defect will depend on the weather. Transport to the turbine must be possible with the available ships. So a visit to an offshore farm requires a span of time during a climatic window, which enables safe transport and safe working conditions at the site. These conditions depend on climatic factors, so the down-time of a turbine in connection with a corrective repair will be statistically distributed in accordance with the climatic factors.

Modelling methods

All maintenance actions can be broken down into a sequence of time spans, i.e. time for mobilising the repair staff, waiting for an acceptable climatic window to appear, transport, maintenance at the turbine, and the transportation to return. A formula for this time sequence has been set up. It takes into account preventive and corrective maintenance, and the time spans are handled as statistical distributions. It expresses the down-time as the sum of all repair hours with a turbine stop and all mobilisation and transport times as well as waiting time caused by an unsuitable climatic condition in cases of corrective maintenance.

At the site at Rødsand, identified for a future farm, climatic measurements have taken place for a couple of years. For the modelling work these weather situations have been classified according to accessibility of the wind farm with ships of different sizes.

The climatic window was modelled with a Monte Carlo simulation. The distributions of wind, waves etc. form the input to a Markov chain for climatic states in order to secure coherence between the half-hour climatic values to be used in the simulation. Using this, turbine down-time was simulated.

Publication in 2000: 57

Palle Christensen, Jette L. Paulsen

Figure 1. Repair works at Tunø knob Wind Turbine Site (Photo: Elsam)

Development of a user interface for a dual band radio for the Danish national railways

One consequence of the establishing of the new Øresund Bridge between Denmark and Sweden is the need for Danish trains and train drivers to be able to operate effectively in the two countries. Not only are there technical differences between the two countries regarding overhead voltage etc, but the communication systems between trains and the train control centres in the two countries are different. This means that in each train two different radio systems must be available in order to ensure connection to the control centres. In 2000 the Danish State Railways (DSB) have started to develop a new dual

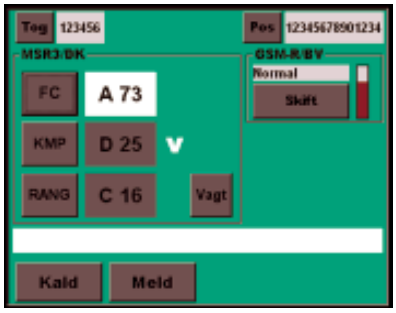


Figure 1. The central part of the design showing the proposed interface for the MSR-3 system.. The radio is listening on channel A73, and has a guard on channel D25. Pressing the Call button ("Kald") will send a communication request to the command post FC. The "Meld" button will give the train driver the possibility to send a predefined message to the FC command post.

mode radio system. The new system implements both the analog MSR-3 radio system (used in Denmark) and the digital GSM-R radio system (partly implemented in Sweden) in a common system so that the train driver has a single interface to operate both systems. The GSM-R system (based on the GSM mobile phone standard, R means Railway) is the emergent European standard for train radio communication.

In order to ensure that the user interface was designed with due respect to human factors, Risø was involved in the project. Our task was to evaluate the design of the proposed user interface design and suggest changes in the design. Subject experts were interviewed with regard to functionality and working conditions of the train drivers. It turned out that the best way to carry out an evaluation of the different designs was to develop prototypes of the proposed design. These prototypes were then used as the common media for discussing design and changes to the design. A number of different prototypes have been developed and the final one shown in figure 1 will be the one used to evaluate the design. "Real" train drivers will

View from the train driver's position crossing the Øresund Bridge. The interface to the current MSR-3 radio is shown on the left and the current GSM-R system is the handset shown to the right of the speed indicator.

be shown the interface and will be asked to manipulate the different controls. In order to facilitate the evaluation, the prototypes have been implemented on a touch screen.

The following principles have been used for the "final" version of the prototype user interface:

- Useful features from the MSR-3 radio used today have been implemented.
- The interface for the two radio systems should be as similar as possible, meaning that even if the technology behind the two systems are very different, common operations should be carried out in the same manner.
- It must be clear for the operator which part of the interface is active and which part is used to display information

The prototypes have been developed in close co-operation with SAIT-STENTO Danmark A/S, which are responsible for the implementation and the technical interface to the hardware.

