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Competitive policies in the Nordic Energy Research and Innovation Area eNERGIA

Part 2: Technology reports

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Preface

This report outlines the energy research and innovation policy in the Nordic and Baltic countries – Denmark, Finland, Iceland, Norway, Sweden, Estonia, Latvia and Lithuania.

The report is the result of the research project Competitive policies in the Nordic Energy Research and Innovation Area (eNERGIA). The project was co-funded by Nordic Energy Research and NIFU STEP. The objective of the project was to determine possible policy interventions targeted at the development and commercial promotion of promising renewable energy production technologies in the Nordic countries.

The report is based on an analysis of the framework conditions for the sector innovation systems for energy production, with a focus on research and innovation policy in the Nordic and Baltic countries. We identified the key actors and institutions in all the eight countries studied. In addition, we conducted a performance assessment based on the quantitative indicators of publishing and patenting, international collaboration and funding data. Using these indicators as a basis, we conducted an analysis of the strengths, weaknesses, opportunities and threats (SWOT analysis) of the Nordic sector innovation systems for energy production. This analysis identified common or diverging characteristics, challenges, framework conditions, energy-technology specialisation and, most important of all, cases of good practice in key technologies.

The project included two workshops, and the results of these are also reported here. The outcomes of the workshops have been used in several parts of the project:

- A Nordic workshop on the environmental consequences of deployment at scale of these technologies to replace existing energy systems, with a focus on wind energy and photovoltaic energy, carbon dioxide capture and storage, and second-generation bioenergy.
- A Nordic workshop on policy implications for Nordic Energy Research.

The report comprises three parts:

Part 1: Country reports
Part 2: Technology reports
Part 3: Special reports

The results are summarised in the *Synthesis report.*

The authors of these reports are Antje Klitkou, Trond Einar Pedersen, Lisa Scordato and Åge Mariussen. We want to thank Nordic Energy Research for funding this project and our colleagues from NIFU STEP for their comments on the project. In addition, we would like to thank the participants at our workshops and the interview partners in our case studies for their valuable contributions.

Oslo, 1 July 2008

Per Hetland
Director

Liv Langfeldt
Head of Research in Research and Innovation Policy

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Introduction

This (Part 2: Technology reports) is the second report about the results from the eNERGIA project. The first report deals with the countries covered by the eNERGIA project, while the third report sums up the SWOT-analysis, the eNERGIA workshops and the case studies of good practice. A short synthesis report summarises the entire project.

This second report mainly deals with selected renewable energy technologies from different perspectives. The report comprises the following nine chapters.

Chapter 1 is the presentation of the selected renewable technologies (solar photovoltaic technology, wind technology, 2^{nd} generation bio-energy technology, wave technology and hydroelectric technology) and a subsequent elaboration of the status of the technologies in the Nordic and Baltic countries.

Chapter 2 gives an overview of patterns of international R&D collaboration as seen from the countries in question.

Chapter 3 draws on technology specific patenting data and bibliometric data, describing the level of technology specific activity in each country.

Chapter 4 and 5 describe the status of renewable energy production and renewable energy research respectively in each country.

The four last chapters are relatively brief descriptions of the situation in the Nordic and Baltic countries. *Chapter 6* gives an overview of the venture capital situation. *Chapter 7* is about market regulations and *Chapter 8* is about social concerns. Finally, *Chapter 9* addresses infrastructural challenges.

2. Technology reports

The technology reports give a short overview of the energy technologies and an analysis of the current status of the technology field by country, including R&D activities, important organisations and companies, international collaboration and political instruments and measures to develop the respective technology.

2.1 Solar photovoltaic energy

Photovoltaic technology (PV) has many advantages compared to other types of energy technology. It is modular, clean, easy to maintain, and can be installed almost anywhere to suit the needs of the user. The electricity produced can be used directly, stored locally, or fed into an existing electricity grid. On the negative sides of PV belong environmental impacts such as scarce and toxic materials and waste issues (de Wild-Scholten 2008).
PV is a solar power technology that uses solar cells or solar photovoltaic arrays to convert light from the sun directly into electricity. Photovoltaics is also the field of study relating to this technology. The manufacture of photovoltaic cells has expanded dramatically in recent years. According to the International Energy Agency, the total worldwide PV capacity in terms of gross electricity generation was 1636 GWh (IEA 2008). Another source (Marketbuzz 2008) reports that world PV market installations reached a record high of 2,826 megawatts (MW) in 2007, representing growth of 62% over the previous year. According to the Environmental and Energy Study Institute inWashington, the world PV market was growing at approximately 25 percent annually in 2006 (EESI 2006).

PV systems are utilised in several forms:

- *Consumer applications:* watches, calculators, garden lights, alarm devices, etc.
- *Industrial applications:* telecommunication relays, cathodic protection, tele-measurements, and all applications for which the electrical consumption is small compared to grid connection like parking meters even in towns, or emergency phones along highways
- *Remote dwellings in industrialised countries:* thousands of dwellings in Europe are too far from the grid to be connected, but they can benefit from PV-generated electricity for lighting, television, refrigeration, etc.
- *Decentralised rural electrification (DRE) in developing countries* concerns about 1.7 billion people in the world according to official IEA figures. DRE aims to meet:
    - *Basic needs:* potable water, water for livestock, refrigeration and lighting for a dispensary,
    - *Improved quality of life:* residential lighting, telephone service, radio and television and community lighting (street lighting, schools, meeting halls, etc.),
- *Small-scale motorisation for development:* pumping for farming irrigation, vegetable gardening, storage, motorisation for mills, presses, small craft industries, etc.

The standard technology is production of cells (wafers) based on refined and purified silicon. Until recently, the solar cell industry has used by-products of the ICT industry as this input. The core cluster in this industry, accordingly, was Silicon Valley in California.

Today, however, the demand for solar cell panels and the production capacity has exhausted this resource. The Norwegian actor REC is providing new capacity through new production capacity in USA (Mariussen 2008). This has also created a demand for new technologies for refining silicon. Norway has one of the world's largest natural deposits of silicon. Several Norwegian actors are attempting to develop new upstream technologies to exploit this opportunity.

In the application of silicon, the existing wafer technology is making effort to increase efficiency in converting light to energy. The capacity is increasing. To the Norwegian producers, another advantage is access to cheap hydroelectric power in producing the wafers, which is an energy-intensive industry in itself.

Another competitive front is finding more cost-efficient alternatives to wafers. Actors in Denmark and the USA are active in developing paint (ink) as an alternative. In the wafer industry itself, there is a pressure to increase efficiency within the framework of the existing technology.

Solar cells require protection from the environment and are usually packaged behind a glass sheet. When more power is required than a single cell can deliver, cells are electrically connected together to form photovoltaic modules, or solar panels. A single module is enough to power an emergency telephone, but for a house or a power plant the modules must be arranged in arrays. Although the selling price of modules is still too high to compete with grid electricity in most places, significant financial incentives in Japan and then Germany triggered a huge growth in demand, followed quickly by production. Although module prices have risen and plateaued, it is expected that costs and prices will fall to 'grid parity' in many places around 2010.

Many corporations and institutions are currently developing ways of increasing the practicality of solar power. While private companies conduct much of the research and development on solar energy, colleges and universities and institutes also work on solar-powered devices. Most research is being carried out in Germany, Japan, USA and Australia.

The most important issue with solar panels is related to capital costs (installation and materials). Due to economies of scale, solar panels become less costly as people use and buy more — as manufacturers increase production to meet demand, the cost and price is expected to drop in the years to come. Related to this is also the negative impact of PV from the exploitation of scarce and toxic materials. There is also an emerging awareness about the need for waste management systems. Outdated PV installations are special waste. There is need to establish systems that can take care of the waste problem.

Table 1: Regulatory framework for PV in Nordic and Baltic countries

Denmark	No specific PV programme, but settlement price for green electricity.
Estonia	Feed-in tariff; RPS for electricity; green certificates
Finland	Investment subsidy up to 40%.
Latvia	Feed-in tariff: double the average sales price, for 8 years, then reduction to normal sales price; RPS for electricity (6% by 2010); national investment programme for RES since 2002; "soft" loans granted by the Latvian

	Environmental Investment Fund.
Lithuania	Feed-in tariff: 0.056€/kWh
Sweden	No specific PV programme. Electricity certificates for wind solar, biomass, geothermal and small hydro. Energy tax exemption.
Norway	No specific PV programme. Plan of entering the Nordic certificate market

*adapted from A. Jäger-Waldau, H. Ossenbrink, H. Scholz, H. Bloem and L. Werring, 19th European Photovoltaic Solar Energy Conference and Exhibition, Paris, June 2004; S. Pietruszko (PV-NAS-NET coordinator), private communication

Regulation

Financial incentives, such as preferential feed-in tariffs for solar-generated electricity and net metering, have supported solar PV installations in many countries including Germany, Japan, and the United States. The table above gives an overview over regulation that has an effect on PV energy production in the Nordic and Baltic countries.

International collaboration

The report "The State and Prospects of the European Energy Research"[1] concluded in the assessment of European photovoltaic R&D that the field of crystalline silicon is quite well established, but the costs have to be reduced gradually and that thin film and other new concepts (like dye-sensitised cells, organic cells or nanotechnology-related concepts) still have little market penetration, or they have so far been limited to laboratory or trial stages and need a major breakthrough. The report gave also an overview of the funding in this field for EU FP5 and 6.

R&D projects funded by the European Framework programmes 5 and 6 concentrated mainly on four tasks: material research, system development, integration of PV in buildings and standardisation, but two third of the funding went to R&D on materials (Figure 1).

[1] European Commission (2006). The State and Prospects of the European Energy Research: Comparison of Commission, Member and Non-Member States' R&D Portfolios. 121 pp.

Photovoltaics Technology Paths (Strategically important areas and topics)	EC Funding in					
	FP5			FP6		
	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€
Materials, cells and modules	33	83.58	44.50	9	80.86	49.94
Christalline silicon	12	29.80	18.50	3	37.49	20.70
Thin film	10	25.55	11.43	3	24.00	18.29
Others	11	28.22	14.57	3	19.37	10.95
Systems	10	18.26	9.83	2	15.75	4.50
Building integrated PV1	7	12.29	5.64	2	17.00	6.69
Standardisation	5	5.40	3.10	1	0.00	7.00
Cooperation and Coordination	6	2.94	2.53	3	5.18	4.92
Dissemination and Demonstration	24	145.80	39.70	2	3.44	1.50
Total PV	85	268.26	105.30	19	122.23	74.55

Figure 1: Photovoltaic research funding in FP5 and FP6*. Source: The State and Prospects of the European Energy Research. 2006. Annex III 2
*FP5 data includes all projects listed in [European Photovoltaics Projects 1999-2002], funding data according to CORDIS; FP6 was based on preliminary data.

The improved Nordic collaboration in photovoltaics is the aim of the Nordic Centre of Excellence in Photovoltaics. The Nordic Centre consists of seven public research organisations within the Nordic region undertaking R&D on solar cells: Institute for Energy Technology (IFE), Danish Technological Institute, Helsinki University of Technology, Norwegian University of Science and Technology, Uppsala University, Ioffe Physico-Technical Institute in St. Petersburg, and Tallinn University of Technology.[2]

The Nordic solar photovoltaic industry is expanding rapidly, including companies like Elkem Solar AS, Renewable Energy Corporation AS (REC), Metallkraft AS and NorSun AS in Norway; NAPS Systems Oy, Rautaruukki Oy and Okmetic Oy in Finland; Gaia Solar A/S and Topsil Semiconductor Materials A/S in Denmark; Gällivare PhotoVoltaic AB, Arctic Solar AB and Solibro AB in Sweden. There are also many sub-suppliers to the companies working directly in the main value chain.

Solar photovoltaics is also a special research topic in several Lithuanian R&D groups, where the focus is on the use of nanotechnology for improved production of solar cells (compare section on Lithuania).

[2] For further details see: http://www.ife.no/ife_news/2007/nordisksolcellesenter/view?set_language=en

Bibliometric and patenting evidence
When comparing the results from the bibliometric and patent analysis the most striking result was that the level of publishing and patenting in both channels of knowledge disseminations are quite diverging. The bibliometric study revealed strong positions for Sweden and Finland in that field, followed by Denmark and Norway (Figure 38, Figure 39 and Table 42), while the patent study found evidence for patenting almost only in Norway (Figure 31, Table 28 and Table 29). The well-developed science base in Sweden has lead to technological applications in the field of second-generation PV, thin film solar cells, while the Norwegian PV industry cluster has mainly exploited the competencies on crystalline silicon based PVs.

Denmark
PV power installations are concentrated on the on-grid market. In 2006, Denmark had a Photovoltaic Peak Power Capacity of 2.9 MWp in total.

R&D programmes and organisations
On the initiative of the Danish Energy Agency, the REFU Advisory Body on Energy Research formulated in April 2006 a Strategy for energy research, development and trial based on the Energy strategy 2025 (Advisory Committee on Energy Research, 2006). In addition, special strategies for the different fields of energy RD&D had been developed in collaboration with industry and the Ministry of Science, Technology and Innovation, without giving priority to the different strategies. One of the strategies was about solar panels Energistyrelsen, Elkraft System and Eltra, 2006). The strategy argued that Denmark has not so many possibilities to acquire strong positions in first and second generation solar cells, but will concentrate the efforts on 3rd generation solar cells (PhotoElectroChemical and polymer solar cells). Relevant R&D organisations are the DTU, AAU and Risø. Recently have Polymer based solar panels received high attention at the DTU.

- SOL-300 Solar Panels project lasted from 1998 to 2001, and was based on experiences from the Danish project Solbyen (1996–1999)–where 30 houses received solar panels.[3]
- SOL 1000 Project was financed by the Danish Energy Authority and administered by EnergiMidt.[4] The objective of this project was to support the application of photovoltaic technology all over Denmark, to develop further the technical, economic and design of photovoltaic solutions, to reduce the costs, to stimulate the Danish manufacturing industry to produce applications both for the Danish market and for export, to establish and coordinate a network of potential actors in the field of photovoltaic technology.
- Third-generation Photovoltaics Project: Polymer Photovoltaic (Solar cell) Research project conducted at Risø (2003–2005). Project for fundamental understanding and the development of new concepts for polymer based photovoltaics (solar cells) which is an emerging scientific field that could have a major impact on energy production in the future (Risø National Laboratory, 2005).

[3] Link: http://www.sol300.dk/indexsol300.htm
[4] Link: http://www.sol1000.dk/indexsol1000.htm

Norway
PV power installations are concentrated on the off-grid market. In 2006 Norway had a Photovoltaic Peak Power Capacity of 7.668 MWp in total, 7.540 of that off-grid (Bugge & Salvesen, 2007).

R&D programmes and organisations
NYTEK
The R&D programme NYTEK (1995–2000), organized by the RCN and financed by the Ministry of Petroleum and Energy, supported R&D in the field of new renewable energy sources. Photovoltaic was competing with bioenergy, wind, waves, hydrogen, thermal solar energy and others. During 1998–1999 NYTEK funded R&D in the field of solar grade silicon at a level of NOK4m each year. The background for this research was the above-mentioned strong national metallurgical silicon industry (silicon has been used in aluminium production) and a new silicon wafer industry.

NYTEK supported the development of R&D capacity at Agder University College and the NTNU by funding several PhDs and PostDoctoral projects (Madsen, 2002).

RENERGI
RENERGI has not a strong focus on photovoltaic energy, but has also funded relevant projects to a smaller degree.

Norway has a well-developed R&D base in material and process technology that has been important for the development of companies applying these technologies and finally also for the Norwegian solar photovoltaic industry cluster. Important R&D organisations are the University of Oslo, NTNU and SINTEF.

Industrial activities
The Norwegian solar photovoltaic industry cluster consists of following companies: REC Group, Elkem ASA, Sensonor ASA and several other companies.
REC has a number of subsidiaries: REC Solar Grade Silicon, REC Advanced Silicon Materials, REC ScanWafer, REC SiTech, REC ScanCell, REC ScanModule and Solar Vision. There are also plants outside Norway, as for example REC ScanModule AB in Sweden. Elkem ASA has following relevant subsidiaries: Elkem Solar and Silisium.

Publishing
Norwegian R&D organisations have increasingly published on PV, collaborating mainly with the USA, Germany and the UK. Main R&D organisations are the University of Oslo, the NTNU and Sintef (compare Figure 40, Table 59 and Table 65).

Patenting
In the field of patenting Elkem and the REC Group are especially important, but also other companies have patent applications in the field of technology (Table 29).

Sweden
The total installed PV power installation in Sweden was just about 6 MW at the beginning of 2008. The biggest share is concentrated on the off-grid market. However,

the share of installations integrated in buildings is increasing steadily, mainly as a consequence of the investments support for solar cell systems in public buildings that was introduced in May 2005 (the support system will end in December 2008).

R&D programmes and organisations
The Swedish Energy Agency funds RD&D projects aiming at increased cell and module efficiency and lower production costs as well as system studies of PV as an energy source and as a building component. The Swedish Energy Agency participates in PV-ERA-NET, which is a European network aiming at increased collaboration and coordination between national PV RTD programmes. Sweden also participates in the International Energy Agency's Photovoltaic Power Systems Programme.

The Ångström Solar Center (ÅSC) research programme at the University of Uppsala is funded by the Swedish Energy Agency and the EU. Some research is also funded by Nordic Energy Research. The long term goal of the activities is to develop the thin-film solar cell technology so that it can provide renewable electricity at large scale. Focus is on second-generation solar cells, so-called CIGS solar cells. At the Royal Institute of Technology (KTH) research is carried out especially t on hird generation solar cells, so-called Grätzel solar cells. The budget of the programme period between 1996 and 2005 was 150 Mkr (€15.8m).

Other universities in Sweden with research activities on solar cells are Linköping, Lund and Chalmers University.

The Solar Electricity Programme (SolEl-programmet) is an applied and user driven R&D programme for solar cell systems. The programme is funded by the Energy Agency and by other actors within the energy and building sector and the manufacturing industry. The current funding period stretches from 2008-2010 and is administered by Elforsk.

Industrial activities
The solar cell industry in Sweden has grown rapidly the last years, in parallel with the strong development on the world market. It is foremost the manufacturing of modules, i.e. imported solar cells that are assembled for immediate use. The majority of the production is exported to foremost, Germany and Southern Europe. The five biggest industries in module manufacturing in Sweden are: GPV, ArcticSolar, REC ScanModule, PV Enterprise and n67 Solar. Furthermore, there are two companies working with the commercialisation of thin-film technique, Solibro and Midsummer, the first one being a spin-off company from the University of Uppsala.

Publishing
Swedish R&D organisations have increasingly published on PV, collaborating mainly with the USA, Germany and the UK. Main R&D organisations are the University of Uppsala, the KTH, Linköping University, Chalmers University and Lund University (compare Figure 40, Table 59 and Table 65).

Patenting
In the field of patenting is especially Solibro AS important (Table 29).

2.2 Wind energy

Wind energy has been used by mankind for many thousands of years. Wind power is the conversion of wind energy usually into electricity, using wind turbines. The locations for wind turbines are normally onshore, near-shore or offshore.Wind turbines that generate electricity today are new and innovative. A few technical innovations represent the start of the modern wind turbines and the expansion of wind power for electricity production such as the use of synthetics to make rotor blades. Developments in the field of aerodynamics, mechanical/electrical engineering, control technology, and electronics provide the technical basis for wind turbines commonly used today (World Wind Energy Association, 2008).

