Nordic Energy Research

Research and Development Activities 2003-2006

Contents

ABBREVIATIONS

FC	Fuel cell
GDP	Gross domestic product
GWh	Giga Watt per hour
kWh	kilo Watt per hour
IEA	International Energy Agency
NER	Nordic Energy Research
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaic
R&D	Research and development

Editorial

Birte Holst Jørgensen

In a situation where the Nordic countries, Europe and the whole world face major energy challenges with respect to energy supply, effects of climate changes and economic development, we believe that the development of sustainable, affordable and clean technologies and systems is crucial to help meet these challenges.

Nordic Energy Research has focused its project portfolio around five core areas of Nordic benefit

- Integration of the energy market
- Renewable forms of energy
- Energy efficiency
- The hydrogen society
- Consequences of climate change on the energy sector

Over Nordic Energy Research's 20 years of work, we believe to have contributed to a general heightening of competence and capacity for energy related research. For example the education of Ph.D. candidates is one concrete way we have contributed, since they take their knowledge with them even if they do not stay in research; some go into the energy sector in a company or a business, whereas some go into government. Further, we believe to have strengthened the energy research area through the network building that comes with transnational co-operation, and the possibility to deepen knowledge in small specialised research groups. There are several areas where the Nordic Region has research groups in the international forefront and we are proud to say that our research portfolio for 2003-2006 holds a very high quality.

In this final report for 2003-2006 we have interviewed several of our project managers to give some insight into the wide range of research topics we support research in. It is new technology for solar energy, networks for fuel cells, instruments for efficient energy markets, CO_2 capture, to name but a few.

Though our resources are limited, we have steady funding from the Nordic governments and our targeted support for high quality research has given results. E.g. our projects have educated 35 Ph.D. candidates and produced nearly 800 publications.

We believe also that a small but targeted funding may be the crucial contribution to kick-start a large project. This is echoed in our stakeholder interview.

In this final report we also bring an overview of the public spending on energy related R&D in the Nordic countries. It seems that after some years with relatively low public spending there is now an upward trend.

Birte Holst Jørgensen
Managing Director, Nordic Energy Research

Project portfolio 2003-2006

The project portfolio for 2003-2006 consisted of 15 separate but well co-ordinated projects, covering a wide range of topics around new energy technology and efficient markets. Twelve of the projects were finalised in 2006, two in 2005, and one in 2004. The projects are distributed among the thematic core areas as follows:

In the core area **Consequences of Climate Changes** there are two projects.

Impacts of Climate Changes on Renewable Energy Sources and their Role in the Energy System (CE)

- extensive simulations, scenario descriptions and analyses regarding the future development
- project costs 13.2 MNOK (of which 11.4 MNOK from Nordic Energy Research (NER))
- project manager Árni Snorrason, National Energy Authority, Iceland
- main partners from Denmark, Finland, Norway and Sweden

Nordic CO_2 Sequestration (NoCO_2)

- study and development of different potential methods for cost efficient CO_2-emission elimination (capture, transport, storage)
- project costs 15.6 MNOK (of which 13.3 MNOK from NER)
- project manager Anders Lyngfelt, Chalmers University of Technology, Sweden
- main partners from Denmark, Finland and Norway plus Estonia, Lithuania and Russia

Two projects in the core area **Integration of Energy Markets**

Nordic Energy Market Integration, Energy Efficiency and Climate Changes (NEMIEC)

- analysis of effective energy markets in a socio-economic context and of regulatory and policy instruments to promote sustainable solutions.
- project costs 16.8 MNOK (fully financed by NER)
- project manager Torstein Bye, Statistics Norway
- main partners from Denmark, Finland, Iceland and Sweden

Comparison of Nordic Regulatory Models

- comparative analysis of network regulation in Finland, Sweden, Norway and Denmark
- project cost 650 000 NOK (125 000 NOK from NER)
- project manager Arne Utne, EBL-Kompetanse, Norway
- main partners from Finland, Sweden and Denmark

The core area **Renewable Energy Resources** consists of four projects

Nordic Graduate School of Biofuel Science and Technology (Biofuel GS)

- strengthening of the bioenergy knowledge through intensified cooperation in the Ph.D.-education and research
- project costs 17.0 MNOK (fully financed by NER)
- project manager Mikko Hupa, Åbo Akademi University, Finland
- main partners from Denmark, Norway and Sweden plus Estonia, Latvia and Lithuania

Competitive Solar Heating Systems for Residential Buildings (REBUS)

- coordination of education, research and development in solar heating technology
- project costs 13.8 MNOK (of which 7.7 MNOK from NER)
- project manager Simon Furbo, Technical University of Denmark
- main partners from Sweden and Norway plus Latvia

Solar Electricity – from Materials to System Integration

- strengthening of R&D-activities and commercial development in the PhotoVoltaic-area
- project costs 14.4 MNOK (fully financed by NER)
- project manager Arve Holt, Institute for Energy Technology, Norway
- main partners from Denmark, Finland and Sweden

Large-Scale Integration of Wind Energy into the Nordic Grid

- development of models/model modules to be used as tools and support in planning of big wind power parks
- project costs 9.8 MNOK (of which 4.9 MNOK from NER)
- project manager Ola Carlson, Chalmers University of Technology, Sweden
- main partners from Denmark, Finland and Norway

Six complementary projects in the core area **Hydrogen Technology**

Nordic and Baltic Applied Fuel Cell Technology Research Network (Nordic FC-net)

- stimulation of collaboration between Nordic and Baltic interest groups from industry and research
- project costs 1.8 MNOK (of which 1.4 MNOK from NER)
- project manager Preben Vie, Institute for Energy Technology, Norway
- main partners from Denmark, Finland and Sweden

Hydrogen Production – Electrolysis

- development of high stability components and better total processes
- project costs 4.5 MNOK (of which 2.0 MNOK from NER)
- project manager Finn W. Poulsen, Risø National Laboratory, Denmark
- main partners from Norway

Bio Hydrogen

- activities regarding the potential to produce hydrogen via biological processes
- project costs 15 MNOK (of which 6.0 MNOK from NER)
- project manager Peter Lindblad, Uppsala University, Sweden
- main partners from Denmark, Finland, Iceland and Norway plus Estonia and Latvia

Integration of advanced hydrogen storage materials and systems (NORSTORE)

- development of advanced materials for H2-storage and integration of these into the infrastructure
- project costs 9.0 MNOK (fully financed by NER)
- project manager V. A. Yartys, Institute for Energy Technology, Norway
- main partners from Denmark, Finland, Iceland and Sweden plus Latvia and Russia

New Metal Hydrides for Hydrogen Storage

- strengthening of the cooperation between researchers focusing on development of new, especially light metal, hydride materials for H2-storage
- project costs 4.4 MNOK (fully financed by NER)
- project manager Bjørn Hauback, Institute for Energy Technology, Norway
- main partners from Denmark, Finland, Iceland and Sweden plus Lithuania

Nordic Hydrogen Energy Foresight

- provide decision support for companies, research institutes and government in defining R&D priorities for H2 energy
- project costs 6.1 MNOK (of which 1.5 MNOK from NER)
- project manager Per Dannemand Andersen, Risø National Laboratory, Denmark
- main partners from Finland, Iceland, Norway and Sweden

The core area **Energy Efficiency** consists of one project

Underground cold storage for use of renewables in hybrid cooling of buildings (REKYL)

- researching more efficient methods for thermal and cold storage
- project costs 1.3 MNOK (of which 0.7 MNOK from NER)
- project manager Reto Hummelshøj, COWI A/S, Denmark
- main partners from Norway. Sweden and Finland

BROAD PARTICIPATION FROM THE NORDIC REGION AND BEYOND

There are nearly 300 participants, including senior researchers, Ph.D. students, representatives from business and others, involved in Nordic Energy Research's projects. About one fourth of all project participants are women.

Table 1. Participating research institutions

Chalmers University of Technology, Sweden
Copenhagen University, Denmark
Danish Technological Institute
Energy Institute, Lithuania
Estonian Institute for Sustainable Development
Gothenburg University, Sweden
Helsinki School of Economics, Finland
Helsinki University of Technology, Finland
Institute for Energy Technology, Norway
Kaunas University of Technology, Lithuania
Linköping University, Sweden
Lund Institute of Technology, Sweden
Lund University, Sweden
National Environmental Research Institute, Denmark
Norwegian Institute for Research in Economics and Business Administration
Norwegian Institute for Water Research
Norwegian University of Science and Technology, NTNU
Riga Technical University, Latvia
Risø National Laboratory, Denmark
Roskilde University, Denmark
Royal Institute of Technology, Sweden
Russian Academy of Sciences
SINTEF, Foundation for Industrial and Scientific Research, Norway
St. Petersburg State University, Russia
Statistics Norway, Research Department
Stockholm School of Economics, Sweden
Stockholm University, Sweden
Tallinn Technical University, Estonia
Tampere University of Technology, Finland
Tarttu University, Estonia
Technical Research Centre of Finland, VTT
Technical University of Denmark (DTU)
University of Akureyri, Iceland
University of Bergen, Norway
University of Iceland
University of Joensuu, Finland
University of Jyväskylä, Finland
University of Latvia
University of Oslo, Norway
University of Tampere, Finland
Uppsala University, Sweden
Vilnius Gedimas Technical University, Lithuania
Åbo Akademy University, Finland

There are 43 participating research/academic institutions from the Nordic Region and the adjacent areas (Latvia, Lithuania, Estonia and Northwest Russia). Most of the institutions have several participating researchers from different departments at the institution.

In addition to the academic and research institutions, there are 47 other participating institutions, companies, organisations, foundations, etc. (see Table 2).

Sweden and Norway have the largest proportion of project participants with 23% and 21% respectively. Norway has the majority of project managers, as six of the 15 projects are managed by researchers based at Norwegian institutions (see Table 3).

Approximately 10 MNOK of the project funding has been spent exclusively on activities and project partners in the Nordic Region's adjacent areas. This has resulted in high participation; as much as 14% of the project participants come from these countries.

Mobility of research staff has been encouraged; mobility involves a stay of 3-6 months at another Nordic institution, and in this period, over 80 mobility grants have been paid out.

