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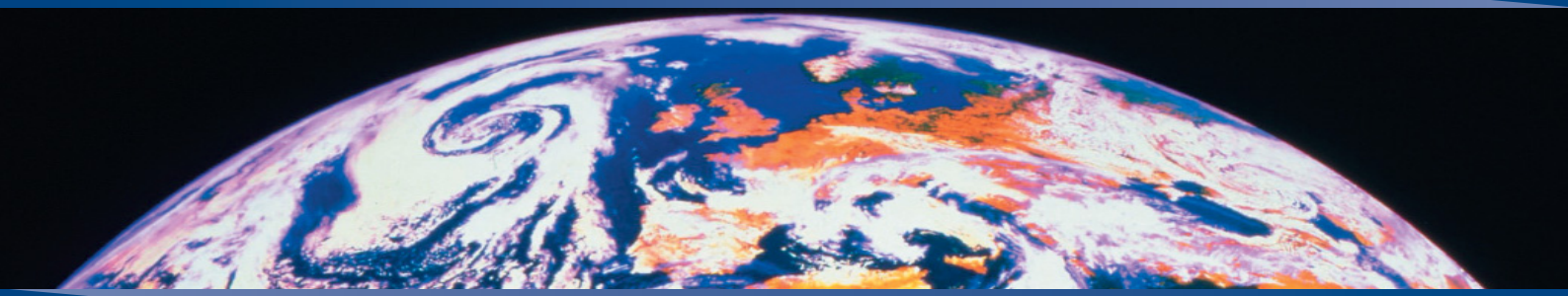
Edited by Nijs Jan Duijm, Elin Jensen, Hans Larsen and Stine Skipper



Risø National Laboratory

April 2002

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Systems Analysis Department

Annual Report 2001

Edited by
Nijs Jan Duijm, Elin Jensen,
Hans Larsen and Stine Skipper

Risø National Laboratory
Roskilde . Denmark

April 2002

This report describes the work of the Systems Analysis Department at Risø National Laboratory during 2001.

The department is undertaking research within Energy Systems Analysis, Energy, Environment and Development Planning – UNEP Centre, Safety, Reliability and Human Factors, and Technology Scenarios.

The report includes summary statistics and lists of publications, committees and staff members.

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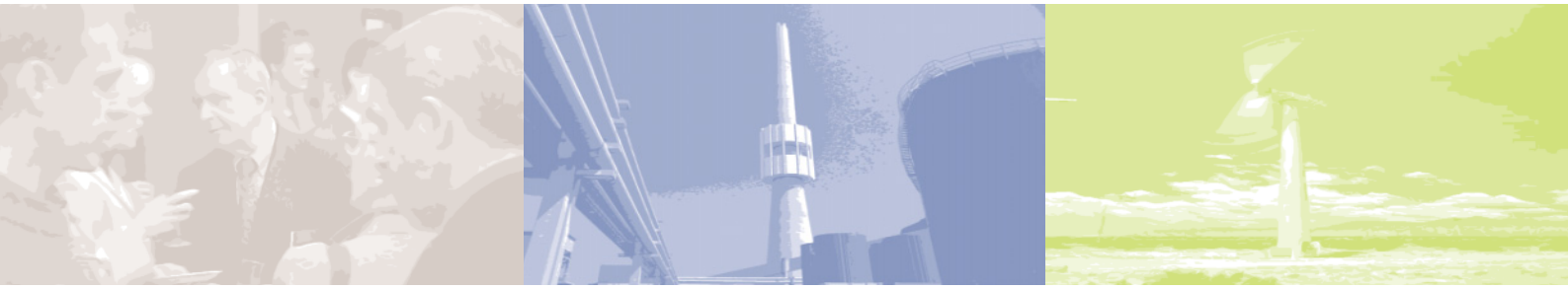
Systems Analysis Department



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Contents

4 Introduction

Energy, Environment and Development Planning

6 UNEP Collaborating Centre on Energy and Environment – International activities and UNEP support
7 Sustainable Energy
10 Climate Change

Energy Systems Analysis

12 Distributional Implications of Evironmental Taxation in Denmark
13 Green markets
14 Development of renewable energy technologies at liberalised market conditions
15 Hydrogen via electrolysis as a power-regulation component
16 Applying benchmarking analysis to the Danish district heating sector

Technology Scenarios

17 Sensor Technology Foresight
18 DECENT: Decentralised generation technologies – potentials, success factors and impacts in the liberalised EU energy market
19 Prospective Life-Cycle Assessment of Future Wind Energy Technology

Safety, Reliability and Human Factors

20 SafetyNet – A European networking activity to improve process safety in industries
20 Supporting the Application of EU Directives in Eastern European Countries
21 Nordunet2
22 Extreme Eye-tracking
23 Applying Eye-Movement Tracking for the Study of Topographic Map Design
24 Error Management in Air Traffic Control
24 CHMI – Centre for Human-Machine Interaction

26 Summary Statistics

27 Publications

34 Scientific Advisory Panels

35 Committees

36 Staff 2001

Introduction

Hans Larsen

The year 2001 was characterised by a high level of activity in the department and in particular by a strengthening of international commitments, both through an increased volume of international research contracts, and a significantly higher number of international publications.

In 2001 a new performance contract for Risø was negotiated with the Ministry of Science, Technology and Innovation for the period 2002 to 2005. The new strategy, developed in 2001, formed the basis for the contract. According to this, the core research areas for Risø are:

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

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

The Systems Analysis Department undertakes research within all four areas. Involvement in long-term energy research is particularly extensive.

The research activities are undertaken within the following research programmes:

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

The research in the department develops and applies methods for Danish society and international organisations concerning strategies and policies in relation to long-term energy development, with focus on post-Kyoto goals. Furthermore, the department undertakes research in relation to safety and reliability of industrial production, as well as decision-support systems in relation to investments in research and new technology.

The department has a number of Scientific Advisory Panels to strengthen the contacts and interactions with Danish and international scientific communities and end users of results, e.g. industry, governmental authorities, and international organisations. The Panels are asked to give strategic advice on the direction 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 annual plan for 2002.

The department increased its external income in 2001, thus maintaining the positive trend of recent years. In 2001, 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 contracts with industrial companies – especially in the energy sector. The remaining 32 per cent of activities were financed by governmental appropriations.

The total turnover of the department in 2001 amounted to approximately DKK 57.0 mill. (Eur 7.68 mill.).

By the end of the year, the total number of employees in the department was 67. This included an academic staff of 62, namely, engineers, natural scientists, and economists as well as social and behavioural scientists of whom nine were PhD students in co-operation with various universities in Denmark and abroad. There were five secretaries and technical support staff. During 2001 one staff member earned a PhD degree.

Hans Larsen, Head of Department

Energy, Environment, and Development Planning, UNEP Centre

John M. Christensen

This programme is the institutional framework for the UNEP Centre, with the objective of being a leading international research and advisory centre on energy, environment and sustainable development, primarily in partnership with UNEP and developing-country institutions. Activities focus on development of analytical tools, analysis of global, regional and national energy and environment issues, and building analytical and planning capacity in developing countries.

The Centre celebrated its ten-year anniversary early in 2001 and has continued the expansive development trend with a gradual increase in externally funded activities. The core work with UNEP is developing very positively, especially around a growing number of joint project activities funded by, among others, the UN Foundation, GEF, and bilateral donors. Work in support of UNEP's climate change strategy has similarly expanded, especially on analytical and capacity development activities related to the Clean Development Mechanism (CDM).

The broader sustainable development activities are receiving increased attention, especially in relation to the longer—term synergies with future climate convention targets but also at micro level in relation to work on sustainable development and rural-energy-development indicators.

A new transport sub-programme has been formulated, and the first collaborative activities have been initiated with ECLAC in Latin America and IGES and KEEI in Asia. In the context of transport activities, the Centre and UNEP have also agreed to host a new international website on the health effects of air pollution, in collaboration with the WHO, the World Bank, the US EPA, and others.

John M. Christensen

Energy Systems Analysis

This research programme develops methods for analysing energy, environmental, and economic issues and their inter-relations, as well as methods for assessment of new energy technologies and their adaptation to complex energy systems.

The Centre on Environment, Economy, and Society is a joint activity with the National Environmental Research Institute (NERI), and comprises the combined 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, estimation and forecast of emissions, and sector analyses within land use, transport, and energy. In 2001 the centre agreement was renegotiated and extended for the next four years.

Major activities in 2001 within the Energy Systems Analysis Programme were:

- Analysis of green-certificate markets, development of analytical models for the market, organisation of an international workshop, and editing a special issue of "Energy Policy" with papers from the workshop.
- Analysis of the distributional effects of environmental taxes showing that individual taxes have very different distributional effects, but on average environmental taxes have effects similar to value added tax (VAT).

Other analytical activities were concerned with the efficiency potential in district heat production, the potential and economy of biogas production, and analysis of instruments supporting the development of renewable energy technologies.

Frits M. Andersen

Frits M. Andersen

Technology Scenarios

This 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 research focuses on the development of theories and research methodologies for technology analysis based on case studies and empirical problems. The research centres on two research themes. The first theme is technology foresight studies and other methodologies for prioritising in science and technology. The second research theme is integration of foresight and life-cycle assessment (LCA). Empirically, the program focuses on areas such as energy and environmental technologies, biotechnology and new industrial technologies (i.e. nano-technology and sensor technology).

In 2001 a sensor technology foresight project was carried out and finalised in cooperation with Sensor Technology Centre A/S. The foresight project was the first of its kind in Denmark, where there is a limited tradition for technology foresight compared to other European countries. Other projects have been carried out for, and in cooperation with, the Danish Agency for Trade and Industry, the Danish Forest and Nature Agency, and a number of other Danish and European organisations and universities.

Per Dannemand Andersen

Per Dannemand Andersen

Safety, Reliability and Human Factors

This 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 employs a multi-disciplinary team of scientists who co-operate to solve a variety of problems that follow from the use of complex technology in a society where safety and reliability have a high priority.

The year 2001 was characterised by extensive preparatory work to enable the start of six larger EU-financed projects for the following years, including increased engagement in support to EU-candidate countries in Eastern Europe. One new noticeable EU-financed project is "SIRTAKI" to develop emergency-management systems for tunnels. This project has already attracted attention from Danish tunnel operators. In the area of risk analysis for process industries, the Danish counties continued to ask for support to review the industry's safety reports. As can be expected, questions related to the process industry's vulnerability with respect to terrorist attacks are now being raised as well.

Nijs Jan Duijm

Nijs Jan Duijm

UNEP Collaborating Centre on Energy and Environment - International activities and UNEP support

Celebrating ten-year anniversary at the UNEP Centre.

A number of important events have taken place in 2001 for the Energy, Environment and Development programme as the institutional framework for the UNEP Collaborating Centre on Energy and Environment (UNEP Centre).

The UNEP Centre celebrated its ten-year anniversary in March at a seminar at Risø with participation of the Danish Minister for Development Cooperation – Ms. Bundegaard, the UNEP Executive Director – Dr. Töpfer, and the Managing Director of Risø – Dr. Kjems. All three expressed their satisfaction with the achievements over the past ten years, and also stated their strong support for continued collaboration and further development.

An international evaluation was undertaken in 2001 by UNEP (La Rovere, July 2001) with the overall conclusions that the UNEP Centre was working well and the present level of core funding was appropriate combined with an increasing number of projects funded by other sources. The institutional arrangements were found to work well and the flexibility embedded in the set-up was considered essential for the continued success. The main new recommendation of the evaluation was to strengthen internal administrative support. In addition, it was recommended that more emphasis should be put on development priorities and sustainable energy projects. The evaluation finally recommended that the core project between UNEP, Danida and Risø should in the future be extended to four years in order to increase long-term programme planning.