Steen Weber, Chr. Rud Pedersen, Hans Andersen and Jette L. Paulsen

Evaluating usability of web sites

One of the key factors that determine whether a web site is successful or not is its usability. If users cannot find their way around a site they are liable to jump to another, and a customer or client may have been lost. But how can usability be measured? As it turns out, evaluation methods that have been developed for in safety systems such as aviation and shipping may be applied to targets such as web pages that entail no hazards at all - beyond possibly financial ones.

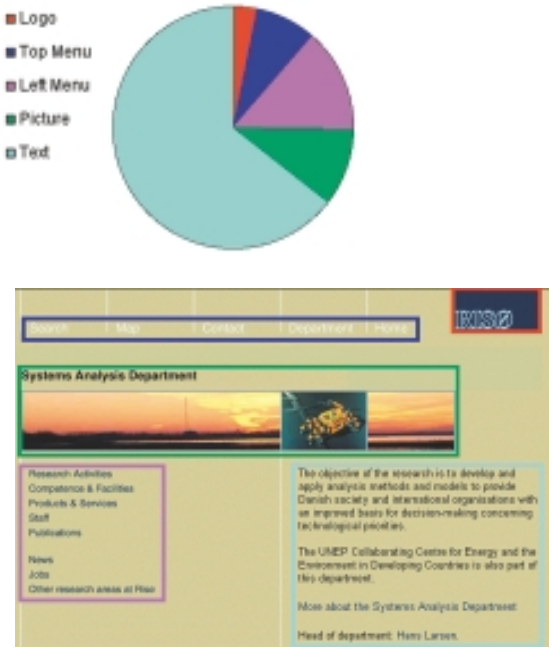


Figure 1. The Figure shows how much time the user has spent on different parts of the page. Such an analysis will reveal how much time is spent on menus compared to the informative parts (here the text). If relatively long time is spent on the menu it indicates that the user does not understand the menu items.

Based on many years of experience with evaluating safety critical applications and analysis of human-machine interaction, the Human Machine Interaction Laboratory has in recent years adapted the advanced and sometimes labour intensive methods of safety critical evaluations to the measurement of web site usability. By applying eye tracking to a web pages the following question can be answered in a non-intrusive way.

- Where is the user looking?
- Does the visual appearance match the task and purpose of the web site?
- Where does the user look most of time?
- How complex is the task?

Chr. Rud Pedersen, Hans H.K. Andersen, Steen Weber

Centre for Human - Machine Interaction

To cope with the rapid development of new technologies, the Centre for Human-Machine Interaction has conducted basic research in work analysis and ecological interface design during 2000 to improve the design and implementation of new computer-based systems. Field studies have been carried out in co-operation with industry and organisations where problems related to user interface and functionality can be identified. Co-operation with industry has also served to validate hypotheses by tests of system prototypes, and will lead to a fast transformation of basic research results into the development of an innovative technology with direct bearing on commercial competitiveness.

A cognitive work analysis has been applied to e-commerce in the "Cogito" EU project with partners from Germany and Italy. The evolution of e-commerce and interactive internet services has led to both a constantly increasing number of modern web sites and to an increase in their functionality. This makes them complicated to use and places too high cognitive demands on the users. This problem is currently being solved by new, pro-active, intelligent, personalised *agents* who co-operate with the users.

> ***Intelligent agents*** *are programs, used extensively on the web, which perform tasks such as retrieving and delivering information and automating repetitive tasks. Agents are designed to make computing easier. Currently they are used as web browsers, news retrieval mechanisms, and shopping assistants. By specifying certain parameters, agents will "search" the Internet and return the results directly back to your PC.*

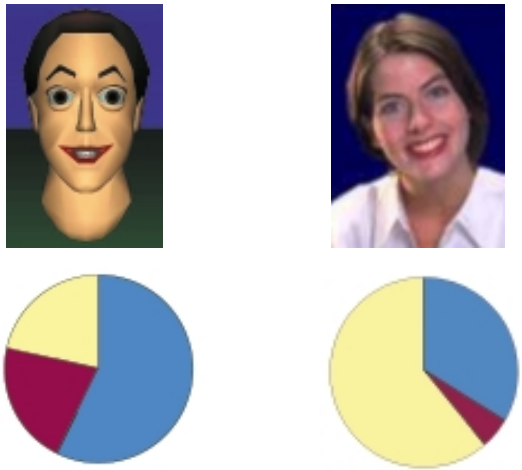
The purpose of the agent is to improve e-commerce sites as related to user friendliness, support of performance on the site, and in the end to convert visitors of the site into customers.