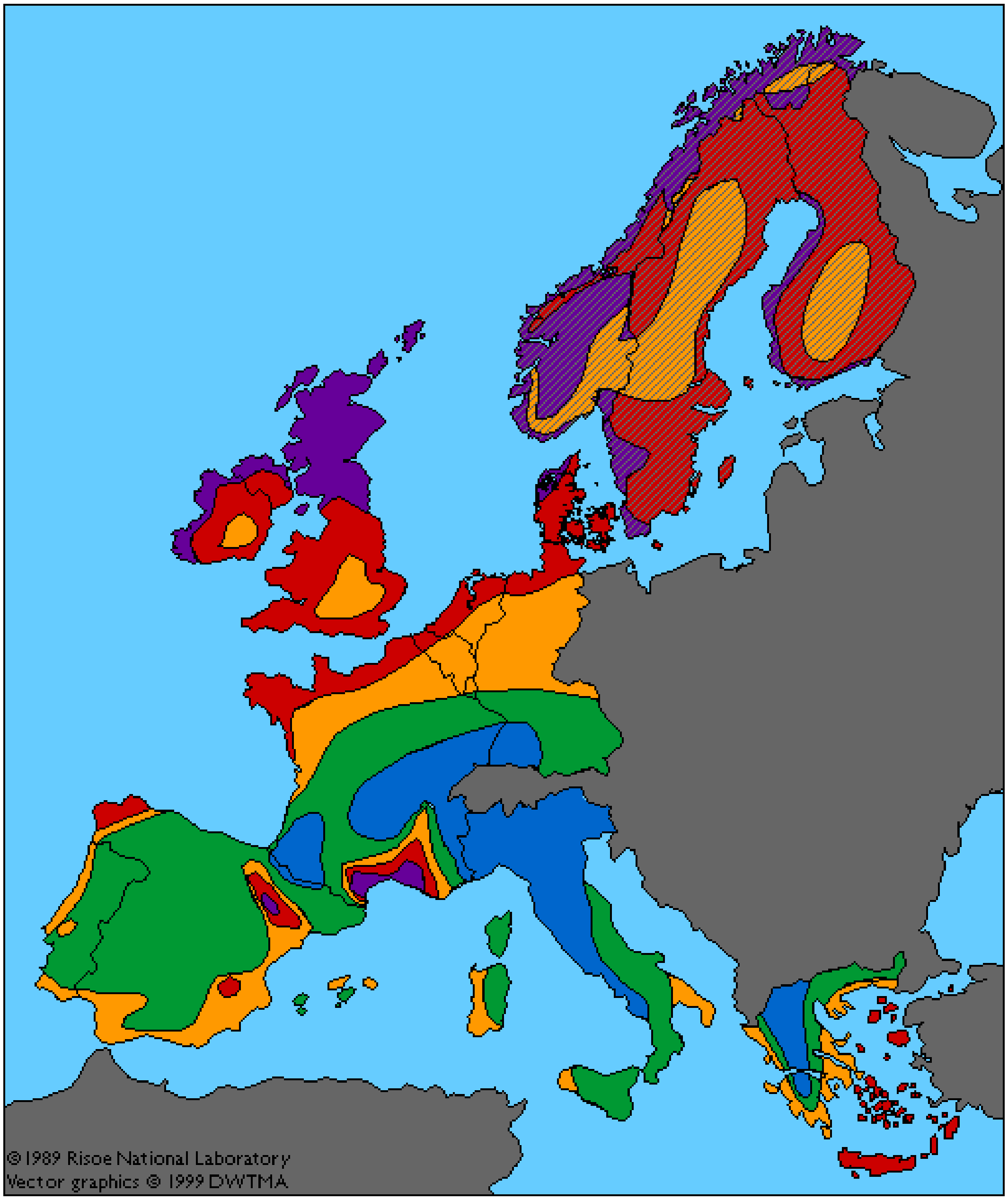
Wind energy is the leading renewable energy technology and it is the most rapidly growing alternative electricity generation in the world. In particular, wind energy is making a significant contribution to reaching national goals for reducing carbon emissions. The pioneering countries in Europe are Germany, Spain and Denmark. During the last five years energy from wind has increased with 40 per cent every year. According to the latest IEA Wind Energy report, cumulative installed wind power capacity increased 26 per cent worldwide in 2006 and electrical production from wind also increased 20 per cent in IEA Wind member countries. The electrical production from wind met 1.42 per cent of the total electrical demand in reporting IEA Wind countries.

Table 2: Reference values for wind energy Nordic and Baltic States for 2006. Source: IEA Wind and National Wind Energy Associations

Country	Total installed capacity MW	Total annual output TWh	Generation as% of national electric demand	Number of turbines	Targets
Denmark	3 137	6 108	17%	5 274	N/A
Sweden	571	0.986	1%	812	10 TWh by 2015
Norway	325	0.671	0.55%	155	3 TWh by 2010
Finland	86	0,154	0,2%	96	31% of RES-E by 2010
Iceland	-	-	-	-	-
Estonia	58.10 (2007)	160 GWh	2%	31	5,1% RES by 2010 Wind not specified
Latvia	27	N/A	N/A	41	N/A
Lithuania	56	13.7 GWh		37	170 MW by 2010

A recent trend in wind turbine technology is *repowering*, that is the replacement of older, smaller, turbines with fewer, larger ones. In 2006, countries like Denmark, Germany, Italy and the Netherlands removed old turbines and added new machines with the result of a significant increased capacity of energy production.

In national programme funding, Denmark and Sweden reported R&D budgets that increased significantly. In Norway and Finland it increased slightly. According to publishing statistics, Denmark and Sweden are ranked 10th and 12th in an international comparison (Table 54, Figure 43).



Wind resources at 50 meters above ground level for five different topographic conditions: 1) Sheltered terrain, 2) Open plain, 3) At a coast, 4) Open sea and 5) Hills and ridges.

	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²	m/s	W/m²
	>6.0	>250	>7.5	>500	>8.5	>700	>9.0	>800	>11.5	>1800
	5.0-6.0	150-250	6.5-7.5	300-500	7.0-8.5	400-700	8.0-9.0	600-800	10.0-11.5	1200-1800
	4.5-5.0	100-150	5.5-6.5	200-300	6.0-7.0	250-400	7.0-8.0	400-600	8.5-10.0	700-1200
	3.5-4.5	50-100	4.5-5.5	100-200	5.0-6.0	150-250	5.5-7.0	200-400	7.0-8.5	400-700
	<3.5	<50	<4.5	<100	<5.0	<150	<5.5	<200	<7.0	<400
			>7.5							
			5.5-7.5							
			<5.5							

Figure 2: European wind sources. Source: European Wind Atlas (Troen & Petersen (1989).

Some of the strongest wind resources are observed in Northern Europe (see Figure 2). Winds are particularly strong along the entire coastline and large parts of the inland of Norway. The Swedish south-western coastline has particularly good wind conditions. Also Finland has exellent wind sources. Denmark has good wind conditions in the north-west. Mapping of wind sources indicates that all four Nordic countries have large potential for further developing wind power.

International collaboration
The EU report 'The State and Prospects of the European Energy Research' distinguished between three technology paths that have been funded under EU FP5 and 6: large-size wind turbines, integration and managing of wind power and wind farm development management. The funding streams have been increasingly gone to wind farm development management and large size wind turbines (Figure 3).

In October 2006, the Wind Energy Technology Platform (TPWind) was launched as an industry-led initiative supported by FP6 and channelled through the European Wind Energy Association. The primary aim is cost reduction through research and economies of scale. TPWind consists of stakeholders from industry, government, civil society, R&D Institutions, finance organisations, and the wider power sector.

Wind Technology Paths (Strategically important areas and topics)	EC Funding in					
	FP5			FP6		
	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€
Large size wind turbines	10	27.68	14.98	4	37.95	19.46
Integration and managing of wind power	7	12.99	7.15	4	7.75	4.43
Wind Farm development management	3	4.02	2.23	2	34.03	7.70
Total Wind	20	44.69	24.36	10	79.74	31.59

Figure 3: Wind energy research funding in FP5 and FP6. Source: The State and Prospects of the European Energy Research. 2006. Annex V 4

Sweden

In 2007, there were 812 wind turbines in Sweden which in total produced approximately one per cent of the electricity in Sweden. In an international comparison Swedish wind power is relatively modest. The first wind power stations were built in 1975 in Skåne and Gotland. Näsudden II, Gotländska Matilda are so far the largest wind power plants in Sweden. Thanks to the Lillegrund offshore wind farm the annual installation rate is expected to double (International Energy Agency, 2007).

National policy and targets
The new conservative/centre coalition has expressed the ambition to continue the previous government's targets for increase of wind power production by endorsing the

March 2006 Wind Power Bill. The Bill presented a number of proposals to facilitate and foster the development of wind energy: reduction of the real estate tax for wind power from 0.5% to 0.2%, establishing a knowledge centre for wind energy, financial support for municipalities for their planning for wind power, definition of new goals and suggestions for the permitting process (International Energy Agency, 2007).

The national target is to increase the total out put from wind energy from today's 0.986 TWh/year to 10 TWh/year before 2015. According to recent estimates from the Swedish Energy Agency the wind power production will be around 7 TWh in 2015. By the end of 2007 the Swedish Energy Agency will present a new planning target for wind power for the year 2020.

Vattenfall and E.ON are the leading utilities for offshore wind energy development in Sweden. Many new investors are entering the wind power market lately (International Energy Agency, 2007).

Incentive programmes
Before the electricity certificate system was introduced, Sweden had a subsidy or environmental bonus for wind power. This system is being phased out and will cease in 2009. In 2006, the Parliament decided to extend the electricity certificate system until 2030.

There are three main incentive programmes for the promotion of wind power:
1. Electricity certificates (although no specific quotas for wind power)
2. Production support, the so called environmental bonus (being phased out)
3. Support for technical development in coordination with market introduction for large scale plants offshore and in the artic area.

RD&D programmes
The Swedish Energy Agency is the main funding body for energy research in Sweden. For the period 2003–2007 the Agency was running a programme to support technical development in coordination with market introduction, for large-scale plants offshore and plants in the Artic area. The budget was of SEK350m (€38m). The programme will continue another five years until 2012 with an additional SEK350m.

Vindval- rersearch on the environmental impact of wind power (managed by the Swedish Energy Agency) is the name of a "knowledge programme" aimed at finding out what impact wind turbines has on natural life and people. The programme is aimed at improving knowledge of the environmental effects of windpower deployment and operation. The results are to be used in planning procedures and Environmental Impact Assessments. A main purpose is to facilitate the process of getting environmental permits to build wind power stations in Sweden. The programme lasts from 2005 until 2009 and has a budget of €3.8m SEK.

The Vindforsk programme ended in 2005 but the new programme Vindforsk II was launched in 2006 and runs until 2008 with a budget of €4.9m. Elforsk, the Swedish

Electricity Utilities' R&D Company manages the programme. The programme involves both basic and applied research. Research areas include: grid integration, external conditions, standards, O&M, project development, impacts on the environment and public acceptance.

RD&D Programmes for wind power in Sweden 2003–2012

- Vindforsk II 2006–2008 (SEK45m).
- Vindval 2005–2007: Environmental impact and public acceptance. Six projects commenced in 2005.
- Vindval II 2008–2012: Environmental impact and public acceptance (SEK350m).

Sweden participates well in international research programmes on wind energy. All but one (Task 19) research task groups of IEA Wind have Swedish research groups participating (International Energy Agency, 2007).

Research organisations

National research is carried out in close co-operation with several partners in the Swedish wind energy program, Chalmers University, Uppsala University, Teknikgruppen and the Royal Institute of Technology (KTH), University of Gothenburg, Stockholm University and University of Lund. These institutions are representing areas such as electrical power engineering, meteorology and structural dynamics.

Publishing

Swedish research groups have contributed substantially to publishing in the field of wind energy (compare Figure 41). The research groups collaborate mainly with partners in the USA, Germany, Denmark, the Netherlands and the UK. The main Swedish R&D organisations that are active in publishing on wind energy are Lund University, Uppsala University, University of Gothenburg, Chalmers University of Technology, the KTH and Stockholm University (compare Table 66).

Patenting

Regarding patenting has Sweden fewer activities, but especially should be mentioned here AB SKF and Deltawind AB (compare Table 31).

Infrastructure

During 2007–2008 the government will give financial support (SEK60m) to the planning of new wind power plants (Hay, 2007).

Table 3: Planned wind power projects with total installed capacities exceeding 25 MW, for construction and commissioning 2007-2009. Source: Swedish Energy Agency

Project	Company	No. of wind turbines	Calculated production in TWh
Lillegrund wind farm	Vattenfall AB	48	0.33
Havsnäs wind farm	RES Skandinavien AB	48	0.25-0.37
Uljabuouda	Skellefteå Kraft AB	12	0.10
Vänern	Vindpark Vänern Kraft AB	10	0.10
Total		118	0.78-0.90

Denmark

The Danish wind turbine industry has a 30 per cent share (in 2007) of the global market and employs more than 25,000 people, making it the world leader in wind power with 5000 MW/year being exported. Furthermore, close to 20% of Danish domestic electricity production comes from wind. The development of wind power in Denmark is characterized by a close collaboration between publicly financed research and industry in key areas such as research and development, certification, testing, and the preparation of standards. The total production of wind power in Denmark has increased between 2006 and 2007 by 1 069 GWh and in 2007 amounted to 7 173 GWh (Energistyrelsen, 2008). The Danish government has recently undertaken new political initiatives to promote renewable resources. For wind energy the initiative consists of the construction of new offshore wind farms and a repowering scheme for the replacement of turbines. In 2008 a process started to offer two offshore wind turbine farms of 200 MW each or possibly one farm of 400 MW with the prospect to commissioning the wind farms in 2012 (Danish Minister of Climate and Energy, 2008).

In June 2005, the government launched the Energy Strategy 2025. The goal is to double the share of renewable energy in the Danish energy supply and at the same time reduce the use of fossil fuels by 15%, by 2025. According to estimates the wind energy share will account for 50% of electricity production in 2025 (International Energy Agency, 2007).

The new municipalities have the responsibility for wind turbine planning. The two largest wind farms are at Horns Rev and at Nysted in the south of Lolland. Following the political agreements from 2004, two new offshore wind farms will be constructed.

Main industrial activities

Today, the major Denmark-based manufactures of large commercial wind turbines are Siemens Wind Power and Vestas Wind Systems A/S. In 2006 the global market share of these two manufacturers was more than 35%. A major supplier is LM Glasfiber A/S.

There are two major organisations in Denmark representing the owners and the manufacturers. These are the Danish Wind Turbine owners Association and the Danish Wind Industry Association.

All wind turbines can obtain certificates or a bonus for twenty years. The planned renewable energy certificate system has been postponed.

RD&D programmes

Since 2006 a major increase in the RD&D funding occurred and a further increase is expected for 2007. The public funds for RD&D have increased gradually from DKK273m in 2005 to DKK448m in 2007. In addition, the national research councils and the newly established High Technology Foundation may also provide funds for energy research.

The Danish Energy Authority is responsible for the administration of the Energy Research Programme (EFP). The total funding in 2006 for wind energy projects supported by EFP was DKK11.3m.

The Danish Council for Strategic Research also increased the budget for energy and environmental research to DKK 108m. In 2005, DKK13.8m was granted to wind projects.

R&D organisations
Risø National Laboratory is the largest research institution for wind energy in Denmark. The research is planned and implemented around four themes: climate conditions, wind turbine design, electrical systems, control and integration and society markets and energy systems. Wind energy research is also carried out at the Technical University of Denmark, University of Aalborg and the University of Copenhagen.

Danish research teams are actively involved in international cooperation projects. At the EU level a contract has been signed that establishes a large project called UpWind. Risø National Laboratory is the coordinator of the project. Furthermore, Denmark participates in several IEA Wind Tasks (International Energy Agency, 2007).

Publishing
Denmark is the most important actor regarding scientific publishing in the field of wind energy and has increased the output especially during the last years (Figure 41). Denmark is mainly collaborating with Germany, the USA and Sweden in this field and the main R&D organisations that publish are Risø National Laboratory, the University Aalborg and the Technical University of Denmark (compare Table 60 and Table 66).

Patenting
Most important are here the companies Vestas Wind System A/S, LM Glasfiber A/S and NEG Micon A/S (takeover by Vestas). Interestingly, the Risø National laboratory also has some patent activities (Table 31).

Finland
Finland's energy sources comprise 26% nuclear energy, 13% hydropower and 31% combined heat and power (coal, gas, biomass and peat). Biomass is used intensively by the paper and pulp industry. Progress in increasing wind power capacity has been slow compared to the goals set in the 2001 National Climate Strategy. Later, in the updated National Climate Strategy in 2006, the target of 500 MW for wind power by 2010 was removed. According to estimates between 200MW and 300MW of wind power capacity can be foreseen by 2010 (International Energy Agency, 2007).

However, recent developments indicate that initiatives are being taken to increase wind power production in Finland. Fortum, a major Finnish energy company has stated that they are planning large-scale wind power generation together with the National Forest

Enterprise. According to a preliminary survey, a 800–900 MW offshore wind farm can be built in the Pitkämatala area and a 350–400 MW plant in the Maakrunni area. The two farms' combined output will be equivalent to the annual electricity consumption of approximately 200,000 detached houses (120 m2) with electric heating. An environmental impact assessment will be carried out at the beginning of the project. According to initial estimates, the Pitkämatala and Maakrunni wind farms could probably begin generating electricity in 2014–2016. Concern has been expressed by wind power developers with regard to the current power prices. A sizeable increase in renewables based energy production, also wind and especially offshore wind power generation is not commercially viable with current power prices, says Fortum. Green certificates implemented at Nordic level would be the most cost efficient of supporting renewable energy sources for the consumers, according to Fortum (Fortum press release 17.06.2008).

Most of the wind turbines are located along the Finnish coast lines. The largest projects are located in Pori and in Tornio. There were 113 wind turbines in operation in Finland in March 2008. Several projects are in the building phase. The environmental benefit of wind power production in Finland exceeded 100 million tonnes of CO_2 savings in 2005.

One of the largest manufacturers of wind turbines in Finland is WinWinD, from 2007 owned by an Indian company. WinWinD has manufactured 23% of all turbines in Finland. The company has also started to export turbines, mainly to Sweden and Portugal.

National incentive programmes

At the national level there are some incentives for wind energy installations. An investment subsidy up to 40% can be awarded. In addition, there is the possibility of a tax refund of €6.9 /MWh, which corresponds to the tax on electricity paid by household consumers.

Research activities and funding

There has not been a national research programme for wind energy in Finland since 1999. However, individual projects can receive funding from the National Technology Development Agency (Tekes). Priority is given especially to the development of market-oriented projects.

Finnish research teams are actively involved in IEA Wind Tasks 19, 21, 24 and 25. These operate under the DENSY programme. Other programmes that are energy and climate relevant are CLIMBUS and the project Demand for Finnish Energy Technology and Business Opportunities in Global Markets. At the enterprise level there are many technology development projects.

The Technical Research Centre of Finland (VTT) and the Finnish Meteorological Institute (FMI) are participating in two Nordic Energy Research Projects. One is on grid integration; the second is investigating how climate change affects renewable energies. Wind energy research is also carried out at the University of Helsinki and Helsinki University of Technology.

Publishing
Finnish research groups have contributed to some degree to scientific publishing on wind energy, especially during the last years (Figure 41). They collaborate mainly with Germany, Sweden and the USA. The most active R&D organisations are the University of Helsinki, the VTT, the Helsinki University of Technology and the Finnish Institute for Marine Research (compare Table 60 and Table 66).

Patenting
There were only a few patent applications from Finland registered in this technology field, but Winwind Oy should be mentioned in this context (Table 31).

Norway
The total installed wind generation in Norway in 2006 was 325 MW, generated by a total of 155 wind turbines. The production capacity is of 1TWh/year. Interest in developing wind power is high. The target for wind power is 3 TWh above the 2001 level by 2010. In 2006, projects for more than 1200 MW were approved by the Norwegian authorities. About 0.55% of the renewable energy supply comes from wind power (International Energy Agency, 2007).
The Norwegian government will support the construction of floating wind turbines at sea. There have been defined two milestones: 2009 first pilot project, 2013 first mini wind park.[5]

Main industrial activities
Until recently there has not been significant wind turbine manufacturing in Norway. Today there is the Scanwind Group AS, a Norwegian-based wind turbine manufacturer. Umoe Ryving is a wholly owned subsidiary of Umeo Mandal where core competence is in the design and manufacturing of light weight materials. Recently the company has started to specialize in the production wind turbine blades. The company Devold AMT is an important supplier of glass and fiber carbon mats for turbine blades.
Several projects are in the planning phase. Havgul AS has applied for a permit to develop three offshore wind parks outside Ålesund on the Norwegian West coast.

The Norwegian companies Sway and StatoilHydro are exploring the possibilities of floating wind turbines at sea, by utilizing technology from oil and gas activities in the North Sea.

Norwegian technology strongholds in wind energy are related to challenges such as strong, turbulent winds and extreme climates through numerous projects. Norwegian companies have developed special know-how from the oil and gas and shipping industry which are relevant for specifically developing offshore wind power (Norges vassdrags- og energidirektorat, 2007).

Norsk Hydro has developed a combined wind/hydrogen trial plant on the island of Utsira outside Hagesund. The project aims at showing how wind power and hydrogen fuel cells

[5] According to the Minister of Petroleum and Energy, Aslaug Haga at the Energiuka 21 in Oslo. 5th February 2008.

can work together to secure renewable electricity supply for a remote community. The technology is not yet commercially competitive.

The Norwegian energy company, Statkraft, operates wind farms at Smøla, Hitra and Kjøllefjord in Norway. Statkraft has also sent a proposal for an assessment of several wind farm projects to the Norwegian Water Resources and Energy Directorate (NVE).[6] Additionally should be mentioned the wind energy related activities of Statkraft outside Norway. Statkraft and its partner, Catamount Energy Corporation, have been given a licence to build Blaengwen Wind Farm in Wales in the UK.

National R&D programmes
RENERGI is the national research programme for renewable energy and is managed by the Research Council of Norway. The allocated budget for wind energy research in RENERGI was €1.5m in 2006.

Wind projects that were approved for funding are:

- A study on the potential of offshore wind energy
- Concepts for the development of floating wind turbines
- Several projects dealing with wind resource mapping.

R&D organisations
SINTEF Energy Research, the *Institute for Energy Technology (IFE)* and *NTNU* have jointly undertaken the initiative to develop a test station for wind energy at the Midwestern coast of Norway. The test site opened in 2005. The three organizations have established jointly a Centre for Renewable Energy to coordinate research and initiatives in the field of renewables among the respective organisations.

The Wind energy strategic programme 2003–2007 is a project carried out at NTNU jointly with the Institute for Energy Technology and SINTEF Energy Research and SINTEF Applied Mathematics. The aim of the project is to strengthen Norwegian competence in wind energy. The Research Council of Norway is financing the project and additional financing comes from Statkraft. The programme has a total budget of NOK19.65m.[7] The University of Bergen and the University of Oslo are also conducting significant research on wind energy.

The previous programme period for the development of wind energy technology was carried out during 2001–2005 and with a total budget of NOK12.12m.[8] Apart from RCN, the project received financial support from Statkraft, Norsk Hydro and Umoe Ryving.

Publishing
Norwegian R&D organisations have contributed actively to scientific publishing in this technology field (Figure 41). They collaborated mainly with the USA and Denmark. The main R&D organisations are the NTNU, the University of Bergen, the SINTEF Group and the University of Oslo (Table 60 and Table 66).