On the basis of the positive outcome of the evaluation, the three founding organisations have recommended a new four-year core contract, which will ensure further stability and form the basis for project-based expansion. On the basis of the administrative recommendations of the evaluation, an Administrator has been recruited who will further develop the internal project management systems and support the Head of Centre.

Regarding programme activities, significant expansion has taken place, both in the areas of energy for sustainable development and climate change. Details on the individual activities are presented in the following two sections, but overall it is worth highlighting the increasing activities funded by the UN Foundation. The African Rural Energy Enterprise Development (AREED) programme was started in 2000 but has been expanded significantly in 2001 and complemented by a similar programme in Brazil (BREED). Two planning grants from UNF were executed on innovative financing for energy efficiency and solar PV. The first has already led to a new full project starting in 2002 in Brazil, China and India, in collaboration with the World Bank.

The Sustainable Energy Advisory Facility (SEAF) pilot phase, funded by Danida through UNEP, was successfully completed and a new larger SEAF programme has been developed and submitted to Danida for possible funding in 2002. The expanded programme would involve formalisation of the collaboration with a number of regional centres in a network which would identify SEAF project opportunities; facilitate technical assistance; and link the participating centres with the UNEP Centre, both on co-ordinated assistance tasks and on an integrated research programme.

Regarding climate change, activities have developed in specific analytical areas such as baseline approaches for Clean Development Mechanism (CDM) projects, where an international workshop was hosted in collaboration with the OECD and the IEA in May 2001 at Risø. The

workshop made significant progress towards better understanding of the applicability of different analytical approaches in selected key sectors, but also revealed the difficulties in reaching standardised baselines.

The strong involvement in CDM analytical issues and the applicability of various approaches to developing countries also led to a collaboration with the Secretariat for the Framework Convention on Climate Change (FCCC), where the Centre provided support in the preparations for the CDM Executive Board (EB), initially in the area of so-called small scale projects. This collaboration is expected to expand into broader support for the CDM EB work in the Secretariat in 2002.

Practical pilot studies on potential Clean Development Mechanism projects and related national capacity-building needs have been continued in a number of African countries and are expected to expand into a multi-regional effort in 2002, with an expected major capacity building programme to be funded by the Dutch Government.

While the analytical activities focus on issues primarily related to the Kyoto Protocol, broader work is undertaken in relation to other aspects of the Framework Convention on Climate Change itself. A major new line of activity is focusing on what in popular terms is called "development first". This implies analysis and policy work on how a sustainable development focus can have strong synergies with climate change, especially in developing countries. In collaboration with a number of institutions in all regions, a large analytical and science policy dialogue programme has been put together to explore these synergies further. International organisations like UNEP, OECD, IEA and others are involved in the formulation of the initiative.

The Centre organised a UNF sponsored workshop in Paris in October on sustainable development and climate change, with participants from major developing countries. The meeting was held directly prior to COP 7 and the leading Framework Convention on Climate Change (FCCC) negotiators participated from these countries. They were very positive about the new initiative and the opportunity to discuss longer-term SD and CC issues in an informal context. The "new framework" was generally regarded as the best way forward for constructive involvement of the developing countries in the future agreements on participation in the FCCC.

On the more immediate FCCC participation of developing countries, the work on the national communications support programme has continued. The main activity has been to review draft communications from a large number of countries to help improve the quality of formal communications.

More details on many of these activities are given in the following sections. It should be mentioned that two new Ph.D. studies have commenced in 2001. One focuses on the institutional framework for environmental programs in developing countries, and is financed by Risø, while the other deals with organisational aspects of decentralised rural electrification, and is funded by the Council for Development Research.

Finally, general collaboration with the UNEP energy programme continues to expand, mainly through the many new projects mentioned, but also through close interaction and collaboration between staff at the energy office in Paris and at the UNEP Centre.

John M. Christensen

Publications in 2001: 12, 42, 61

Sustainable Energy

UNEP Centre's initiative on sustainable energy has been implemented through capacity-building and dissemination programmes in energy efficiency, renewable energy, energy policy and support to local initiatives in these areas.

One of the important events during the year was the ninth session of the Commission on Sustainable Development (CSD 9), that took place in New York from 16 to 27 April. Energy for sustainable development was one of the two major topics of the session, and the UNEP Centre was involved in the preparation process.

As part of the preparations, the Centre, jointly with UNDESA (Department of Economic and Social Affairs), and the Kenyan Government organised an African high-level meeting in January 2001. The key energy issues in Africa were discussed, followed by a ministerial declaration on Energy and Sustainable Development of African Governments. The declaration included strategies for action and ways of strengthening regional co-operation in the areas of energy and sustainable development, and was presented at CSD9 by Kenya on behalf of African Governments. The UNEP Centre co-ordinated the technical segment of the meeting, provided inputs through a number of papers, and published the proceedings of the meeting, which are available on the website (www.uccee.org).

As an adjunct to the regular CSD9 meeting, the UNEP Centre took part in a side event on "Energy for Sustainable

Development – a regional approach". At this meeting, UNEP's Executive Director chaired a panel of ministers and high-level experts. The event was extremely well attended and concluded that more emphasis needed to be put on regional approaches, including strengthening regional centres of excellence. One goal is to link existing regional centres under a new expanded SEAF project (see below), an approach that was strongly supported by the other speakers.

Sustainable Energy Financing

In the last few years, the UNEP Centre's focus on sustainable development and energy programmes has been broadened to integrate it's expertise on project financing, renewable energy technologies, and project development with the energy development policies of developing countries. Three programmes serve to assist developing countries in reshaping their energy economies:

- The Renewable Energy and Energy Efficiency Investment Advisory Facility (IAF)
- The Rural Energy Enterprise Development (REED) programme
- The Sustainable Energy Advisory Facility (SEAF)

In addition to this, two projects, one jointly with the World Bank on "Developing Financial Intermediation Mechanisms for Energy Efficiency Projects in Brazil, China and India" and the other "Designing Micro-credit Schemes for Consumer Financing of Solar Photovoltaics in Southern India" were under preparation in 2001.

Renewable Energy and Energy Efficiency Investment Advisory Facility

The IAF makes expert advisory services available to financial institutions for evaluating specific renewable-energy (RE) and energy-efficiency (EE) investments in developing countries. Many RE and EE projects often fail to receive financial support from these financial institutions due to such factors as lack of in-house skills to evaluate or negotiate projects, limited access to reliable technical information and operational data, and the lack of flexibility to adopt new financing practices.

Some examples of the types of issues that can be addressed through the IAF include environmental liability risk analysis, legal review of performance or power purchase agreements, product marketing studies, and valuation of carbon credits. To date, the IAF has supported 12 investment evaluation studies on projects with a total investment of more than $47.9 million. The UNEP Centre assists in managing the IAF, processing applications for support, and promoting the facility in the financial sector.

Rural Energy Enterprise Development

One of the key problems facing renewable-energy and energy-efficiency projects in developing countries is the lack of business planning and enterprise development. Financed by the UN Foundation and implemented by UNEP with the help of the UNEP Centre and E&Co, a US-based non-profit organisation, the REED program addresses this problem by helping to develop successful enterprise development expertise in rural areas. REED involves working with the private sector and local NGOs to identify potential business opportunities in the rural energy sector, and to prepare a sound business model and financial proposal for the project. REED provides financing to support these business development activities, but more importantly it also supports the implementation and capitalisation of the business plans, either through loans, or by purchasing a minority share in the business. Finally, REED works with financial institutions in rural areas to help them assess the rural energy business sector and integrate these kinds of projects into their portfolios. Launched in 2000, REED has been successfully implemented in Africa (AREED), where four projects in three countries (Ghana, Senegal and Zambia) received a total of $201,500 in investment. The UNEP Centre provides managerial and administrative support and has the specific responsibility to ensure the sustainability and reliability of the programme beyond its current phase—by establishing partner organisations and structures and organising training workshops.

A similar project, DEERB (Desenvolvimento de Empresas de Energia Rural no Brasil), was started in Brazil in 2001. A detailed assessment of current renewable energy and rural electrification activities in the North-east was completed during the second half of 2001.Forthcoming phases will develop the capacity of local NGOs and financial institutions, and will package investment opportunities for environmental venture funds. The UNEP Centre is responsible for technical assistance to the project, especially on policy issues.

Sustainable Energy Advisory Facility (SEAF)

Supported by the Danish Ministry for Foreign Affairs, the Sustainable Energy Advisory Facility (SEAF) was initiated in April 2000 and has been fully operational since October 2000. SEAF has been designed to provide swift and flexible support on very specific needs regarding a broad range of sustainable energy topics, and to do so in manner that draws on other work and catalyses other resources. The facility aims to demonstrate that small and targeted interventions at just the right time can make significant contributions to further implementa-

Photos: NREL and Electronorte

tion of specific policies and projects that spur the development and application of sustainable energy strategies and technologies. The SEAF activities are planned to be extended in close collaboration with a group of regional 'centres of excellence' already active in the area, where energy, environment, and development intersect.

SEAF has supported a variety of projects. SEAF interventions, for example, include a National Photovoltaic Programme (NPVP) in Botswana, which combines a credit facility to household or small businesses for the purchase of PV systems with a quality control and maintenance service; and support to Ghana's ministry of Energy/Public Utilities regulatory Commission (PURC) to develop a subsidy reform package and an energy-service concession structure to secure stable markets for renewable energy service providers.

Developing Financial Intermediation Mechanisms for Energy-Efficiency Projects in Brazil, China and India.

Initiated jointly with UNEP and the World Bank, and funded by the UN Foundation (UNF), the UNEP Centre has helped in formulation and submission of the proposal, which was approved in principle in November 2001. The objective of the programme is to achieve major increases in energy-efficiency investments by the domestic financial sectors in Brazil, China and India by developing energy-efficiency-investment project-packaging capacity, both in existing financial institutions and through new entities.

The programme will achieve this by undertaking multiple activities designed to overcome the various market barriers present in each country. These activities include technical assistance, training, and applied research covering the following four areas of country interest: development of commercial banking windows for energy efficiency; support for Energy Service Companies (ESCOs); guarantee funds for energy efficiency; and equity funding for ESCOs/energy efficiency projects.

Designing Micro-credit Schemes for Consumer Financing of Solar Photovoltaics in Southern India

The long-term goal of the project is to bring modern electricity services to rural Indian households and enterprises in an environmentally sustainable, climate-friendly manner. This initial phase of the proposed project involves designing, in collaboration with one or two Indian finance institutions, a rural finance facility for solar system purchases that would use UNF resources to buy down the initial risks of lending to this sector. The UNEP Centre worked jointly with UNEP and the local consultants in India in putting together the concept paper for the facility. The inputs were obtained from the various stakeholders through meetings with them during August 2001. The design of this facility has almost been finalised, and as a result of this work, a further request for approximately $2 million will be submitted to UNF for implementing the credit facility.

Experience with PV systems in Africa

The UNEP Centre has recently published summaries of selected PV cases from 13 African countries in a booklet entitled 'Experience with PV systems in Africa'. Notable are some commonalities and differences in the implementation approach and its implications on the success of a project. This publication is available at the website (www.uccee.org).

Capacity building in Malaysia: developing an energy-economic model

Through participation in the Danced-supported capacity-building project headed by Rambøll, the UNEP Centre has been developing an energy-economy model for Malaysia. The model is a CGE model including the energy sector. The aim of this specific component is primarily to analyse effects of relative changes in prices of energy consumption. The model and data collection has been carried out in close collaboration with Rambøll and participants from various local institutions: PTM (Malaysia Energy Centre), University Tenaga Nasional and the Malaysian Institute of Economic Research.