The methods performed for the user requirement elicitation in Cogito were based mainly on investigations using questionnaires and from a focus group established and run by Risø.

The experiment was performed in two parts: The first makes use of individual "interviews by doing" sessions using various e-commerce sites with and without intelligent agents. In the second part the complete group discussed ideas, wishes, and constraints as related to the use of intelligent agents.

During the sessions requirements were extracted and structured in relation to a compressed means-end hierarchy using the terms: the overall strategic goals, the procedures needed for supporting these goals, and the operations necessary for building up these procedures. Furthermore, during the focus group discussion the importance of the appearance of the intelligent agent were discussed and tested by a word association test, in which a number of agents were classified considering the appearance related to the trustworthiness and the seriousness of the agent.

The user requirements will be analysed in more detail and presented prioritised to the software developers. Later, user profiles will be analysed to extract usage patterns from the data given about user communities. This helps content providers tailor their offers to the customers' needs, and can be used to generate assumptions about new users. The new conceptual challenge for ecological



Cogito Eve

Figure 1. Two examples of intelligent agents and their evaluation, yellow indicates positive evaluation, blue negative, and brown neutral.

design of agents is to apply models of human behaviour at work into agents' behaviour on the web.

Inherent in the conceptual tools for ecological design is the idea that user-friendly design of technology is informed by a knowledge organisation based on abstraction hierarchies of work domains and decision tasks. Therefore, work in 2000 has also identified a number of such hierarchies, which are called "Ecological Classification Schemes". These are urgently needed to structure collaboration via communication technologies.

Publications in 2000: 7, 16, 68, 80, 84, 103, 104
Annelise Mark Pejtersen, Verner Andersen

Validation of Human Error Classification

It is widely recognised that human and organisational errors are responsible for the majority of accidents and incidents in safety critical domains such as aviation and maritime operations. To enhance safety in these domains it is therefore important to collect and analyse accident and incident data in order to recognise patterns across critical situations that, superficially, may not look alike.

Risø has led a large-scale test of a comprehensive incident classification system or "taxonomy" designed to classify human errors and associated causal factors involved in incidents in Air Traffic Control. The development and testing of the system (HERA: Human Error in Air Traffic Management - Phase 1) was supported by Eurocontrol (The European organisation of Air Traffic Control) and made in collaboration with the National Air Traffic Services (UK) and Eurocontrol.

The HERA system is one of the most comprehensive - and therefore rather complex - classification systems available, comprising seven groups of psychological and other factor categories. To enhance the usability of the system a computer-based training program (CBT) was developed containing examples of "errors" as well as exercises that teach users to apply HERA.

Due to the complexity of the system it is of considerable interest whether professional users will be able to apply such a system reliably (see Table 1 depicting the HERA taxonomy groups). A test was therefore carried out to ascertain whether professional users would agree when classifying *descriptions* of events into the categories contained in the HERA taxonomy. The event descriptions used for the test were excerpted from authentic incident reports describing "close encounters" in European airspace.

The test of the HERA system involved 26 professional users recruited from different European countries. They were introduced to the classification system over 1-3 days. They then studied and classified descriptions of 20-30 events involved in incidents when airliners have breached separation minima. The results of the experiment showed that users were largely in agreement about the psychological error categories: professional incident investigators achieved agreement of more than 60% over and above chance agreement. On the other hand, they were slightly less in agreement about the classification of the technical and organisational factors involved in incidents.

The validation experiment was the largest experiment of its kind so far, and its results will be used to shape the refinement of HERA and similar classification systems. This is done in order to establish robust databases from which conclusions can be drawn about patterns of causes of incidents and accidents. This enables more efficient counter-measures to be developed.

Publication in 2000: 1
Henning Boje Andersen, Thomas Bove

Table 1. The 7 dimensions of the HERA taxonomy.

Outside factors:
1. Task
2. Information
3. Performance Shaping Factors
The individual act:
4. External Error Mode, the action was too late, too early, an omission…
5. Which Cognitive Domain was involved (memory, perception, judgement)?
6. Internal Error Mode, which function failed?
7. Psychological Error Mechanism, which mechanism lies behind the failure?