Figure 1. Project participants by country of origin

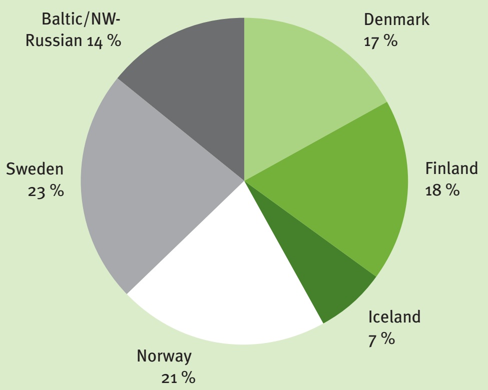


Table 2. Other participating institutions

ABB AB, Finland
AGA AB, Sweden
AllSun A/S, Denmark
BKK Nett, Norway
Bodø Energi, Norway
Cicero, Norway
COWI A/S, Denmark
Dalane Energi, Sweden
Danish Association of Engineers
Dansk Gasteknisk Center, Denmark
EBL-Kompetanse, Norway
ECON Analyse, Norway
Elforsk, Sweden
Ellehauge & Kildemoes, Denmark
Energi E2 A/S, Denmark
Energinet.dk, Denmark
Enfo, Finland
FOI Swedish Defence
Fortum Distribution, Finland
Fortum Oil and Gas, Finland
Iceland Meteorological Office
Interconsult ASA, Norway
IRD Fuel Cells, Denmark
Lyse Nett, Norway
Metro Therm A/S, Denmark
Mining Institute, Russia
National Energy Authority, Hydrological Service, Iceland
National Environmental Research Institute (DMU), Denmark
National Power Company, Iceland
Nordic Council of Ministers/Electricity Market Group
Norsk Hydro ASA, Norway
Norwegian Water Resources and Energy Directorate, NVE
Røros Elektrisitetsverk, Norway
SMHI, Swedish Meteorological and Hydrological Institute
Solar Energy Research Centre, Sweden
Solar und Wärmetechnik, Steinbeisstiftung für Wirtschaft, Germany
SolarNor, Norway
Solentek, Sweden
Statkraft, Norway
Stockholm Environment Institute, Sweden
Sunnhordaland Kraftlag, Norway
Tallinn Centre, Estonia
Trondheim Energiverk Nett, Norway
Vattenfall AB, Sweden
Velux A/S, Denmark
Viken Nett, Norway
Wärtsilä, Finland

Table 3. Project managers' nationality (country of institution)

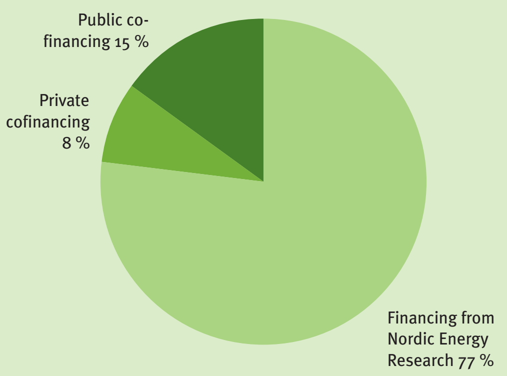
Denmark	4
Finland	1
Iceland	1
Norway	6
Sweden	3

The Nordic Energy Research projects are well connected internationally, and two thirds of the projects are involved with research initiatives and networks beyond the Nordic Region. That is e.g. EU research networks, International Energy Agency (IEA) initiatives, other graduate schools or centres of excellence, etc.

VALUABLE PROJECTS

The overall worth of the project portfolio is about 145 MNOK (approx. 18 million euros), taking into account the additional financing from other public and private financiers; 110 million from Nordic Energy Research and 35 million from other public and private sources. Approximately 8% of the total project budget is financed by private companies.

Figure 2. Project portfolio worth 145 MNOK (approx. 18 milllion euros)



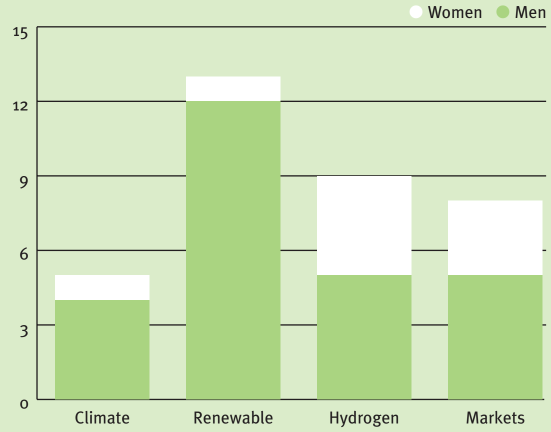
Active user-involvement has been encouraged, and 10 out of the 15 projects have participation from potential users of the research results, i.e. decision makers in business, industry and government are involved in setting the research agenda and in discussing and using the research results.

SCIENTIFIC RESULTS

The following results are gathered from Nordic Energy Research's project managers September 2006. The project period 2003-2006 has produced 35 completed Ph.D. degrees, of which 26% by women. The figure below shows the distribution of the Ph.D. degrees on core thematic area.

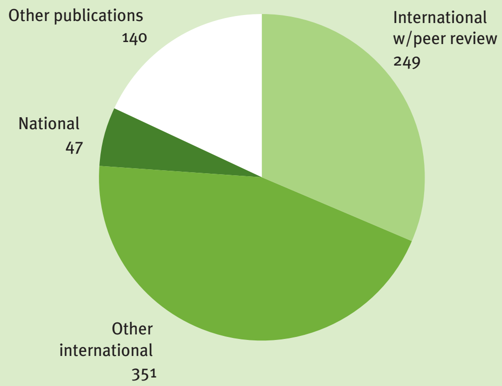
Two of our projects have applied for three patents, in the area of hydrogen technology.

Figure 3. Ph.D. degrees per core area, divided by gender



The Nordic Energy Research projects have published nearly 800 academic articles and papers, and more than a third of these are in internationally renowned journals with referee systems (peer reviews).

Figure 4. Total number of publications (787) divided by type



If we look at the productivity of the researchers involved in the projects, specifically the total number of publications per researcher in international journals with peer review, the project Climate and Energy stands out with an average of over 3 articles per researcher; the second best projects are NEMIEC and NOCO$_2$ with an average of 1.7 articles in international journals per researcher.

Detailed final reports for each project can be downloaded from Nordic Energy Research's website www.nordicenergy.net.

Box 1. The project portfolio at a glance

- 290 project participants
- 9 nationalities
- 787 publications
- 35 Ph.D. degrees
- 3 patents
- 80 mobility grants

Insight into research

– Interviews with some of Nordic Energy Research's project managers

The following interviews have been published previously in the Nordic Energy Research quarterly Newsletter ORKA.

Reto Hummelshøj

ENERGY EFFICIENCY: UNDERGROUND COLD STORAGE IN BUILDINGS CAN SAVE ENERGY

In the Northern European countries we seldom think about the fact that the need for air conditioning or cooling systems for regulating room temperatures is actually quite large. But a tendency towards architectonic solutions with large glass facades, increased use of IT-equipment and higher demands of comfort has caused a situation where lowering the room temperature using cooling systems is typically needed three months of the year. The electrical consumption for cooling systems in newer office buildings is in average 10-15 kWh per m2 a year. An interesting alternative to traditional cooling systems can be to use cold stored in the underground or in groundwater reservoirs.

The project, ReKyl, which is co-funded by Nordic Energy Research and the European Commission shows that the electrical consumption used for cooling can be reduced by 70-80% if conventional compressor cooling systems are replaced by or combined with the solutions, which in the environmental area go under the name UTES (Underground Thermal Energy Storage).

Apart from savings on energy, a number of side rewards can be achieved by using UTES-technology such as: a reduced emission of climate gasses and toxics as well as a reduction of noise compared to the conventional cooling systems.

“When the UTES-method is combined with heat pump-technology the cooling method becomes highly interesting – also from a commercial point of view. The investments have a repayment period of less than 12 years and in the best case four years”, says project manager Reto Hummelshøj at COWI.

Unknown technology needs to be extended

Since 2003, scientists from the Rekyl-project with representatives from the North, Central Europe and Germany have worked towards spreading the knowledge (and use) of underground cooling for reducing the room temperature in for example office buildings.

“The positive results from the Rekyl-project mainly lie in the learning process where useful exchange of information and sharing of knowledge about UTES-technologies have smoothed out the great differences between how far the individual countries have come in understanding the technologies”, Hummelshøj says.

In this way, the experiences from the Rekyl-project have already been used for the planning of a new, large UTES-cooling system which is to be installed in the new head quarters of DR, the Danish National Radio – for the time being the largest building project in Denmark. The building covers an area of 125,000 m2 and has a cooling requirement of 12.2 GWh a year. The cooling system is based on the so-called ATES-technology (Aquifer Thermal Energy Storage) which in combination with free cooling will cover more than 70% of the cooling need for the building as well as for the process (IT-cooling).

Cooling handbook

One of the central tasks in the Rekyl-project has been to make a practical handbook, a so-called “Pre-Design Guide” for the use of actors such as building engineers, investors, authorities and energy companies that wish to consider groundwater cooling as a serious alternative to the traditional cooling supply.

The handbook gives short and easily accessible information about the different technology concepts which take into account the different qualities (climate, geology etc.) that characterise the participating countries (Sweden, Denmark, Norway, Finland, Germany and Lithuania). It gives advice about how the actors can save time and money in the design process as well as guidance about choice of systems that can reduce capital as well as operational costs.

Box 2. Terminology of thermal energy storage

Aquifer Thermal Energy Storage (ATES) = Storage in groundwater-magazine
Borehole Thermal Energy Storage (BTES) = Storage in earth using vertical earth tubes (closed system)
Cavern Aquifer Thermal Energy Storage (CTES) = Storage in water-filled cavities such as a closed mine

Arve Holt

SOLAR CELLS: THE NORDIC COUNTRIES CAN COMPETE WITH THE BEST

Network building and education of research graduates; that is the main objective of "Nordic PV – A Nordic Scientific Project on Solar Electricity", led by Arve Holt from Institute for Energy Technology (IFE). In collaboration with colleagues at IFE and five other research communities in the Nordic countries he has participated in the extensive Nordic solar panel project. "Before the work of Nordic PV was begun, there was no research network in the Nordic countries in the area of solar cells. Through the project we have established a network of researchers, which has brought the competence together. And in 2006 four Ph.D. students will graduate", says Arve Holt.

Network building and education of researchers has primarily taken place through conferences and seminars. There have, for instance, been two so-called "hands-on" seminars, where research representatives from each of the Nordic countries lectured to candidates and their research colleagues about different methods of manufacturing a solar cell.

"The participants (typically 9-12 researchers/students) have been given the opportunity to try for themselves to make different types of solar cells in the laboratories – from start to finish. This provided a good introduction to different processing techniques, e.g. production of the surface coating, which determines the transmission of light. In this way, the best processing techniques can be transferred from each community", says Arve Holt. Furthermore, the research students in the Nordic PV project have spent at least three months in another Nordic country every year (that is 9-12 months in total), where they have contributed to the laboratory work.

Industrial participation

A distinct feature of the Nordic research community within solar cell technology is the close cooperation with industry. According to Arve Holt, industry's interest in cooperation is enormous. "In the Nordic PV project we have deliberately defined and selected the assignments for the students within those core areas in which we are already cooperating closely with industry. "A large part of my work is related to industry projects. At IFE we have, for instance, a Ph.D. student on the PV project, who has been working with solar cell companies in laboratories – with both a Swedish (Solibro) and a Norwegian (REC) company. In this case the objective is the improvement of so-called "contact mounting" – connector technology, which is the technology for conducting electricity from the solar cell".