Jyoti Painuly

Publications in 2001: 40, 51, 69, 70

Climate Change

Building national capacity

The United Nations Framework Convention on Climate Change (UNFCCC) commits all countries to submitting regular national communications, including GHG emission inventories and, as appropriate, assessments of relevant policies on adaptation and mitigation. In 2001, the UNEP Centre continued to support this process through the National Communications Support Programme in collaboration with the UNDP and UNEP. Activities have included a large number of reviews of draft national communications and direct country missions to provide support to national report development. Jointly with the Energy Systems Analysis Programme, tools for GHG emission inventories have been developed and a number of colleagues from developing countries have been trained. Special focus has been on industrial gasses, which recently have been included in the Kyoto Protocol, and emission estimates for the agricultural sector.

Pilot projects have been undertaken jointly with national teams in Ghana, Uganda, Gambia and Zimbabwe to develop and assess the institutional capacity required to use the opportunities offered through the Clean Development Mechanism (CDM). These pilot projects are part of the project "Sustainable Development and Climate Change Finance", which also involves regular meetings with African FCCC negotiators to discuss key FCCC issues. The pilot projects focused on developing the capacity of governmental, non-governmental and private sector institutions to understand the economic principles underlying the CDM and how it will be implemented.

The application of the CDM rules and procedures to specific projects in developing countries has been examined in a more detailed manner in another project involving study of a specific wind-energy farm in Egypt. Various baseline methods and approaches for assessment of wind-power projects have been tested in order to evaluate which methods and approaches seem to be most suitable for assessment and evaluation of renewable-energy projects under the CDM.

Analytical work related to the Kyoto Mechanisms

The Kyoto Protocol of the UNFCCC includes three so-called flexibility mechanisms that enable countries with an emission-reduction commitment to offset this commitment by "buying" greenhouse-gas emission credits in other countries. This can be done through Emission Trading, Joint Implementation (JI) projects, and Clean Development Mechanism (CDM) projects. Developing countries that do not have an emission-reduction commitment according to the Kyoto Protocol can supply the CDM projects to countries with a commitment. The November 2001 Marrakesh Accords create the first practical basis for the implementation of the Kyoto mechanisms.

Several UNEP Centre projects have addressed methodological and practical aspects of the flexibility mechanisms with particular focus on CDM, as mentioned above. A recent climate change mitigation study conducted and reviewed by the UNEP Centre, suggests that the potential supply of cost-effective CDM projects from developing countries, in particular related to energy-efficiency improvements and renewable energy, is significant. These countries could benefit from participation in the CDM, if the Kyoto mechanisms are designed and implemented in a way, where the benefits of trade are shared among the parties, and if projects are selected that support national development objectives.

One of the difficult analytical issues that needs to be decided in order to make the Kyoto mechanisms operational is the issue of generally valid methodologies for determining baselines for JI and CDM projects. The baseline describes how emissions would have developed in the absence of a JI or CDM project, and thereby establishes the basis for evaluating the emissions reductions generated by a project.

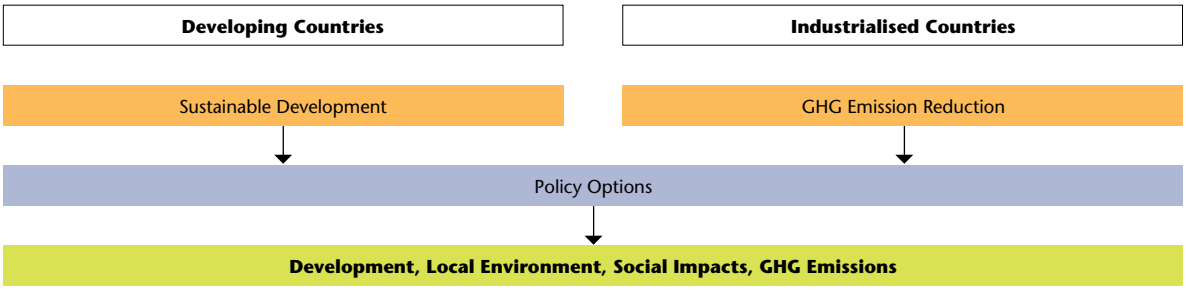
Jointly with the OECD and the IEA, from 7 to 9 May 2001 an expert workshop was organised entitled "Identifying feasible baseline methodologies for CDM and JI projects". The workshop brought together around 100 participants from all continents, including government officials, and technical and sector experts, for a discussion of both cross-cutting issues and sector issues, including energy supply, energy demand, heavy industry and transport.

In the context of international emissions trading, countries may incur the risk of overselling their emissions quota, because there is no ultimately responsible institution that can enforce legislation. Building on their year 2000 work, the UNEP Centre together with Margaree Consultants tested various specifications to prevent overselling, and these were reflected in the UNFCCC negotiating texts, both in Bonn and Marrakesh in 2001.

Sustainable Development and Climate Change Implications

Earlier work has been continued and expanded regarding methodologies and application of guidelines for assessing economic, social and environmental dimensions of climate change policies.

A new methodological approach for assessing sustainable development indicators for potential climate-change-mitigation projects in developing countries has been developed and tested in a number of case studies for Botswana, Mauritius, Thailand and Zimbabwe. The



purpose has been to estimate synergies and trade-offs between development objectives, such as employment generation, local air pollution control, equal income distribution, and global climate change policy objectives in the form of reduced greenhouse gas emissions.

The UNEP Centre was invited by the United Nations Foundation to organise a workshop in Paris in October 2001 about sustainable development and climate change. Experts, governments and business sector representatives from Brazil, Argentina, China, India, Iran, South Africa, South Korea, and the Alliance of Small Island States participated. The workshop discussion concluded that an integrated sustainable development and climate-change policy could be a very import step in establishing a global partnership about climate-change policies, where the mutual interests of the various parties could be met simultaneously, as illustrated in figure 1. The activities are planned to continue with national workshops and establishment of a research network.

Intergovernmental Panel on Climate Change, IPCC

The IPCC has recently published its Third Assessment Report, TAR, where UNEP Centre staff have played a major role in the work on Mitigation Policies conducted by Working Group III. The special areas that have been coved are costing studies and methodologies, policy instruments, and decision-making approaches.

One of the new conclusions by IPCC WGIII is that research on inter-linkages between sustainable development and climate-change policies is an emerging area, where the work until now primarily has been of a conceptual nature. However, there are a number of studies that have assessed important aspects of the issue without covering all economic, social and environmental dimensions of sustainable development.

The IPCC has concluded that various energy efficiency improvements with a net economic benefit have been assessed to exist in buildings, transport and manufacture in addition to the introduction of more efficient conventional power production technologies and transmission systems. The net benefits of these policies reflect that these options have a significant fuel-saving value and increase the reliability of energy supply. The realisation of this economically attractive climate-change mitigation potential depends on the ability to overcome various barriers and implementation costs that have not been fully considered in all the studies that are covered by the IPCC.

On the basis of earlier climate change mitigation work, UNEP Centre staff have especially contributed to the development of a comprehensive review and assessment of methodologies and costing studies, including direct economic costs and benefits, as well as broader development aspects of climate-change policies. Five lead authors from the UNEP Centre have contributed to the TAR and one of them as a convening lead author.

Climate change, conservation and adaptive capacity in Costa Rica

A PhD project undertaken in conjunction with the Environmental Change Institute at the University of Oxford aims to explore the implications of climate change for conservation management in Costa Rica, with the specific case study of the Guanacaste Conservation Area. In determining vulnerability the project has created climate and impact scenarios, using the new IPCC emissions scenarios, and a dynamic vegetation model. With regard to adaptation, the research evaluates existing adaptation measures and strategies in Guanacaste. It then goes on to examine the concept of adaptive ecosystem management, and barriers to its implementation.

Kirsten Halsnæs

Publications in 2001: 3, 7, 13, 18, 19, 24, 29, 39, 52, 55, 60, 68

Distributional Implications of Environmental Taxation in Denmark

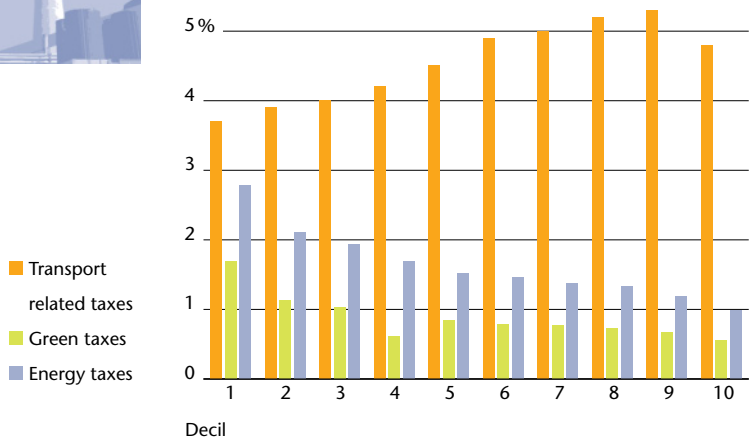
Environmental taxes imposed on households have been introduced in many countries. However, few countries have reached the level of environmental taxation that is seen in Denmark today.

In a project that was finalised in 2001 and supported by the Danish Energy Research Programme, we examined the empirical evidence from the broad range of environmental taxes in Denmark. The study was carried out in collaboration with the National Environmental Research Institute and the Danish Institute of Local Government Studies.

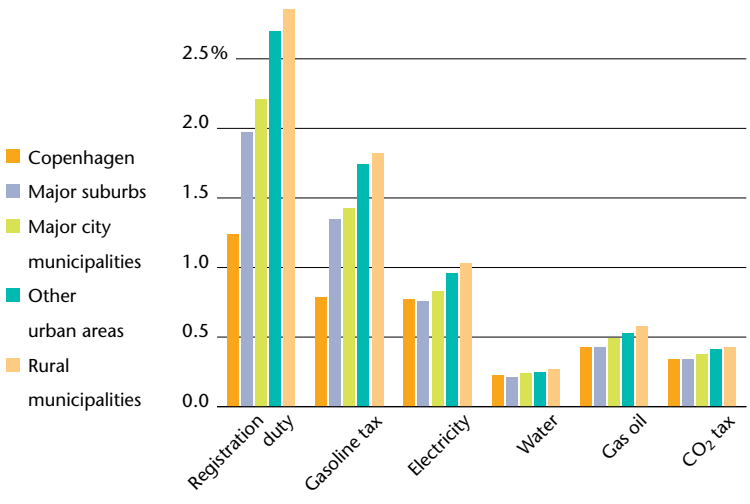
The distributional analysis is based on a combination of household expenditure surveys and samples drawn from governmental registries. Data for 1997, collected by the former Danish Ministry of Economic Affairs and covering around 3.3% of the Danish population, is the main data source for the analysis. A range of socio-economic variables and detailed tax monitoring information, as well as public transfers are included in the data for each person and household. The data is combined with the household expenditure survey from Statistics Denmark.

Major categories of environmental taxes

(percentage of disposable income for persons in the sample distributed over income deciles)



Residential location and selected environmental taxes



The main finding is that environmental taxes have a regressive distributional impact. This result, however, does not tell the full story, as the aggregate environmental taxes also hide the very large difference that exists between energy taxes and green taxes compared to transport-related taxes. The figure compares the distributional effect of the three aggregate types of environmental taxes. All persons in the sample are divided into deciles based on the disposable income of the household. The figure shows the three environmental taxes as a percentage of disposable income. Transport-related taxes increase with income, except for the last decile, whereas green taxes and energy taxes both decline in importance with rising income.