REMAP Research Management under Rapid Change

Management of research is based on decisions taken at a high level of uncertainty and involves a number of different actors and different perspectives (e.g. the political system, researchers, managers, research institutions, firms, inter-organisational collaborations, etc.). Thus, a dynamic and interdisciplinary understanding is needed for the management of these complex processes. With the aim of improving this understanding a joint research project, Research Management Processes under Rapid Change (REMAP), was inaugurated late 1999. Partners in the project are Copenhagen Business School, Danish Institute for Studies in Research and Research Policy, Risø National Laboratory, Danisco Cultur Innovation, Haldor Topsøe A/S, TeleDanmark A/S, NKT Research Center A/S, Reson A/S and Astion A/S.

The results of Risø's activities in 2000 in the REMAP-project are briefly mentioned in the following.

A PhD-course on management of research and innovation was developed and organised in co-operation with Copenhagen Business School's Institute for Management, Politics and Philosophy. 12 PhD-students from Risø and one from the Danish National University Hospital participated in the course in the Autum of 2000. The course was divided into three modules. Module 1 covered an introduction to central theoretical themes in management of innovation and research. Module II contained project-work during which the students taking the starting point in their own research prepare an economic and/or managerial perspective of their project, for example an analysis of business potentials, research strategy and business plan for establishment of a firm. The project work was typically reported in reports of 5-10 pages. 5 hours of tutorials were allocated to each project. Module III was arranged partly as a mini-conference during which the students present their projects and partly lessons on application oriented issues as writing business plans, patenting, project management of PhD projects. Furthermore, Professor Henry Etzkowitz of University of New York at Purchase gave a presentation on the Triple-Helix relation between industry, science and government. Based on very positive and satisfying feedback from the students, the course will be repeated in 2001, and participants from industry and other research organisations are welcome.

A PhD-project with the title "Corporate Equity Venturing - in gaining innovation capabilities and sustaining competitive advantage" has been initiated in co-operation with Copenhagen Business school. Furthermore, a second PhD-project concerning aspects of scenario methodologies in research strategy processes under the new mode of knowledge production has been prepared and will be initiated in the beginning of 2001.

Mobility of scientists is also an important element of the REMAP project. A Postdoc. and a PhD student from Risø have been located at Copenhagen Business School, and an associated professor from Copenhagen Business School and a senior scientist from Danish Institute for Studies in Research and Research Policy have been visiting scientists at Risø.

February 25th a project workshop was held on research management in the future. The aim was to suggest and discuss the most important driving factors (i.e. values) for good research management in the future. 12 participants from REMAP's research organisations participated in the workshop, and two external speakers were invited to give introductions reflecting archetypal Mode 1 and Mode 2 perceptions of research management. The participants

Module 1 of the PhD-course on management of research and innovation

First day:
The role of science in society
Research and Knowledge. The new science - MODE 2 research and research quality.

Second day:
Innovation theory and innovation strategy
Introduction to innovation theory. How research can contribute to value creation and how it is captured. Managing Knowledge. Group work on innovation potentials and other applications of participants' PhD-projects.

Third day:
Technology foresight and strategy processes
Introduction to Technology Foresight - contexts and methodologies. Research strategy processes. Group work on research strategies in the participants' organisations. Introduction to scenario methodology. Group work: Scenario process in leading to a long term research strategy on a selected research area or PhD-project.

Fourth day:
Management of research
Management challenges in small research based firms. On being a high-tech entrepreneur. Management of knowledge in small high-tech firms. Research management: Management of Order, Autonomy and Control, Incitement Structures.

were split in two groups that discussed future characteristics of research management from two approaches. The first group (primarily managers and senior scientists) discussed driving factors for research management. From these drivers scenarios for research management could be derived. The other group (primarily younger scientists) discussed their visions and expectations for research management in 2030. Based on these visions and expectations important issues could be derived.

A seminar on Goal Setting and Prioritizing Processes in Research was held at Risø November 28th 2000. Six speakers from Denmark and abroad gave presentations on their organisations' pratical experiences concerning research strategy processes. The presentations covered research organisations, universities and industry. 35 participants from research, industry and government agencies participated in the seminar.