[6] For more detailed information on Statkraft see: http://www.statkraft.com/pub/wind_power/index.asp
[7] http://www.energy.sintef.no/prosjekt/SIP/SIP_JOT/wind.asp
[8] http://www.energy.sintef.no/prosjekt/vindkraftteknologi/index.asp

Patenting
Norwegian R&D organisations and companies have contributed to patenting in this field to a lesser degree, but activities by Sway AS, Norsk Hydro ASA and OWEC Tower AS should be mentioned (Table 31).

Iceland
Despite the large potential for wind power in Iceland, there are no activities in this field. A study on wind mapping has been made but the costs of developing wind farms are too high compared to the abundant renewable energy sources present today in Iceland, such as geothermal and hydropower.

Latvia
Since the first half of the 1990 there have been small installations of wind power in Latvia. In 2005 there were 41 wind turbines with a total capacity of 27 MW. The biggest wind park, Veja park is located near the city of Liepaja at the Baltic Sea coast. There are some positive trends for the potential increase of wind power capacity following the granting of licences by the Ministry of Economics for the installation of wind power plants of 160 MW. Latvia has optimal conditions for a extensive installation of onshore and offshore wind power generators (Renewable Energy Policy Review Latvia 2004). The target is to install new wind generators with capacity 135 MW by 2010 (Šlihta, 2006).

Estonia
The islands of west Estonia, the coastal areas of North-West Estonia and South-West Estonia, and also the coastal areas of North Estonia and Lake Peipus are the most prospective areas of application for wind power. Taking into account the current situation of the power system, it is possible to install wind generators in Estonia to the extent of 90-100 MW, but this would endanger the operation quality of the power system. It is possible to erect 30–50 MW wind turbines without any such negative effects. In addition to the problems relating to power networks, the more widespread use of wind resources is restricted by relatively small electric load, great unit capacity and poor manoeuvring ability of the existing units and groups of power stations.

The strong links of the Estonian power system with the Latvian and Russian power systems, which enable covering variations in wind power energy supplies alleviate the problem. The technical limit for the installation of wind generators in the Estonian power system is 400-500 MW, but this requires investments to power networks and power stations to ensure the transmission, regulation and the necessary wind power resources (Renewable Energy Policy Review Estonia 2004).

By 2005, the total capacity of electricity producing wind turbines in Estonia is approximately 30 MW. According to the governments ambitions their total capacity will reach 500 MW by 2030.

The biggest operating wind parks in Estonia are:

- Pakri
- Viru Nigula
- Hiiumaa offshore wind park.

R&D organisations
Tallinn Technical University is the main research centre for wind energy research in Estonia (see Table 66).

Interest organisations
The Estonian Wind Power Association is member of the European Wind Energy Association. Its goals are to provide a common voice for the wind power developers and related organisations in Estonia, to provide a platform for joint activities, to promote wind energy in Estonia, and thereby contribute to the main objectives of energy policy in Estonia and Europe, and to the security of energy supply through wider use of renewable energy.

Lithuania
Lithuania has assumed an EU renewable growth commitment of 7% by 2010. The Government has set wind energy as a priority sector and established the capacity requirement for power plants to be built annually by the end of 2009. Currently, renewable generation accounts for 3% of the total output. The bulk of such output according to the Lithuanian Wind Energy Association is generated by hydro power plants. In order to ensure the wind power generation share, 200 MW of power plants needs to be built.
The construction of a pilot wind park with total capacity of 4 MW is planned on the sea coast in Klaipeda County. By 2010, 170 MW capacities of wind turbines will be installed in Lithuania. In Lithuania, such zones are situated only along the Baltic sea coast. From an economical point of view, the most efficient windmills would be large-sized plants installed offshore or close to the coast. Lithuania does not have very good conditions for wind energy due to low wind velocity. The most favourable wind energy potential is located in western and north- western Lithuania. Wind energy can be efficiently used in zones where the average wind speed exceeds 5-6 m/s. Average wind speed is 5 –5.5 m/s at 10 m height or less in the coastal zone. In the middle of Lithuania, wind speed is 3.5 or 4 m/s. Lithuania also has some problems because of the lack of available land for wind turbines (Renewable Energy Policy Review Lithuania 2004).

Offshore sites for wind turbines between Sventoji and Palanga are very complicated because of coastal shipping problems. Wind turbines may be erected in depths of 20 m according to legislation measures.

Interest organisations
The Lithuanian Wind Energy Association is the interest organisation for wind energy.

R&D organisations
Important Lithuanian R&D organisations are the Lithuania Energy Institute – the Laboratory of Renewable Energy. Research, modelling and forecast of onshore wind variations at the Lithuanian Baltic Sea cost are some of the activities on wind energy carried out at the Lithuanian Energy Institute's Laboratory of Renewable Energy. Data analysis of wind velocity and direction measurements is carried out in the Laboratory. Wind power prediction models are being developed and wind energy resources in Lithuanian territory are estimated. The Energy Institute cooperates with the Wind Energy Department of Risø National Laboratory in Denmark.

Other research organisations focusing on wind energy are the Strategic Self Management Institute and the Klaipeda University, Coastal Research and Planning Institute.

International project collaboration
Lithuania is one of the countries participating in the POWER project–Perspectives on offshore wind energy development in marine areas in Lithuania, Poland and Russia.[9] This is a project with the goal of establishing the conditions for effective development of wind energy production in the Baltic Sea coastal zones of three neighbouring countries, Lithuania, Russia and Poland. Use of renewable energy sources, including wind, is an important component of sustainable development of these regions, which may result in measurable positive economic, ecological and social effects.

This objective should be achieved by attracting potential investors by means of the project's main product, a map of optimum locations for offshore wind farms, especially focused on principles of sustainable development, including preservation of nature values in marine cross-border areas.

Wind Energy in the BSR (Baltic Sea Region)–Planning Construction and Investment, 2003–2005 was a programme partly financed by the European Regional Development Fund (ERDF) covering the period 2000–2006.

The main project themes encompassed:

- Improvement of the wind-energy-conditions in less developed areas (image, spatial planning, law, economy)
- Promotion of the wind-energy-idea all over the BSR
- Initiating international co-operations for an exchange of knowledge, know-how and experiences regarding public work, spatial development, technology, law and economy

Experiences with the first projects of Western-European companies in Poland, Lithuania, Latvia, Estonia and Russia show significant difficulties caused by an insecure financial situation, a lack of standards, a lack of relevant laws and difficult cooperation with authorities.

[9] http://corpi.ku.lt/power/

2.3 Second Generation Bioenergy

Bioenergy is energy produced by the transformation of biomass, such as plant or animal material to heat or fuels. *Biomass* means the biodegradable fraction of products, waste and residues from agriculture (including vegetal and animal substances), forestry and related industries, as well as the biodegradable fraction of industrial and municipal waste.

Bioliquids comprise liquid fuel for energy purposes produced from biomass; *Biofuels* comprise liquid or gaseous fuel for transport produced from biomass (European Commission, 2008). Biomass is considered renewable because it is replenished more quickly when compared to the millions of years required to replenish fossil fuels. Commonly bioenergy is used for heating and transport purposes. An overview of the value chain for bioenergy from a technology perspective is presented in Figure 5. So called *second-generation biofuels* are made from lingo-cellulosic biomass feedstock using advanced technical processes. Ligno-cellulosic sources include woody, carbonous materials that do not compete with food production, such as leaves, tree bark, straw or woodchips (Figure 6). An overview of the biomass feedstock used and the name production processes for both first and second-generation biofuels is given in Figure 4.

First generation (conventional) biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Conventional bioethanol	Sugar beet, grains	Hydrolysis & fermentation
Vegetable oil	Pure plant oil (PPO)	Oil crops (e.g. rape seed)	Cold pressing/extraction
Biodiesel	Biodiesel from energy crops Rape seed methyl ester (RME), fatty acid methyl/ethyl ester (FAME/FAEE)	Oil crops (e.g. rape seed)	Cold pressing/extraction & transesterification
Biodiesel	Biodiesel from waste FAME/FAEE	Waste/cooking/frying oil/animal fat	Transesterification
Biogas	Upgraded biogas	(Wet) biomass	Digestion
Bio-ETBE		Bioethanol	Chemical synthesis
Second generation biofuels			
Biofuel type	**Specific names**	**Biomass feedstock**	**Production process**
Bioethanol	Cellulosic bioethanol	Lignocellulosic material	Advanced hydrolysis & fermentation
Synthetic biofuels	Biomass-to-liquids (BTL): Fischer-Tropsch (FT) diesel Synthetic (bio)diesel Biomethanol Heavier (mixed) alcohols Biodimethylether (Bio-DME)	Lignocellulosic material	Gasification & synthesis
Biodiesel	Hydro-treated biodiesel	Vegetable oils and animal fat	Hydro-treatment
Biogas	SNG (Synthetic Natural Gas)	Lignocellulosic material	Gasification & synthesis
Biohydrogen		Lignocellulosic material	Gasification & synthesis or Biological process

Figure 4: Overview of biofuels and the feedstock and the processes used in their production. Source: Biofuels Research Advisory Council (2006)

The bioenergy sector has had a remarkable increase during the last 10–15 years in the Nordic countries, especially in Sweden, Denmark and Finland. The gross energy consumption from bioenergy varies from 4.2% in Norway to 20% in Finland. Both the type and level of resource and type of use of biomass varies between the four countries. In Finland and Sweden black liquor is mainly used, together with wood products and wastes. In Denmark 48 per cent of biomass originates from forestry. In Norway firewood and forest residues are important biomass sources. In Iceland the use of bioenergy in heating is limited to municipal solid waste The Baltic States have great potential for increased use of bioenergy in the future. The forest area covers a large percentage of the total area and present large areas of potential forest fuel resources (Bioenergy in the Nordic Countries, 2007).

Important factors contributing to the development of bioenergy in the Nordic countries' electricity production are targeted policy instruments such as the Biomass Action Plan Agreement 1993 and 1997 in Denmark and the introduction of the Green Certificates system in 2003, and energy tax exemption for bioenergy in Sweden. In Finland feed-in tariffs for peat in electricity generation and tax subsidies on renewables has contributed to the increased use of bioenergy.

The development of bioenergy depends strongly on fossil fuel prices and on political commitment. With a view of reducing Europe's dependency on oil and of contributing to the fight against climate change the European Commission (EC) has taken the initiative to several directives on how to increase use of bioenergy in Europe. In 2003, the Biofuel directive (2003/30/EC) was adopted. The directive sets up the goal of utilising a minimum of 5.75% biofuels by 2010. In January 2007, the EC presented the "Renewable Energy Roadmap" where a mandatory target of 20% for renewable energy share of energy consumption in the EU by 2020 is proposed. To fulfil this target, energy from biomass, especially from wood, is expected to play a major part. In addition, the EU leaders have committed to raising the share of biofuels in transport to 10 per cent by 2020. The target is binding and has the conditionality that the biofuels produced are so-called *second-generation biofuels* (European Commission, 2007). The reason of this is mainly the raising concerns about the sustainability of those first-generation biofuels which are produced from agricultural crops and therefore compete with food production. Second-generation biofuel technologies are able to manufacture biofuels from biomass and waste in a more energy-efficient and sustainable way.[10]

Significant efforts in relation to cellulose ethanol are being made internationally. Countries such as the United States, Canada, Spain, China and Sweden are currently preparing pilot plants for cellulose-based production of ethanol. There are many R&D environments in the Nordic countries trying to develop new techniques for the production of second-generation biofuels. Many new initiatives are taking place at industry level. There are numerous examples of pilot plants being established in the Nordic countries as a result of industry-university collaboration and government funded R&D programmes.

So-called *third-generation biofuels* are increasingly receiving more attention by researchers. This is a process mainly linked to hydrogen or methanol produced through gasification of biomass or waste. Research shows that methanol production holds much

[10] Food and Agriculture Organization of the United Nations (2008)

better perspectives for the future compared to second-generation biofuels. The advantages of this type of process is a much more significant CO_2 reduction than that of second-generation bioethanol, and may be put to use as fuel for modern electric cars equipped with fuel cells (Skøtt, 2007).

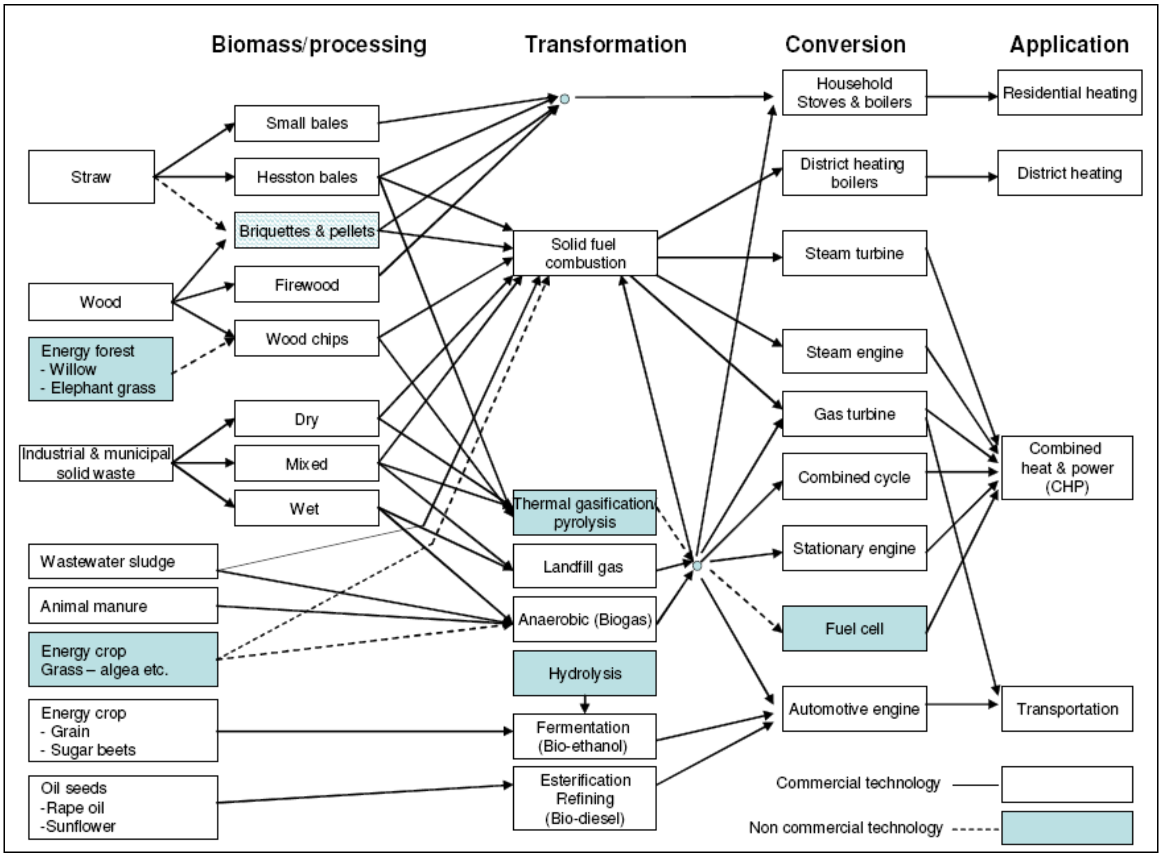


Figure 5: Bioenergy Value Chain from a Technology Perspective. Source: Econ (2007)

Research and development programmes in the bioenergy field are important instruments across all Nordic and Baltic States. Because of the natural resources available there is great potential to further increase the use of bioenergy in the Nordic countries and for export.

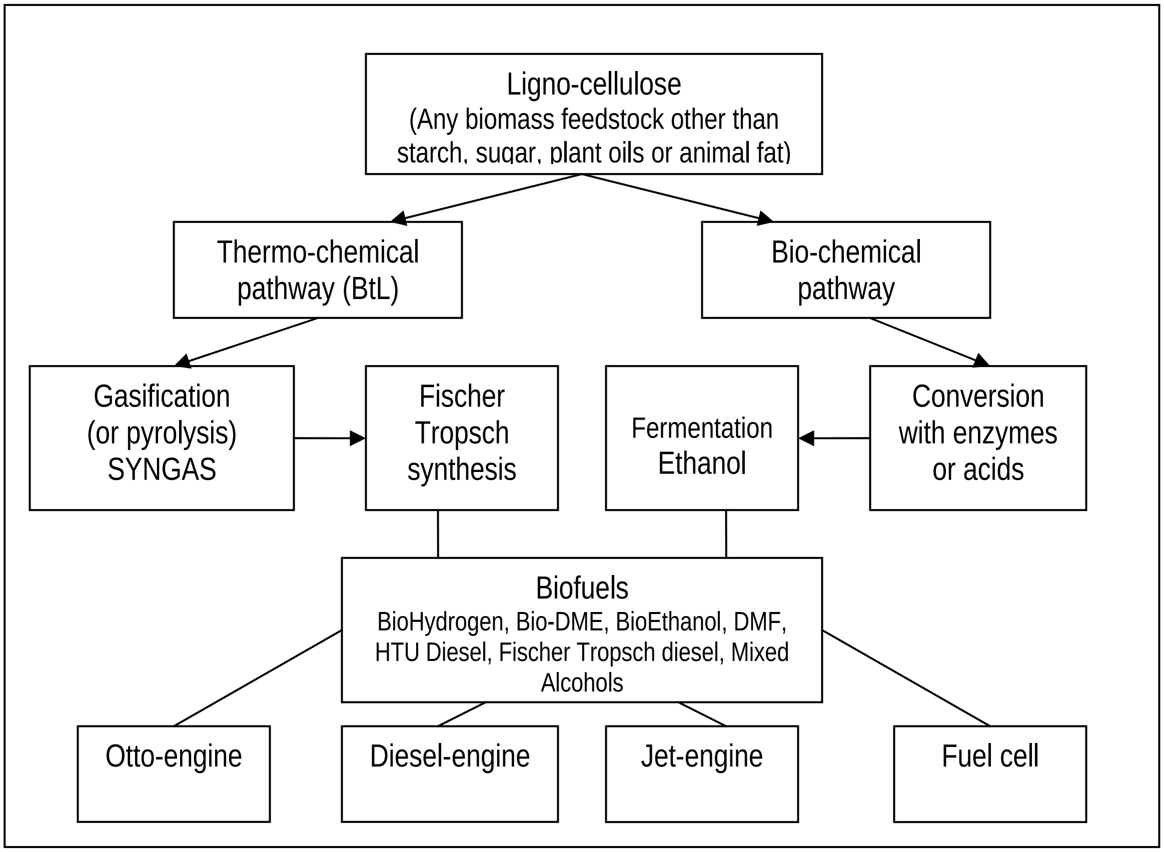


Figure 6: Second generation biofuels: value chain from a technology perspective. Source: NIFU STEP

Bibliometric and patenting evidence

Comparing the results from the bibliometric and patent analysis, the most striking result is the diverging level of publishing and patenting in both channels of knowledge dissemination. The bibliometric study revealed strongest positions for Sweden and Denmark, followed by Finland and Norway (Figure 44, Figure 45 and Table 44), while the patent study found evidence for patenting mainly in Denmark (Figure 33, Table 33 and Table 32). This can be explained by a long tradition of relevant expertise from the strong Danish food industry that has been transferred to the bioenergy sector.

International collaboration

The EU report ‘The State and Prospects of the European Energy Research’ (2006) distinguished between four important areas that have been funded under EU FP5 and 6: feed stocks, biofuels, transformation of biomass to electricity, and heat and standardisation. The funding for R&D for feed stocks has been halved from EUFP5 to FP6, but the funding of R&D for biofuels and the transformation process has increased considerably (Figure 7).

Bioenergy Technology Paths (Strategically important areas and topics)	EC Funding in					
	FP5			FP6		
	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€
Feeds tock (Crops and waste)	17	132.76	25.16	3	14.55	12.64
Biofuels	23					
Liquid fuels	7	285.6	18.85	5	63.37	32.47
Gasification	23	41.59	20.55	7	65.67	30.52
Biomass/-fuels to electricity and heat	33					
Combustion	9	19.41	8.64	8	74.27	33.30
Co-firing/CHP	24	57.81	29.13	4	26.06	12.24
Supporting Actions Standardisation	13	12.68	8.15	3	7.05	6.19
Total Bioenergy	86	549.85	110.48	30	250.97	127.36

Figure 7: Bioenergy research funding in FP5 and FP6*. Source: The State and Prospects of the European Energy Research. 2006. Annex VII 3
* FP6 includes funding up to the third call and doesn't include data from thematic "biomass to hydrogen"-projects

Norway

Norway has abundant bioenergy resources. Bioenergy covers approximately 25 per cent of energy demand in Norwegian wood processing and wood working industry (Norges vassdrags- og energidirektorat, 2007). Approximately nine percent, or 14 TWh, of the stationary energy consumption in Norway originates from bioenergy sources. Almost half of the consumption comes from wood in households. The production of first-generation biofuels, especially biodiesel from imported plant oils–rape and soy, is increasing heavily. The production of bioethanol for transportation purposes is currently in a development phase.