The comparison of the three categories leads to the conclusion that, on average, green taxes and energy taxes are regressive in contrast to transport-related taxes, which are neutral or progressive. Transport taxes correspond to nearly 50% of the total environmental taxes paid by households, which is the main reason that, overall, environmental taxes only seem to be slightly regressive.

The socio-economic characteristics of households are another important classification to examine with respect to the burden of environmental taxes. The relationship between residential location and tax burden was found to be important. Environmental taxes constitute a higher fraction of income in rural areas compared to urban areas.

Rural households pay a higher proportion of their income on environmental taxes than households located in cities. This is especially pronounced for vehicle registration duties and petrol taxes, reflecting the facts that public transport is not available on the same scale in rural areas as it is in urban centres, and that populations in rural areas are more widely dispersed. A similar explanation can be given for the more widespread use of gas oil and electric heating, as district heating and natural gas networks are less common in rural areas. The general conclusion is that the impact on rural households from environmental taxes is higher than for other parts of the population.

The results from this study show that the environmental taxes in Denmark are regressive on average, which is in line with the results from most other international studies. The study also shows that there are considerable differences between the different types of taxes, and that transport-related taxes are progressive. Compared to other indirect taxes, environmentally related taxes on average are less regressive than VAT.

Henrik K. Jacobsen

Publication in 2001: 87

Green markets

Common EU policies for emission reductions are currently being widely discussed, especially the introduction of a market for tradable permits for CO_2-emissions to achieve emission reductions within the power industry and other energy intensive industries. In parallel with this, markets for tradable green certificates (TGCs) to deploy renewable energy technologies are being developed in a number of countries, among these Denmark, Italy, Sweden, Belgium (Flanders), England and Australia. Although these national initiatives for a green certificate market are fairly different, they could be a starting point for establishing a common EU certificate market. However, interactions between national targets for greenhouse gas emissions and these international instruments for emission reductions are not a trivial matter, especially seen in relation to the possible contributions of these instruments to achieving national greenhouse gas reduction targets and renewable energy deployment.

In 2001 Risø was involved in a number of projects analysing the interactions between green markets. The following highlights some of the results of the Risø contributions to the projects.

If the EU 2010 targets for renewable deployment are to be fulfilled, an increase in renewable produced energy of more than 90% compared with 1995 is required. According to the Rebus analyses, this can be achieved in an EU-wide international TGC trading scheme at the equilibrium price of a green certificate of 6.2 €/kWh in 2010. The total EU-wide costs of meeting the 2010 renewable energy deployment targets are estimated at €17.6 billion.

The analytical effects of introducing national emission permits and green certificates, and the corresponding quotas as regulatory mechanisms, not only to reduce emissions from electricity production, but also to ensure a certain deployment of renewable energy has been shown by Risø to have an impact on the consumer price. The effect on the consumer price is rather an ambiguous increase with the introduction of a green quota. There is a choice between quotas leading to a lower consumer price and quotas leading to a higher consumer price. As a result of this, it has been shown that it is always optimal to reach only a renewable energy deployment goal by the use of green certificates. However, to reach an emission goal it is sometimes most favourable, with respect to consumer prices, to use green certificates and sometimes to use emission permits.

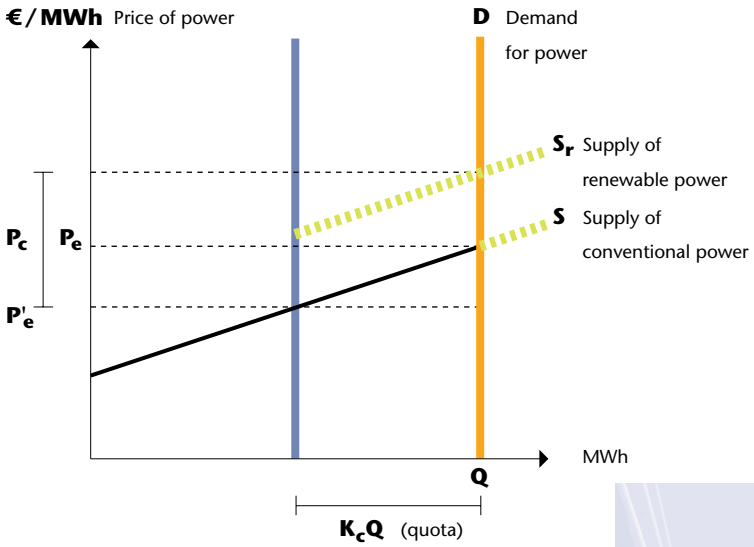
An inherent self-contradiction exists between national emission reduction targets and international liberalised power markets. Thus, if the primary goal is to fulfil the national CO_2-reduction targets, then a separate introduction of an international TGC market into a liberalised power market cannot be recommended, because those countries most ambitious in implementing renewable energy technologies will only partly be gaining the CO_2-reduction benefits themselves. A remedy to this problem is to link the international TGC market with an international tradable permits market, though it still requires that the national quotas for the two markets be adjusted in a co-ordinated manner.

Finally, an international workshop on emission trading and green markets was arranged in 2001. The workshop was attended by 40 experts from 8 countries. A number of papers from the workshop were selected for publication in a special issue of "Energy Policy".

Klaus Skytte and Poul Erik Morthorst

Publications in 2001: 44, 46, 59, 64, 101, 138, 139, 140

Change in prices when introducing a green quota



Is it possible that the introduction of a green quota for renewable energy can lower the consumer price of power?

This is illustrated in the figure above, where a green quota is introduced changing the consumer price from pe to $p_e' + K_c\ p_c$. Assume a green quota of 10% (K_c), a marginal cost of developing renewables of 34 øre/kWh, and that the power price then changes from pe = 21 øre/kWh to pe' = 18 øre/kWh. Then the certificate price is p_c = 34 - 18 = 16 øre/kWh. This implies a consumer price of $p_e' + K_c\ p_c$ = 18 øre/kWh + 0.1 x 16 øre/kWh = 19.60 øre/kWh.

Development of renewable energy technologies at liberalised market conditions

A telling transition is presently going on from national, technology-oriented support schemes for renewable energy to more market-based schemes, where all renewable technologies have to compete. Without any additional support, one can fear short-term-based market designs that do not ensure continuous development of renewable technologies.

The programme participates in two projects within development of immature renewable energy technologies under liberalised market conditions; a project financed by the Danish Energy Research programme and a PhD project. The projects survey the historical development of the technologies and try to describe the causal interrelationship between regulation, support and technological development.

In 2001 a critical, technical and methodical survey of recent technological and economic diffusion theories was made, e.g. experience curves. Several interviews where held with experts on renewable energy technologies or on support schemes in order to compare the empirical and theoretical development of different technologies. In addition, an empirical data analysis for wind turbines was made.

Experience curves

The crux of diffusion theory is that a technology develops through a diffusion process that includes improved efficiency and cost reduction. The observed pattern is often the same. The unit cost decreases concurrently with an increase in cumulative production. There is a learning effect – the more you produce the better you become at making the technology.

In a technology's first years, cost reduction is faster than in the later years. Observed unit cost at different levels of cumulative production can be approximated by a power function. This function is called the experience curve and it helps to illustrate the technical progress as function of cumulative production.

Case study — wind

The figure shows an experience curve for wind turbines in Denmark. The small circles represent the observed data, whereas the bold line is the experience curve estimated on the observed data. The figure is illustrated in a double logarithmic diagram, which implies that the experience curve is drawn as a straight line. The slope of the line represents the unit cost reduction that can be found by doubling the cumulative capacity of wind turbines. This was estimated at a 19% unit cost reduction per doubling of the cumulative capacity.

Examining the figure it is seen that there are plateaux in the observed data. In order to find an explanation for these plateaux, several other variables were looked at. One of these was the wind-turbine size.

The sale of wind turbines is dominated by a standard size for some years, before a new standard size takes over. By comparing the developments in standard sizes and cumulative capacity, identification of the different plateaux was possible. This is illustrated the short straight lines in the figure.

Thus it appears that one of the important driving parameters behind the experience curve for wind turbines is the up-scaling of new turbines. Of course, even turbines of the same size are seen to get more cost-effective, but the significant reductions in investment per capacity unit are related to the development of larger sizes.

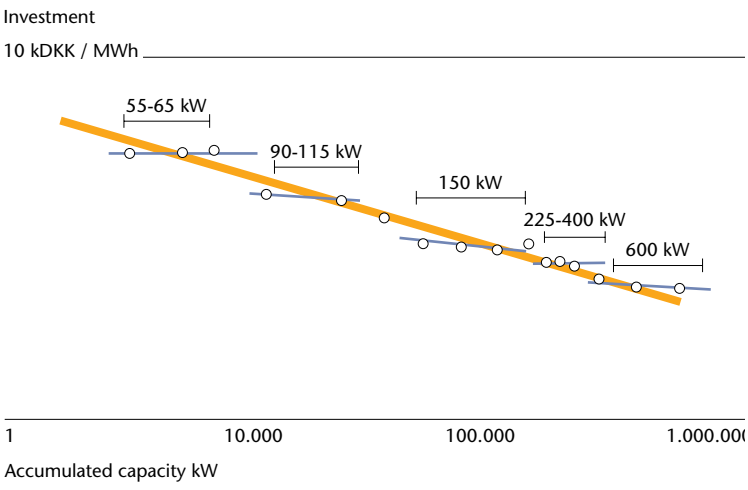
Other variables might be important for determining the shape of the experience curve than the scaling effect mentioned above. Among these time, R&D funding, and the level of the Danish feed-in tariffs were tried as explanatory variables. It was found that there is multicorrelation between these variables. In other words, not only the cumulative capacity, but also many other variables influence the technological development, and it is the casual relationships between these that determine the development of a technology.

These causal relationships will be examined further in the two research projects over the coming year.

Klaus Skytte and Stine Grenaa Jensen

Publications in 2001: 59, 63, 100, 139

Plateaux in the experience curve caused by scaling effects



Hydrogen via electrolysis as a power-regulation component

Options for large-scale introduction of hydrogen in the Danish energy system have been analysed in the study 'Hydrogen as an energy carrier - scenarios for future use of hydrogen in the Danish energy system'. The study was carried out by Roskilde University, Risø National Laboratory, Danish National Oil and Gas Company, Elkraft Systems, and Energy E2 for the Danish Energy Agency.

The regulation problem

Risø contributions to the project primarily concern data and scenario analyses with a focus on options for development up to 2030. Scenarios for fuel substitution using hydrogen in the transport sector and so-called regulation scenarios have been developed.

The regulation scenarios focus on the potential of hydrogen as a storage medium for dealing with the substantial variations in renewable power generation. The scenarios describe alternatives to international trading, e.g. at the Nordic Pool, to handle such variations. Hydrogen production via electrolysis on surplus electricity generated is considered taking into account the following hydrogen utilisation options:

1. Hydrogen as a fuel for transport.
2. Hydrogen as part of an electricity storage system.
3. Hydrogen supplied to the national natural-gas grid.

The consumption side for hydrogen in the scenarios requires constant supply throughout the year, and large-scale hydrogen storage in underground caverns has been assumed for levelling out the production to a constant supply.

Regulation costs if the hydrogen price equals NG price

A range of systems has been analysed that differ as to the degree of (heat) constraints occurring in the Danish power system in 2030. In the figure these systems are parameterised along the x-axis using the surplus electricity generation in the systems as the parameter.