Industry Oriented Technology Foresight

National technology foresight programmes often focus on national or governmental policies on science and technology. Although industrial competitiveness, creation of new jobs and new business opportunities are key issues in national foresight programmes, companies' and especially SMEs' strategic possibilities and needs often come as a second priority in the design of foresight programmes. As only very large firms are able to carry out comprehensive in-house technology foresight projects this leaves a need for developing and offering such strategic tools for small and medium size enterprises. The concept of technology foresight is based on a range of practical methods, which offer a means for strategic management of research and technology. It is a toolbox with a set of different tools, which can be combined depending on the context. The challenge is to select the set of tools that match a given context. A preparatory project financed by - and carried out in 2000 in co-operation with - the Confederation of Danish Industries (Dansk Industri) and the Central Organisation of Industrial Employees in Denmark (CO-Industri) took up these challenges.

International experiences on technology foresight have been studied - especially the experiences in Germany and the UK. The practical experiences on a foresight project of the German pharmaceutical firm Janssen-Cilag GmbH were also studied.

The main outcome of the preparatory project was a detailed description for a firm oriented technology foresight project in Denmark, based on international experiences and special Danish conditions. The overall aim of the suggested project is to contribute to the competitive advantage of companies based on technology and science. Furthermore, the project aims at strengthening the societal interest for technology. The suggested project has three parts. Part one is a technology foresight in each of the three sectors. Part two comprises implementation of the general results in selected firms within the sectors. Such a phase is seldom included in traditional national foresight programmes, but is perceived as of paramount importance in an industry oriented foresight project. Part three comprises systematic collection of experiences and anchoring of these experiences in ongoing research in strategy and research management. Based on this a road map for industry oriented technology foresight can be established.

The preparatory project revealed a number of issues to take into account when planning firm oriented technology foresight projects. Some large and medium size firms has indicated interest technology foresight and in carrying out such foresight projects within their own organisations. But a range of worries was raised concerned sector-wide projects. Key staff from firms' R&D departments is usually very busy and spending time on processes without direct benefit for the firm is often perceived as waste of time. During longer panel processes with 6 or 10 meetings over a year there is a risk that participation in expert panels comes as a second priority. The preparatory project has suggested means to mitigate this and increase the attractiveness in participating in sector-wide panels. Another issue is affiliated with the increased competitive business environment. Firms are reluctant in sharing ideas and point of views with representatives from other firms - even with firms in non-related sectors. Firms often seek to develop new business opportunities in related area - related markets or related technologies. And another firm from a different business sector might be developing the same business opportunity from another angle of attack. By letting senior R&D staff participates in the same expert panels - even of generic scientific areas - there is a worry that revealing such strategic consideration in one firm might inspire another firm to discover the same business opportunity. The preparatory project also in this case suggested means to overcome this consideration.

An important outcome of this preparatory project is the acquired knowledge on technology foresight in the Technology Scenarios research programme at Risø. The study of the international experiences, the considerations on the pre-conditions for technology foresight in a Danish context and the quite detailed considerations on how to plan a foresight project have made the Technology Scenarios research programme well-equipped to carry out foresight projects. These experiences have been utilised in a foresight project on sensor technology.

Per Dannemand Andersen

Sensor Technology Foresight

In order to strengthen a strategic outlook on sensor technology, Sensor Technology Centre A/S (STC) has decided to carry out a sensor technology foresight project in co-operation with the Technology Scenarios research programme.

Sensor Technology Centre A/S (STC) is the result of a joint initiative by five Danish approved Research and Technological institutes (the so-called GTS-institutes), and STC is part of the Danish Sensor programme to which the Danish government has granted app. 14 MEURO for a special effort on sensor technology. STC aims at facilitating the knowledge and competencies necessary for the development, production, and application of sensors. STC establishes and operates projects necessary for the development of new sensor technologies. One of the foremost tasks of STC is also to create networks

This sensor technology foresight project has four objectives. The first objective is to present some scenarios of the future developments in sensor technology with respect to technology, application and market issues in a timeframe of 2000 to 2015. The second objective is to contribute as decision support in prioritising research, development and commercialisation of sensor technology. The third objective is to maintain and develop STC's networks within sensor technology. Finally, it is the projects objective to test elements of a technology foresight methodology in a quite narrow area of technology. The primary target groups for the results of this project are Danish decision-makers within sensor technology. That is STC A/S, the Danish Agency for Trade and Industry and Danish firms involved in sensor technology.