"The level of interest from industry seems to indicate that there is a certain quality to our research, and that we are able to compete internationally", thinks Arve Holt. He emphasises the Norwegian "Renewable Energy Corporation" (REC) – with an estimated worth of approximately 50 billion NOK – as an example of a company that is quoted on the stock exchange and is in the premier league for production of solar cells.

Has the network collaboration contributed to novel results?
"Technology and knowledge transfer has taken place between the groups, which can contribute to improving both the existing (and dominant) solar cell technology, i.e. so-called "multi-crystalline silicon solar cells", and new technologies, which are about to become commercially interesting".

"We have looked at new possibilities and solutions in each other's laboratories. We have exchanged samples and tested each other's products, which has provided training in new techniques. Even though there have been no direct investments, we have gained access to a larger "pool" of processing equipment. That would not have happened without the network", Arve Holt declares.

The price must go down

The network project has a large scope. In one of the sub-projects they are working on solar cells in mobile applications. One example is the prototype of a solar cell incorporated into a bag, which can be used for charging mobile phones. "This got great media coverage", says Arve Holt. Others have been working on improving the interaction between architecture and solar cells, such as different solutions for how solar panels can be integrated both in building materials and in architecture.

However, the greatest share of activity in the PV projects (about 80%) is focussed on material research with a view to developing highly efficient low cost solar cells, and to develop materials that extend the lifecycle of the panels. "In one of our projects ("Development of highly efficient silicon based solar cells") the aim is to increase the efficiency from 15% to 18-20% (within existing technology) by introducing a novel design and cheaper production methods. This is where the major research challenges are found today", says Arve Holt.

In the follow-up of the Nordic network collaboration, the project group wishes to focus their effort on material research, which is less dependent on the type of material the solar cells are made of. Arve Holt thinks that this will provide greater benefit to all the partners of the project. Examples include casing and lifecycle of solar panels, 2D and 3D modelling of solar cell structures, contact mounting on solar cells and solar panels, as well as light capture.

Box 3. Sub projects within the project

- Contact mounting of solar cells
- Development of highly efficient silicon based solar cells
- Characterisation of multi crystalline silicon
- Test and development of photo electrochemical solar cells on novel substrates
- Internal stability of CIGS thin film solar cells
- Novel solutions for casing of PV modules
- Solar cells of tomorrow
- Solar cells in mobile applications

Anders Lyngfelt

RESEARCHERS WORK HARD TO STOP CO_2 FROM SLIPPING INTO THE ATMOSPHERE

The Nordic countries have a lot of potential for leading the way in the development of techniques for sequestrating CO_2", Anders Lyngfelt, head of the "Nordic CO_2 Sequestration" (NOCO$_2$) and professor at Chalmers Tekniska Högskola in Gothenburg, says. The project aims at developing new technology to separate and store CO_2 in connection with the burning/transformation of fuel.

The programme is broadly set out in theme as well as in geography. In addition to research environments from the Nordic countries, Lithuania, Latvia, Estonia and North West Russia also participate; and a range of very different sequestration technologies are represented.

"The research is still in the starting phases, even though the Nordic and Baltic countries have come far when compared internationally. Norway and Denmark have for example mapped the areas in the North Sea which are suitable for storing CO_2. Norway is the first country in the world to use geological storage of CO2 on a large scale. Since 1996 one million ton has been stored a year in the Utsira-formation in the North Sea. Denmark has recently opened the world's largest demonstration plant for CO_2-capture. The Swedish company Vattenfall has just taken the first steps towards the development of the world's first CO_2-free power plant in Germany.

Because of the broad geographical composition of researchers, the work is taking place on a lot of different fronts. "Each individual country has its own premises and challenges. In Estonia the energy production has for example primarily been based on the very polluting oil shale. Therefore, it has been natural to study the possibilities for separating CO_2 from the ashes that are produced during the burning of oil shale. Russia and Latvia are researching the possibilities for storing CO_2 in geological formations and have for example identified interesting areas with large storing possibilities in North West Russia. Researchers in Finland and Lithuania are looking at the possibilities for storing carbon dioxide by using natural minerals and bi-products from the industry."

Box 4. Partners of the NoCO$_2$ project

- Dept. of Energy Conversion, Chalmers University of Technology, Sweden.
- Dept. of Energy and Process Engineering, Norwegian University of Science and Technology, Norway.
- Laboratory of Energy Engineering and Environmental Protection, Helsinki University of Technology, Finland.
- Dept. of Chemical Engineering, Technical University of Denmark.
- Department for Environmental Engineering, Kaunas University of Technology, Lithuania.
- Laboratory of Inorganic Materials, Tallinn Technical University, Estonia.
- Department of Energy Systems and Environment, Riga Technical University, Latvia.
- Mining Institute, Saint-Petersburg, Russia.

Looking for efficient CO_2-sequestration technologies

Norway, Denmark and Sweden are putting great focus on the development of methods for the separation of CO_2 from flue gasses from gas and coal fired power generation. So far there is only limited experience with CO_2-separation from the combustion in a power generation process, and the methods that do exist are expensive. At the Norwegian University of Science and Technology (NTNU) researches from the NoCO$_2$-project are developing a methodology for minimizing the cost of recycling CO_2 from industry facilities and power generation.

Their colleagues at the Technical University of Denmark (DTU) have been exploring how CO_2 can be captured from combustion of coal by post-combustion scrubbing with (alkanol) amines. Anders Lyngfelt and his partners in Sweden have explored two promising methods for producing hydrogen from natural gas with CO_2-separation. "Both processes are based on chemical looping combustion, a promising technique for combustion of fossil fuels with small energy losses. This is because the combustion air and fuel never mix and hence no separation step is needed", Anders Lyngfelt explains.

Efficient CO_2-separation and storage requires researchers to develop technological solutions. A combination of technologies and strategies is necessary before a leading technology (or technologies) can be identified. This is one of the main conclusions from the researchers participating in the NoCO$_2$-programme.

Torstein Bye

INSTRUMENTS FOR THE NORDIC POWER MARKET

Nordic Energy Market Integration, Energy Efficiency and Climate Change (NEMIEC) is first and foremost a doctoral program that aims at heightening the competence level on central issues in the energy market. Two of the themes NEMIEC has chosen to investigate further, are questions that have created extensive public debate in the North: Is there misuse of market power in the Nordic market, and what effect will statutory markets for electricity certificates have on the Nordic power market?

Project manager in NEMIEC, Torstein Bye at Statistics Norway points out that the research is broadly founded and directed at several current issues. At present, he especially wishes to emphasise results from the work on electricity certificates –"Intuitively, you should think that an obligation to buy electricity from renewable energy through trade with certificates would lead to more expensive electricity, but this as a matter of fact is not the case. Instead, the power prices are reduced, partly because existing energy providers are pressured on their earnings/margins, and partly because more electricity production is put on the market. This result came as a surprise, not just to us, but to the authorities as well", says Torstein Bye.

Does this mean that existing energy providers, for example Vattenfall and Statkraft, and not the electricity consumers support the renewable energy production financially?
"Yes. In a market for electricity certificates no public authority decides the size of the support system – as is the case with traditional subsidies/tax-arrangements. Therefore, the effects of the electricity certificates are more unpredictable, as they are decided by the market. It turns out that the certificate market results in existing energy providers (regardless of production technology) obtaining less profit. This smaller income goes to paying the extra costs that are necessary for financing the new renewable energy production. Normally, you would think that the certificate arrangement worked as tax on the end-use consumption, so that the electricity consumers would pay the extra expenses that new production with renewable energy costs, Torstein Bye explains.

Besides looking specifically at the effects of an electricity certificate market, NEMIEC has investigated what happens, when you introduce different kinds of energy and environmental political means simultaneously – how, for example, is the connection between an international CO_2-qouta system and national arrangements that support renewable energy production?

No signs of market power in the Nordic power market

An ever recurring topic is the use and misuse of market power in the power market. NEMIEC has thoroughly discussed this subject, inter alia at topical seminar in Stockholm 2004. The seminar was arranged in collaboration with SESSA (European forum on electricity market reforms) and had European as well as American participants. At the seminar, researchers and students from NEMIEC presented analyses, which showed that the Nordic energy market in 2002/2003 worked according to the framework regulation –"There is no sign of abuse of market power on the Nordic market even though the market concentration in some (price) areas can be high during certain periods. It is hard to demonstrate in full whether some have misused their dominating position without access to the confidential data of the power companies, but research is being made to find alternative means of disclosing abuse of market power on the Nordic energy market", Torstein Bye says.

COMPETITIVE RENEWABLE ENERGY FOR RESIDENTIAL BUILDINGS

Today solar heating technology normally cannot compete with traditional forms of room heating where price is concerned. But now researchers from the REBUS project – Competitive Solar Heating Systems for Residential Buildings – take up the challenge. They want to shorten the way towards commercialising the technology. Apart from appealing to the environment and price conscious, the consumers are to be tempted by good design. ”But it is obvious that larger challenges lie in using the solar energy in the North than in the South. It is colder, the winters are longer and this typically means a larger need for heating, the further North you go. This calls for bigger and better storage systems so that the solar energy can be stored from sun rich to sun poor periods”, says head of the REBUS project Simon Furbo from DTU, the Technical University of Denmark.

On a world basis solar energy for heating purposes is still only used to a moderate degree (approximately 42,000 GWh in 2001). But the distribution is increasing by about 30% a year globally. In Europe, Austria and Germany are considered to be the leading countries in developing and using solar energy technology. In the North and the Baltic countries on the other hand, the development is evolving somewhat slower.

There are compelling reasons for spreading the use of solar energy in the North in spite the fact that sunrays to a greater extent belong to countries under Southern skies. For despite the Northern position, the annual sun radiation in Norway is for example 1,200 times the country’s total annual use of energy. And the potential for using solar energy for heating is considerable in that at least 25% of Norway’s energy consumption goes to heating residential buildings.

Combi-heating cheapest

A part of the REBUS program consists in developing new so-called combi-solutions in which solar heating is used in combination with either nature gas or wood pellets to be used for the heating of rooms and household water. The research institutions in Sweden and Denmark (SERC and DTU) work with the industry on developing systems that will be able to cover 50% of the energy consumption of a private home with solar energy. The concept consists in producing total solutions that contain a kettle for heating based on nature gas/wood pellets and a (or maybe several) heating storage container that can collect the solar energy. Compared to other ”separate” systems these total solutions shall make it possible to install the plants faster and make the systems more reliable.

”A special feature of the research in REBUS is that it also involves industrial partners (Metro Therm A/S, Velux A/S, Solentek AB and SolarNor). This means that a strong focus is put on the development and improvement of techniques that give more energy for the money’s worth. Hopefully, the work in REBUS will result in the development of better concepts and techniques than those, which exist today. Our goal is to develop solar heating solutions that form the basis for an industrial venture and for putting the products on the market”, Simon Furbo says.

After the termination of the project in 2006 the goal is for the new combi-plants to be ready to be produced by the industry. For the time being an extensive test of a number of prototypes is being made in the laboratories and later in 2005 a number of demonstration plants are to be built.