In the Government Declaration (*Soria Moria erklæringen*) from 2005 the red–green government's commitment to fostering the development of bioenergy was announced. In the latest *White Paper on Climate (*St.meld. nr. 34, 2006–2007) the government states the wish to put in place "target oriented and coordinated policy measures for an increased use and expansion of bioenergy up to 14 TWh by 2020". The long-term target set by the Norwegian authorities is 30 TWh more renewable energy and energy savings by 2020 compared to 2001. According to the Nordic Bioenergy project the goal is that Norway shall recycle 80 per cent of the waste of which 50 per cent is transformed into energy.[11] At the beginning of 2008 the government presented a bioenergy strategy for increased production and use of bioenergy. The target of an increase of 14 TWh before 2020 is maintained (*Strategi før økt utbygging av bioenergi*, 2008).The strategy has been

[11] Nordic Bioenergy project http://www.nordicenergy.net/bioenergy/index.cfm?path=108

criticized by bioenergy stakeholders in Norway (e.g. the Norwegian bioenergy association and Bellona) for the lack of substantial policy instruments to foster an increase in bioenergy. In relation to the bioenergy strategy a background report was commissioned by the Ministry of Petroleum and Energy. The report *Bioenergy in Norway*, was compiled by the Eastern Norway Research Institute in collaboration with the Norwegian Forest and Landscape Institute and the Institute for Strategic Studies and published in November 2007 (Langerud, Størdal, Wiig and Ørbeck, 2007).

The production of pellets is steadily increasing of which the most part is exported to Sweden, Finland and Italy. The total production capacity of wood pellets has increased from 35,000 tond to 135,000 tons in 2007 (Norges forskningsråd, 2007).

Bioenergy RD&D environments and programmes in Norway

Bioenergy research in Norway is carried out in university faculties, research institutes and in firms. The most prominent R&D environments in bioenergy are the Norwegian University of Life Sciences in Ås (see the report by Hoen, Trømborg and Nielsen, 2007), the Institute for Energy Technology (IFE) in Kjeller and NTNU, SINTEF and the Paper and Fibre Research Institute (PFI) in Trondheim. The research activities are, however of a lesser extent than that carried out in Sweden and Finland (Norges forskningsråd, 2007).

For second-generation biofuels especially NTNU followed by SINTEF, the University of Oslo and the UMB are the most active R&D environments at university and institute levels.

SINTEF has long experience in bioenergy research and working with industry to develop products for biomass and waste, and is largely involved in international research platforms such as the IEA. SINTEF Energy Research is a major partner in Energy research projects at EU level. Since February 2006, SINTEF is coordinating one of EU's major programmes in the field of bioenergy: NextGenBioWaste. The programme will demonstrate innovative solutions in large-scale systems for waste and biomass combustion for the entire supply chain from fuel via conversion to ash treatment and use.

PFI (The Paper and Fibre Institute) is coordinating a project which is looking at technologies that can make production of bioethanol from cellulose and hemicelluloses more profitable. The project title is *Cost effective production of renewable liquid biofuel and biochemicals from Scandinavian wood materials*. Many partners from industry and universities are participating in the project such as Statoil, Estra and the University of Bergen. The project receives financial support form the Norwegian Research Council's programme for renewable energy RENERGI.

Other research projects on bioenergy running under RENERGI in the period 2001–2009 include:

- Second-generation biofuel–technology development and impacts on biomass markets, UMB
- Catalytic conversion of biomass producing promising liquid bio-fuels, NTNU

- Forest-based bioenergy in Norway: Economic potential, market interactions and policy means, Norwegian University of Life Sciences, Department of Ecology and Natural Resource Management (INA)
- Innovative concept for cost effective distributive energy production based on waste and biomass, Norsk Inova AS
- Production of synthetic biodiesel (BTL) in Norway, Norsk Pellets Vestmarka AS
- Cost Effective Utilization of Bioenergy - Advanced Biomass and Waste Combustion, SINTEF Energy Research AS
- Socio-Economic Drivers in Implementing Bioenergy Projects - Norwegian participation in IEA Bioenergy Task 29 2006-2009, Energigården
- M-BIP: E6 as a biogas highway from Gothenburg to Oslo–establishment and testing of petrol stations for biogas in Fredrikstad, Fredrikstad Biogass AS
- Market near project–Development and testing of biodiesel based on soya bean oil and synthetic biodiesel (BTL), Denofa AS, Dep. Fredrikstad
- BIP-M, Pilot for production of synthetic biodiesel from biogas in Norway, ZERO - Zero Emission Resource Organisation

ENOVA and Innovation Norway currently have theresponsibility for administering several financial support mechanisms for increased production and consumption of bioenergy. Relevant programmes under the auspices of ENOVA are “Heating-, processing of biofuels” and “Heating”.[12] The Bioenergy Programme is carried out and administered by Innovation Norway. The programmes commenced in 2003 and there is no end date foreseen at the moment. The financial support for 2007 was NOK33.5m (€4.14m) – an increase of €7.5m compared to 2006. The support can be used for investment, evaluations and knowledge creation in the bioenergy field.

The government is considering establishing a new public enterprise with the role of promoting environmentally friendly energy carriers and energy systems for transportation. The new organisation (TRANSNOVA parallel to GASSNOVA) will receive funding from the Ministry for Transport, the Ministry of Petroleum and Energy, and the Ministry for the Environment. Among other organisations, TRANSNOVA will play an important role in providing investment support to trial and pilot plants for biofuels. The agency will come into operation in 2009 (St.meld. nr. 34 (2006-2007)).

Main industrial activities

Several new initiatives for developing second-generation bioethanol are taking place at industry level. The main industries currently focusing on the development of second-generation biofuels in Norway are StatoilHydro, Borregaard and Weiland AS. Today, Borregaard is one of the most important actors for developing new technology for the production of bioethanol. The newly established firm, Weyland AS, is currently developing a pilot plant for producing bioetanol from scrap wood and paper with funding from the Norwegian Research Council. StatoilHydro and Norsk Skog are investigating

[12] *Enova* is a public company owned by the Ministry of Petroleum and Energy. Enova’s objectives are to limit energy use considerably and to increase annual use of water-based central heating based on new renewable energy sources, heat pumps and waste heat of 4 TWh by the year 2010

the possibility of producing synthetic biodiesel from wood, i.e. *second-generation biodiesel*. The goal is to open a full-scale production plant within five years (Norges forskningsråd, 2007).

Recently, StatoilHydro acquired a 42.5% share in a new biodiesel plant in Lithuania. Production at the Mestilla plant will have a capacity of almost 100,000 tonnes biodiesel per year. Linas Agro, the Lithuanian agricultural company, will be the other major shareholder with a 57.5% stake.

In collaboration with Norwegian forest owners, Norske Skog is establishing a joint venture to develop and produce synthetic fuels from Biomass-to-Liquids processes. A prototype facility will be built in connection with Norske Skog Follum at Hønefoss. The technological pathway is the Fischer-Tropsch (FT) synthetic diesel production from woody biomass, but the venture will also consider other lignocellulosic biofuels.

Sweden

The usage of bioenergy has increased gradually in Sweden since the mid-1990s. One important instrument for the increase of bioenergy for district heating is the tax on CO_2. The electricity certificate system, which came in to force first of May 2003 with the intent to increase the renewable energy production, has also made it more profitable to use bioenergy based heating. The main source for biomass in Sweden is forest based. Of the total 110 TWh bioenergy that is produced approximately 90 per cent comes from forest and the forest industry.

More than 60 per cent of district heating (approximately 40 per cent of the heating market in Sweden) fuel today is biomass. For the period 2008—2010, the Swedish government is supporting the development of second-generation biofuels and a sustainable extraction of biomass with SEK150m (€15.9m).

Bioenergy RD&D environments and programmes in Sweden

Sweden has a long history of processing cellulose raw materials from forestry products and boasts world-class expertise and world-leading companies such as SEKAB. The company has worked with researchers at various universities and departments, but particularly with the Faculty of Engineering at Lund University. In 2004, a pilot plant opened for the production of ethanol from wood chips. At present, an intensive development project is under way at the facility with the aim of verifying and further developing the process technology prior to the next stage of technological development. For further information compare our case study.

The most prominent R&D environments in bioenergy are at Lund University, the Swedish University of Agrarian Science, Chalmers University of Technology, Royal Institute of Technology (KTH), Umeå University, University of Göteborg, Luleå University and Linköping University. The Swedish Institute for Agricultural and Technical Engineering (JTI) has several research programmes related to the bioenergy field, several with international cooperation.

The Unit of Biomass Technology and Chemistry at the Swedish University of Agricultural Sciences (SLU) is carrying out research on bioenergy. Analyses of bio fuels are done at a certified laboratory. SLU-BTK is 2007 to 2010 hosting the national research programme for fuel pellets. The Biofuel Technology Centre, a national research pilot plant for solid biofuels such as pellets and briquettes, is also a part of the Unit.

The Swedish Energy Agency is managing the Biofuel Programme (Bränsleprogrammet). The programme commenced in January 2007 and will be concluded in 2010. This has an annual budget of SEK40m (€4.22m). The research activities cover both fundamental and industry driven projects. The programme focuses on three thematic areas *–forestry, agriculture and refining*, and on horizontal areas such as *strategic knowledge*. The programme is not supporting research on first-generation liquid biofuels.

The Ethanol Programme finances research on cellulose based ethanol technology at universities, higher education and research institutes and the development of the ethanol pilot plant in Örnsköldsvik. The programme is managed by the Swedish Energy Agency and has a duration of four years from 2007 to 2010. The budget for the period 2009–2010 is SEK20m.

CHRISGAS is a project is funded by the EC 6th Framework Programme and the Swedish Energy Agency. It runs for 5 years beginning 1 September 2004. Sixteen partners representing industry and research from 7 EU member states are involved in the Project. The aim of the CHRISGAS Project is to demonstrate, within a five-year period, the production of a clean hydrogen-rich synthesis gas from biomass. The project is coordinated by Växjö University.

Svebio, the Swedish Bioenergy Association has been participating and is currently engaged in several national as well as international projects:

Swedish Bioenergy Group	co-operation between Svebio and the Swedish Trade council for the export marketing of Swedish know-how, technology and equipment in the field of bioenergy
BioHeat	international project to stimulate heating of public facilities with biofuels
K4RES-H	*Key issues for Renewable Heat in Europe* is an EU-project aimed at developing the basis for an action plan for heating with renewable energy
Boosting Bio	an EU-project developing a vision and strategy for increased use of bioenergy in the EU-25
Bio E-train	an EU-project developing a university level internet based education in the field of bioenergy
BIO-CHP	an EU-project comparing operational data from some 60 European CHP-plants and developing *best practice guidelines* for European CHP production
Pellets for Europe	a completed (2005) EU-project aimed at disseminating information about the different national pellets markets in Europe

Leading edge bioenergy companies in Sweden

The Swedish environmental technology Council (Swentec) has identified and mapped the leading edge competence in the areas of renewable fuels (biofuels) and renewable energy (bioenergy) that constitutes a high export potential in Sweden. The results show that there are between 3500 and 4000 companies active in the area of environmental technology (clean tech) in Sweden, of which 1200 are involved in export. About 80% of these companies are small with fewer than 10 employees. Some of the factors behind the apparent difficulty for these companies to grow are the lack of venture capital, too few business entrepreneurs. Regarding biofuels specifically, Swentec concludes that there are more than 100 actors and between 300 and 500 suppliers. The size of the companies varies depending on its position in the value chain. Typically, small companies dominate in the raw material part, medium-sized companies in the manufacturing part and large companies in the user part. When ownership is considered, there is a clear majority of government-owned firms in manufacturing, while only private owners are found among users (Swedish Environmental Technology Council, 2007).

Swentec estimates that in the bioenergy field there are between 200 and 300 actors and between 450 and 700 suppliers in Sweden today. Also bioenergy companies are predominantly small and medium-sized. Private ownership is larger than in biofuels but large plants are predominantly government-owned.

Leading edge biofuels companies are:
Suppliers: Ageratec, Alfa-Laval, Atrax Energi, Flotech, Läckeby Water, Malmbergs, Processkontroll, Swedish Biogas International, Process och Industriteknik, Scandinavian Biogas, VVBGC, YIT
Manufaturer: Sweden Bionergy SEKAB (world leader in cellulosic ethanol).

Leading edge bioenergy companies are:
Suppliers: Biopress, Bruks Klöckner, Hotab, Janfire, Järnforsen Energi System, KMW Energi, Kvaerner Power, Petrobolagen, Pilum, Radscan Intervex, Rottne, Saxlund, Sweden Power Chippers, TPS, Värmebaronen
Manufacturer: Chemrec, Econova Energy, Lignoboost, Neova
Raw material: HMAB, Lantmännen Agroenergi
Usage: Rindi Energi, Talloil (Swedish Environmental Technology Council, 2007).

The BioAlcohol Fuel Foundation
The BioAlcohol Fuel Foundation (BAFF) is a knowledge and information led organisation involved in projects of sustainable transport around the world. The foundation is responsible for projects related to production, distribution and usage of bioethanol as well as knowledge and information of systems change towards sustainable transport systems based on biofuels.

The leading organisations in the foundation are:
- Chermatur Engineering AB
- SAAB Automobil AB
- SEKAB
- Skellefteå Kraft AB
- Utveckling Sundsvall AB, FOKUSERA
- Örnsköldsviks Kommun

Finland

Bioenergy accounts for 20% of primary energy consumption in Finland and 10% of electricity demand, but opportunities have been identified to increase the use of bioenergy by 35% over the next decade. Bioenergy accounts for 85% of Finland's renewable energy production.[13] Finland is committed to increasing its share of biofuels by 2010 in accordance with EU requirements. The government has drafted a Bill where the share of bio-based fuels should be increased to 5.75% by 2010. The Ministry of Trade and Industry has established a group for transport biofuels which has proposed thlaunching a national development program in order to develop new Finnish production technologies for second-generation biofuels. The aim is to introduce new biofuels into the market by 2015.

A feed-in tariff for biogas plants is on the agenda of the current government. It is planned to start in 2008 and to include plants of up to 20MW. Biofuels benefit from tax exemptions under certain conditions. Biogas used as motor fuel, for instance, is exempt from excise duty. A new law on the promotion of biofuels entered into force on 1 January 2008. The law will oblige fuel distributors to supply a minimum of 2% biofuels to the transport market in 2008, with annual increases so that it will be at least 5.75% by 2010 (Renewable Energy Fact Sheet for Finland- European Commission 2008b).

In Finland, the bioenergy industry has been particularly advantaged by the successful developments obtained in energy R&D. The pulp and paper industries are the main drivers. Research activities cover the entire process chain such as biomass residues from forestry and wood industry operations, feedstock pre-processing, conversion to solid, gaseous and liquid biofuels as well as economic and environmental issues associated with the use of bioenergy (Energy research in Finland, 2006).

International cooperation plays an important role in bioenergy research in Finland: Finnish groups are present at the International Energy Agency (IEA Bioenergy) and in the EU Research Framework Programme (Energy research in Finland, 2006).

Bioenergy RD&D environments and programmes in Finland

The Technical Research Centre of Finland (VTT) is the largest in Finland as well as one of Europe's largest research and development units in the bioenergy field, especially in forest biomass. VTT has extensive cooperation with industry and international research programmes and organisations. VTT with its Knowledge Cluster Energy and Pulp and Paper supported by activities in other clusters probably has the largest capacity in bioenergy research concentrated in a single organisation worldwide. Furthermore, VTT is coordinating the EU Network of Excellence on "*Overcoming the Barriers to Bioenergy*". Examples of research activities in bioenergy carried out at VTT are:

- Fuel processing and handling
- Biomass fuel production
- Liquid biofuel technologies (pyrolysis, process assessments of thermo chemical conversion, production of transportation fuels, use of liquid biofuels in engines and vehicles)
- Recovered fuel technologies

[13] Bioenergy in Finland, www.environment.fi

- Pellet and briquette production
- Recovered fuels.

The Biorefine programme for 2007–2012 funded by Tekes aims at generating new expertise and innovative technologies in the processing of biomass and at applying it to the creation of processes, products and services related to biorefineries. The budget of the programme is about €137 m. A further objective is to promote the development and use of second-generation production technology in biofuels for transport, which is also a major goal set out in Finland's energy policies.[14]

An important step in fulfilling the national biofuel target of 5.75% was the setting up of one of Europe's most advanced gasification test equipment designs for the development of second-generation transport biofuels in 2006. The equipment is used for refining synthesis gas from biomass for the production of diesel fuels. The equipment was introduced by VTT Technical Research Centre in 2006. The project is co-financed by Tekes, VTT and nine industrial companies (Andritz, Foster Wheeler Energia, Neste Oil, Vapo, MetsäBotnia, M-Real, Rintekno, StoraEnso, UPM and PVO). The total budget is €4m. In the second phase 2008–2009, it is estimated that the plant will have the output capacity of 50 MW. The third phase, commencing in 2010, encompasses the construction of a trial plant which will be able to cover about three per cent of the transport biofuel demand. The total cost of the development and trial phase will amount to approximately €300m. The commercialisation of the first plants is foreseen in 2012–2014. The research team at VTT is cooperating with the Helsinki University of Technology, the IEA Thermal gasification group, European projects and US-DOE programmes.[15]

The most prominent universities in bioenergy research are the University of Helsinki, the Åbo Akademi, Helsinki University of Technology (TKK). The Centre for Energy Technologies (CET) at Helsinki University of Technology shall facilitate the development of new energy technology solutions. The following units with focus on bioenergy research are part of the CET:

- *Department of Automation and Systems Technology*
    - Automation: Focus areas are automation in energy technology, distributed energy production, bio-energy treatment, fuel-cell based power supplies, service and maintenance systems for ITER.
- *Department of Energy Technology*
    - Energy Economics and Power Plant Engineering: Focus areas are energy economics, energy markets, energy systems, risk management, optimization. Industrial energy efficiency (methods, measures), process integration (methods, measures), combined heat and power (CHP) in industry, drying (wood, bio-fuels, sludges), district heating and cooling.
    - Energy Engineering and Environmental Protection: Focus areas are environmental technology, bio-energy in power production, combined heat and power (CHP) technologies, process-integration (optimization, simulation), combustion and gasification.

[14] http://akseli.tekes.fi/opencms/opencms/OhjelmaPortaali/ohjelmat/BioRefine/en/etusivu.html
[15] www.vtt.fi

Denmark

Since 1990 the importance of bioenergy in Denmark has steadily increased, both in agriculture and in forestry. Biomass is the largest contributor to the increased consumption of renewable energy in Denmark that accounts for 16% of total energy consumption. The production of bioenergy in 2005 amounted to 23 TWh; an increase of 780 GWh since 2004. The growing use of bioenergy mainly takes place in the CHP sector which almost exclusively uses straw and woodchips as raw material inputs.

The government goal is that the share of heating plants using renewable energy will increase from today's 60% to nearly 100% by 2020. The Danish government aims at increasing the share of biofuels for transport up to 10% of total consumption by 2020. As a result of the joint political vision for biofuels four projects on bioethanol are being planned.

The Danish parliament has expressed the importance of increasing the use of biogas in the near future. The number of research and demonstration projects on wood, cereals, straw, animal waste and waste from food producing industries as input to the energy sector are steadily increasing. In 2006, the total public financial support for biomass (DKK 38.9m) and biofuels (DKK 99.8m) was DKK 140m (€17,5m). This trend is supported by a governmental initiative to double the expenditure on research in energy technology, reaching one billion DKK by 2010. An important policy instrument is the Biomass Agreement that is expected–according to the Danish Biomass Association – to increase the use of bioenergy further.

The main supporting measure for biofuels is the removal of the CO_2 tax on biofuels (effective since January 2005). Biomass is also exempt from CO_2 duty (compare the Renewable Energy Fact Sheet for Denmark – European Commission, 2008a).

Bioenergy RD&D programmes in Denmark

In the new *Energy Technology Development and Trial Programme* (EUDP) that starts in 2008, among the listed priority areas there are second-generation biofuels for transport and other usages for biomass and fuel cell technologies. For 2008, the EUDP has earmarked DKK85m for the production of bioethanol for the transport sector based on second-generation technology.

A strategy for research, development and trial and biomass technology and electricity and nuclear heating in Denmark was formulated by the Energy Agency and Energi.dk in 2003. The strategy indicates priority areas for the technological development for combustion and thermal gasification of solid biomass such as straw, wood etc. into electricity and heating. The Energy Agency has also elaborated a strategy for research and development of liquid biofuels. The strategy is to be seen in the framework of the government’s overall Energy Strategy 2025 formulated by the Ministry of Transport and Energy in June 2005.

The Energy Research Programme (Energiforskningsprogrammet - EFP) under the Danish Energy Authority provided funding for energy research and technological development projects. Bioenergy research was one of the main areas of investigation of the programmes, more specifically on:

- Biomass and cogeneration plants
- Liquid biofuels.

Bioenergy RD&D environments in Denmark
The most prominent organisations in bioenergy research are the Technical University of Denmark with Risø Laboratory, the Danish Institute of Agrarian Science and the University of Copenhagen.

The Danish Center for Biofuels (DCB) is a unique collaboration between three research groups from The Technical University of Denmark (DTU), Risø National Research Laboratory (now a part of the DTU) and the Royal Veterinary and Agricultural University (now part of the University of Copenhagen). The aim of the centre is to support development and creation of sustainable technologies for the utilisation of biomass, primarily for the production of bioethanol, biogas and bio-hydrogen, through research, education and industrial collaboration.[16]

Iceland

Compared with the other Nordic countries, both use of bioenergy and research in the filed is not extensive in Iceland. Traditionally, Iceland has acquired advanced knowledge on the utilization of geothermal and hydropower resources, and more recently on the production, storage and trial of hydrogen as an energy carrier in the transport sector. However, emphasis is increasingly put on acquiring knowledge in the production of methane, biodiesel, ethanol and hydrogen from waste or biomass.