The project comprises of six tasks. Task one is titled Technology Mapping. The purpose is to identify the boundaries and categories of the technological landscape to be analysed. Task two is a Technology Scanning aiming at establishing the state-of-the-art within sensor technology and to define boundary conditions for sensor technology over the next 15 years. The third task is a number of case studies in order to analyse important mechanisms in sensor technology breakthroughs. In task four technology is linked to the marked, and the purpose is to establish a prospective discussion of the development trends of the interaction between market and technology over the next 15 years. Task five is a Delphi survey that is carried out in order to improve validity and reliability of the sensor foresight. Finally, task six comprises the processing and combination of results and dissemination of the findings. This final task also consists of discussion and processing of the various elements of the previous tasks within technology mapping, case studies, technology scanning and the Delphi survey. As an integrated element of the analysis and compilation of results, an expert panel will be invited to comment on the preliminary results of the Delphi rounds in order to interpret and comment on the findings in time to do necessary follow ups on the foresight.

The project was initiated in October 2000 and will be finalized medio 2001.

Birte Holst Jørgensen

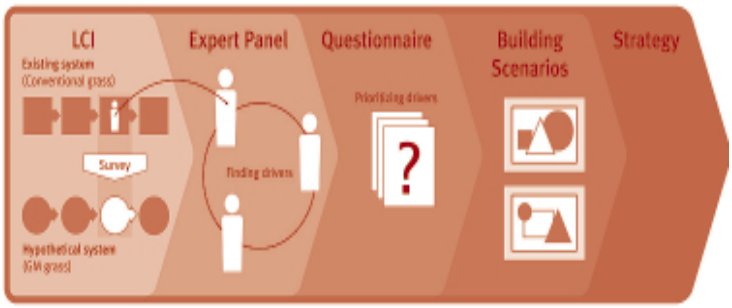


Figure 1. The methodological framework and hierarchic flow used for the analysis of the GM-ryegrass

Finding the drivers for the utilization of a GM crop technology

Technologies are becoming more and more complex, largely as a result of the modern world's endeavour to increase productivity. One result of this complexity is a new type of uncertainty about our future, an uncertainty whose distinctive feature is disagreement amongst experts about the future consequences of present-day technological innovations. The complexity and advanced nature of modern biotechnology is an example of such technologies. Because its extensive implications for society regarding prosperity, risk and ethics, make a view of the future that is comprehensible and transparent to society desirable to secure a judicious deployment.

Therefore, we have performed a feasibility study where we investigated methodologies for strategic planning and regulatory decision-making in technologies involving genetically modified (GM) ryegrass. The planning and regulatory decisions of both the biotechnology industry and public authorities are considered.

The method used combined a technology foresight (TF) framework (Figure 1), using a life cycle inventory (LCI) to define the problem complex and a stakeholder panel to identify drivers (of change) that influence the direction of future developments.

Kristian Borch

Summary Statistics

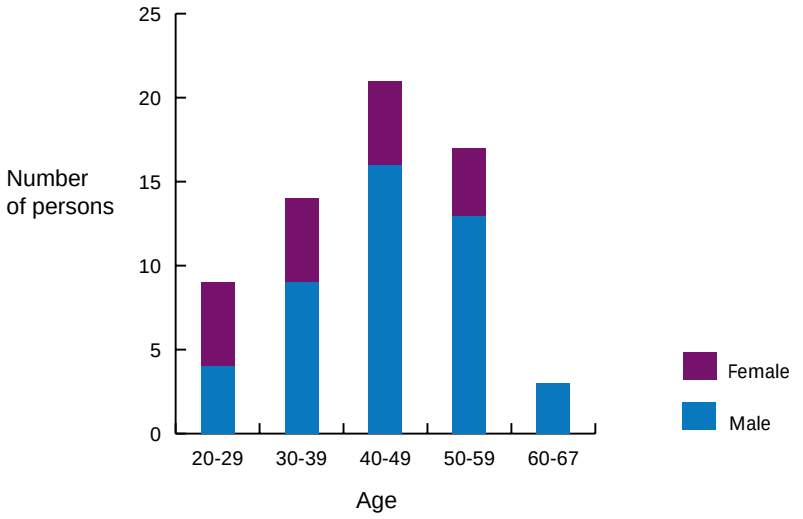
By the end of the year the total number of employees in the department was 64, of whom 19 were women and 45 men. More than 90 per cent of the staff have an academic background. The age distribution shows that approximately one-third of the staff is between 40 and 49 of age. One-quarter is in the range 50-59 years and one-fifth 30-39 years of age.