IMPACTS OF CLIMATE CHANGE ON RENEWABLE ENERGY SOURCES

In the future everybody expects renewable energy sources to play an increasingly important role in reducing negative global climate impacts, e.g. extreme weather situations. However, few think about the fact that renewable energy sources can also be influenced by the climate impacts they were designated to reduce. Árni Snorrason is working on this topic.

Árni Snorrason is a climate researcher from Iceland who manages the pan-Nordic project Climate and Energy (CE). One focus in this project is on the impact of global warming on the hydropower systems. Hydropower is the renewable resource that is most affected by climate variability and change. Countries such as Norway, Sweden, Iceland and Finland, where much of the electricity production is based on hydropower, are especially sensitive to variations in stream flow as they might influence hydropower operation and design. In Norway hydropower contributes 99% of electricity production, in Iceland 80%, in Sweden 40-50% and in Finland 10-20%.

Any change in precipitation volumes and patterns will immediately affect the hydropower-sector. E.g. a dry year will typically mean higher power prices and higher dependency on electricity imports from the continent. Furthermore, since an important part of the precipitation falls as snow and is stored from winter to spring and summer, changes in temporal and spatial distribution of temperature will affect the hydropower as well. In addition, some hydropower in the Nordic countries partly relies on glacial melting which will be greatly affected by climate variability and change.

Bioenergy will also be affected by climate change in the long run, but here the response time is much longer. With regards to wind and solar energy, climate variability and change will have minor impacts on their productivity, Árni Snorrason says.

Worst case scenario – what do you think can become the most negative impact of climate change on the energy sector in the Nordic countries?

"The most negative impact would be extreme changes. If weather extremes increase, larger floods might be generated with different regional characteristics. This could increase the risk of e.g. dam failure. If drought conditions on a regional scale become more severe, which is possible even if the present scenarios generally produce higher total precipitation, a serious condition could surface within the whole region".

The market itself will find the "right" energy mix

Do you see a need for other mechanisms / strategies (i.e., alternatives to current renewable energy technologies) that may prove more robust (and more efficient) towards possible climate change impacts, e.g. power generation from nuclear, CO_2 clean coal or gas?

It is most likely that the production potential of the renewable energy will increase with a change in the climate. Some risk issues need to be addressed, but in general I believe that the industry will develop itself according to what the technology allows and the marked dictates. I think the market will choose the right mix for the future, but it is necessary to create the right conditions for that market and to generate alternatives through focussed research.

It is, in my opinion, absolutely necessary to create the conditions for a common Nordic research, since the critical mass for the generation of significant results will only be created through a joint effort, Árni Snorrason concludes.



Preben J. S. Vie
Bjørn C. Hauback
Volodymyr Yartys

STRONG HYDROGEN RESEARCH AND NETWORKS IN THE NORTHERN REGION

Preben J. S. Vie, Bjørn C. Hauback and Volodymyr Yartys manage three complementary projects for Nordic Energy Research in the core area "the hydrogen society". All three are based at the Norwegian Institute for Energy Technology (IFE), which is a stronghold for hydrogen research in the Nordic Region.

We ask them what value the transnational Nordic co-operation adds to their work as researchers. At first, it seems obvious that there are possibilities to take advantage of synergies and obtain large-scale benefits in research cooperation, including several countries. But it is not only the economies of scale that attract the researchers, it is very much also a matter of scope. I.e. with networks and research groups that cross borders, there is a larger opportunity to specialise and engage in deep knowledge about a topic.

Creating a meeting place

Preben Vie coordinates the Nordic and Baltic Applied Fuel Cell Technology Research Network, and the aim of this network project is to support local technology development and applied fuel cell research by stimulating knowledge exchange and cooperating in research and development areas. The network aims at facilitating both local technology development and applied fuel cell technology research in the Nordic and Baltic regions, by strengthening the cooperation within research and development and exchange of knowledge on fuel cells. For the duration of the project, there has been a big interest in participating: "Today, the network has over 140 members from more than 42 organisations all over the Nordic and Baltic countries.

Do you think that the project has succeeded?
"Yes – on the whole. There has been created a better basis for local technology development. The network has established a meeting place that gives the opportunity of gaining new contacts. It would have been more difficult without this network. For example, better bonds between various Nordic research groups have been created, and the different Nordic groups have probably better knowledge about each other.

According to Preben Vie, the biggest benefit of the network project has been to create a forum where researchers, who otherwise would not have met, can meet in order to discuss their work in an informal forum. "Normally, we as researchers are gathered at big international conferences, where there is little or no time to really discuss in small groups. There is a bigger chance for dialogue and getting to know each other when you meet in Nordic workshops and smaller fora. The smaller groups the better," Preben Vie thinks.

Through the network project, have you felt a larger international interest in your research?
"Several Canadian research groups have expressed a desire to participate in the Nordic networks, and probably the network would be opened for more countries quite soon", says Preben Vie.

Together we stand

Bjørn Hauback manages the project "New Metal Hydrides for Hydrogen Storage", which is also a network project.

Through the Nordic research project, Bjørn Hauback is responsible for gathering the Nordic competences in the area, and making them visible to the rest of the world. He has been positively surprised over the significant ties that have been made between the Nordic partners. "Actually, I'm very impressed by what has come out of this project. The project has been a focused on networking and is not a research project as such. The goal has been to further cooperation in the Nordic countries plus partners from Baltic countries. Among other things, the project has resulted in publications with more Nordic research partners than I have experienced earlier," Bjørn Hauback says.

Bjørn Hauback also thinks that the network project has led to increased visibility of the Nordic Region in an international context. "Every other year, the world's largest conference in our field, International Symposium on Hydrogen – Metal Systems is held (this year it will be in Hawaii). In the Nordic network group we are working towards having the next conference held in Iceland, in 2008. I think that this initiative is a result of the Nordic partners working in a more coordinated way.

Bjørn Hauback is convinced that new, solid cooperation relations have been established, which would not have existed without this project. "It is obvious that the Nordic Region is an important international player when we appear as one unit. Together we are able to contribute more and are more attractive to work with. The Nordic network project has contributed directly to us becoming Nordic partners in larger international projects. Specifically: "Today, four partners in our Nordic network group are involved in the largest EU project in hydrogen storage ever. IFE helped initiating the EU project, and therefore it was obvious to involve the Nordic research partners we already had good cooperation experiences with," Bjørn Hauback says.

Nordic research groups at the forefront

Professor Volodymyr Yartys manages the NORSTORE programme, "Integration of Advanced Hydrogen Storage Materials and Systems into the Hydrogen Society".

"Through the NORSTORE project, we have succeeded in gathering the strongest research competences from all Nordic countries (Risø National Laboratory, Helsinki University, Uppsala University of Technology and the University of Iceland). All of the research environments have contributed with complimentary competences which have helped strengthen the research area in the Nordic Region. As a part of the NORSTORE project, a close cooperation with Latvia and North-Western Russia has also begun, which has been very fruitful," Volodymyr Yartys says. As a Russian national, he also very much enjoys supervising two Ph.D. students from The University of St. Petersburg and The Russian Academy of Science respectively. One of the projects is focused on developing a mechanism of decomposition of metal hydride storage (a method where hydrogen is tied to a metal and stored as a meta powder).

"The strategy behind NORSTORE is to make projects that involve contributions from at least two different institutions, including not only Ph.D. students, but also Post-docs. For the project group as a whole, the most important activity has been the annual workshops where every group reports about their work and progress during the year. Every year we also invited internationally distinguished experts in the field of hydrogen storage and hydrogen as energy carrier and external specialists to present invited talks at these conferences". This allowed creating an interaction between the NORSTORE and international projects in the field", says Volodymyr Yartys.

The NORSTORE project particularly benefits from strong contributions from the Icelandic research group, since Iceland is a pioneer in hydrogen economy. When the government of Iceland decided to aim for a hydrogen economy in 1998, it was clear that renewables (hydroelectric energy and geothermal energy) would play an important role in its development as the basis for the primary energy. Thus, one of the key results of the NORSTORE project so far has been the initiation of the first hydrogen system analysis performed in Iceland.

Volodymyr Yartys is certain that the NORSTORE project has contributed to strengthening the Nordic research network in his research area. "I think Nordic Energy Research contributes to putting development of hydrogen technology in focus. This focus (and support) has allowed us to make groups under sort of hydrogen umbrella".

The life as a Nordic Ph.D. student

- From a Swedish, Latvian and Russian point of view

Sven Hermansson, Liga Grinberga and Marina Tsygankova have something in common: They have all received a Ph.D. scholarship from Nordic Energy Research, and have stayed at another Nordic research institution than the one they originally come from. Academically, however, they work within areas quite far apart. Sven Hermansson, a Swedish national, works with "mathematical modelling of bio fuel combustion processes;" Liga Grinberga, originally from Latvia, works on "hydrogen storage materials and systems", whereas Marina Tsygankova' s, a Russian national, focuses her research around the Russian energy market.

It can be difficult to describe precisely which new possibilities a Nordic scholarship opens up, and how a Nordic scholarship differs from a national scholarship. But for Liga Grinberga it meant the possibility to get into a whole new area of research: "I heard about the NORSTORE project in Latvia from my supervisor J. Kleperis, just after finishing my master studies. He informed me of the possibility of participating in the project. The meeting with the Nordic research environment has also given Liga Grinberga a linguistic break-through in her career. "The biggest difference is that it has forced me to speak and write in English. After a period of time, it was easier to communicate with other people in conferences, by e-mail or just on the street."

Sven Hermansson was already involved in a Nordic research environment when he received the scholarship from Nordic Energy Research through the Nordic Graduate School of Bio Fuel Combustion and Sciences (biofuelGS). "I would say that the greatest difference between a national and a Nordic scholarship is that there is a greater opportunity to specialise within the Nordic cooperation since the chance of finding students and projects that are working in the same area as oneself is larger. I think our graduate school in bio fuel science and technology has been quite unique since it involves some of the world leading research institutions in the area of BioFuels," says Sven Hermansson.

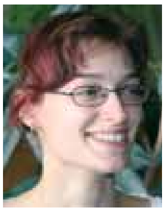
Marina Tsygankova started to work at Statistics Norway Research Department before starting her Ph.D. studies. Here she heard about the Nordic Ph.D. scholarship from the head of her research unit. "The main difference between a national and a Nordic scholar ship is the amount of funding available. Ordinary Ph.D. scholarship is quite small in Russia and students have to work part-time somewhere else in order to finance their Ph.D. Another important aspect is the contacts students make during the Ph.D. projects".

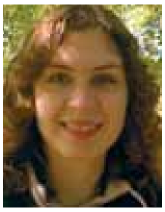
Sven Hermansson is currently on a 2.5 months stay in the Department of Inorganic Chemistry in Åbo Academy in Finland. "My stay here has been successful so far and very interesting. I meet students, both from biofuelGS and other programmes, and I get competent supervision from senior researchers. I think that the possibility of complementing each other within the Nordic universities is excellent."