The most active university in terms of publishing of articles in bioenergy is the University of Iceland. The Agricultural University of Iceland (RALA) has been involved in a research project under FP6 on the sustainable usage of herbaceous biomass together with the Icelandic biomass company and other European research partners from Germany and Ireland.

Estonia

In January 2007, the Estonian Government approved a Biomass and Bio-Energy Development Plan for 2007–2013.[17] The Plan was prepared by an inter-ministerial commission in 2006 and will be implemented in two main stages. The first implementation stage started in 2007and will continue in 2008, focusing on the realization of necessary research and dissemination of information about bioenergy. During the second phase (2009–2013) the government is considering introducing further measures such as tax instruments, subsidies, public procurement. The goals defined are to guarantee the effective and sustainable utilization of the Estonian land and biomass resources, taking into account ecological, economical, social and cultural aspects. According to the Ministry of Agriculture, the aim for 2025 is to for 100% of heat and 6% of electricity to be produced from biomass (2007).

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[16] http://www.biofuels.dk/Forside_UK.htm
[17] http://ec.europa.eu/energy/res/biomass_action_plan/doc/nbap/information/estonia_en.pdf

At present, 21% of heating is produced from wood fuels. Approximately 75 per cent of heating is dependent on wood and peat fuel. According to the Ministry of Agriculture bbout 1% of electricity is produced from renewable resources, mainly from hydro and wind power (2007). The Estonian rural development plan also contains several measures to promote bioenergy through investments in bioenergy production (40%) and planting short rotation forests.

Universities and research institutes
In terms of publishing the Tallinn Technical University, the University of Tartu and the Estonian Agrarian University are the most important.

Interest organisations
The Estonian Biomass Association (EBA) is a non-profit organisation founded in 1998. It is a voluntary union of its members. EBA is engaged in renewable fuels research, resources estimation, sustainable development of renewable types of energy and promotion of the use of environmentally friendly fuels at both the state and individual level. The Estonian Biomass Association is a member of the European Biomass Association.

Latvia
Wood is the most important local bioenergy resource in Latvia both by volume and by usage. Firewood has a solid position in the energy balance and its proportion in heat production is increasing as is the use of biomass for power production. The consumption of wood for production of energy in household consumption exceeds 50%. The use of wood briquettes and pellets in the heating of individual houses is steadily increasing (Hansen et al., 2006). In accordance with the EC Biofuels Directive, the Latvian Government has adopted the 5.75% target.

Important policy documents on bioenergy are:
- National Program “Production and Use of Bio-fuel in Latvia (2003–2010)" (2003),
- Action Plan for Implementation of the Program “Production and Use of Bio-fuel in Latvia (2003–2010)” (2004).

Laws and regulations
- Act on Bio-fuel (2005)

Bioenergy RD&D environments and programmes in Latvia
The Forestry and wood-processing technology programme is a state research programme running for the period 2005–2009. The programme has the following priorities: forest development, rational utilisation of wood biomass, chemical processing of timber. According to Erawatch Latvia, the programme is managed by the Latvian Institute for Wood Chemistry and has an overall budget of €3.55m.

Lithuania
Energy produced from biomass is about 7%. Recourses of domestic fuels are 60% wood fuels, 35% peat, straw and biogas just 1%.Wood comprises the largest part of solid

biomass in Lithuania. According to estimates by the Renewable Laboratory at the Lithuanian Energy Institute, approximately 80% of wood fuel sources are currently consumed in energy production. The authorities support establishment of plantations. There is not yet a significant production and consumption of biodiesel and bioethanol (Hansen et al., 2006).

Lithuania has several programs to develop and increase the usage of biomass. The planned capacity of electricity generation from biomass should reach 30 MW in 2010. The planned balance of renewable energy for 2010 is wind (2.5%), biomass (1.7%), hydro (3.5%), and solar, geothermal, waste (0.025) – a total of 7.7%. The state has approved a long-term strategy in order to increase the usage of biomass in electricity generation. According to the strategy the biggest potential for growths lies in wood fuels (forest residues, short rotation energy wood) and straw (Hansen et al., 2006).

Bioenergy RD&D environments and programmes in Lithuania

The most prominent universities are Kaunas University of Technology and the Lithuanian University of Agriculture. The Lithuania Energy Institute, Laboratory of Renewable Energy is conducting research on bioenergy. In 2006 research was carried out mainly on biomass and biogas research of solid biomass usage for energy production.[18]

Table 4: Bioenergy technology strongholds in Nordic and Baltic States. Source: Nordic Bioenergy project and other national sources

Country	*Technology*	*Application*
Denmark	– Biomass combustion – biogas technologies – grate firing of municipal solid waste – large-scale centralized biogas plants using animal manure – enzymes in second-generation ethanol production	– Export of biomass – District heating
Sweden	– Biomass in district heating – pellet production, pellet boilers, pellet burners and stoves – energy crops such as Salix – functioning biofuel market, including production of cars and ethanol and efficient distribution network.	– District heating – Transportation
Finland	– Commercialisation and use of biomass combustion from farm level to the world's biggest power plants. – fluidised bed combustion technology that allows for low-grade fuel like bark and sludge – biomass gasification test equipment	– District Heating
Norway	– First-generation biodiesel. – fish wastes for biodiesel (however stopped due to too high levels of iodine according to the European Standard EN 14214 for biofuels)	– Heating – Transportation

[18] http://www.lei.lt/main.php?m=257&k=9

Iceland	– Ethanol/methane – hydrogen from waste or biomass	– Transportation purposes
Estonia	– Wood fuels for heating – a development plan for bioenergy and biomass research is under implementation	– Heating – Electricity
Latvia	– Forestry and wood processing technology – wood fuels	– Heating – Electricity
Lithuania	– Solid biomass for energy usage	– Heating – Electricity

2.4 CO_2 capturing and storage

Carbon capturing and storage (CCS) is a technological approach to mitigating global warming by capturing carbon dioxide (CO_2) from large point sources such as power plants and subsequently storing it instead of releasing it into the atmosphere. The following description of the different technological pathways is based on information provided by several sources (IEA Greenhouse Gas R&D Programme; European Commission, 2004; Intergovernmental Panel on Climate Change, 2007).

Technology for *capturing* CO_2 is already commercially available for large CO_2 emitters such as power plants; however, capture is pointless without storage. Storage of CO_2, on the other hand, is a relatively untried concept and as yet no large-scale power plant operates with a full carbon capture and storage system.
CCS applied to a modern conventional power plant could reduce CO_2 emissions into the atmosphere by approximately 80–90% compared to a plant without CCS. Capturing and compressing CO_2 requires much energy and would increase the fuel needs of a plant with CCS by 10-40%. These and other system costs are estimated to increase the cost of energy from a power plant with CCS by 30% to 60% depending on the specific circumstances.
Storage of CO_2 is envisaged either in deep geological formations, deep oceans, or in the form of mineral carbonates. In the case of deep ocean storage, there is a risk of greatly increasing the problem of ocean acidification, a problem that also stems from the excess of carbon dioxide already in the atmosphere and oceans. Geological formations are currently considered the most promising sequestration sites, and these are estimated to have a storage capacity of at least 2000 Gt CO_2.

CO_2 capture
Capturing CO_2 can be applied to large point sources, such as large fossil fuel or biomass energy facilities, industries with major CO_2 emissions, natural gas processing, synthetic fuel plants and fossil fuel-based hydrogen production plants. Broadly, three different types of technologies exist: Post-combustion, pre-combustion, and oxy-fuel combustion.
In *post-combustion*, the CO_2 is removed after combustion of the fossil fuel – this is the scheme that would be applied to conventional power plants. Here, CO_2 is captured from flue gases at power stations (in the case of coal, this is sometimes known as “clean coal”). The technology is well understood and is currently used in niche markets.
The technology for *pre-combustion:* either carbon or nitrogen is removed from the process before the combustion. This is widely applied in fertilizer, chemical, gaseous fuel (H_2, CH_4), and power production. In these cases, the fossil fuel is gasified and the resulting CO_2 can be captured from a relatively pure exhaust stream.
In *oxy-fuel* combustion (sometimes inappropriately referred to as “zero emission” fossil fuel power plants), nitrogen is removed from the air before combustion with fossil fuel and the lignite is burned in oxygen instead of air. This produces a flue gas consisting only o carbon dioxide and water vapour, which is cooled and condensed. The result is an almost pure carbon dioxide stream that can be transported to the sequestration site and stored. The technique is promising, but the initial air separation step demands a lot of energy.

In *pre-combustion decarbonisation* the carbon is removed in the form of CO_2. The remaining fuel is hydrogen. Hydrogen can be used as an energy carrier (Jordal and Anheden, 2005).
An alternate method, which is under development, is *chemical looping combustion* (CLC). Chemical looping uses a metal oxide as a solid oxygen carrier. Metal oxide particles react with a solid, liquid or gaseous fuel in a fluidized bed combustor, producing solid metal particles and a mixture of carbon dioxide and water vapour. The water vapour is condensed, leaving pure CO_2 which can be sequestered. The solid metal particles are circulated to another fluidized bed where they react with air, producing heat and regenerating metal oxide particles that are re-circulated to the fluidized bed combustor.
A few engineering proposals have been made for the much more difficult task of capturing CO_2 directly from the air, but work in this area is speculative and conceptual at this point. Capture costs are estimated to be much higher than from point sources, but may be feasible for dealing with emissions from diffuse sources like automobiles and aircraft.

CO_2 storage
Various forms have been conceived for permanent storage of CO_2. These forms include gaseous storage in various deep geological formations (including saline formations and exhausted gas fields), liquid storage in the ocean, and solid storage by reaction of CO_2 with metal oxides to produce stable carbonates.
Geological storage or *geo-sequestration*. This method involves injecting carbon dioxide directly into underground geological formations. Oil fields, gas fields, saline formations, un-minable coal seams, and saline-filled basalt formations have been suggested as storage sites. Here, various physical (e.g. highly impermeable caprock) and geochemical trapping mechanisms would prevent the CO_2 from escaping to the surface.
CO_2 is sometimes injected into *declining oil fields* to increase oil recovery. This option is attractive because the storage costs are offset by the sale of additional oil that is recovered. Disadvantages of old oil fields are their geographic distribution and their limited capacity.
Unminable coal seams can be used to store CO_2 because CO_2 adheres to the surface of coal. However, the technical feasibility depends on the permeability of the coal bed.
Saline formations have been used for storage of chemical waste in a few cases. The main advantage of saline aquifers is their large potential storage volume and their common occurrence. This will reduce the distances over which CO_2 has to be transported. The major disadvantage of saline aquifers is that relatively little is known about them compared to oilfields.
Another proposed form is the *CO_2 storage in the oceans*. Two main concepts exist. The 'dissolution' type injects CO_2 by ship or pipeline into the water column at depths of 1000 m or more, and the CO_2 subsequently dissolves. The “lake” type deposits CO_2 directly onto the sea floor at depths greater than 3000 m, where CO_2 is denser than water and is expected to form a “lake” that would delay dissolution of CO_2 into the environment. The environmental effects of ocean storage are generally negative, but poorly understood. Large concentrations of CO_2 kills ocean organisms, but another problem is that dissolved CO_2 may eventually equilibrate with the atmosphere, so the storage would not be

permanent. Much more work is needed here to define the extent of the potential problems.

An additional method of long-term ocean-based sequestration is to gather crop residue such as corn stalks or excess hay into large weighted bales of biomass and deposit it in the alluvial fan areas of the deep ocean basin. Dropping these residues in alluvial fans would cause the residues to be quickly buried in silt on the sea floor, sequestering the biomass for very long time spans. Alluvial fans exist in all of the world's oceans and seas where river deltas extend to the edge of the continental shelf such as the Mississippi alluvial fan in the Gulf of Mexico and the Nile alluvial fan in the Mediterranean Sea.

A third concept is to *convert the CO_2 into bicarbonates* (using limestone) or hydrates. In this process, CO_2 is exothermically reacted with abundantly available metal oxides which produce stable carbonates. This process occurs naturally over many years and is responsible for much of the surface limestone. The reaction rate can be increased, for example by reacting at higher temperatures and/or pressures, or by pre-treatment of the minerals, although this method can require additional energy.

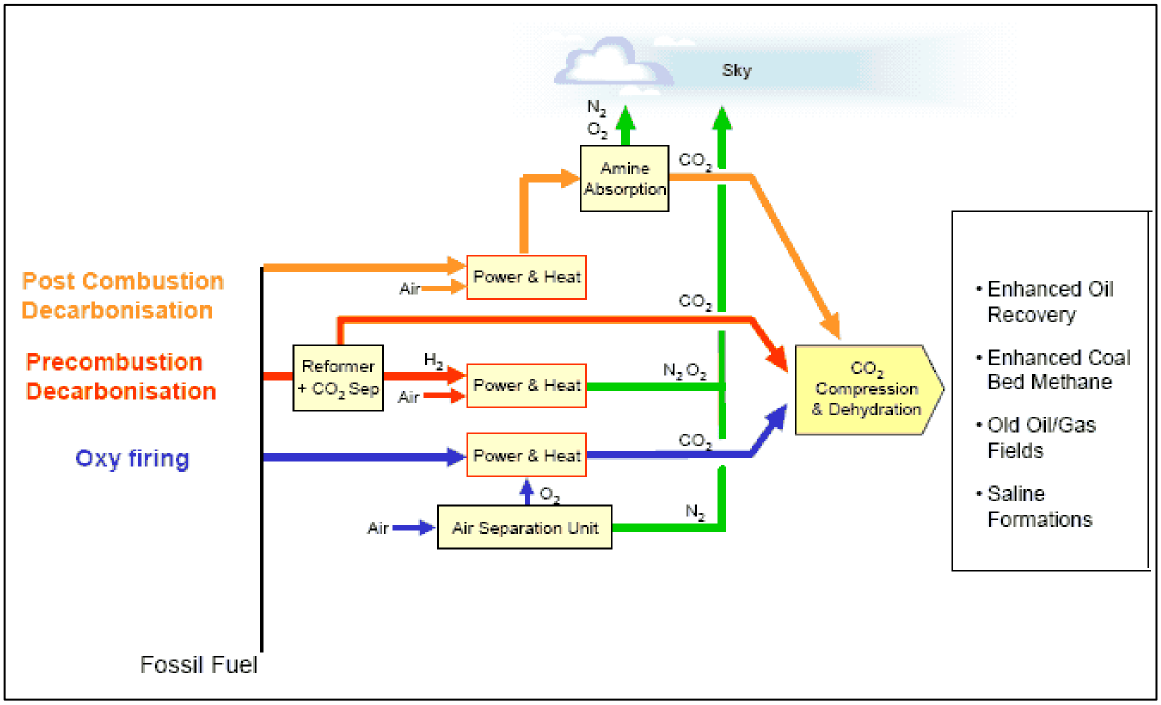

Figure 8: CO_2 capturing and storage–Value chain. Source: Zero (from international project CO_2 Capture Project – CCP) Source: Zero

Environmental impact

Possible leakage of CO_2 from storage sites to the atmosphere or to the oceans have been addressed in several reports and researchers are calling for long-term monitoring of geological storage sites (Haugan, 2008 and Nordic Council of Ministers, 2007). International and national regulations have to be developed.

International collaboration projects

These are the main CCS related projects financed by the European Commission:

Project title	Funding Agency	Total Budget	Start year
CO_2 Geological Storage R&D Project	EUFP6	€3.59m	2006
CO_2SINK	EUFP6	€15m	2004
CASTOR: CO_2 from Capture to Storage	EUFP6	€15.8m	2004
Enhanced Capture of CO_2 (ENCAP)	EUFP6	€22m	2004
Innovative In Situ CO_2 Capture Technology for Solid Fuel Gasification	EUFP6	€2m	2004
CO_2NET EAST	EUFP6	€0.29m	2006
Assessing European Capacity for Geological Storage of Carbon Dioxide (EU GEOCAPACITY)	EUFP6	€1.9m	2006
CO_2GeoNet	EUFP6	€6m	2004
CO_2STORE	EUFP5	€2.5m	2003
Advanced Zero Emissions Power Plant (AZEP)	EUFP5	€9.3m	2001
Natural Analogues for the Geological Storage of CO_2 (NASCENT)	EUFP5	€3.3m	2001
Grangemouth Advanced CO_2 Capture Project (GRACE)	EUFP5	€3.2m	2001
Assessing European Potential for Geological Storage of CO_2 From Fossil fuel Combustion (GESTCO)	EUFP5	€3.76m	1999
The Development of Next Generation Technology for the Capture and Geological Storage of Carbon Dioxide from Combustion Processes (NGCAS)	European Commission and industry sources	€0.64m	2002
CO_2 Capture Project (CCP)	European Commission DG Research US Department of Energy Klimatek, Norway	$28m	2000
Saline Aquifer CO_2 Storage (Sleipner project)	Phases 0 and 1: Energy industry companies = 51% European Commission = 40% National authorities = 9% Phase 2: Energy industry companies = 56% European Commission = 35% National authorities = 9%	n/a	1999
The Underground Disposal of Carbon Dioxide (JOULE II)	European Commission Joule Programme	£1.28m	1993

We can distinguish between two groups of projects:

- Group of projects where mainly oil and other companies were involved together with national authorities targeting at the improvement of different types of technologies for capturing CO_2 and storingge CO_2 in geological formations around producing and depleted oil and gas fields and deep saline formations
- Group of projects mainly targeting the geological exploration of Europe for finding suitable geological formations for storage of CO_2, involving a broad range of public research organizations and national authorities.

The EU report The State and Prospects of the European Energy Research (2006) distinguished between four important areas funded under EU FP5 and 6: CO_2 capture (distinguishing between pre- and post combustion), geological storage of CO_2, sequestration of $CO_{2,}$ and networking tasks. The main funding went to CO_2 capture and geological storage and for both topics the funding has increased (Figure 9).

Capture and Storage of CO_2, associated with cleaner fossil fuel plants Technology Paths (Strategically important areas and topics)	EC Funding in					
	FP 5			FP 6		
	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€
CO_2 Capture	2	12.5	5.5	3	35.35	18.13
Pre-consumption CO_2 capture	1	3.2	2.1	2	25.08	12.60
Post-consumption CO_2 capture	1	9.3	3.4	1	10.27	5.525
Geological Storage of CO_2	6	17.2	9.1	3	26.25	16.83
Sequestration of CO_2						
Chemical/mineral sequestration of CO_2						
Other seperation techniques						
Other Related Research and Cooperation (incl. Networks)	1	2.1	1.4	1	1.58	0.85
Total CO_2 Capture ans Storage	9	31.8	16.0	7	63.23	36.43

Figure 9: CCS research funding in FP5 and FP6*. Source: The State and Prospects of the European Energy Research. 2006. Annex VII 3

* The funding of the CASTOR project has been split across the different technology paths to give a clear indication of the funding available to each technology path. Analysis in the above table is provided for the projects funded until the third call of proposals and other projects for which information was available.

The different RD&D funding of CCS can be a measure for the political commitment to CCS as has been demonstrated recently (Tjernshaugen, 2008). In this respect Norway is one of the leading countries of the world, with 18% of the worldwide €115 m government funding on CCS in 2005 (compare also Nordic Council of Ministers, 2007 and Riis, 2008).

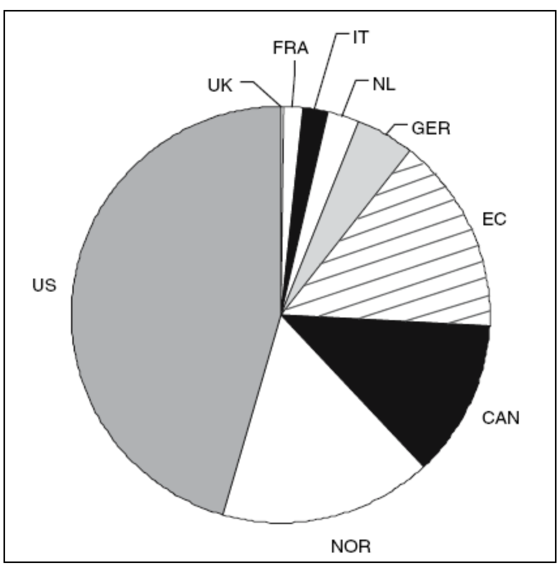

Figure 10: CCS RD&D Budget in 2005. Measured in 2005 USD. Source: Tjernshaugen (2008)

Denmark

R&D Environments

Important R&D environments for CCS are the Geological Survey of Denmark and Greenland (GEUS).

Policy instruments and policy measures

The Danish authorities have implemented several policy instruments and measures for strengthening the focus on reducing carbon dioxide emissions. In 1992, the previous tax system was replaced with a combined energy and CO_2 tax, but renewable energy was exempt from this tax. Subsidies were introduced for environmentally friendly forms of electricity production. Denmark thereby achieved a high focus on developing the capabilities for producing renewable energy, especially wind mills.

CCS has not been one of the main focus areas under the Energy Research Programme (EFP). The new Energy technology development and trial programme (EUDP) has CO_2 capturing as one of a broad range of focus areas, but CO_2 capturing has to share funding with other energy related areas, like biomass and wind technology, hydrogen and fuel cell technology, energy efficiency, energy system approaches, more efficient oil and gas recovery, more efficient production of electricity and heat. The Danish National Advanced Technology Foundation has funded a collaborative project on the use of CO_2 for enhanced oil recovery. Project partners are DONG Exploration and Production, DONG Energy, the DTU, GEUS and the Danish Geotechnical Institute GEO.