The number of publications in 2000 totalled 114. The number of international publications rose from 45 in 1999 to 49 in 2000, while the number of conference contributions in proceedings declined from 50 to 40 in the same period.

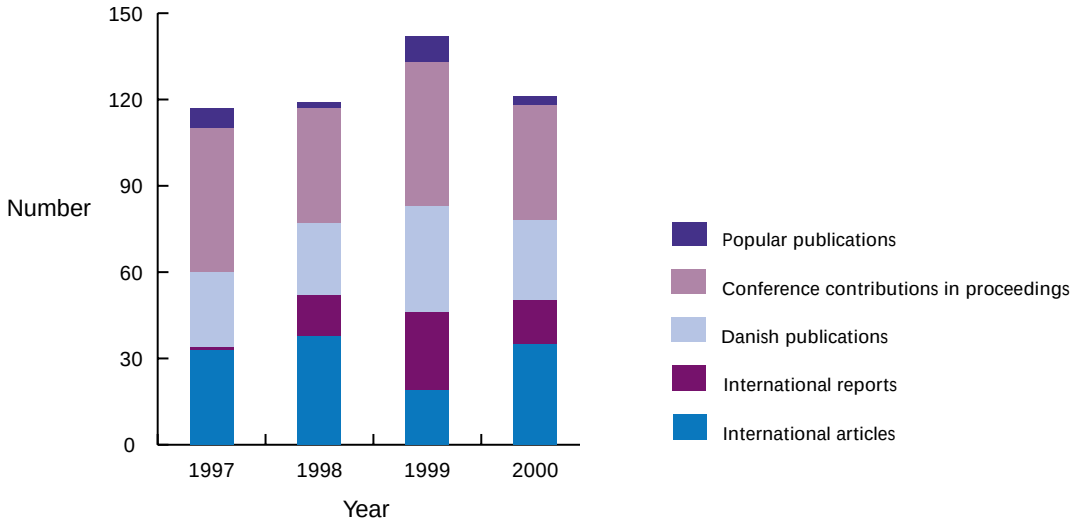
Staff 2000

	Females	Males	Total Staff
Academics:			
Head of department and programmes	0	5	5
Research specialists	1	1	2
Senior scientists	4	24	28
Scientists	3	5	8
Technical/administrative staff	3	2	5
PhD students	3	7	10
Postdoc fellows	1	0	1
Technicians	0	1	1
Secretaries	4	0	4
Total staff	**19**	**45**	**64**