"Another very positive thing that comes with the possibility of, for a period of time, being situated at another university in another country the exchange between institutions, is that you get to experience a different kind of working atmosphere, and even if we think that we are all the same in the Nordic countries, another culture than the one at home. I think that is very useful, not only because of the abundance of new ideas for research, but also as life experience," says Sven Hermansson.

During Liga Grinberga's scholarship education, she has worked for about five months at Risø National Laboratory in Demark. Compared to a national scholarship, the Nordic scholarship leads to

Liga Grinberga
Sven Hermansson
Marina Tsygankova





compulsory work at a foreign laboratory. It also leads to an opportunity to get to know more professionals and scientists in the field, as well as a possibility to use equipment that is not available at the home institution, Liga Grinberga says.

Networking in the Nordic region and beyond

"The NEMIEC programme, which I am part of, organises general meeting for all students once a year where we get the chance to present and discuss our papers with senior researchers. I think this has been very helpful and has given me great motivation to finish my papers. In addition NEMIEC organised a range of conferences and seminars which also included international top researchers in my field. The participation in this programme has certainly helped my network building", Marina Tsygankova tells.

Sven Hermansson has also broadened his network. "Meeting other Ph.D. students and researchers that share the same deep interests gives new possibilities for collaboration. Due to combining research groups across the Nordic borders, there is the possibility to split into new and focussed research groups. Not only does that give new knowledge about the course subject itself, but it also gives great input on what the other universities are doing research on, and ideas for possible collaboration. These kinds of advanced courses, that are specifically aimed at my subject, solid-combustion research, are very difficult to find elsewhere, and is a very important area for a graduate school to fill, he says."

"The social activities under the Nordic seminars and courses are great for networking. We Ph.D. students have gotten to know each other well during these course sessions, not only professionally, but also personally. I think this will be a great asset in our future careers," says Sven Hermansson.

"NORSTORE's annual conferences/workshops were also an important venue for networking. The conferences meant the opportunity to meet new people; some famous and well known lecturers in the field; and to know the culture, history or nature of the conference site. Every year, the annual meeting was held in a different and really fantastic place: Norway, Iceland, and Denmark. I also appreciated the possibility to get to know other people and their way of working. So I feel really privileged to be part of this Nordic programme", says Liga Grinberga.

All three students emphasise the networking aspect and the contacts as well as the extended chances of focussing on a specialised area as the big advantages of the Nordic programmes over the national. Liga, Sven and Marina have gained contacts and knowledge that might entail career opportunities beyond the national borders.

Box 5. Three Ph.D. students on three projects

Liga Grinberga, Latvian University participates in the NORSTORE project – Integration of Advanced Hydrogen Storage Materials and Systems into the Hydrogen Society) and is Ph.D. student at Department of Physics and Mathematics of University of Latvia

Sven Hermansson, Department of Energy and Environment, Chalmers University of Technology, Sweden: The Nordic Biofuel GS project – Specific research topic: Mathematical modelling of the combustion of solid bio fuels.

Marina Tsygankova, Statistics Norway – Ph.D. student in the Nordic NEMIEC-project (Nordic Energy Market Integration, Energy Efficiency and Climate Change)

Transnational research collaboration

– from a stakeholder's point of view

Helle Brit Mostad

As former head of research at SINTEF, and responsible for the co-ordination of the research in New Energy at Hydro, Helle Brit Mostad has several years of experience participating in transnational research collaborations. Helle Brit Mostad has no doubts that research and development must be seen in a larger, international context.

"Few countries have all of the building blocks that are necessary in order to be able to develop the best solutions. Several countries can benefit greatly from collaborations in the most basic of areas, such as safety issues and standardisation of technologies/equipment for hydrogen production. Analysis, which contain a benchmarking of different types of technologies, can also have a great value for many, and thus be a suitable area of collaboration," says Helle Brit Mostad.

"When it comes to the hydrogen area, where commercial break through is due in the distant future, I think that it is more expedient with a large number of countries participating, both when it comes to getting the best competence environments, and because the development of hydrogen and fuel cell technology takes up a lot of resources," says Helle Brit Mostad.

Too many chefs...?

Helle Brit Mostad has, first and foremost, participated in EU projects (such as HyWays and FC-Ship), but also in the Nordic Hydrogen Energy Foresight project, which was financed jointly by the Nordic Innovation Centre and Nordic Energy Research. This particular project has been a good starting point for improving the Nordic collaborations in the hydrogen and fuel cell areas.

"I think that smaller projects of this type can give a much better profit; in smaller groups creativity can flourish," says Helle Brit Mostad. She thinks that it is important to be careful with starting up too many comprehensive projects and warn not to underestimate the resources for administration and coordination associated with large project and many players. Especially the EU has a tendency to prioritise large projects with many partners, who don't always fit well together. This type of project is hard to administrate, and misunderstandings can easily occur.

Have you experienced conflicts of interest in research, which is close to commercialisation, such as demonstration projects?
"For the past year, I have mostly dealt with research and develop-

ment of hydrogen technologies and systems, which at the current time only have had a limited market potential. Therefore, I haven't personally experienced conflicts of this type; however, there are obviously more challenges connected to research collaborations, where business opportunities are right around the corner.

"It may be better to discontinue the collaboration when a demonstration project is finished. In case an industrial player finds it profitable, you would try to continue developing whole or parts of the project on a more commercial basis. Even though the establishment of, for example, a hydrogen station or a renewable energy system continues to hold a lot of developing elements, equipment that is connected to the system can already be on the market, and can be offered by several suppliers. That is why it can be preferable to outsource parts of the assignment to different equipment suppliers".

Nordic Energy Research has relatively small budgets to distribute. How can a small publicly funded institution contribute to demonstration projects?

"I feel that it's important to focus on the applied research and development effort, especially when it comes to development and demonstration of new energy systems. Industry must, of course, show a will to spend their own money on demonstration projects, but I think that the support from e.g. Nordic Energy Research can be necessary when it comes to starting up new projects. In a lot of cases, these means are an absolute necessity in order to get industry participation. A small contribution can in this way easily be the start of a large project. Furthermore, the support from Nordic Energy Research can be a sort of seal of approval, which makes it easier to market a demonstration project, for example with regards to EU participation," Helle Brit Mostad says.

The "Scandinavian Hydrogen Highway Partnership" (SHHP) is a good example of Nordic research collaboration, whose success and industrial sponsoring to a certain degree depend on co-financing from the Nordic Innovation Centre and the EU. The goal of the project is to establish a connected hydrogen passage from Stavanger via Kristiansand, Porsgrunn and Drammen to Oslo and from there through Sweden and Denmark all the way to Germany.

Energy and knowledge in the North

The Nordic region is home to approximately 25 million people, and is known as a wealthy region with abundant energy resources. The Nordic countries have a long tradition for co-operation, which rests on a shared history and common values, which are inherent in the Nordic welfare state. The Nordic countries are stable and well functioning democracies, with highly developed economies and safe communities. Following the foundation of the Nordic Council in 1952 and the Nordic Council of Ministers in 1971, co-operation has developed in a range of areas, including a common labour market, a passport union and research and development.

Box 7. R&D expenditure in the Nordic countries

	GDP, million euro (2005)	R&D/GDP % (2004)	Private R&D / GDP % (2004)	Public R&D/ GDP % (2004)
Finland	155 000	3.4	2.3	0.9
Denmark	205 000	2.4	1.4	0.7
Norway	230 000	1.7	0.8	0.7
Sweden	285 000	3.9	2.6	0.9
Iceland	13 000	2.9	1.2	1.1
Nordic countries	888 000	2.9	1.7	0.9
Japan (2004)	2 960 000	3.1	2.3	0.6
USA (2004)	9 126 000	2.7	1.7	0.8

Source: OECD (2006)

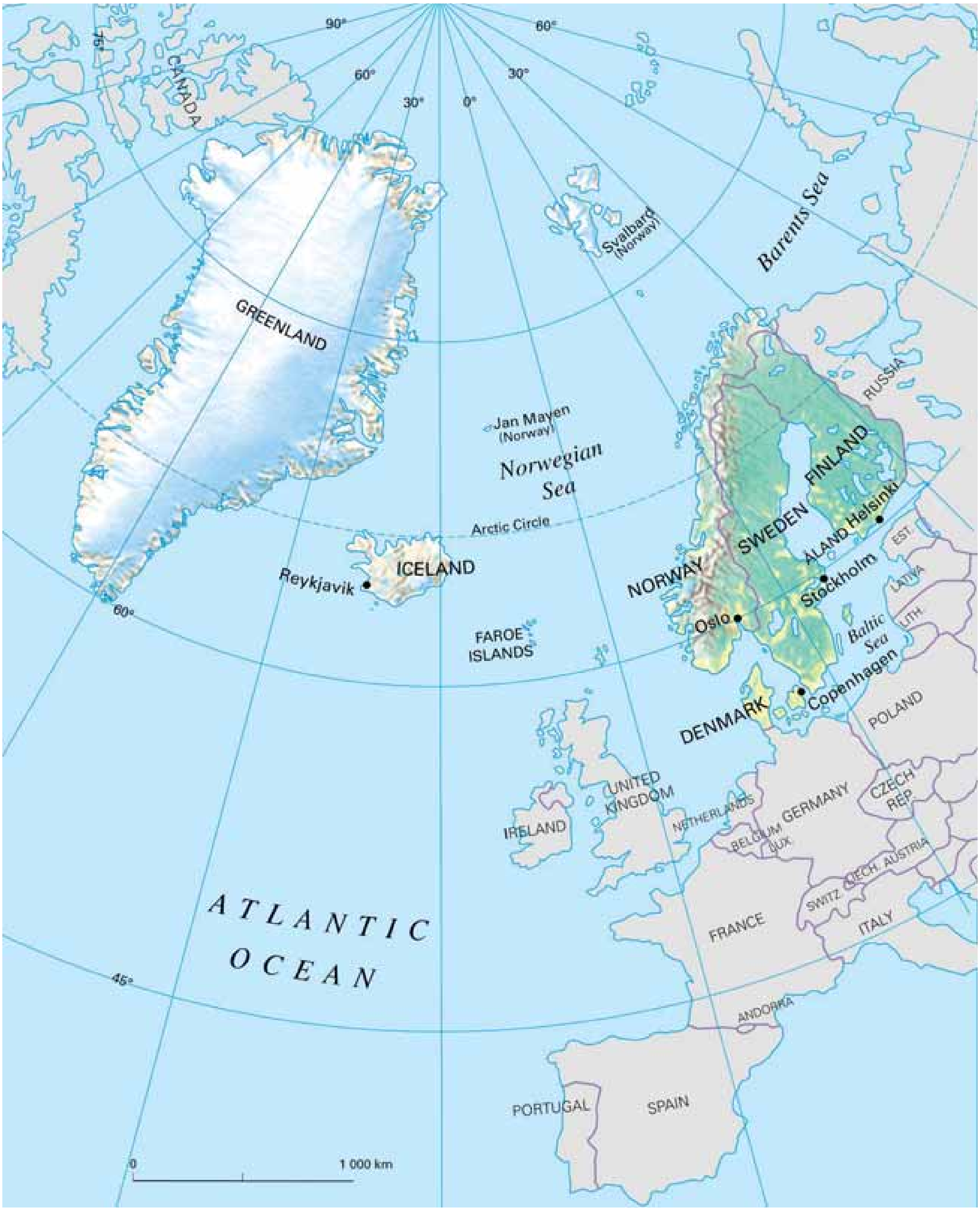
On average the Nordic countries invest approximately 2.8% of their GDP in R&D activities. The Barcelona Declaration adopted by the EU, sets forth a target of 3% expenditure on R&D as a percentage of GDP within 2010; two thirds of this shall be funded by private sources, and one third from public sources.