International collaboration projects

Denmark is a member of the Carbon Sequestration Leadership Forum (CSLF).[19]
The international activities in CCS of Danish actors in CCS are rather limited and concentrated on the Geological Survey of Denmark and Greenland (GEUS) and some energy companies, like DONG Energy, Elsam and Energi E2.
GEUS has participated or is still participating in ten European projects:

- Assessing European Potential for Geological Storage of CO_2 From Fossil fuel Combustion (GESTCO)
- Grangemouth Advanced CO_2 Capture Project (GRACE)
- CO_2STORE
- CASTOR: CO_2 from Capture to Storage
- CO_2GeoNet
- CO_2 Geological Storage R&D Project

[19] "The Carbon Sequestration Leadership Forum is an international climate change initiative that is focused on development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the CSLF is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology. The CSLF is currently comprised of 22 members, including 21 countries and the European Commission. Membership is open to national government entities that are significant producers or users of fossil fuel and that have a commitment to invest resources in research, development and demonstration activities in carbon dioxide capture and storage technologies."
Quotation from the CLSF's homepage: http://www.cslforum.org/about.htm

- The Development of Next Generation Technology for the Capture and Geological Storage of Carbon Dioxide from Combustion Processes (NGCAS)
- Saline Aquifer CO_2 Storage (Sleipner project)
- CO_2NET EAST
- Assessing European Capacity for Geological Storage of Carbon Dioxide (GEOCAPACITY)

CO_2STORE conducted several case studies, one of them about Denmark. The Danish study considered a deep saline aquifer at the Havnsø reservoir in north-western corner of Sjælland. The reservoir is a large domal structure lying partly on-shore and partly off-shore. The reservoir is close to two major CO_2 sources with combined annual emission of about 6 Mt CO_2 (10% of the total Danish CO_2 emissions).

Recently Elsam has been particularly engaged in CCS projects under EUFP6. In 2006, Elsam launched a pilot unit in Esbjerg for capturing CO_2 in a post-combustion separation process from real fumes from a coal power plant. The pilot unit will be the largest installation in the world for capturing CO_2 at low concentrations in large volumes of gases and at low pressure. The pilot unit is capable of treating 1 to 2 tonnes of CO_2 per hour.

Patenting

Union Engineering A/S has been patented in the field of CCS (Table 35).

Publishing

Publishing in the field of CCS has not been in the focus for Denmark, but there are at least some achievements. The most visible organisations are here the Copenhagen University and the Technical University of Denmark (Table 45 and Table 68).

Finland

R&D Environments

CCS related R&D is of minor importance for Finland. The main R&D environments for CCS R&D are the University of Helsinki, the Helsinki University of Technology and VTT Valtion Teknillinen Tutkimuskeskus.

The international evaluation report for energy research in Finland 1999–2005 summarised the findings of the panel regarding the importance of CCS-related R&D for Finnish energy research as following: “While there is some work on carbon capture and sequestration (CCS), it is considered a small effort and a technology that has limited advocates. Since Finland has adopted an aggressive programme to reduce CO_2 emissions by energy efficiency, nuclear and biomass utilisation, the low investment in CCS can therefore be justified given that it is not applicable to automotive emissions and the emissions from power plants fired with fossil fuels is decreasing” (Energy Research in Finland 1999–2005, 2006: p. 31).

Finland funded from 1999 to 2002 a national R&D programme – Climtech. Here, CCS was one of six subject areas. According to the recent report on CCS by the Nordic

Council of Ministers resulted the funded research “that there are no suitable storage sites in Finland” (Nordic Council of Ministers, 2007: p. 15).

International collaboration projects
Finland is not a member of the Carbon Sequestration Leadership Forum (CSLF), and was involved in just one EU funded project on CCS: the project Innovative In Situ CO_2 Capture Technology for Solid Fuel Gasification (started in 2004 under EUFP6). Here is VTT Valtion Teknillinen Tutkimuskeskus one of the partners.

Patenting
There could be identified one CCS related patent from a Finnish company, Cuycha Innovation Oy (Table 35).

Publishing
Main R&D environments for publishing on CCS R&D are the University of Helsinki and the Helsinki University of Technology (Table 68).

Norway

R&D Environments
Important R&D environments for CCS are the NTNU, the SINTEF Group, the University of Bergen and the Institute for Energy Technology. Researchers from the NTNU started to publish on CCS before 1987.

Policy instruments and policy measures
The Norwegian authorities have implemented several policy instruments and measures for strengthening the focus on CCS. The introduction of CO_2 emission taxes for petroleum-related activities on the continental shelf in 1990 (in force since 1991) was a driver for oil and gas companies to engage in CCS R&D. As Tjernshaugen (2008) has shown funding of RD&D on CCS has high priority in Norway. Compared to other countries Norway has the highest share of funding on CCS per million GDP. The Norwegian Government has allocated NOK1,125m to RD&D with CCS in 2008 (compare also Figure 10). Several R&D programmes will be described shortly.

The Norwegian Commission on Low Greenhouse Gas Emissions was appointed by the Norwegian government in 2005 (NOU, 2006). The Commission had to develop scenarios of how Norway can reduce its emissions of greenhouse gases by 50 to 80 percent by 2050. The final report was presented to the Minister of the Environment in October 2006. One of the conclusions of the report was that CCS is one of many measures for reducing greenhouse gas emissions: gas and coal fired power plants have to implement CCS, in addition should also process industries with large pulse emissions implement CCS. The report also emphasised the need for higher energy efficiency and increased use of renewable energy sources.

KLIMATEK–Technology for the reduction of greenhouse gas

KLIMATEK was a result of an initiative of the Norwegian Ministry of the Environment, the Ministry of Petroleum and Energy and the Ministry of Trade and Industry. The programme had a budget of ca. 612 mill NOK, started in 1997 and ended in 2001. After 2001 projects related to this area are located at the EMBA Programme (Energy, environment, construction and installation) at the Research Council of Norway. EMBa was finished in 2004 and RENERGI took over.

RENERGI

RENERGI had the task to support CCS related R&D only for a short period – from 2004 to 2005.

CLIMIT programme

The CLIMIT programme was launched in 2005 and is the national programme for gas power technology for CO_2 capture and storage (CCS). Gassnova SF and the Research Council of Norway are administering the programme. The programme shall promote research, development and trial of CCS technologies. Annually, the Norwegian government allocates more than €16m to CLIMIT. With the co-funding by the industry total R&D expenditures amount to more than €50m annually. Main areas of activities are:

- power generation and CO_2 capture to reduce the costs of carbon dioxide capture
- transport and storage of CO_2 to create public acceptance for geological storage

Gassnova SF

Gassnova SF is a government centre of CCS expertise. It was established in 2005 as a Government Centre for Gas Power Technology and in 2007 became a state-owned enterprise. Gassnova shall be an adviser to the government on CCS, support technology development in CCS–capture, transport, injection and storage of CO_2, and is responsible for the management of several strategic projects in CCS, like the European CCS Test Center Mongstad, the full-scale carbon capture plant on Mongstad, the full-scale carbon capture plant at Kårstø and transport and storage of CO_2 (Riis, 2008). The main focus is on environmentally-friendly gas power technology due to the huge gas reservoirs on the Norwegian shelf. Gassnova promotes networking between public research organisations, industry and public authorities. Funding is eligible for a broad range of activities–from R&D projects to full scale realisation. Gassnova receives revenues from the Gas technology fund. This fund was established in 2004 and has about €250m available of which Gassnova receives about €10m per year.

Main industrial actors in CCS

StatoilHydro

The Norwegian oil and gas companies StatoilHydro (formerly two separate companies – Statoil and Norsk Hydro) is the main industrial actor in the field of CCS.
The company has been involved in following thirteen EU funded projects:

- Assessing European Potential for Geological Storage of CO_2 From Fossil fuel Combustion (GESTCO)
- Advanced Zero Emissions Power Plant (AZEP)
- Natural Analogues for the Geological Storage of CO_2 (NASCENT)

- Grangemouth Advanced CO_2 Capture Project (GRACE)
- CO_2STORE
- CO_2SINK
- CASTOR: CO_2 from Capture to Storage
- Enhanced Capture of CO_2 (ENCAP)
- The Development of Next Generation Technology for the Capture and Geological Storage of Carbon Dioxide from Combustion Processes (NGCAS)
- CO_2 Capture Project (CCP)
- The Underground Disposal of Carbon Dioxide (JOULE II)
- Saline Aquifer CO_2 Storage (Sleipner project)
- CO_2NET EAST

StatoilHydro is involved in four large-scale commercial projects on CCS at different levels of maturity:[20]

- The Sleipner field in the North Sea with storage of CO2 since 1996
- The Snøhvit gas field with LNG production and CO_2 storage in aquifers since 2007 in Northern Norway
- Salah in Algeria
- The carbon capture facility at the Mongstad refinery, west Norwegian cost

An important driver for the high activity level of StatoilHydro has been the introduction of carbon dioxide taxes by the Norwegian government.
StatoilHydro has 11 years' experience with CO_2 storage at the *Sleipner* field in the North Sea, where 1 million tonnes of CO_2 have been stored annually in the Utsira formation.

The *Snøhvit field* in the Barents Sea consists of a LNG production site where the natural gas will be liquefied. Because CO_2 would freeze to a solid when producing LNG it has to be removed prior to the liquefaction of the natural gas. The capturing process is a conventional amine process. The captured carbon dioxide will be transported in a pipeline back to the Snøhvit field and injected into a geological layer of porous sandstone below the gas containing layer, the Tubåen formation. The annual storage of carbon dioxide will be around 0.7 million tons per annum.

The project *In Salah* in the Sahara in Algeria aims at a capturing of 1.2 million tonnes CO_2.

European CO_2 Test Centre Mongstad (TCM)

Background for the Test Centre is Statoil's Energiverk Mongstad project, a refinery with a combined heat and power plant for which the Norwegian government demanded that a CO_2 capture and storage plant has to be constructed simultaneously. An agreement about CO_2 capture at Mongstad was signed in 2006.

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[20] For more detailed information on StatoilHydro's activities in CCS see also: http://www.statoilhydro.com/en/TechnologyInnovation/ProtectingTheEnvironment/CarboncaptureAndStorage/Pages/CaptureAndStorageOfCO2.aspx

Two stages of development are planned for Mongstad:

First large scale test facilities have to be installed – the CO_2 Test Centre Mongstad. The TCM shall have an annual capture capacity of 100,000 tonnes of CO_2. Beside StatoilHydro and the Norwegian authorities represented by Gassnova a number of foreign companies are also owners of the TCM including Dong Energy (Denmark), Shell (The Netherlands) and Vattenfall (Sweden).

The next phase will use the results of the TCM and will aim at the construction of a full-scale CO_2 capture plant at Mongstad. The final design and size of the large-scale facilities will be decided in 2012. The full-scale plant will be in place by the end of 2014, and will have a capacity of 1.3 Mt CO_2/year.

Aker Clean Carbon[21]

Another important industrial actor is Aker Clean Carbon, a company established in 2007 by Aker ASA and Aker Kværner (now Aker Solutions). Aker ASA and Aker Kværner have long experience with patenting in the field of the decomposition and combustion of hydrocarbons and the use of carbon media for storage of hydrogen. The purpose of the new company is to accelerate CO_2 capture technology.
The company will build the world's first and largest CO_2 capture facility of its kind based on a unique technology concept – JustCatch Bio™, a technology concept based on the combination of two processes:

- The use of a bio power plant with CO_2 capture to produce steam
- The use of this steam to heat the amine in a post-combustion CO_2 capture in a natural gas power plant.

The technology concept of JustCatch Bio™ can be seen as an approach to realising the "carbon negative energy" proposed by Bellona in its recent report on how to combat global warming (Birkeland et al., 2008).
Aker Clean Carbon is participating in the competition for building a trial plant at Kårstø, where Aker CCT is working for to demonstrate JustCatch Bio™. The planned budget framework for the new CO_2 capture plant is NOK875m (facility investments NOK725m, operating costs for 3 years NOK150m); the facility will be in operation in 2009, removing 100,000 tonnes CO_2 from exhaust emissions.[22]

International collaboration projects

Norway is a member of the Carbon Sequestration Leadership Forum (CSLF).
The Norwegian oil and gas companies StatoilHydro (former two separate companies: Statoil and Norsk Hydro) is a very active participant in the majority of the CCS projects funded by the European Commission. Other industrial actors are Industrikraft Midt-Norge AS, Det Norske Veritas AS, Hammerfest Energi and Sargas AS. When looking at public research organisations the SINTEF Group is most important, but also the NTNU,

[21] For more detail see our case study in NIFU STEP rapport 27/2008.
[22] For more details see our case study and the press release of Aker Clean Carbon: http://www.akercleancarbon.com/publish_files/080124_Aker_Clean_Carbon_PME_1100.pdf

the NGU Geological Survey of Norway, the Norwegian Institute for Water Research and the IRIS - International Research Institute of Stavanger should be mentioned.

Norwegian participation in EU funded projects on CCS:
- Assessing European Potential for Geological Storage of CO_2 From Fossil fuel Combustion (GESTCO)
- Advanced Zero Emissions Power Plant (AZEP)
- Natural Analogues for the Geological Storage of CO_2 (NASCENT)
- Grangemouth Advanced CO_2 Capture Project (GRACE)
- CO_2STORE
- CO_2SINK
- CASTOR: CO_2 from Capture to Storage
- Enhanced Capture of CO_2 (ENCAP)
- The Development of Next Generation Technology for the Capture and Geological Storage of Carbon Dioxide from Combustion Processes (NGCAS)
- CO_2 Capture Project (CCP)
- The Underground Disposal of Carbon Dioxide (JOULE II)
- Saline Aquifer CO_2 Storage (Sleipner project)
- CO_2GeoNet
- CO_2NET EAST

Patenting

Patenting in the field of CCS is mainly a domain of former Statoil and Norsk Hydro (compare Table 35: Nordic patenting organizations in CCS. Source: Delphion). In addition should be mentioned that Aker Clean Carbon submitted under the PCT in 2007 seven patent applications covering several parts of the technological solution JustCatch Bio^{TM}.

Publishing

Norwegian publishing in the field of CCS has increased considerably since 2004 and Norwegian researchers are collaborating closely with researchers from the USA, France, the UK, Canada, the Netherlands and Sweden. The main research organisations are the NTNU, SINTEF Group, the University of Bergen and the Institute for Energy Technology, but also companies contributed to the Norwegian publishing output in this field: again Statoil and Norsk Hydro were most active (Table 68).

Sweden

R&D Environments

Important R&D environments for CCS are Chalmers University of Technology in Gothenburg, Lund University and the company Vattenfall. Chalmers University of

Technology has an Energy Centre which from 2004 to 2006 had CCS as a priority research area.[23]

International collaboration projects

Sweden is not a member of the Carbon Sequestration Leadership Forum (CSLF), but nevertheless Swedish R&D environments have been active in European R&D projects on CCS. Important environments are Chalmers University of Technology in Gothenburg, Lund University and the company Vattenfall.

Swedish participation in EU funded projects on CCS:

- Assessing European Potential for Geological Storage of CO_2 From Fossil fuel Combustion (GESTCO)
- Advanced Zero Emissions Power Plant (AZEP)
- Grangemouth Advanced CO_2 Capture Project (GRACE)
- CO_2STORE
- CO_2SINK
- CASTOR: CO_2 from Capture to Storage
- Enhanced Capture of CO_2 (ENCAP)
- Innovative In Situ CO_2 Capture Technology for Solid Fuel Gasification
- CO_2 Geological Storage R&D Project

Patenting

We could not identify any relevant patents from Swedish R&D environments or companies.

Publishing

Swedish R&D results in CCS have been published increasingly, especially in 2006. Main collaborating countries are the USA, the UK and Norway. Important R&D organisations engaged in CCS publishing are Chalmers University of Technology in Gothenburg, Lund University, KTH and Uppsala University. The company Vattenfall has also been active in publishing on CCS (compare Table 68).

Main industrial actors in CCS

Vattenfall is the main Swedish company active in CCS. Vattenfall is Europe's fourth largest generator of electricity and the largest generator of heat. The company is active not just in Sweden, but has also strong positions in Germany, Poland, Denmark and Finland. The company emits about 90 million tonnes of CO_2 per year and has the target to reduce CO_2 emissions by 50 per cent from 1990 to 2030. Vattenfall has been involved in eight European projects on CCS.

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[23] Chalmers EnergiCentrum: Techniques, systems and consequences for society of CO2 separation and storage. http://www.cec.chalmers.se/eng/prio_omr_tekniker_system.aspx

Vattenfall is concentrating in an Oxyfuel Pilot Plant in Schwarze Pumpe in Germany on the further development and validation of the oxy-fuel technology, assessing that this technology results in the lowest costs at present and it is suitable for coal power plants.

Vattenfall is also cooperating with other actors in the above-mentioned Test Centre Mongstad based on amine-based post combustion technology.

In February 2008, Vattenfall commenced with the implementation of a full-scale trial project in Denmark, nearby Aalborg. The project is related to a coal power plant and will be operative in 2013.

Besides Vattenfall, there are also global industrial players which are active in Sweden. E.ON and Alstom will launch a 5MW CO_2 capture trial plant at Karlshamn Power Plant in southern Sweden. The trial plant will be based on Alstom's chilled ammonia-based technology and be operative in 2008.

Baltic countries

R&D Environments

R&D on CCS has not been in focus in the Baltic countries, but there are some R&D environments that have been involved in research tasks such as the Tallinn Technical University and the University of Tartu in Estonia, the State Geological Survey (SGS) in Latvia and the Lithuanian Geological Survey and Institute of Geology & Geography (IGG) in Lithuania. R&D is mainly concentrated on geological storage possibilities in the Baltic region.

Policy instruments and policy measures

We could not identify any relevant policy instruments or policy measures regarding CCS.

International collaboration projects

The Baltic countries are not members of the Carbon Sequestration Leadership Forum (CSLF), but have participated in three of the EU projects on CCS:

- CO_2 Geological Storage R&D Project, together with Vattenfall and GEUS
- CO2NET EAST, were the Tallinn University of Technology in Estonia participated together with StatoilHydro and several geological or geophysical R&D organisations from Czech Republic, Poland, Slovakia, Hungary, Croatia and Romania.
- Assessing European Capacity for Geological Storage of Carbon Dioxide (GEOCAPACITY), coordinated by GEUS with participants from 25 countries, among them Tallinn University of Technology, the Institute of Geology & Geography (IGG) in Lithuania and the Latvian Environment, Geology & Meteorology Agency (LEGMA).

Main industrial actors in CCS

Eesti Energia is producing rather high amounts of carbon dioxide. Therefore the company has developed a technology to cope with this pollution. The technology utilises a process for neutralizing alkaline ash transport water through a reaction with liquid CO_2. In 2007 Eesti Energia launched a R&D project on the potentials for CO_2 capture by alkaline ash that is generated as a residue during power generation.

Patenting

We could not identify any relevant patents from Baltic R&D environments or companies.

Publishing

We were able to identify some publishing activities on CCS in Estonia, mainly at the Tallinn Technical University and the University of Tartu (Table 68).

2.5 Wave energy

Wave energy, which is a non-polluting and renewable source of energy, is created by natural conversion of part of the wind energy above the oceans. Wind energy is created by natural conversion of part of solar energy. Just below the ocean's surface the wave energy flow is typically five times denser than the wind energy flow 20 m above the sea surface, and 10 to 30 times denser than the solar energy flow. Hence, there are good prospects for development of commercial wave-power plants, which in the future may become significant components for providing energy to many coastal nations.[24]

Technological maturity of ocean energy

According to a report from the European Ocean Energy Association on the status of ocean energy the sector has improved strongly over the last 5 years. A number of large-scale test installations are under development in European and worldwide. There is only one ocean energy system in Europe which has been operating for many years. This is the tidal barrage system at La Rance, France which according to the European Ocean Energy Association has an installed power of 240 MW and produces an average of 600 GWh/year. Considering the harsh marine environment, the main challenge in the design of ocean energy systems is to achieve high reliability, low cost and safety. The learning experience during prototype testing is very expensive because of the high deployment and operational costs, especially for off-shore devices. One can distinguish five different types of ocean energy systems: wave energy, tidal energy, marine current energy, salinity energy, thermal energy. To date, wave and tidal energy are the most advanced types of ocean energy systems under development. (European Ocean Energy Association- SET Plan meeting 7th May 2007)

At present, several companies are testing large-scale systems in real sea conditions using different technologies.

Wave Energy systems under development in Europe are:

- Limpet, Islay, UK
- European Pilot Plant, Azores, Portugal
- Pelamis, Orkneys, UK and Portugal
- Wave Bob, Ireland
- OE Buoy, Ireland
- FO^3, Norway
- SSG, Norway
- Wavestar, Nissum Bredning, Denmark
- Wave Dragon, Nissum Bredning, Denmark

Tidal Stream systems include:

- Marine Current Turbines; UK
- Ponte di Archimede, Italy
- Open Hydro, Ireland

[24] NTNU Wave Research Group

At present there is no commercially leading technology amongst ocean energy conversion systems. Contrary to wind, it is expected that there will be different technologies depending on the location.

Comparing the RD&D funding, the UK and the USA are in dominant positions. Regarding the Nordic and Baltic countries, Norway holds afairly strong position (Figure 11).