Surplus power generation above 12% of the initial annual electricity demand complies with the criteria chosen for installing and initiating electrolytic hydrogen production, as indicated in the figure. Residual surplus power generation not captured for hydrogen production decreases along the x-axis.

The introduction of hydrogen may not await specific demands to emerge, e.g. in the transport sector. In quantities up to 5-10% of the energy content, hydrogen may be added to natural gas without causing problems in the NG grid. Thus, hydrogen from surplus electricity may substitute natural gas in the present energy system without a need for large investments for its distribution and on the consumption side, if the resulting gas characteristics do not fluctuate.

Expected costs associated with handling power surplus generation in the Danish system in 2030 via electrolytic hydrogen production and the subsequent feeding of hydrogen into the NG supply system in regulated flows are presented in the figure. The y-axis shows the overall premium or cost increase of electricity associated with recuperating a major surplus power generation from within the Danish system.

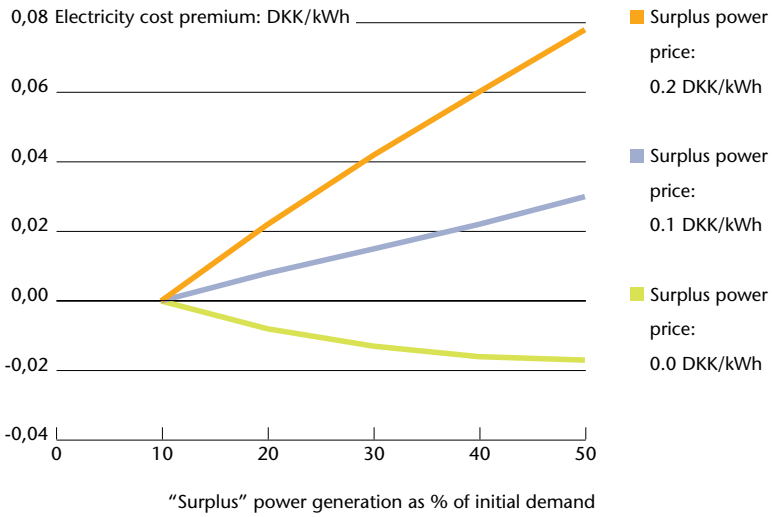
It is assumed that hydrogen can be sold at a price equivalent to natural gas. A price of DKK 35 /GJ is used which corresponds to the long-term NG price forecast by The Danish Energy Agency.

In the figure the regulation cost premium is shown for different prices assumed for surplus electricity. Economic break-even (at y=0) for handling surplus generation via hydrogen technology as described, occurs if the market price of surplus electricity is about DKK 0.05 /kWh_{el}. Such a price could form a long-term backstop price on surplus power generated and short-notice power regulation.

If large-scale demand for hydrogen develops (e.g. for fuel-cell vehicles), pure hydrogen will exceed the NG price. Hydrogen priced at say 50% above the NG price corresponds to a break-even price of about DKK 0.10 /kWh_{el} for surplus electricity.

Electricity cost premium

for handling surplus power generation in 2030 via electrolytic hydrogen production. It is assumed that hydrogen is supplied to the NG grid in a constant flow at a price of DKK 0.13 /$kWh_{hydrogen}$ (the value of O_2 production is not included)



Lars Henrik Nielsen
Publication in 2001: 97

Applying benchmarking analysis to the Danish district heating sector

During 2001, a research group consisting of researchers from Risø, KVL (The Royal Veterinary and Agricultural University of Denmark) and AKF (Institute of Local Government Studies - Denmark) conducted research supported by the Danish Energy Agency on a project investigating the size and nature of potential efficiency gains in the Danish district heating sector.

The research was motivated by a revision of the Danish Heat Supply Act of May 2000 explicitly stating that district heating tariffs should no longer be set according to actual cost, but rather, they should reflect the cost of efficient operation.

The research group conducted large-scale comparison based on a sample of Danish district heating plants consisting of approximately 250 units with an annual total expenditure of almost one billion euro on operation and fuel. The analysis relies on the production and cost data stated in the annual reports of the district heating plants to the Danish District Heating Association during the years 1999 and 2000. It is worth noticing that the use of this type of data closely corresponds to the options available to the regulatory authority.

The method for comparison of the individual district heating plants is Data Envelopment Analysis (DEA). This method has been used for numerous analyses of public utilities, public services, and private corporations in order to structure cost information. The analysis assigns each production unit with an efficiency measure indicating how much of the actual cost would have been incurred if production were taken over by efficient producers.

The potential efficiency gains are approached at three levels in the study. At all levels the DEA method generates new cost estimates for the entire sample of district heating plants. The figure illustrates the central variables in the analyses and the estimated savings potential.

The first approach, the *societal* level, relies on the assumption that all customers could be served by the best practice known today. The analysis indicates a 53% savings potential. This number applies both to CO_2 emissions and expenditures net of electricity sales. It is uncertain whether these efficiency gains can actually be realised, since the number does not reflect existing economies or diseconomies of scale.

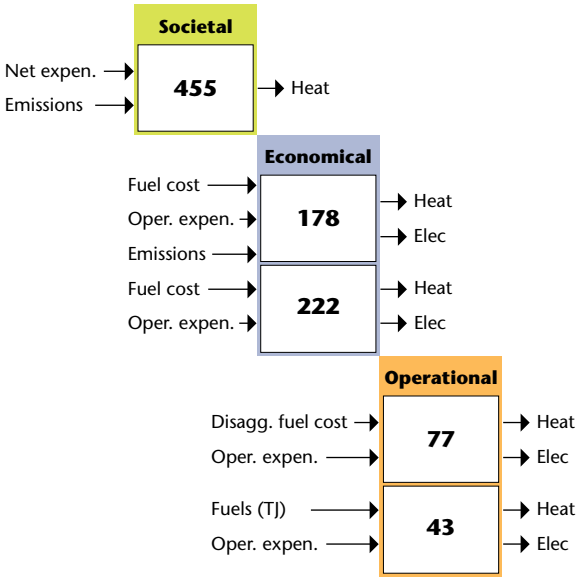
The second approach, the *economical* level, still evaluates district heating plants solely on their overall economic performance, but this time performance is adjusted to take proper account of scale of production. Costs are divided into fuel cost and operating expenditures. The analysis shows that, including CO_2 emissions, the plants have a savings potential equal to 21%. Ignoring CO_2 emissions raises this figure to 26% because emissions are no longer penalised.

The third approach, the *operational* level, respects that specific plants have specific fuel compositions. The analyses use disaggregated information on the fuel cost, dividing fuels into three groups, natural gas, oil and coal, and biofuels. Focusing on the cost incurred in the three fuel groups leads to a 9% savings potential, with almost half of the plants being fully efficient. Ignoring cost data on fuels, and focusing on the energy content instead reveals a mere 5% savings potential.

Inputs (left) and outputs (right) in the five benchmarking approaches

The numbers in the boxes are the calculated potential efficiency gains in million €.

Actual total cost of the 250 plants is 853 million €.



The analyses show that using only accounting data to regulate Danish district heating plants will most likely not result in detection of large efficiency gains, since models respecting the short-term technological lock-in will only identify minor gains.

Peter Fristrup

Sensor Technology Foresight

Sensor technology is a rapidly growing area of research with many products already on the market that promise to continue to have a critical role in technologies of the future. In order to strengthen industry's, organisations' and policy makers' strategic outlook, a sensor technology foresight was performed in a collaboration with the Sensor Technology Center.

The study analysed six categories of sensors (electromagnetic, mechanical, electrical, magnetic, chemical, nuclear) covering 13 sub-categories and in addition a number of systemic issues. A scanning process concerned with "looking ahead" was performed through scanning topics in the open literature and by arranging four thematic expert workshops - two Danish workshops and two international workshops. The themes for the international expert workshops were "Technological Premises" and "Technology and Market". During structured brainstorming sessions the experts were asked to formulate statements and visions about trends in sensor development. The scanning process resulted in 217 topics and statements central to the future development and use of sensors.

Next, a Delphi questionnaire was performed in order to improve the validity and reliability of the sensor foresight. Such a questionnaire must not be too voluminous. The number of statements should therefore be limited to about 50, and experts were asked to answer a number of variables to the statements (e.g. time horizon for realising the statement, potential market volume, barriers for realising the statement). On the basis of the 217 topics, 130 statements were formulated. Out of the 130 statements, 50 statements were selected based on an expert rating processes combining index of sensor type, technological feasibility, and potential market volume. Approximately 1,000 sensor experts received the Delphi questionnaire, and 174 responded. This gives a response rate of approximately 17%, which is neither high nor low compared to international experience of response rates. Half of the respondents came from academia and more than one third came from industry. 90% of the respondents came from Europe, of which the largest group came from Denmark (38%).

Index on market impact by sensor type

One of the questions in the Delphi questionnaire concerned "Market sectors most heavily impacted by the statement". For each sensor type the number of respondents has been normalised resulting in a market impact index. A general conclusion is that health care is the market sector most heavily impacted by new sensor technology. It also appears that new sensor technology will affect food processing and the environment sector.

Brainstorm – Workshop on technological premises

There will be less impact in sectors such as construction/housing, and wood & textile. All sources of information, i.e. literature, workshops, questionnaires, indicate the same pattern regarding the future attractiveness of sensor types. MEMS (Micro-Electro-Mechanical Systems), optical sensors, and biochemical/biological sensors together with systemic issues are all expected to be the most interesting sensor types over the next 10 years regarding market volume.

Top-ten lists of statements can be drawn out of the survey ranked according to the different variables. A top-ten list was prepared on the basis of the combined index of technological feasibility and potential market volume among expert and knowledgeable respondents. The top-ten list comprises topics covering all types of sensors, except electrical and nuclear sensors. MEMSs are highly appreciated together with sensors that are small, low-cost, and flexible. Sensors are also expected to be developed as integrated systems with multiple applications. The markets most influenced by the future development of sensors change from topic to topic. For the topics on biosensors, the impact is especially apparent for the food and health markets. These markets are also impacted by MEMS sensors. The study revealed that the most important barriers to realising the expected technological development in sensor technology are limited cross-disciplinary collaboration, limited cross-sectorial collaboration, and lack of qualified human resources. For the topics on sensor communication and motion control, the lack of standardisation is also highlighted as a barrier. Limited cross-sectorial collaboration is especially emphasised as a barrier in topics on MEMSs and measurement of water quality.

The study revealed conflicting assessments of the

future of biosensors. On the one hand widespread use of biosensors and the development of DNA sensors are included in the top-ten list; on the other hand the inclusion of elucidation of implanted bio-sensors and the use of human-like sensors at the bottom of the list of technological feasibility partly contradicts the positive assessments.

Birgitte Rasmussen, Birte Holst Jørgensen and Per Dannemand Andersen
Publication in 2001: 82

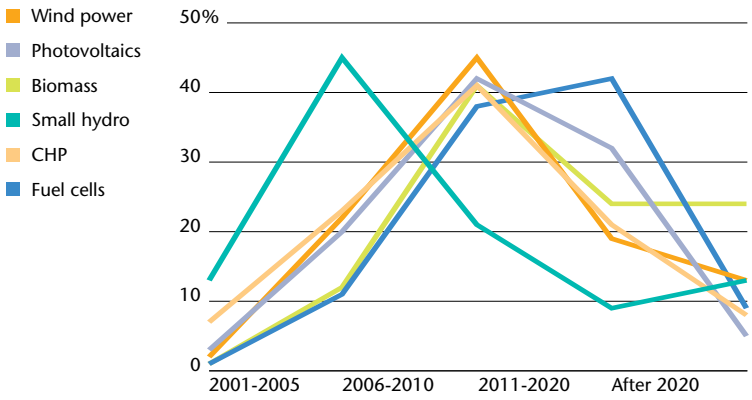
DECENT: Decentralised generation technologies - potentials, success factors and impacts in the liberalised EU energy market

Decentralised technologies for generating power and heat are becoming increasingly popular worldwide. The EU goal of covering 12% of domestic power consumption in 2010 with renewables is mostly to be fulfilled by decentralised technologies. The main objective of the DECENT project is to analyse potentials, success factors and barriers for the development of decentralised technologies within EU energy markets. Thus, an important part of the DECENT project is to identify the main driving factors behind the development of these technologies. DECENT is financed by the EU 5th Framework Programme and carried out in collaboration with other European research institutes. The project will be finished in 2002.