Both Finland and Sweden as good as fulfil the Barcelona targets with well above average spending on R&D/GDP. Norway has the lowest score on these indicators with only 1.7% of GDP being spent on R&D. In comparison with Japan and the United States,

Box 6. The Nordic countries in brief

	Finland	Denmark	Norway	Sweden	Iceland	Faeroes	Greenland
Total area, km2	338 145	43 376	323 802	450 295	1 033	1 396	2 166 086
Land area	304 473	42 709	30 4280	410 335			
Ice-free land area, km2					89 600		410 449
Forest and plantations, km2	203 060	5 159	74 698	226 340	1 481		
Lakes and streams, km2	33 672	667	19 522	39 960	2 700		
Mean temperature	January -5.7° C	January 3.4° C	January -3.8° C	January -2,8° C	January 0.5 ° C	January 3,7° C	January -8.7° C
C	July 16.6 ° C	July 17.6° C	July 16.0	July 17,1° C	July 11.5 °	July 10,9° C	July 5.8° C
Mean precipitation mm	643	724		533	936	1 501	351
Population (2005)	5 236 600	5 411 400	4 603 900	9 011 400	293 600	48 400	57 000
Form of government	Republic	Constitutional monarchy	Constitutional monarchy	Constitutional monarchy	Republic	Home rule – within the kingdom of Denmark	Home rule – within the kingdom of Denmark
Membership of EU	January 1995	January 1973		January 1995			January 1973 to February 1985
Membership of EEA			January 1994		January 2004		

Source: Nordic Council (2005)


CANADA
GREENLAND
ICELAND
Reykjavik
Svalbard (Norway)
Barents Sea
Jan Mayen (Norway)
Norwegian Sea
Arctic Circle
FAROE ISLANDS
NORWAY
SWEDEN
FINLAND
RUSSIA
ÅLAND
Helsinki
Stockholm
Oslo
Baltic Sea
Copenhagen
DENMARK
EST.
LATVIA
LITH
POLAND
UNITED KINGDOM
IRELAND
NETHERLANDS
BELGIUM
LUX
GERMANY
CZECH REP.
SWITZ
LIECH.
AUSTRIA
FRANCE
ITALY
ANDORRA
PORTUGAL
SPAIN
ATLANTIC OCEAN
90°
60°
30°
0°
75°
45°
0
1 000 km

the Nordic average spending on R&D is in the same league, but when we look at the private funding's share of R&D in particular, some countries stand out; Japan is well above the Nordic average – together with Sweden and Finland (see Box 7).

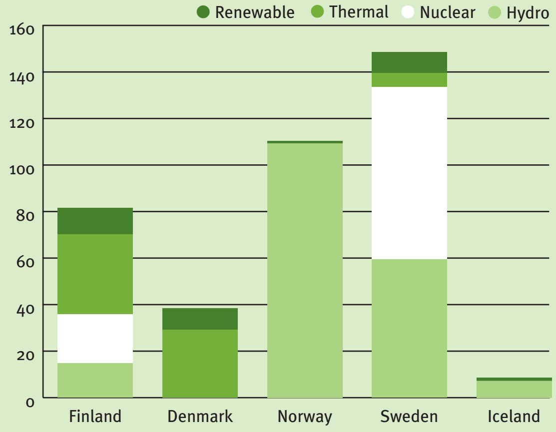
Energy in the North

The Nordic countries have a remarkably high share of renewables and non-fossil energy compared to the OECD average. The average share of renewables, hydro and nuclear in the Nordic countries accounts for nearly 30% of primary energy consumption, compared with 5% for the OECD as a whole.

In electricity generation, like in overall energy consumption, the Nordic countries have a high share of renewables. Albeit, the energy mix in electricity generation differs considerably between the Nordic countries. In Norway, nearly all electricity is generated from hydropower, whereas Sweden and Finland use a combination of hydropower, nuclear power, and conventional thermal power. Denmark relies mainly on conventional thermal power, but wind power and other renewables are providing an increasing part of the demand for electricity, accounting for nearly 25% of the power generation.

The overall picture for the Nordic Region is that well over half the power generation comes from renewable sources such as hydropower and other renewables. Nuclear power accounts for nearly 25%, and conventional thermal generation for roughly a fifth.

Figure 5. Generation mix in the Nordic countries 2004 (TWh)



Source: Nordel (2004)

The Nordic countries differ in their generation mix. Hydropower is the dominating renewable source in Norway and Iceland and also plays an important role in Sweden and Finland. Wind power is in particular significant in Denmark where at the same time coal is widely used. Sweden and Finland have nuclear power, but while Swedish plants are planned to be phased out, Finland is constructing a new plant.

Public spending on energy research & development

The oil crisis that occurred during the 1970s served to kick-start energy research throughout the world. However, since the beginning of the 1980s, spending on energy R&D has decreased. This applies to the USA and the other IEA countries[2], including the Nordic countries.

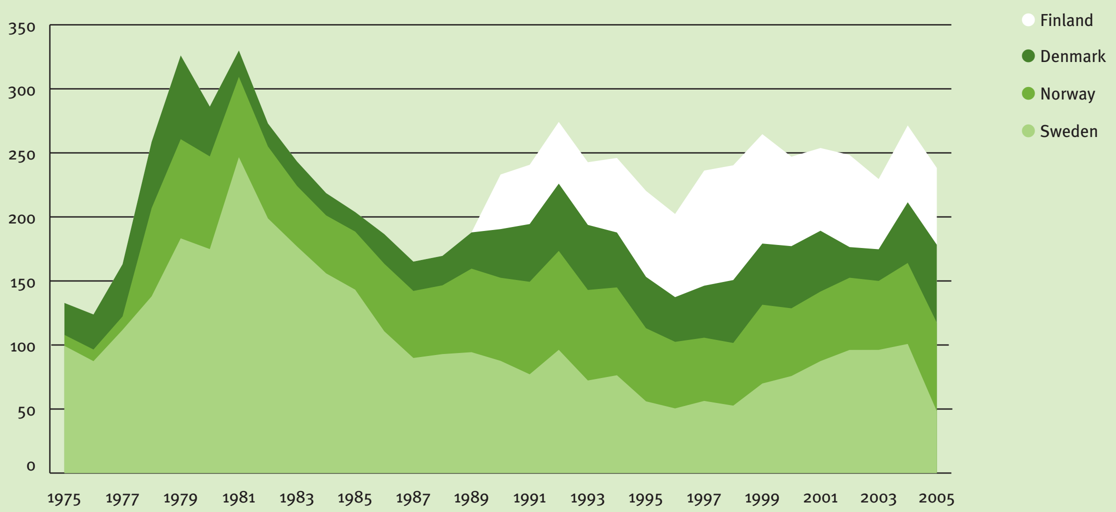
The drastic reductions in government spending on R&D energy in the Nordic countries are in large part due to reduced spending on nuclear research; e.g., Denmark and Sweden together reduced their spending on nuclear R&D by over 80% from 1975 to 2005.

Today more than 90% of the total energy research spending in the Nordic countries is used on non-nuclear energy areas. In total the Nordic countries (excluding Iceland) spend approximately 212 million euro on non-nuclear energy research in 2005, of which spending on renewable energy research accounts for 30%.

During the last 2-3 years in particular Denmark and Norway have increased their energy R&D investments to "historically" high levels with new focus around hydrogen and fuel cells. Sweden saw a drastic cut in its energy R&D spending in 2005, but for 2006 the spending was raised, and Sweden is now near a historically high level[3].

Over the last 20 years, the Nordic countries have been making contributions to public spending on joint Nordic energy research. In the last five years, the total national grants have been a steady 27.5 million NOK annually (approx 3.5 million euros), channelled through the institution Nordic Energy Research.

Figure 6. Total energy R&D spending in Finland, Denmark, Norway and Sweden1975-2005, euro million (2005 prices)

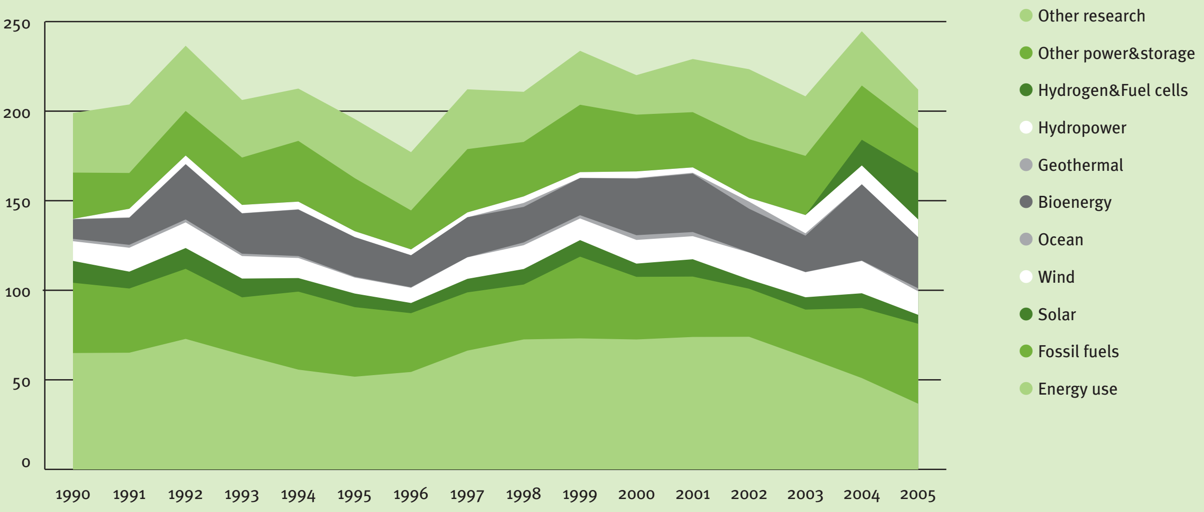


Source: IEA (2005)

2. The only exception is Japan, where public spending has increased, and most of this contribution has been directed at nuclear research (Jørgensen, 2005).

3. 2004 and 2005 figures for Finland are estimates (based on the proposed TEKES budget of the Finish Ministry of Trade and Industry).