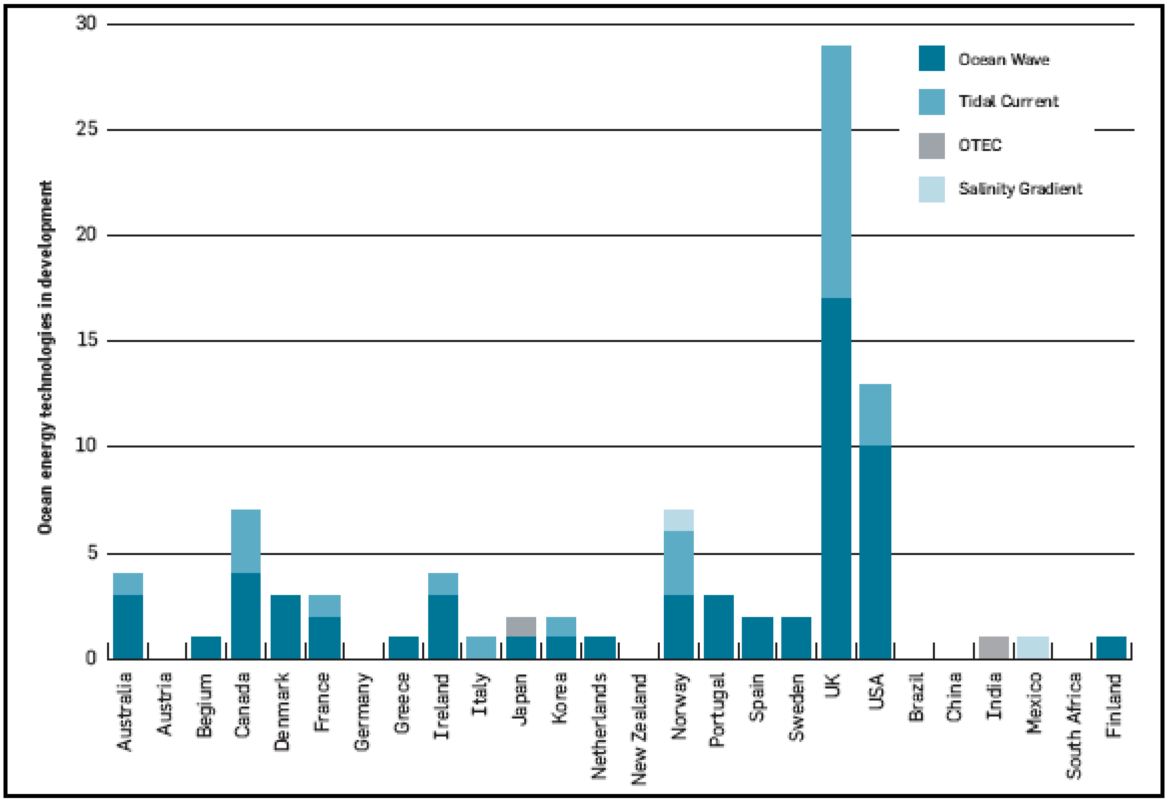

Figure 11: Ocean Energy Technology RD&D projects in March 2006. Source: IEA OES (2007)

Patenting evidence
The results from the patent analysis reveal strongest positions for Norway (Table 36 and Figure 35). This can be explained by the fairly high RD&D funding in this area (Figure 11).

International collaboration
The EU report "The State and Prospects of the European Energy Research" (2006) showed that R&D on wave and tidal energy has been increasingly funded by the EUFPs (Figure 12).

Ocean Technology Paths (Strategically important areas and topics)	EC Funding in					
	FP5			FP6		
	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€	Number of Projects	Eligible Costs in M€	Total EC Contribution in M€
Wave, Tidal	5	7.71	4.45	3	19.91	5.73
Associated RTD (Grid, Drilling)				2	7.47	4.98
Supporting Action	2	3.96	2.40	2	3.40	3.32
Total Ocean	7	11.67	6.85	7	30.78	14.03

Figure 12: Ocean energy research funding in FP5 and FP6. Source: The State and Prospects of the European Energy Research. 2006. Annex VI 1

Sweden

The University of Uppsala has one of Sweden's leading energy research laboratories, the Ångström Laboratory. Here, a new kind of wave energy converter is being developed. The new converter will include a linear generator, adapted to the slow, reciprocal motion of ocean waves. The slow motion under the ocean surface will cause a very limited environmental impact.

A wave power plant has been established outside the West coast of Sweden at Islandsberg. The testing site will be running until 2013–2014.

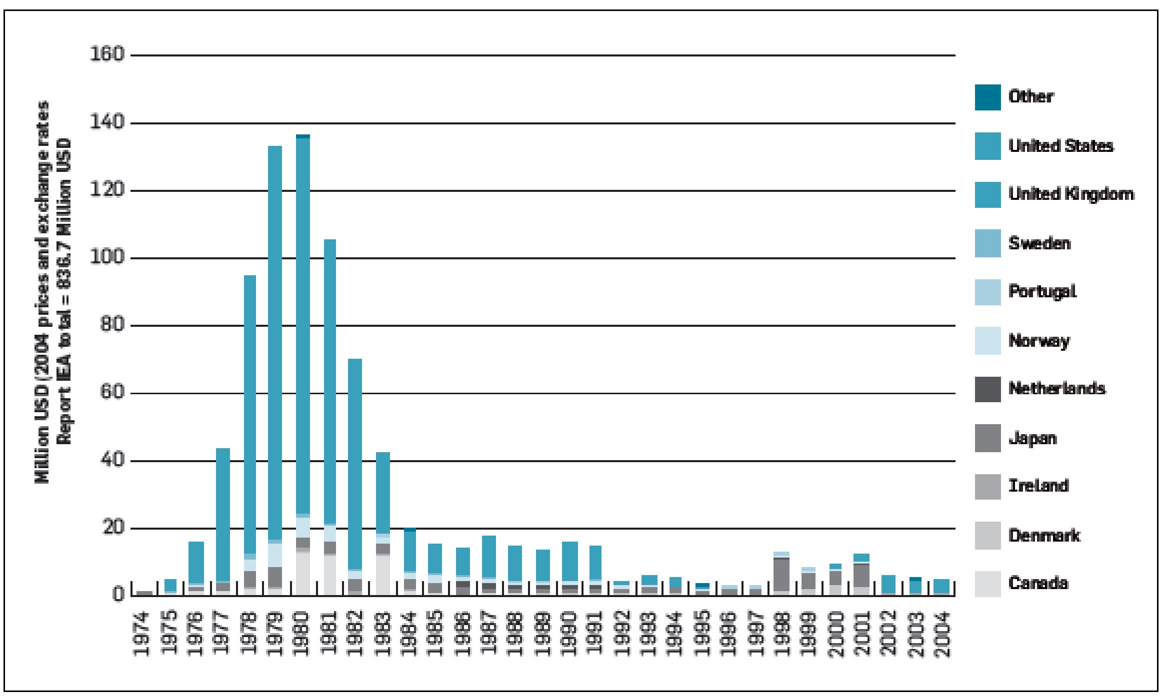

Figure 13: Reported government ocean energy RD&D budgets in IEA member states in 1974–2004. Source: IEA OES Annual Report 2006

Denmark
The wave energy activities in Denmark, the Wave Star and Wavedragon projects, are the main projects at the present time and funded by the state. Aalborg University is particpating in these projects, as well as two Norwegian and other projects.
Other developers are also active in Denmark such as Waveplane, Poseidons Organ and Ramboll and the Danish Wave Energy Association (IEA-OES, 2007).

R&D programmes
In June 2005, the Energy Agency launched a Wave Energy Strategy for Denmark. The strategy was mainly focused on supporting and continuing research, development and trial within already on-going constructions, and new constructions with the precondition that these can demonstrate a technical and economic potential.

In a recent statement to the Energy Policy Committee, the Danish Association for the promotion of Wave Energy concluded that too little is being done to promote the development of wave energy constructions in Denmark. The targets set in the Danish wave energy strategy have been gradually downsized. The Association proposes to make year 2008 the Danish wave energy year.

The Danish Wave Energy Programme 1997–2002 was administered by the Danish Energy Authority (DEA).

Faroe Islands
The Faroe Islands are on the way of becoming first in the Nordic region to generate energy from wave power. The energy company SEV plans to start using the technique by 2010. The project received support from the oil companies ENI and BP within the Faroese Participation Programme (which is part of the first oil exploration licensing round). The Ministry of Petroleum has approved the funding, and the Ministry of Internal Affairs has supported the work within the Environmental Issues Programme.[25]

Norway
There are approximately 15 projects on ocean energy that are funded by the Norwegian government. The total support is approximately NOK15m (€2m), and the total amount spent on ocean energy activities in 2006 is approximately NOK65m (€8 m).

- 60–70% of the projects are concerned with wave power, one project concerns osmotic/salinity power and the rest are based on tidal power.
- Some of the projects relate to technology development and small-scale prototype testing by small development companies.
- Some are larger R&D projects with several project partners.
- There are also ongoing large scale or full-scale prototype projects.

In addition, Norwegian partners are involved in several projects that received support from the EU FP6 programme in 2006 (IEA-OES, 2007).

[25] http://www.sewave.fo/Default.asp?sida=650

Research is currently being carried out at NTNU, SINTEF and IFE on wave energy, tidal energy and salt/salinity power.
The wave energy group at NTNU Department of Physics has been investigating the utilization of ocean waves since 1973. Wave energy is one of several subjects covered in the course Physics and Energy, since the early 1970s.

A number of wave power plats are being planned and constructed in Norway. Norwegian Pelagic Power is planning to install several wave pumps commencing 2007 and plans a full scale installation in 2009.

FO3 is the Norwegian wave project that is mostly developed. Fobox AS finances the project which is located outside Jomfruland in the outer part of the Oslo fjord. Another company is Wave Energy AS that has developed a wave power concept utilizing technologies from the oil sector.
Other Norwegian companies are developing technologies related to ocean power, such as tidal energy, salt power. The Norwegian company Statkraft together with SINTEF have carried out extensive research on salt power. The result is so far a small-scale salt power plant on the Sunndalsøra coast in western Norway and in SINTEF's laboratories in Trondheim. Statkraft has as plans to develop a tidal project outside Tromsø. [26]

WAVEenergy AS is a company based at Aalgard 20 km south of Stavanger, Norway. It was established in April 2004 to develop the Seawave Slot-Cone generator (SSG) concept. WaveEnergy AS currently carries out an EU funded pilot project of the SSG as a wave energy converter at the island of Kvitsøy.

[26] Renewable energy in Norway 2007 www.fornybar.no

2.6 Hydroelectric energy

Hydroelectric power is generated by capturing the kinetic energy of water as it moves from one elevation to a lower elevation by passing it through a turbine. Often, the water is raised to a higher potential energy by blocking its natural flow with a dam. The amount of kinetic energy captured by a turbine is dependent on the head (distance the water is falling) and the flow rate of the water. Another method of capturing the kinetic energy is to divert the water out of the natural waterway, through a penstock and back to the waterway. This allows for hydroelectric generation without the impact of damming the waterway. The existing worldwide installed capacity for hydroelectric power is by far the largest source of renewable energy at 2 993 892 GWh in 2005 (IEA 2008).

Applications

Hydroelectric projects are catagorized upon their size: micro hydro projects are up to 100 kW; systems between 100 kW and 1.5 MW are classified as mini hydro projects; small hydro systems are between 1.5 and 30 MW; medium hydro projects are up to 100 MW: large hydro projects are greater than 100 MW in size. The latter are good resources for baseload power generation because they have the ability to store a large amount of potential energy behind the dam and release it consistently throughout the year. Small hydro projects, generally do not have large storage reservoirs.

Resource Availability

Hydroelectric resource can generally be defined as any flow of water that can be used to capture the kinetic energy of its water. Projects that store large amounts of water behind a dam regulate the release of the water through turbines over time and generate electricity regardless of the season. These facilities are generally base-loaded. Pumped storage hydro plants pump water from a lower reservoir to a reservoir at a higher elevation where it is stored for release during peak electricicity demand periods. Run of the river projects do not impound the water, but instead divert a part or all of the current through a turbine to generate electricity. This technique is used at Niagara Falls to take advantage of the natural potential energy of the waterfall. Power generation at these projects varies according to the seasonal flow. In general, the energy producing potential at any one site is dependent upon the flow rate of the water as well as the hydraulic head.

Environmental Impacts

The damming of rivers for small and large scale hydro applications may result in significant environmental impacts. The first issue involves the migration of fish and disruption of spawning habits. One of the few viable methods coping with this issue is construction of “fish ladders” to aid the fish in bypassing the dam when they swim upstream to spawn. The second issue involves flooding existing valleys that often contain wilderness areas, residential areas, or archeologically significant remains. Related to this point, there are also concerns about the consequences of disrupting the natural flow of water downstream and disrupting the natural course of nature.

In a more positive light, reservoirs resulting from dams may be seen as valuable recreation areas and dams may be seen as assisting in the efforts of flood control, thereby preventing economic hardship to local agriculture and municipalities.

Many environmental groups object to the broad definition of hydroelectric resources as renewable. Numerous classification systems for hydro have developed in attempt to distinguish "renewable" projects. For the most part, this distinction is based on size, although "low-impact," low-head, and run-of-river plants are also often labelled renewable.

Bibliometric and patenting evidence
When comparing the results from the bibliometric and patent analysis the most striking result was that the level of publishing and patenting in both channels of knowledge dissemination diverge widely. The bibliometric study revealed strong positions for Norway and Sweden in that field (compare Figure 50, Figure 52 and Table 46), while the patent study found evidence for patenting almost only in Norway (Table 38, Table 39 and Figure 36).

Finland
The Finnish WEC Member Committee reports that a significant proportion of the natural flows suitable for power production are located in preservation areas (World Energy Council 2007). According to the study *Volume and potential of hydropower in Finland*, 7 400 GWh/annum of the technically exploitable capability (22 600 GWh/annum) is located in conserved water flows. The same study estimates that the following amounts of small-scale (<10 MW) hydropower capacity/generation will be installed during the period to 2020:

- 10 MW (28 GWh/year) in 2005–2010
- 20 MW (48 GWh/year) in 2010–2015
- 53 MW (187 GWh/year) in 2015–2020

The Finnish Government can support the building and production of small-scale hydropower. In practice, investment support has been around 20%, and it has only been granted to plants with a capacity of less than 1 MW. These plants also receive tax subsidies (€4.2/MWh) for the electricity that they produce.

Iceland
Apart from Iceland's geothermal resources, the country's hydropower potential represents virtually its only indigenous source of commercial primary energy. The gross theoretical potential of 184 TWh/year includes 40 TWh of economically exploitable output (World Energy Council 2007). Hydroelectricity production in 2005 was just over 7 TWh, which implies that 17–18% of this economic potential has been exploited. Hydropower provided 16% of Iceland's primary energy consumption and 81% of its electricity generation in 2005. Due to a considerably higher contribution from geothermal power generation, the share of hydro electricity declined to 73% in 2006.

The Kárahnjúkar hydro project in eastern Iceland, will add 690 MW to the existing installed capacity of 1 160 MW. A further 100 MW of hydro capacity is planned. The technically exploitable capability of small-scale hydro plants is reported to be 12.3 TWh/year, equivalent to about 19% of the level for total hydro. Installed capacity of small hydro at the end of –2005 was 53 MW, or 4.6% of total hydro capacity (World Energy Council 2007).

RD&D programmes and organisations
The Hydrological Services Division at the National Energy Authority supplies the power industry, public authorities and others with data and interpretation of the water resources by:

- Operation of a hydrometric network in rivers, lakes, reservoirs and groundwater aquifers
- Monitoring glacial fluctuations, snow balance and climate at high altitudes
- Monitoring water temperatures, sediment load and other physical and chemical properties of water
- Bathymetry of lakes
- Monitoring the ice cover of rivers and lakes during winter
- Developing and maintaining a database on hydrological data and a GIS-based register of rivers, lakes and glaciers
- Scientific processing, evaluation, and publication of basic hydrological data
- Research and development in the field of water resources and hydrology
- Cooperation with the "WMO Commission of Hydrology" and with sister institutes abroad.

Latvia

Although its hydro potential is quite modest – a gross theoretical capability of only about 7 TWh/year – Latvia is of interest for its rapid development of small-scale hydro plants in recent years. Beginning in 1992, after Latvia had regained its independence, a period of reconstruction and building of small hydropower stations ensued. This was largely stimulated by the regulations adopted by the Government on the purchase of electric energy produced in small power plants which, in effect, subsidised the production of electric energy in such stations. In 1996 there were only 16 small hydro stations which generated 4.5 GWh. By 1999, the number in service had increased to 53 and annual generation to 15 GWh. By 2005, the number in service was 140 and annual generation 61 GWh. The total gross generating capacity of Latvia's existing hydro power plants is 1 561 MW, comprised of the following:

Table 5: The total gross generating capacity of Latvia's existing hydro power plants

Plant	Capacity (MW)	Number of units /plants
Plavinas HPP	869	10 units
Kegums HPP-1	72	4 units
Kegums HPP-2	192	3 units

Riga HPP	402	6 units
Small hydro	26	149 plants
Total	1 561	

The Latvian WEC Member Committee notes that new (and not yet approved) Regulations of the Cabinet of Ministers on support of renewable energy (RES-E) sources assume the following utilisation of hydropower up to 2010:

Table 6: Planned development for hydropower in Latvia 2007–2010

	2007	2008	2009	2010
Large hydro > 5 MW				
Share in energy balance, pct	41.28	39.21	37.25	35.39
Annual generation, GWh	1 535	1 535	1 535	1 535
Capacity, MW				
Small hydro < 5 MW				
Share in energy balance, pct	1.04	1.26	1.47	1.64
Annual generation, GWh	68	87	107	125
Capacity, MW	27	35	43	50

The guidelines for the utilisation of RES-E estimate the overall economic potential of small hydro power plants up to 2025 as in the range of 150 to 300 GWh per year. Energy development forecasts of the Latvian power system to 2025 consider the possible construction of new hydro power plants at the river Daugava: Daugavpils HPP (100 MW) and Jekabpils HPP (30 MW).

Lithuania

The Lithuanian WEC Member Committee reports that the construction of large-scale hydro power plants is not contemplated at present owing to environmental and other restrictions. The planned capacity of small-scale HPPs to be constructed by 2010 is about 6 MW. The Government has approved a regulation (No. 1 474: Procedure for the Purchasing of Electricity Generated from Renewable and Waste Energy Sources). According to this regulation, generation is promoted in small-scale HPPs, and feed-in tariffs (€0.0579/kWh) are applied to the purchase of electricity generated by such power plants.

Norway

Norway possesses Western Europe's largest hydro resources, both in terms of its current installed capacity and of its economically feasible potential. *Hydropower & Dams World Atlas 2006* (HDWA 2006) reported a gross theoretical capability of 560 TWh/year, of which 187 TWh was economically exploitable. The hydro generating capacity installed by the end of 2005 had an output capability equivalent to about two-thirds of the economic potential. Actual hydro output in 2005 was around 136.6 TWh, providing virtually all (98.9%) of Norway's electric power generation. That is the highest share in the world according to IEA Key World Energy Statistics 2007. Two major HPPs were under construction at end–2005: new Tyin power plant (1462 GWh) and Øvre Otta (525 GWh). A further 859 MW was licensed for development. The economically exploitable capability applicable to small-scale hydro schemes was reported to be 9 TWh/year, equivalent to 5% of the overall level. Installed capacity of small hydro plants totalled about 1 000 MW at end–2005 with an average annual output capability of 5 TWh.

RD&D programmes and organisations

Norwegian expertise in this field is concentrated at the Norwegian University of Science and Technology (NTNU) in Trondheim, Department of Hydraulic and Environmental Engineering at the Faculty of Engineering Science and Technology. Researchers at the University of Oslo specialise in analysing environmental consequences of hydropower stations for fish resources. The research institute SINTEF Energy Research has been involved in many projects related to turbines for hydropower plants. This work has either been done directly for the power generation companies or for their sectoral organization.[27]

Fundamental Energy Research

Fundamental Energy Research (1996–2000) was a strategic research programme organised by the RCN. The main target areas were renewable energy resources and hydropower. Relevant projects were related to the hydrologic, biological and environmental impact of hydropower.

RENERGI

Renewable energy production is the top priority within RENERGI and one of the main goals is that Norway will continue to be a world leader in hydropower expertise. One special target area regarding hydropower is the optimisation and environment-friendly development of hydropower installations (compare RENERGI – Clean energy for the future: Work Programme 2004–2013).

Research supporting government administration of the water resources

The Norwegian Water Resources and Energy Directorate (NVE) takes part in R&D and international cooperative efforts in fields related to hydropower and is the national competence authority on hydrology.

Sweden

Sweden has one of the highest hydro potentials in Western Europe: the Swedish WEC Member Committee reports a gross theoretical capability of 130 TWh/year, of which 85 TWh is currently economically exploitable. The average annual capability of the 16,100 MW hydro capacity installed at the end of 2005 was 65 TWh, about 76% of the economic potential. Actual hydro output in 2005 was 73 TWh, which provided nearly half (46%) of Sweden's electricity generation. The construction of new hydro plants has virtually ceased on account of environmental and political considerations. Future activity is likely to be very largely confined to the modernisation and refurbishment of existing capacity. There is 985 MW of small-scale hydro capacity installed, which generated a total of 3.8 TWh in 2005.