Technologies considered in DECENT comprise wind power, photovoltaics, biomass plants, small hydropower plants, fuel cells and CHP plants fired with natural gas. An important task of the project has been to analyse case studies for these technologies. As part of this task, Risø has conducted three case studies, all on wind power – two on Danish offshore and on-land installations, and one on a Spanish on-land wind farm. Important findings from the case studies include

- At the core of decentralised development is the right of access to power distribution and transmission grids. In a number of cases investors in decentralised power plants have had a hard job getting grid connections approved by local and regional utility companies.
- As for most other investments, the uncertainty associated with these investments is important for decentralised generation. Fixed feed-in tariffs, as applied by countries such as Germany, Spain and Denmark, are generally observed to be one of the most recognised subsidy schemes in reducing investor uncertainty.
- Environmental concerns are identified as one of the major driving factors behind decentralised development, almost as important as profitability motifs.

Time of occurence for the development of different decentralised technologies as expected by the Delphi respondents



Another important Risø-task in the DECENT study was toanalyse the future development of decentralised generation technologies. To carry out this part of the project, a Delphi survey was undertaken.

The DECENT future study is basically designed as an adapted Delphi investigation, consisting of four rounds. In the first round DECENT experts discussed and agreed upon the central statements about the future development of decentralised energy generation. The second round consisted of a large anonymous survey among external experts about the future development of decentralised technologies. The survey was carried out by Risø. In total 300 electronic questionnaires were sent out to experts using the internet to respond. The third round was a DECENT scenario building phase, which was partly performed as a workshop. The fourth round will concentrate on re-evaluating the scenarios. This will be conducted by a sub-set of seven external experts on decentralised energy generation. So far the first three rounds have been finished, while the fourth round is to be carried out in the near future.

In order to assess the future development of decentralised technologies, the Delphi survey asked a number of respondents to evaluate different framework topics and their impact on future decentralised energy generation in the EU up to 2020. Among these topics were questions concerning spatial planning provision and procedures, security of supply, possibilities for grid access, environ-

mental concerns, EU liberalisation of energy markets, and EU support mechanisms for decentralised plants. Respondents tended to agree in particular on the importance of global environmental concerns, easy and transparent access to the grid, and regional development concerns.

Finally, the respondents were asked to rank and time a number of statements concerning the future deployment and costs for decentralised generation

Among the most important barriers identified are lack of appropriate support mechanisms, insufficient R&D –funding, and unclear spatial planning. shows the expected time of occurrence of the statements grouped for each of the technologies considered.

Birte Holst Jørgensen
and Poul Erik Morthorst

Prospective Life-Cycle Assessment of Future Wind Energy Technology

Including future technology changes in Life Cycle Assessments (LCA) is one of the new developments within Technology Assessment (TA) methodologies.

There is increased focus on technologies' adverse effects on the environment. A characteristic for most methodologies (such as Life Cycle Assessment (LCA) and Environmental Impact Assessment (EIA)) for assessing the environmental effects of technology is that they are based on historical data or on state-of-the-art technology. This is a problem for technologies that are expected to change over a long planning period. Several countries have carried out long-term energy planning for decades - especially since the oil embargo in the early 1970s. Long-range energy policies are often based on today's expectations for the future development of energy technologies' competitiveness and on their environmental attractiveness today. Long-range energy policies can imply introduction of new technologies such as wind power, photovoltaic, fuel-cells and super conducting cables over one or two decades. Energy plans often take into account improvement in the technologies' competitiveness due to new materials and new processes. However, these changes might also affect the technologies' life-cycle environmental impact. Furthermore, electricity-producing technologies have, traditionally, a long economic lifetime – often 20 to 40 years, and the World might look quite different when new energy technologies are to be dismantled and recycled. Therefore, there is a need to develop LCA/EIA methodologies that include future changes in technology and society.

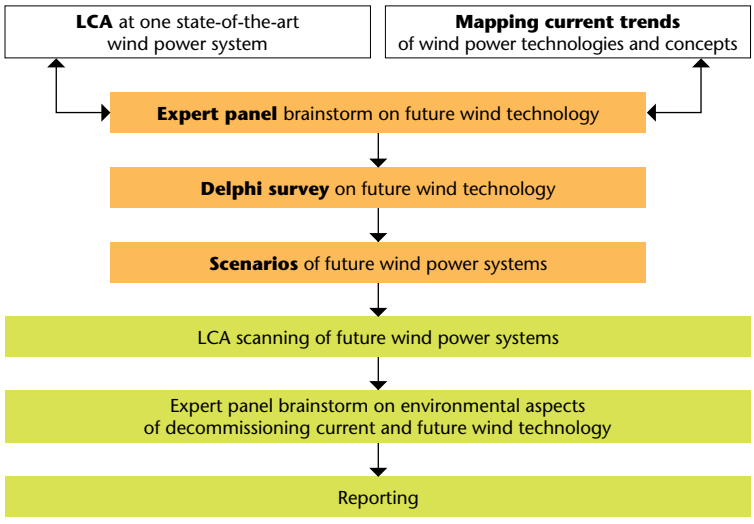
In a research project financed by the Danish Energy Agency and carried out in collaboration with Risoe's Wind Energy Department, this challenge was addressed during 2001. One of the project's aims was to contribute to the development of methodologies for using LCA as a tool for designation of experts and for making perspectives in a long-term. The case analysed in the project is wind-power technology as it might appear by 2020. As can be seen from the figure, the project was carried out in seven parts.

A number of methodologies for prospective studies (Technology Foresight (TF) methodologies) have been applied in the process. Both trend analyses (extrapolation of current trends) and judgmental methodologies (expert panels and Delphi-surveys) have been applied. Also elements of co-nomination processes have been used to identify critical technical issues and experts on these issues.

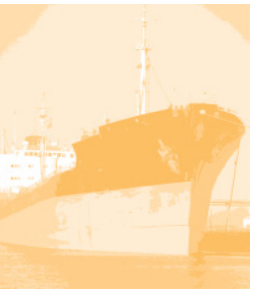
The study has demonstrated, that TF methodologies can be applied to estimate future technological characteristics to be used in prospective LCA studies. The study has also indicated that extracting exact data and information and applying them in LCA studies is a very difficult and time-consuming task. However, a prospective LCA screening based on experts' judgement can be useful in the R&D phases of a new product or technology in order to avoid less environmentally sound design solutions.

Per Dannemand Andersen and Mads Borup
Publications in 2001: 10, 117

Project flow of a project combining Technology Foresight (TF) and Life Cycle Assessment (LCA) methodologies for a prospective analysis of wind energy technology by 2020



SafetyNet – A European networking activity to improve process safety in industries



SafetyNet was a European Thematic Network on Process Safety partially funded under the Brite–Euram Programme (BRRT-CT98-5062) in the period October 1998 – September 2001. The aim of this network was to reduce the time delay between research results and their practical use in industry. Another aim was to stimulate further development of technologies in the field of process safety related to the safe operation of process plants and production facilities and to the prevention of accidents. This is important as statistics have shown that in Europe alone there are: (a) more than 2,000 explosions per year during the storage and handling of combustible materials, (b) 20 accidents per month involving runaway reactions and (c) one large fire (on average) a day leading to a loss of more than 100,000 euro.

The activity started in 1998 with the kick-off meeting at Risø with about 35 participants from research institutions, consultancies and industries from all over Europe. One central activity was to establish a web-site giving information on safety issues (www.safetynet.de). Risø acted as the focal point for Denmark, and was a member of the SafetyNet Steering Committee. An important activity for the Steering Committee during the past year has been to evaluate the achievements in the network and to discuss the future possibilities of the web-site and the network. In 2001, newsletters to inform about e.g. forthcoming meetings, new reports and interesting project were send to more than 500 subscribers every month. Every three months, on-line seminars presenting new knowledge from the research area were made. At national level, meetings were organised by the national focus points to inform about Safetynet and to exchange views and experiences between research institutions and industry.

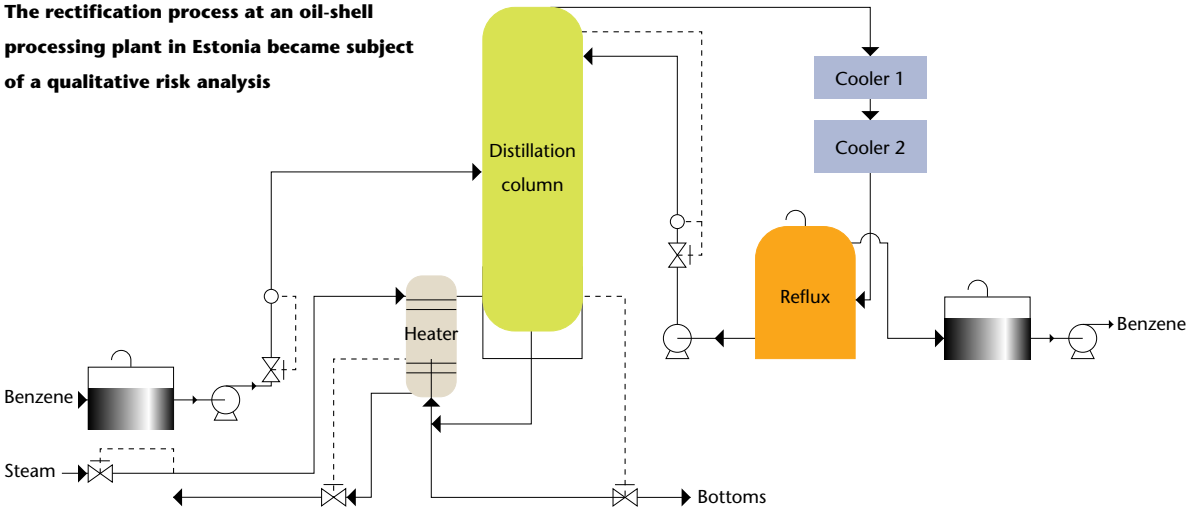
Also in 2001, the second Danish –Swedish meeting took place in Malmö, again arranged by Risø and the Swedish focus point, ØSA (Øresund Safety Advisers). This time, there were presentations and discussions on the theme 'safety management systems' and, as this was also the last meeting during the SafetyNet-funded period, the future was discussed. The participants were very positive about a continuation of the meetings, and therefore we plan to have a 3rd meeting in 2002.

The SafetyNet gave us some very fruitful contacts with European industries in the field of process safety, and it gave inspiration for the development and submission of new European project ideas. One new activity that is expected to start during the next year will be the S2S networking activity.

Frank Markert
Publication in 2001: 50

Supporting the Application of EU Directives in Eastern European Countries

The rectification process at an oil-shell processing plant in Estonia became subject of a qualitative risk analysis



As countries from Eastern Europe seek membership of the European Union, their domestic legislation must comply with EU Directives. One of them is the Seveso II Directive aimed at the prevention of the major hazards involving dangerous substances, and the limitation of their consequences for people and the environment.