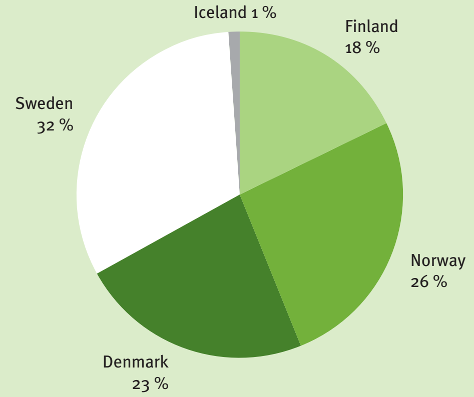
Figure 7. Total non-nuclear R&D spending in the Finland, Denmark, Norway and Sweden, euro million (2005 prices)[3]



Source: IEA 2005

The grant total is steady at 27.5 MNOK, but the allocation between the countries may vary slightly due to the national GDPs. In 2006, the allocation was as described in figure below; Sweden being the biggest contributor with about a third of the total.

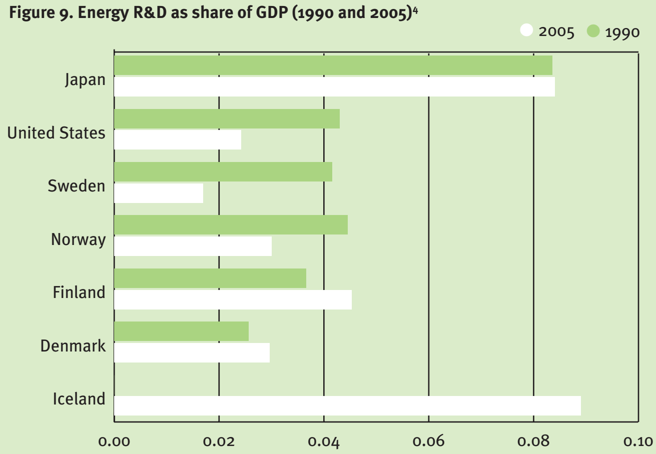
Figure 8. Allocation of national grants to Nordic Energy Research 2005 – A steady total of 27.5 MNOK



Source: NER (2005)

3. Note: Iceland is not included. 2004 and 2005 figures for Finland are estimated to 2003-level.

Figure 9. Energy R&D as share of GDP (1990 and 2005)[4]



Source: IEA (2005), Rannis (2004)

Relative Energy R&D Spending

Among the Nordic countries Iceland is in a class of its own when it comes to relative spending on energy related R&D. With a R&D/GDP ratio of 0.09%, Iceland scores highly also in a global context, together with Japan. Finland is "second best" in the North with a ratio of 0.04%.

In 2005, public energy R&D spending in Sweden dropped to the lowest level over the considered period. However, the Swedish government has almost doubled its funding in 2006. This means that Sweden today might be one of the big spenders together with Finland, followed by Denmark and Norway showing relative expenditures of 0.03%. Since 1990, only Finland and Denmark have increased the relative proportion of energy R&D spending to GDP (see figure below).

Upward trends?

The governments in Norway, Sweden and Denmark have already announced that the total funding with their key energy R&D programmes will increase over the next few years. In Finland, the funding of the major energy technology programmes, managed by the National Technology Agency of Finland, TEKES, will remain unchanged at the high level of 60 million euros until 2012.

In Sweden, it is the Swedish Energy Agency (STEM) who has the sole responsibility for administrating the entire national programme, from support for fundamental research to measures intended to assist the market introduction of new energy technology. The Swedish government has decided to double its energy R&D funding in the state budget from approx. 47 million euros in 2005 to 88 million for 2006. In 2007 and 2008 the spending will be increased even more.

In Denmark, the public funding for energy research is channelled through the Ministry of Science, Technology and Innovation and the Ministry of Transport and Energy.

The Strategic Research Council under the Ministry of Science, Technology and Innovation provides funding within the *Energy & Environment Programme (EnMi)* for energy research projects concerning renewable energy technologies and energy conservation. The funding of 45 million DKK in 2005 (approx. 6 million euros) is expected to increase to 93 million DKK in 2008 (approx 12.5 million euros).

The R&D budget of the Ministry of Transport and Energy will remain unchanged with a total of 229 million DKK in 2006-2008 (approx. 24.5 million euros). The funding is divided on two programmes:

4. Iceland – Estimate from Rannis (2004) – The Icelandic Centre for Research Information Research and development in 2003 – Icelandic R&D investments

- The government funded *Energy Research Programme (EFP)* administrated by the Danish Energy Authority (74 million DKK in 2006, 2007 and 2008)
- The two *PSO-programmes* (Public Service Obligation) administrated by the energy companies – a subsidy payment from customers as a levy placed on every kWh of electricity sold in Denmark (155 million DKK in 2006, 2007 and 2008).

In Norway, the government spending on energy R&D was increased by 83 million NOK (approx 11 million euros) to 450 million NOK (approx 57.2 million euros) in 2006. This increase will be channelled through the Research Council of Norway; 10 million NOK is directed at the RENERGI programme (Clean Energy for the Future), specifically directed at basic research, competence building and technological development within RENERGI's subject areas, renewable energy sources and energy efficiency in particular. 5 million NOK will support the development of environmentally friendly gas power technologies, where the focus will be on research, development and demonstration of different technologies for carbon capture and storage.[5] And 68 million NOK (8.7 million euros) will be allocated to petroleum research (PETROMAKS etc.), related to the Northern areas. The Norwegian Government has signalled a further increase of the funding for energy research.

Table 4. Estimates of R&D energy budgets, according to national key programmes, million euros

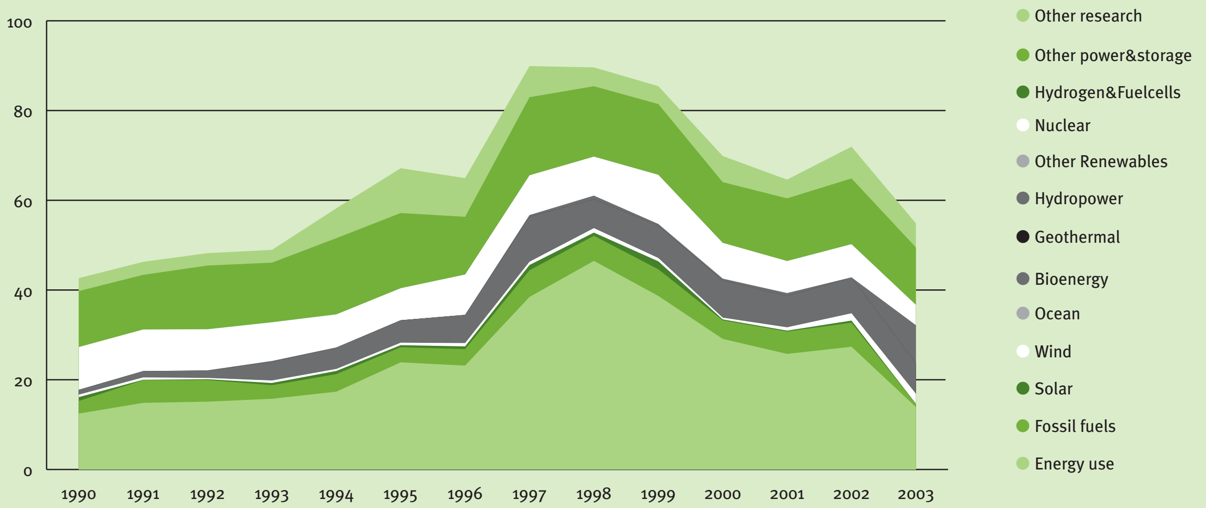
	2005	2006	2007	2008	Key Programmes
Finland	60	60	60	60	TEKES-programmes www.tekes.fi
Denmark	37	45.3	44.5	44.5	EFP; EnMi; 2 x PSO programmes www.ens.dk
Norway	47.1	57.2	n.a.	n.a.	Research Council of Norway www.forsknings-radet.no
Sweden	47.6	88	89.8	91.1	STEM www.stem.se

Sources: Danish Energy Authority (2004); Swedish Energy Agency (2005); Ministry of Trade and Industry, Finland (2005); Ministry of Petroleum and Energy, Norway (2005)

The figures should not be regarded as a complete estimate over total energy R&D funding in each country, but rather used as an indicator of the expected development over the next few years, highlighting the key financial sources/programmes. Due to different sourcing and methodology, the figures may not match the individual country reports from IEA/OECD, which are used as reference in the following country analysis.

Development in the public energy R&D spending: Country characteristics

Figure 10. Development of energy R&D spending in Finland 1990-2003, by technologies/research areas, million euros (2005-prices)

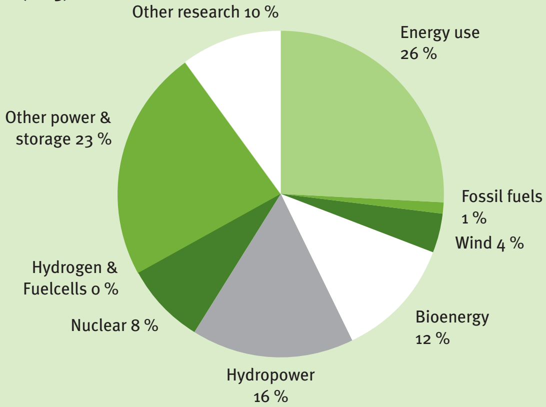


Source: Ministry of Trade and Industry (2005)

Finland

In Finland the total R&D spending in 2003 amounted to approximately 55 million euro (estimated to 60 million euro in 2004 and 2005). Energy conservation and use of bio-energy are prominent energy related R&D areas in Finland. In 2003, these two research areas received 26% of public energy R&D funding in Finland. In comparison, the share of nuclear R&D funding was 8%. From 1999, the share of nuclear R&D spending has gradually been reduced, from approx. 11 million euros in 1999 to 4.6 million in 2003.