Age distribution

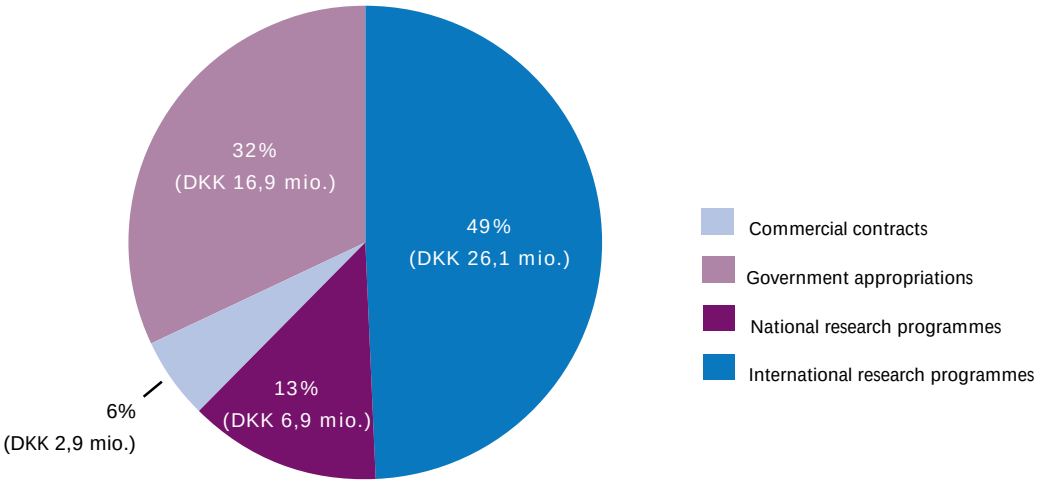


Publications

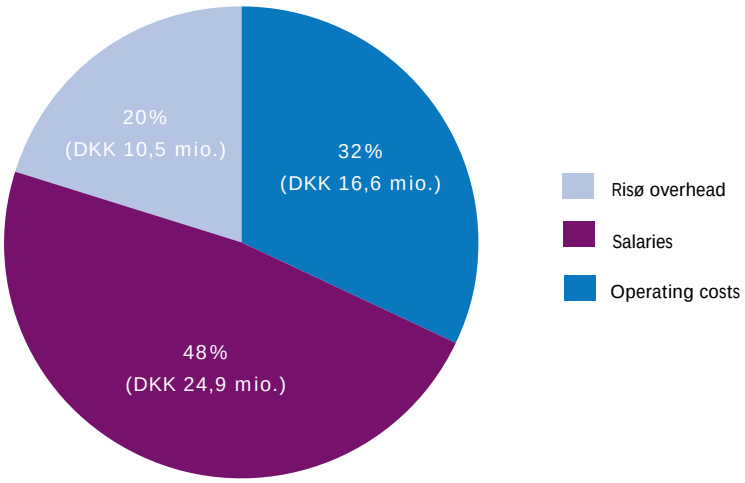


In 2000 total revenues amounted to DKK 52.9 M. At the same time, expenditures were DKK 51.9 M, thus resulting in a surplus of DKK 1.0 M. 32 per cent of the revenues came from government appropriations and 49 per cent from international research programmes. Salaries accounted for 48 per cent of the expenditures, while 20 per cent were Risø overhead.

Revenues



Expenditures



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Palle Christensen, M.Sc. (Elec. Eng.), Senior Scientist
Mark Dunlop, B.Sc. (Comp. Sci.), PhD, Senior Scientist – until 31.07.2000
Carsten Grønberg, M.Sc. (Elec. Eng.), Scientist
Camilla Buhr Hansen, MLISc., Research Assistant
Gunnar Hauland, M.Sc., PhD Student
Morten Hertzum, M.Sc. (Comp. Sci.), PhD, Senior Scientist
Igor Kozine, M.Sc. (Systems Anal.), PhD, Senior Scientist
Kurt Lauridsen, M.Sc. (Elec. Eng.), PhD, Senior Scientist
Leif Løvborg, M.Sc. (Elec. Eng.), Senior Scientist – until 31.03.2000
Frank Markert, M.Sc. (Chem.), PhD, Scientist
Finn R. Nielsen, M.Sc. (Appl. Math. & Phys.), Scientist
Søren Ott, M.Sc. (Phys.), PhD, Senior Scientist
Jette L. Paulsen, M.Sc. (Eng.), Senior Scientist
Christian Rud Pedersen, M.Sc. (Eng.), PhD, Scientist
Annelise M. Pejtersen, M.A. Senior Scientist, Head of Centre for Human-Machine Interaction
Birgitte Rasmussen, M.Sc. (Chem. Eng.), PhD, Senior Scientist
Steen Weber, M.Sc. (Elec. Eng.), PhD, Senior Scientist

Technology Scenarios

Per Dannemand Andersen, M.Sc (Eng.), PhD, Head of Research Programme
Kristian Borch, M.Sc. (Eco-toxicology), PhD, Scientist
Cynthia Horn, MA (Sc., Tech. and Soc.) Research Assistant
Dominic Idier, M.Sc. (Phys.), PhD, Postdoc - until 31.05.2000
Birte Holst Jørgensen, M.Sc. (Social Sc.) PhD, Scientist
Jon Olav Pedersen, M.Sc., PhD Student

Research Technician

Erling Johannsen

Programmer

Søren Præstegaard, until 31.08.2000

Short term guest researchers

Farit Akhmedjanov
Finn Hansson
Kamma Langberg
Toufig Siddiqi

Temporary Staff

Kim Winther
Timothy Taylor
Kai Holst Andersen
Lars Bech Christensen
Oliver Thomas Kopp