The Danish Ministry for Employment in collaboration with the Danish Ministry of the Environment supports the adoption of Major Hazard Legislation in Eastern European countries, and has funded projects to promote the use of hazard identification and risk assessment in connection with the implementation of the

Directive. As part of these projects, Risø's Systems Analysis Department, in collaboration with other Danish institutions and authorities, has held training courses for Polish, Czech, Slovak, and Estonian experts representing authorities, research institutes, and industry. These courses addressed the obligations of the Seveso-II Directive, the contents of the safety reports, and a variety of risk analysis methods, from hazard identification to risk communication.

In 2001, a training project was performed in co-operation with the Estonian Rescue Board. The oil-shell processing plant VIRU AROMAATIKA was chosen as a case to demonstrate the preparation of a safety report. Representatives from the plant and the Rescue Board were introduced to, and guided through, a hazard identification method (HAZOP). Based on this introduction, they performed a scrutinised hazard identification analysis of the rectification plant at VIRU AROMAATIKA (Figure).

This hazard identification was presented and discussed during a two-day workshop in Estonia, in which representatives from 24 companies, institutions and authorities participated. The workshop focussed on hazard identification and risk assessment, as it was revealed that Estonian experience in this area had been lacking.

Development of other case studies, consequence modelling in risk assessment, and emergency planning were also included in the training. The Estonian participants appeared to be very keen on having access to simple, practical software tools, and by providing these, the workshop was also a success in this respect.

Igor Kozine and Nijs J. Duijm
Publications in 2001: 35, 127, 128

Nordunet2

Nordunet2 is a research programme financed by the Nordic Council of Ministers and by the Nordic Governments. The overriding aim of this programme is to help secure the position of Nordic countries at the forefront of Internet development. Its focus is on network utilisation and network-based applications.

Photo: Steen Weber

Team of navigational students during a simulated Search And Rescue (SAR) operation in Risø's Man-Machine Laboratory.

The goal of the Nordunet2 project "Maritime Education in Ship-Handling, Communication and Co-operation through Distributed Networked Simulators" is to give maritime students and professionals opportunities to train for real-world operational missions in an environment that is not constrained by cost, and safety restrictions.

There is agreement among experts that approximately 80% of all navigational accidents at sea are due to human error. Poor communication and co-operation between crew members and other ships seems to cause a significant number of these accidents. To prevent this type of accidents, simulator-based maritime Bridge Resource Management courses have been developed, focussing on inter-crew communication and co-operation in crisis situations. Today, these courses are offered at a number of maritime education centres using high-realism bridge simulators. To facilitate this type of education, physically separated simulators have been networked and course concepts for distributed simulation (pedagogical set-up, scenarios, instructor, replay and debriefing tools) have been developed.

During the final part of the project, Risø has been responsible for the evaluation of the developed software. Search and rescue (SAR) operation is an area where the communication between ships has to be co-ordinated at the accident site in order to achieve the best result in a real-world situation. Six teams of navigation students were used in a set-up where three teams at a time carried out SAR exercises. Physically, they were located at the Danish Maritime Institute, Ålands Sjöfartsläroverk and Risø National Laboratory, but they were manoeuvring their ships in the same waters, and were able to communicate with the On Scene Commander through the specially developed VHF radio.

The evaluation of the project shows that even with the limited number of test subjects used in the evaluation, there is a high degree of satisfaction with the product developed.

The main problem foreseen for the project was the debriefing phase, which without direct observation by a skilled instructor could lead to negative training transfer. The solution used in the project with a debriefing questionnaire, followed by a self-evaluation turned out to be satisfactory from the trainees' point of view. This can be seen both from the responses to the overall evaluation questionnaire, as well as that trainees taking part in the evaluation have experienced an improvement of their overall knowledge of SAR operations.

Steen Weber

Extreme Eye-tracking

Year 2001 has been an exciting year with new challenges and possibilities for eye-tracking and usability studies.

Handheld devices

Eye-trackers bounce infra red light off a user's eyes and follow the reflections to determine where the eyes are looking. They make it easy to collect specific data on users' visual behavior. The eye-tracking study we present here has enhanced, and brought another dimension to, usability and evaluation methodologies in the new domains of handheld devices and wireless eye-tracking. One of our challenges this year has been to perform a usability study on mobile phones. The study comprised an ordinary evaluation combined with eye-tracking. Due to the small size of a mobile phone display, the eye-tracking equipment was forced to its limit regarding accuracy, however it was possible to determine which areas of interest the users looked at and their scan patterns (see Figure 1). While the actual tests were performed using a software-based prototype on a touch-screen PC with a slightly larger display, the pre-tests of the eye-tracking equipment were carried out using a real Nokia mobile phone. The mobile phone emulator display was set at a distance so that it appeared to the subjects to have approximately the same visual size as a real phone closer to the eyes.

An example of eye-tracking on mobile phone display. The red circles indicate user focus (the larger circles the longer time). The yellow boxes are areas of interest used for statistics on e.g. how much time the user spends onnavigation or whether the user sees the item at all. The study proved that eye-tracking can give useful and detailed insight into user interaction with small hand-held devices.

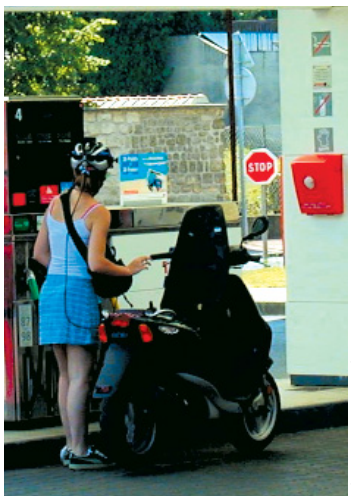


Photo: Lars Jacobsen

Girl wearing wireless eye-tracking helmet at Croissy gas

Going wireless

Our new wireless eye-tracking equipment gives new opportunities to how and where eye-tracking can be performed. Wires to eye-tracking computer no longer fix the test person, meaning that the test person can walk and move freely within a distance of 200 m. For example, with this equipment it is possible to make analyses of security operations in airports, aircraft maintenance routine checks, and ship-bridge harbor operations.

The pilot project with the wireless equipment was performed in southern Europe under extreme conditions. The test person wearing an eye-tracking helmet enters a petrol station driving in his or her own car. The person gets out in the bright sunlight, fills up the car, and makes the payment inside the kiosk. In this scenario good eye-tracking data was obtained inside the car and in the kiosk, outside in the bright sunlight, the infrared light from the sun interfered with the equipment and degraded the tracking percentage. Under cloudy conditions we managed to sample app. 75% of all possible eye-tracking data. In laboratories under optimal conditions we can obtain a rate of app. 85% of all data.

One conclusion is that the wireless eye-tracking equipment works well indoors and outdoors in cloudy weather, and provides the subjects with a high degree of freedom to move freely. The wireless system opens up for new types of eye-tracking studies that will give us new insights into the visual behaviour of operators while moving freely.

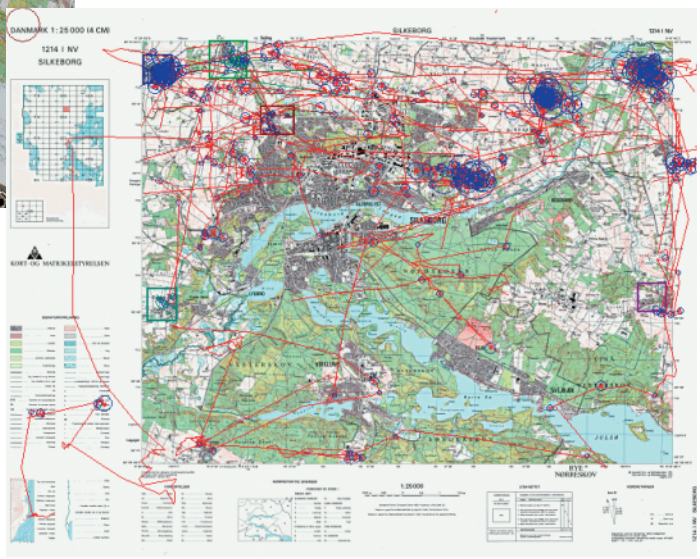
Hans H. K. Andersen, Steen Weber and Rud Pedersen

Publication in 2001: 104

Applying Eye-Movement Tracking for the Study of Topographic Map Design

Photo: Hans H. K. Andersen

The photo on the left shows a test person wearing the eye-tracking equipment while trying to solve one of the tasks given.
The graph shows a trace of the persons eye- movements across the map.



The goal of this study is to evaluate a new method for studying usability of topographic maps. That is, how can we assess the quality of the cartography of a map with regard to communicating cartographic information to the user? How can we assess the quality of achievements in product development if we cannot measure the quality? Map producers may need to carry out quality measurements of map prototypes before releasing their product onto the market, as it is common practice in other industries.

A series of tests were carried out. The aim was to develop a standard method, which can be used to test maps, map prototypes, and other forms of geographical information, in large-scale tests with representative user groups.

The method consists of four parts: 1) evaluation of the efficiency of task solutions 2) eye-tracking, 3) think-aloud method, 4) interview after completing the tasks. The study was based on ten test persons with no specialist map knowledge, but all with a high education. These persons were asked to answer 22 questions with the help of two real topographic maps that differed in design, but covered the same area and had the same content. A video camera was used to observe the subjects and record their answers and verbalised thought processes. Eye-movements were recorded using a helmet-mounted eye-tracking device.

The results measured the time taken to solve each task, the number of words used, and whether the answers were correct or not. The eye movements were used to assess the type of fixation, length and number of fixation and saccades (eye-movements between two fixations). Marks were also given for time taken, strategy and overall performance. Correlation between quantitative factors was sought. The different measurements used to assess the subject also acted as a 'control' to highlight conflicts between what was said by the subject and what the subject actually did. Uniform/similar behaviour or statements by the subjects were also noted. Part of the study was, for example, to investigate the number of eye fixations between map and legend to see if one map design required more consultation with the legend than the other design.

The number of fixations in a map, and the apparent amount of information in a specific area of the image seem to be useful for evaluation of maps. That is, a large number of fixations indicate high complexity. The duration of fixations seems to indicate the level of map complexity as well. That is, longer fixations indicate more cognitive processing, which should be equal to a high level of map complexity. It is remarkable that the subjects were able to answer correctly only approximately half of the questions. Until this study, expectations among the staff at the National Survey and Cadastre were, that this kind of user should be able to answer 85% correctly to these 'normal' questions. The overall conclusion was that the method is useful because the performance of the subjects was uniform.

Hans H. K. Andersen and Steen Weber
Publication in 2001: 111

Error Management in Air Traffic Control

The main objective of Air Traffic Control is to ensure a safe, expeditious and orderly flow of air traffic. This task is carried out with an outstanding reliability record due to the highly developed skills and resourcefulness of the controllers. Operational irregularities caused by human errors do occur, but they are very rarely allowed to develop into truly critical events. How errors are captured and prevented from evolving into critical incidents is largely unknown. While a lot is known about human error mechanisms in ATC and other safety critical domains, few studies have been made of *error management* as such.

The goal of this Ph.D. project is to gain more knowledge of how errors are captured. One of the desired outcomes of this project is to provide a basis for *reinforcing incident prevention strategies*. To do so, it is important to have a structured classification scheme (a taxonomy) in which operational data about error discovery and recovery can be categorised including the underlying circumstances behind these human errors and their capture. To be able to develop a classification system of the error management process, it is useful to have a model that can be used as an organising principle. The model has been developed on the basis of an extensive literature review, analysis of incident reports and critical incident interviews, as well as simulator studies.