Figure 11. Relative energy R&D spending in Finland by technologies (2003)



Source: Ministry of Trade and Industry (2005)

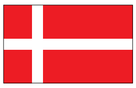
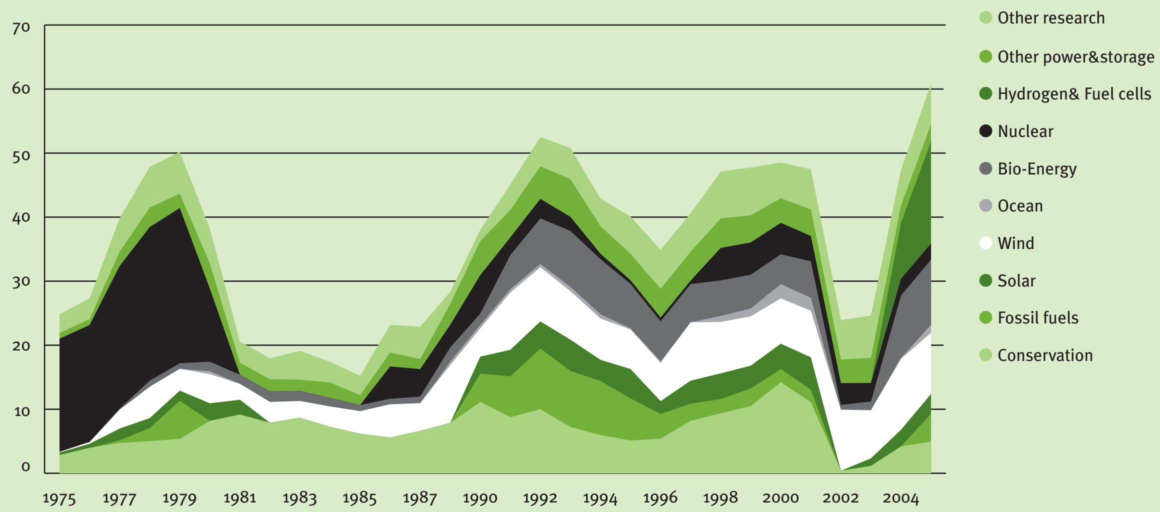


Figure 12. Development of energy R&D spending in Denmark 1975-2005, by technologies/research areas, in million euros (2005-prices)



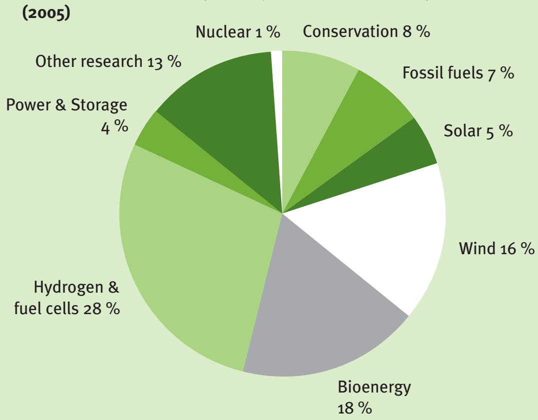
Source: IEA (2005)

Denmark

The government spending on energy R&D activities in Denmark has increased significantly during the past couple of years. In all, the grants for energy research have more than doubled in the years 2004 and 2005, as compared with 2002 and 2003. Today, R&D in the energy field accounts for almost 61 million euro. The 2005 grants for energy research are thus almost at the same level as in the end of the 1970's.

A large proportion of energy research in Denmark is focussed on renewable energy. Hydrogen and fuel cell technology is the largest area of energy research, with 28 % of the spending in 2005. While the research grants for wind power have been relatively stable over the years, the amount of research aid to the bio-energy field shown greater variations. In 2004 and 2005 there has been a re-newed effort in the area, especially tied to transport bio fuels.

Figure 13. Relative energy R&D spending in Denmark by technologies, % (2005)



Source: IEA (2005)

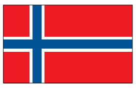
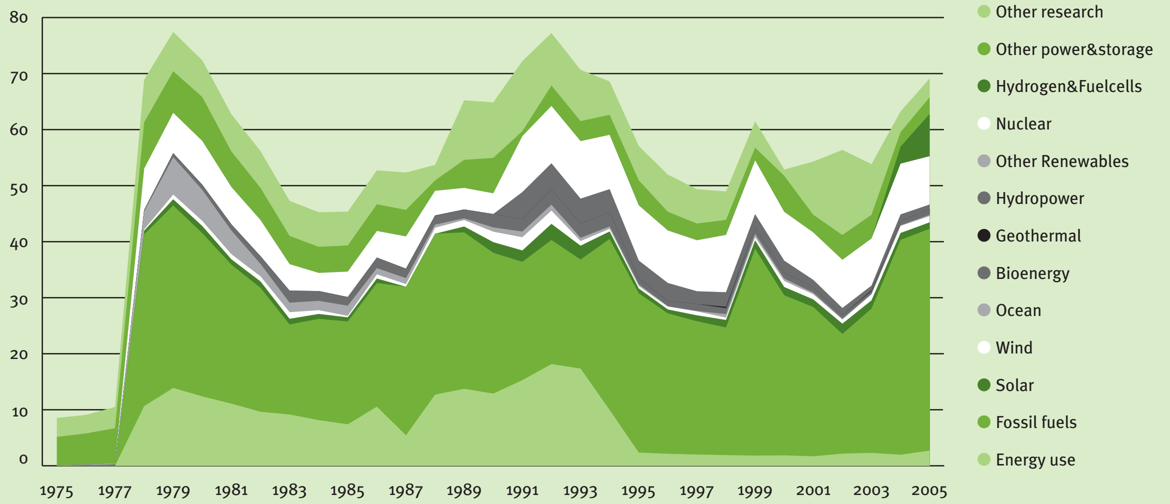


Figure 14. Development of energy R&D spending in Norway 1975-2005, by technologies/research areas, in million euros (2005-prices)



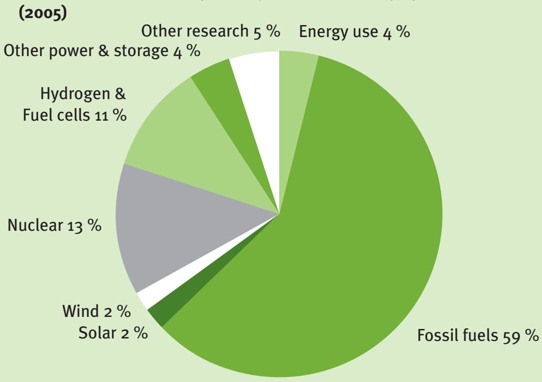
Source: IEA (2005)

Norway

Energy R&D in Norway can be split up into petroleum research, mainly-off shore oriented, and energy, meaning the rest. The total energy R&D in Norway amounted to almost 70 million euros in 2005. Approximately 70% of the funding comes from the Ministry of Petroleum and Energy, channelled through the Norwegian Research Council; other financiers include Statkraft, Gasnova and other ministries.

More than half of the funding is directed at petroleum research. Even though the financial aid to energy research in Norway has increased during the past two to three years, it is still less than when it was at its highest in end of the 1970's and beginning of the 1980's.

Figure 15. Relative energy R&D spending in Norway by technologies, (2005)



Source: IEA (2005)

In recent years, there has been a focus on developing environmentally friendly gas technologies, including CO_2 capture and storage technologies/methods. The share of R&D spending on energy efficiency and conservation technologies is currently at 4%, which is significantly lower than in the 1980's and 1990's. During the past couple of years special attention has been given to the hydrogen and fuel cell fields. Today, research in hydrogen and fuel cells account for approx. 11% of the total energy research.

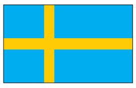
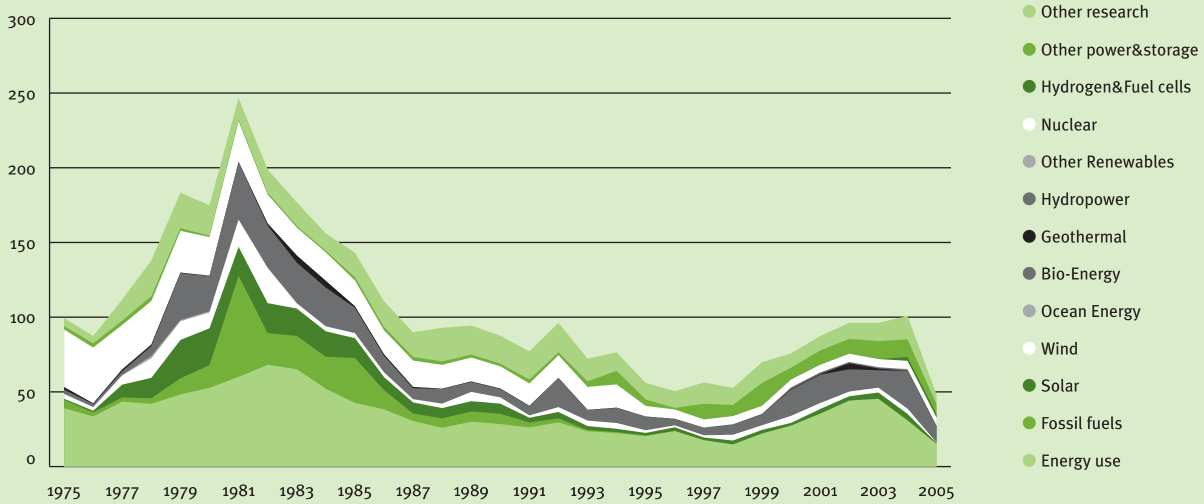


Figure 16. Development of energy R&D spending in Sweden 1975-2005, by technologies/research areas, in million euros (2005-prices)



Source: Swedish Energy Agency (2005)

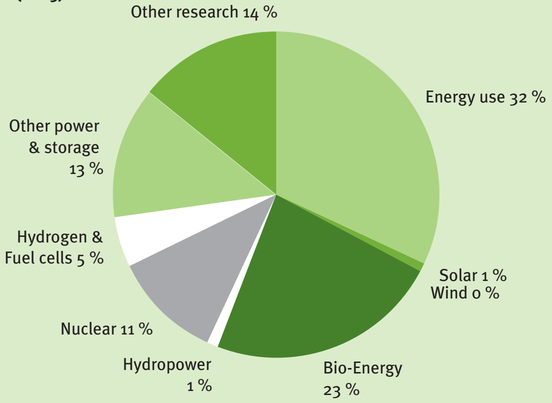
Sweden

The total financing of energy R&D from the government during 2005 amounts to 48 million euro, which is the lowest level since 1974.

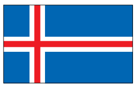
Over the period 1999-2005, government spending on nuclear R&D in Sweden has in average been 5 million euro per year, which is a reduction from an average level of 35 million euro per year from 1975-1981. Further reductions in government R&D expenditures on renewable technologies also explain some of the development in Sweden. In the period 1980 – 1985, the average R&D spending on renewable was 58 euro per year. In the last six years (2000-2006) the amount has been 24 euro per year.

Today, Sweden has substantial research in energy conservation having a share of 32% of total energy R&D expenditures in 2005. In addition, solid and liquid bio fuels are important points of strength in the renewable research area, having a share of 23%.

Figure 17. Relative energy R&D expenditures in Sweden by technologies, (2005)



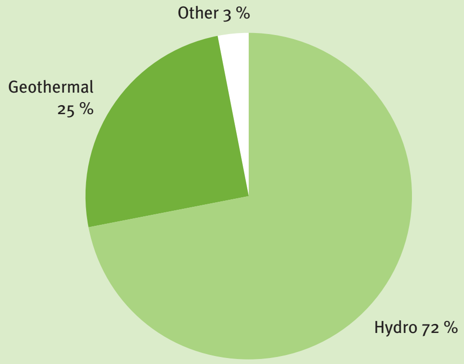
Source: Swedish Energy Agency (2005)



Iceland

The total amount of public energy R&D investment is approx. 8.3 million euro in 2003, channelled through Rannis, the Icelandic Centre for Research and Orkustofnun, the National Energy Authority. Almost two- thirds of the financial support in 2003 went to research in hydrological energy, the second larges post was geothermal energy with about 25% of the funding 2003.

Figure 18. Relative spending on energy R&D by technologies (2003)



Source: Rannis (2004)

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