The model starts out with a threat-management section, which concerns the controller's anticipation of situations that may lead to errors and operational problems. The controller may successfully avoid that a threat (e.g. thunderstorm or radar failure) leads to an error and the result of this can be a continued safe flight. If the threat is not discovered and handled effectively, an error might be the result. The error can be analysed on the basis of the cognitive mechanisms underlying the error. Detection and recovery can follow the error and may happen at different stages in the evolution of the error. Different kinds of responses might be produced and the result may vary from being inconsequential to an undesired state or a new error. A list of contextual factors – so called Performance Shaping Factors – constitutes an integrated part of the framework. On this basis it is possible to identify the positive and negative contribution of generic contextual factors.

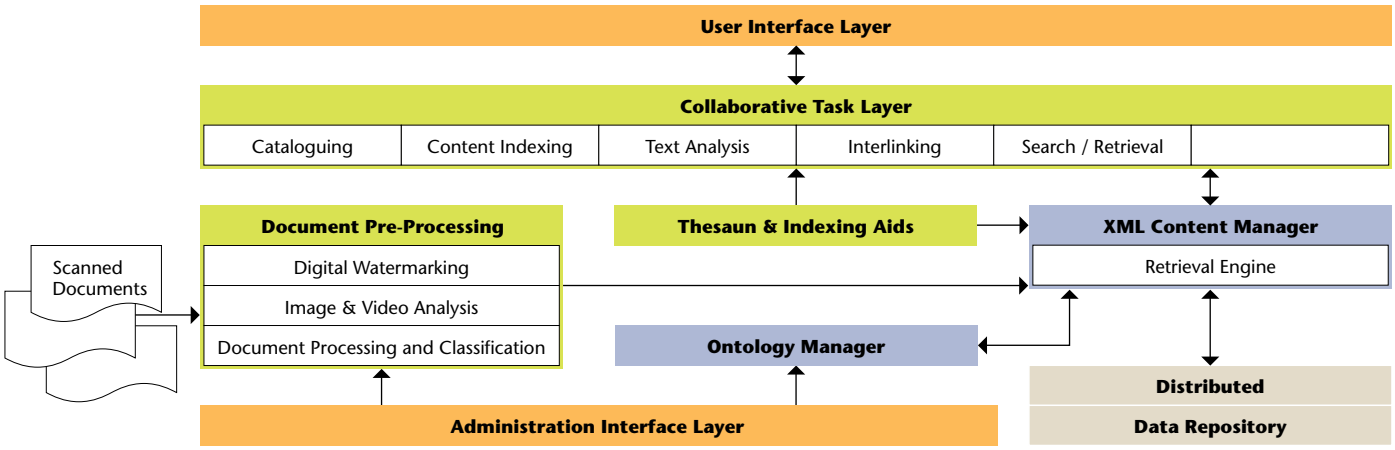
The framework has been evaluated in two different ways. Firstly, the framework has been applied to error events found in critical incidents and in a simulator study. On this basis we learned to what extent consistent classifications can be obtained (both across time and raters). Secondly, the framework has been evaluated by a number of human factors experts. So we obtained both a qualitative and a quantitative evaluation of the framework. The results indicate that the framework allows for fairly robust analyses and that experts find it highly relevant in relation to the study of error management.

Thomas Bove and Henning B. Andersen
Publication in 2001: 110

CHMI – Centre for Human-Machine Interaction

Work analysis, organised according to the principles of Cognitive Systems Engineering, is the core focus of the research in the Centre for Human-Machine Interaction. Detailed work analyses remain crucial to the design and application of complex, computer-based systems. There is, therefore, a considerable need, in both research and industry, for proven ways of conducting work analyses in order to facilitate the development of improved IT designs. During 2001 the Centre for Human-Machine Interaction has continued work analysis of concurrent engineering in software design and initiated analysis of work in archives. In these work domains there is an imperative for collaboration, both inside and outside the organisation, and a tendency for actors to possess considerable strategic freedom in a given task situation. Recognising the vital importance of collaboration as key to innovation within modern organisations CHMI has, during 2001, focussed on supporting the design of *Ecological Collaboratories*; systems that support the core activities in a given work domain whilst simultaneously providing tools for the facilitation of collaboration.

In the EU funded project, Collate, CHMI has, in conjunction with seven partners from across Europe, sought to design a Collaboratory to support task-based activity in film archives. On the basis of field-studies in the three participating archives a clear view of the general, invariant characteristics of this work domain has emerged. The initial results of our research also indicate that there is an important degree of variation in the way the archives organise themselves around the core activities that constitute the work they undertake. The three archives participating in Collate are organised according to contrasting management philosophies, ranging from a hierarchical structure to one in which self-organising groups are favoured and such differences have implications in relation to the design of *Ecological Collaborato-*



The figure represents the structural architecture of the first Collate prototype. CHMI has focussed on the collaborative task layer, specifying the needs of end users on the basis of their existing practice and work tools.

In the next stage of the project CHMI will begin to apply its knowledge of the work domain to support the design of a more extensive connection between the collaborative task layer and the user interface layer.

ries. The work conducted by CHMI has, therefore, garnered results that point to the information needs of the archives in relation to collaborative research. Furthermore, CHMI have also been instrumental in researching the issue of collaborative classification and description of film-archive based materials.

The importance of collaboration is also recognised in the Collaborative Information Retrieval (CIR) project, which, with the support of the National Science Foundation (NSF), CHMI is working on in harness with Boeing, Microsoft Research and the University of Washington. Working on the premise that extant tools to support information retrieval are designed according to the needs of an individual user, the work analysis in this project provides the basis for the proposal of IT designs that will specifically support information retrieval that is undertaken collaboratively. CHMI are currently engaged in the analysis of material obtained from field-studies conducted with a software design team within the Microsoft organisation. The results we have established in this process indicate that concurrent engineering is a context in which CIR activity is readily apparent and yet poorly supported. The analysis conducted by CHMI has sought to identify the needs of actors within a team, the instances in which they have specific collaborative information needs and the methods they currently employ in order to retrieve and exchange information.

Collaboration is also a theme in another CHMI project, CSA, which is about software engineering. One of the most significant issues to emerge from this work relates to the question of trust and, as such, identifies a central element in the process of collaboration. In the software engineering case trust is a collaborative issue. The whole project becomes dependent on a source when one of the engineers makes a decision based on it, and the assessment and selection of sources is therefore an issue frequently raised by the project manager. One of the important roles of the project meetings is to provide a recurrent forum for reviewing the trustworthiness of sources that are being used or considered for use. Though the engineers may not always reach group-wide consensus about the trustworthiness of a source, they will, at least, raise each other's awareness toward the issue in subsequent use of information provided by the source and in future interactions with the source.

Annelise Mark Pejtersen, Bryan Cleal and Morten Hertzum

Publications in 2001: 23, 96, 144

Summary Statistics

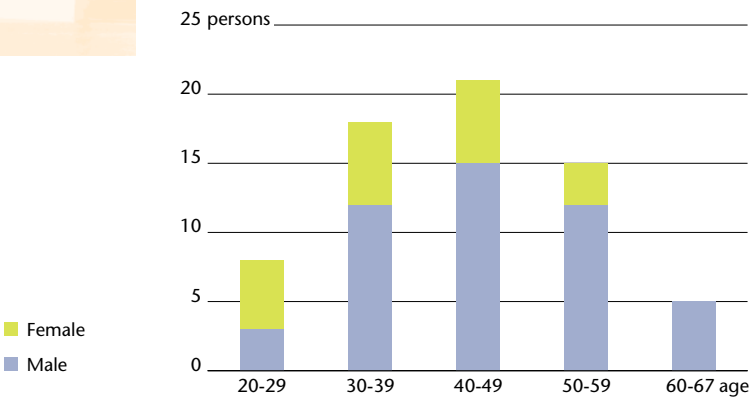
By the end of the year the total number of employees in the department was 67, of whom 20 were women and 47 men. More than 90 per cent of the staff have an academic background. The age distribution shows that approximately one-third of the staff is between 40 and 49 of age. One-quarter is in the range 50-59 years and one-fifth 30-39 years of age.

The number of publications in 2001 totalled 158. The number of international articles rose from 35 in 2000 to 58 in 2001, and the number of conference contributions in proceedings rose from 40 to 53 in the same period.

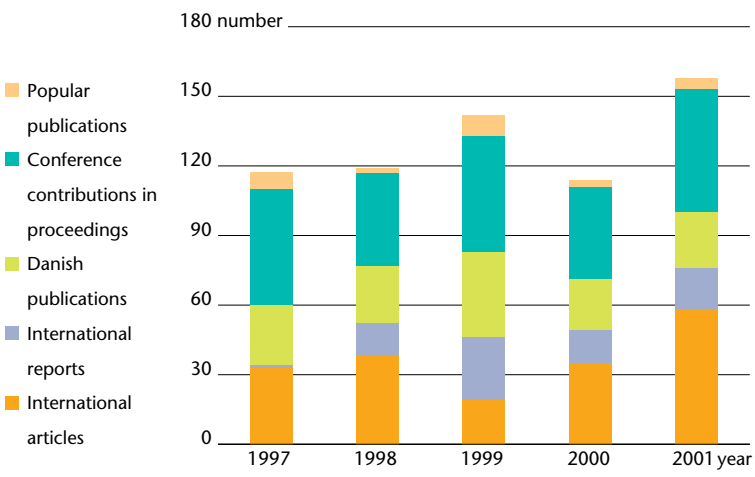
In 2001 total revenues amounted to DKK 57.2 M. At the same time, expenditures were DKK 58.3 M, thus resulting in a deficit of DKK 1.1 M. 32 per cent of the revenues came from government appropriations and 50 per cent from international research programmes. Salaries accounted for 46 per cent of the expenditures, while 22 per cent were Risø overhead.

Staff 2001	Females	Males	Total
Academics:			
Head of department and programmes	0	5	**5**
Research specialists	1	1	**2**
Senior scientists	5	24	**29**
Scientists	5	8	**13**
Technical/administrative staff	2	2	**4**
PhD students	3	6	**9**
Technicians	0	1	**1**
Secretaries	4	0	**4**
Total staff	**20**	**47**	**67**

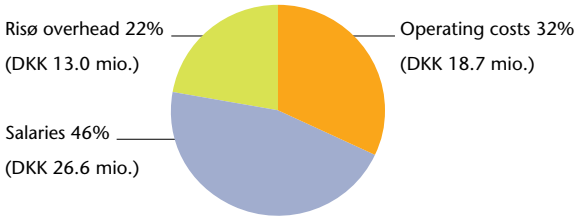
Age and gender distribution 2001



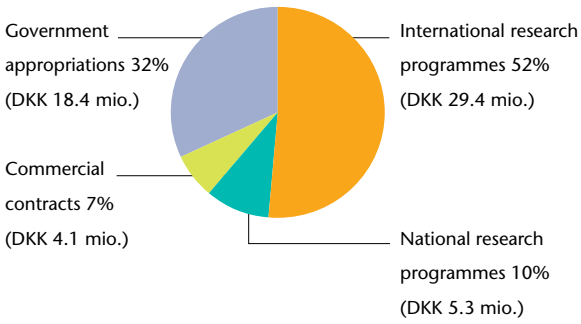
Publications



Expenditures 2001



Revenues 2001



PhDs awarded in 2001 Klaus Skytte, M.Sc. (Math. Econ.) University of Copenhagen

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The results obtained shall **set new trends** for the development of sustainable technologies within the fields of energy, industrial technology and biotechnology.

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