[27] For further information see: http://www.sintef.no/content/page1____3345.aspx

RD&D programmes and organisations

As a consequence of the demands in the EU water directive and the Swedish environmental quality targets, the Swedish Energy Agency in association with Elforsk, The Swedish Board of Fisheries and the Swedish Environmental Protection Agency initiated the 'Hydropower Programme – Environmental impacts, measures and costs in presently regulated waters'. The aim of the programme is to formulate knowledge and measures for an environmentally friendly and effective use of hydropower. The programme commenced in 2000 and will last until 2010. The Swedish Centre for Hydropower (Svenskt VattenKraftCentrum - SVC) aims at securing the knowledge and competence supply for Sweden, for an efficient and reliable hydropower production and for maintaining safety in the dam operations. The Centre is funded by the Swedish Energy Agency, other government agencies, by industry and by several Universities. SVC is mainly working within two competence areas:

- Hydraulic Engineering (Royal Institute of Technology and Luleå Technical University)
- Hydro turbines and generators (Luleå Technical University, Chalmers Technical University and Uppsala University).

3. International patterns of co-operation

3.1 Nordic Energy Research Project portfolio 2003–2010

Nordic Energy Research (NER) is an institution under the Nordic Council of Ministers. It was started as a programme in 1985 and acquired the status of an institution in 1999 (Holst Jørgensen, 2008). Acording to Holst Jørgensen NER shall contribute to following policy tasks: capacity and competence development, industry development and innovation, support for policy processes and international networking. NER is obliged to develop the cooperation with the adjacent areas and the European Research Area (ERA).

The analysis of the portfolio of NER was based on the published project portfolios in the reports published by NER (NER, 2006 and 2006a). The analysis does not cover the Noria policy projects started in 2007. Further information on these projects is available in the Annual report for 2007.

Table 7: Nordic Energy Research Project portfolio 2003–2010: Main subject fields. Source: NER

	Number of projects	Sum project years	Total budget in million NOK	NER funding in million NOK	Share of NER funding
Bio-fuel	4	15	53.3	37.0	69%
Building	1	3	1.3	0.7	54%
CCS	1	5	15.6	13.3	85%
Efficiency	1	4	10.7	8.0	75%
Fuel cells	2	6	10.6	5.8	55%
General	5	18	44.5	34.3	77%
Hydrogen	8	33	59.9	37.9	63%
Market	5	16	29.0	20.4	70%
Solar heating	1	4	13.8	7.7	56%
Solar PV	2	8	25.0	22.4	90%
Wind	2	8	16.8	9.9	59%
	32	120	280.5	197.4	70%

The 32 projects listed in NER reports have been grouped into different subject fields (Table 7 and Figure 14). The subject field with the highest share of funding and also largest number of projects is hydrogen technology, followed by bio-fuels and solar PV. In addition should be mentioned the category “general”, where projects have been grouped including “Impacts of Climate Change on Energy”, “Climate and Energy Systems” and “Nordic Energy, Environmental Constraints and Integration”, and others. If we combine this group with the projects under the market category the result is large groups of projects that are mainly social science and policy-oriented, while the other groups are more or less technology-oriented projects.

All projects require co-funding, but the share of NER funding for the projects varies. The highest proportion of total costs made by NER funding was to solar PV projects (90%) and CCS (85%). The lowest proportions of NER funding were to building (54%), fuel cells (55%), solar heating (56%) and wind (59%) (Table 7).

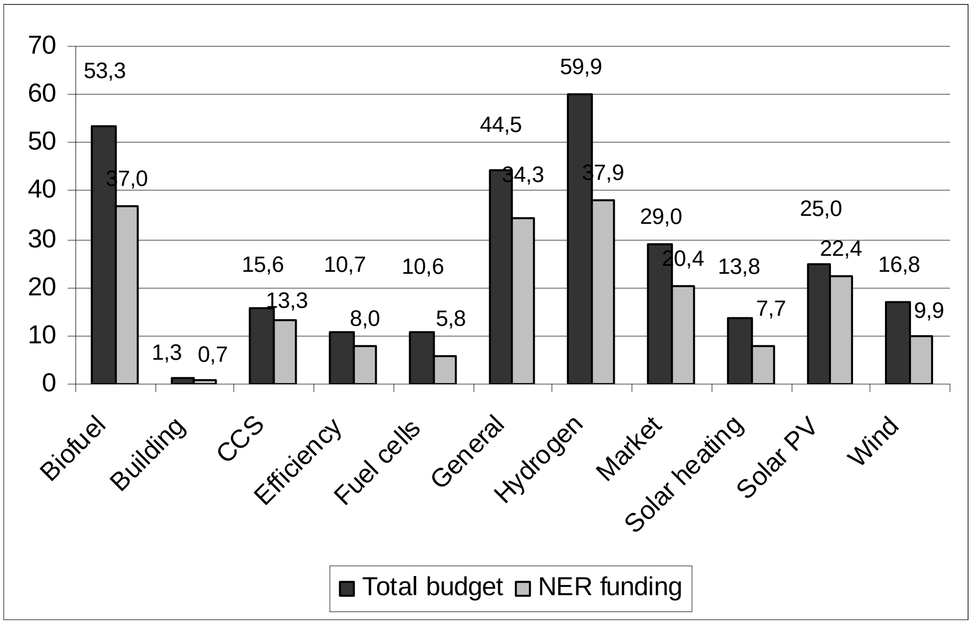

Figure 14: Nordic Energy Research Project portfolio 2003–2010: Budget of main subject fields in million NOK. Source: NER

The projects are mostly collaborative projects, involving participants from different Nordic, Baltic and some other countries. Summing up, the weighted shares of the participating countries give an indication of the distribution of project activities funded by the NER (Table 8 and Figure 15). The countries with the highest shares are Norway (29.2%), Sweden (20.5%) and Denmark (20%), followed by Finland (15.8%) and Iceland (6%). The shares of the Baltic countries and Russia were between 1.7% (Lithuania) and 2.2% (Estonia). The share of the non-Nordic countries is 8.5% altogether.

Table 8: Nordic Energy Research Project portfolio 2003–2010: Sum of weighted shares of projects by country in per cent. N=32. Source: NER

Country	Total	Weighted share
NO	9.4	29.2%
SE	6.6	20.5%
DK	6.4	20.0%
FI	5.0	15.8%
IS	1.9	6.0%
EE	0.7	2.2%
RU	0.6	1.9%
LV	0.6	1.8%
LT	0.6	1.7%
BE	0.1	0.3%
AU	0.1	0.3%
UK	0.1	0.3%
Total	*32.0*	*100%*

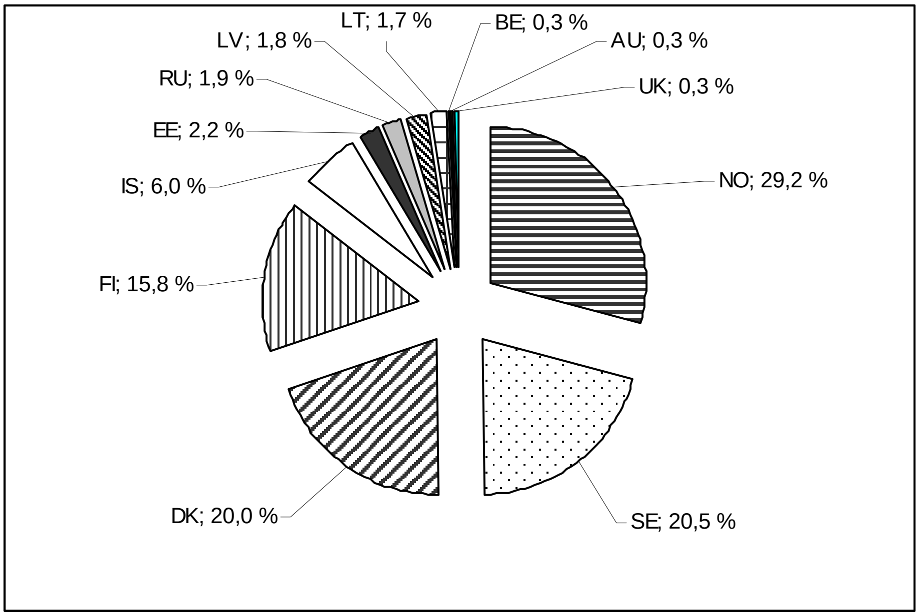

Figure 15: Nordic Energy Research Project portfolio 2003–2010: Sum of weighted shares of projects by country in per cent. Source: NER

The main organisations that have received funding from NER are listed in Table 9 based on absolute numbers of projects and Table 10 based on weighted shares. The main organisations from Denmark are the DTU and Risø National Laboratory (now part of DTU); from Norway, the NTNU, the Institute of Energy Technology and SINTEF, from Sweden Uppsala University and Chalmers University of Technology, and from Finland Helsinki University of Technology and VTT.

Table 9: Nordic Energy Research Project portfolio 2003–2010: Main project organisations funded sorted by numbers of projects with at least 2 projects. Source: NER

Project organisation	Country	Absolute numbers
1. Helsinki University of Technology	FI	8
2. Institute of Energy Technology	NO	8
3. NTNU	NO	8
4. Risø	DK	8
5. Technical University of Denmark	DK	8
6. VTT	FI	8
7. SINTEF	NO	7
8. University of Iceland	IC	7
9. Uppsala University	SE	6
10. Chalmers University of Technology	SE	5
11. University of Oslo	NO	5
12. Elforsk	SE	4
13. Copenhagen University	DK	3
14. ECON	NO	3
15. Helsinki School of Economics	FI	3
16. Lund University	SE	3
17. Riga Technical University	LV	3

18. Statkraft	NO	3
19. Stockholm School of Economics	SE	3
20. Stockholm University	SE	3
21. Tallinn University of Technology	EE	3
22. Tampere University of Technology	FI	3
23. University of Bergen	NO	3
24. Åbo Akademi	FI	2
25. COWI A/S	DK	2
26. Danish Technological Institute	DK	2
27. Göteborg University	SE	2
28. H2 Logic	DK	2
29. IRD Fuel Cells	DK	2
30. Linköping University	SE	2
31. Norwegian Institute of Water Research	NO	2
32. Orkustofnun	IS	2
33. Roskilde University	DK	2
34. Royal Veterinary and Agricultural University	DK	2
35. St. Petersburg State University	RU	2
36. Statistics Norway	NO	2
37. Statoil	NO	2

Table 10: Nordic Energy Research Project portfolio 2003–2010: Main project organisations funded sorted by the sum of weighted shares of projects with at least 1 per cent. N=32. Source: NER

Project organisation	Country	Weighted shares
1. NTNU	NO	5,5%
2. Technical University of Denmark	DK	5,1%
3. SINTEF	NO	4,2%
4. Helsinki University of Technology	FI	4,1%
5. Risø	DK	4,0%
6. Chalmers University of Technology	SE	3,8%
7. VTT	FI	3,8%
8. Institute of Energy Technology	NO	3,7%
9. University of Iceland	IC	3,0%
10. University of Oslo	NO	2,7%
11. Uppsala University	SE	2,5%
12. Elforsk	DK	1,9%
13. Statkraft	NO	1,7%
14. Åbo Akademi	FI	1,6%
15. Lund University	SE	1,6%
16. Copenhagen University	DK	1,5%
17. Helsinki School of Economics	FI	1,5%
18. Stockholm School of Economics	SE	1,5%
19. Tallinn University of Technology	EE	1,5%
20. ECON	NO	1,3%
21. H2 Logic	DK	1,3%
22. Tampere University of Technology	FI	1,3%
23. Riga Technical University	LV	1,2%
24. University of Bergen	NO	1,2%

25. Danish Technological Institute	DK	1,1%
26. Stockholm University	SE	1,1%
27. Linköping University	SE	1,0%
28. Statistics Norway	NO	1,0%

Conclusions

Nordic Energy Research is a limited but very dedicated policy instrument under the Nordic Council of Ministers for supporting energy research and development in the Nordic and Baltic region. The fields of support show a clear focus on new renewable energy technologies. Interesting is also the high share of policy projects that address political and economic needs for changing the existing energy systems. NER has contributed to improved collaboration between the Nordic and Baltic R&D organisations in the field and has triggered considerable co-funding from other sources. In addition to public R&D institutions, the projects also include those managed by R&D intensive firms.

3.2 EU FP5 Non-nuclear Energy research projects

The participation in ENERGY under EU FP6 can be compared according to level of funding (Figure 16). The countries receiving most funding are Germany, France, the Netherlands and the UK. Among the Nordic countries are Sweden and Denmark especially successful.

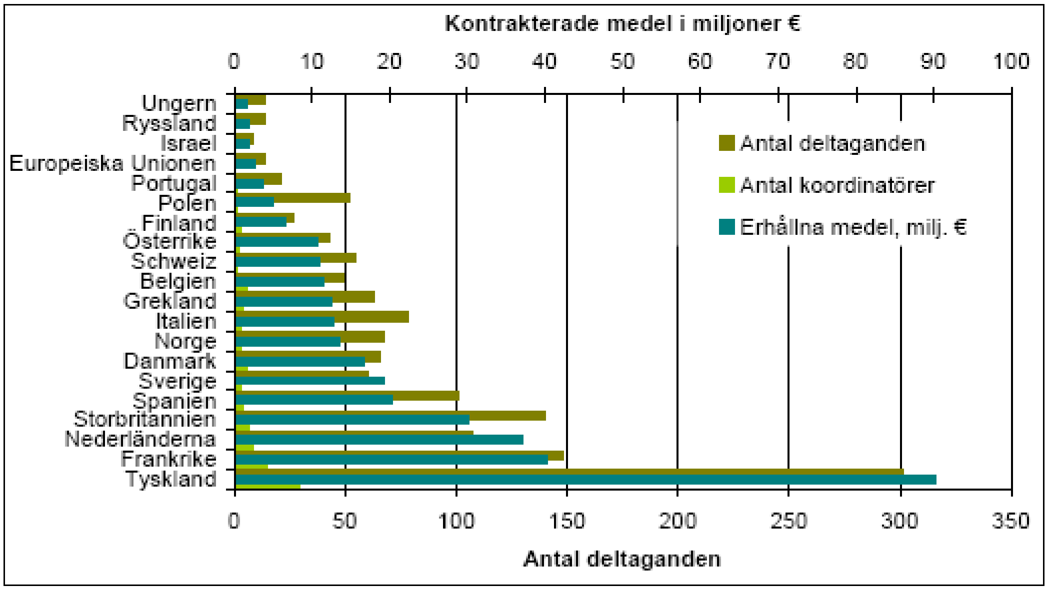

Figure 16: Participation in ENERGY under EU FP6 of the 20 countries receiving most funding. Source: VINNOVA (2007)

In the following an overview is given of EU-collaboration using project data from the 5th Framework programme (EU FP5) based on Cordis' project information database. In the chapter about the selected technologies findings about EU FP5 and FP6 have been given that were published in the report "The State and Prospects of the European Energy Research".

Size and scope of Non-nuclear energy research by weighted shares in the project networks

Collaboration under the 5th Framework programme (EU FP5) can be measured by the number of projects–the scope of energy research–and by the eligble costs - the size of the projects (Table 11 and Table 12). Whenn comparing the ranking based on numbers of projects and eligble costs can be found some differences: Denmark, Sweden and Finland are higher ranked on elible costs than on number of projects, while the opposite is the case for Finland, Iceland and the Baltic countries. This can be explained with the rather high cost level in the Scandinavian countries.

Table 11: Number of projects in Non-nuclear energy research under the EU FP5 by country. All countries with a share of at least one project. Weighted shares (N=971)

Country	Number of projects
1. DE	153.01
2. UK	115.05
3. FR	86.86
4. ES	73.92
5. NL	72.89
6. IT	62.30
7. DK	46.62
8. GR	39.32
9. SE	34.44
10. AT	31.99
11. BE	31.52
12. NO	27.86
13. PL	27.58
14. FI	20.85
15. PT	20.45
16. CH	15.67
17. IE	12.49
18. CZ	9.23
19. RO	8.84
20. BG	8.61
21. SI	8.06
22. HU	7.55
23. SK	6.11
24. IL	6.09
25. EE	5.43
26. LT	4.92
27. CN	4.86
28. CY	3.78
29. LV	3.61
30. RU	2.58
31. IN	2.11
32. ZA	1.48
33. US	1.34
34. IS	1.10
35. LU	1.06
36. BW	1.00
37. CL	1.00
38. EC	1.00

Table 12: Size of projects in Non-nuclear energy research under the EU FP5 by country. Listed all countries with at least €0.85m. Eligble costs (€2 355.5m)

Country	Eligble costs in million euro
1. DE	364.54
2. UK	293.21
3. FR	225.22

4. ES	218.46
5. NL	192.68
6. DK	174.48
7. IT	141.70
8. SE	119.77
9. BR	92.45
10. NO	89.27
11. AT	82.47
12. GR	75.44
13. BE	49.65
14. CH	45.15
15. FI	38.85
16. PT	29.71
17. IE	21.18
18. PL	17.01
19. SI	13.81
20. HU	12.88
21. CZ	11.30
22. IL	9.43
23. LU	5.61
24. RO	3.92
25. BG	3.57
26. LT	2.62
27. SK	2.62
28. US	2.16
29. CY	1.96
30. EE	1.78
31. LI	1.38
32. CA	1.21
33. RU	1.16
34. MT	0.87
35. LV	0.85
36. CN	0.74
37. IN	0.72
38. AU	0.70
39. IS	0.68

Number of projects with Nordic or Baltic participation

Comparing the absolute number of projects in which the Nordic and Baltic countries have participated (Table 13), the analysis show a leading position for Denmark with 195 projects, followed by Sweden (176), Norway (103) and Finland (86). The Baltic countries have participated in a number of projects – between 16 and 22, while for Iceland there was evidence just for 4 projects.

Table 13: Number of EU FP5 projects in non-nuclear energy by country. Source: Cordis

Country	Number of projects
DK	195
EE	22
FI	86
IS	4
LT	17
LV	16
NO	103
SE	176

Important Nordic and Baltic R&D organisations

In the following tables a list of the institutions funded under EUFP5 Energy are given, including the numbers of projects these institutions have been involved in (Table 14 to Table 21). The most important institutions for each country are as follows.

- Denmark: Risø National Laboratory (now part of the DTU) and the DTU
- Finland: the VTT
- Norway: Norsk Hydro, NTNU, Statoil (now StatoilHydro) and SINTEF
- Sweden: KTH and Lund University
- Estonia: Tallinn Technical University
- Latvia: the Institute of Physical Energetics
- Lithuania: the Lithuanian Energy Institute.
-

The strong role of industry players among the Norwegian institutions is especially noteable.

Table 14: Denmark. Source: Cordis

Organisations	Number of projects
RISØ NATIONAL LABORATORY	42
TECHNICAL UNIVERSITY OF DENMARK	26
ELSAM A/S	13
CENERGIA ENERGY CONSULTANTS APS	11
DANISH TECHNOLOGICAL INSTITUTE	10
ESBENSEN CONSULTING ENGINEERS	8
FLS MILJOE A/S	8
GEOLOGICAL SURVEY OF DENMARK AND GREENLAND	8
NEG MICON A/S	5
TECH-WISE A/S	5
VESTAS WIND SYSTEMS A/S	5
DANISH ENERGY AGENCY	4
GREEN CITY DENMARK A/S	4
DANISH BUILDING AND URBAN RESEARCH	3
ENERGI E2 A/S	3
GRAM & JUHL APS	3
LM GLASFIBER A/S	3

Table 15: Finland. Source: Cordis

Organisations	Number of projects
VTT - TECHNICAL RESEARCH CENTRE OF FINLAND	42
HELSINKI UNIVERSITY OF TECHNOLOGY	7
FORTUM CORPORATION	6
FOSTER WHEELER ENERGIA OY	6
AABO AKADEMI UNIVERSITY	5
MOTIVA OY	4
FINNISH METEOROLOGICAL INSTITUTE	3
KVAERNER	3
NAPS SYSTEMS OY	3

Table 16: Iceland. Source: Cordis

Organisations	Number of projects
ICELAND NEW ENERGY LTD	1
ICELANDIC NATIONAL POWER COMPANY	1
RANNSOKNASTOFNUN LANDBUNADARINS	1
THE ICELANDIC BIOMASS COMPANY EHL	1
UNIVERSITY OF ICELAND	1
VAG LTD.	1
VIRKIR ENGINEERING GROUP HF	1

Table 17: Norway. Source: Cordis

Organisations	Number of projects
NORSK HYDRO	24
NORWEGIAN UNIVERSITY OF SCIENCE AND TECHNOLOGY	20
STATOIL ASA	19
SINTEF	17
INSTITUTE FOR ENERGY TECHNOLOGY	10
DET NORSKE VERITAS A/S	8
RF - ROGALAND RESEARCH	6
SCANWAFER AS	4
GEOLOGICAL SURVEY OF NORWAY	3
PROTOTECH AS	3
STATKRAFT SF	3

Table 18: Sweden. Source: Cordis

Organisations	Number of projects
KTH - KUNGLIGA TEKNISKA HOEGSKOLAN	23
LUND UNIVERSITY	21
SWEDISH ENERGY AGENCY	12
VOLVO	12
VATTENFALL AB	11
ALSTOM POWER SWEDEN AB	9
SYDKRAFT AB	8
TPS TERMISKA PROCESSER AB	7

UPPSALA UNIVERSITY	7
CATELLA GENERICS AB	5
CITY OF STOCKHOLM	5
SCANARC PLASMA TECHNOLOGIES AB	4
SP SWEDISH NATIONAL TESTING AND RESEARCH INSTITUTE	4
THE SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES	4

Table 19: Estonia. Source: Cordis

Organisations	Number of projects
TALLINN TECHNICAL UNIVERSITY	10
AS TERMOX	2
ESTIVO AS	2
ESTONIAN FOUNDATION OF EUROPEAN UNION EDUCATION AND RESEARCH PROGRAMMES	2
ESTONIAN POWER AND HEAT	2

Table 20: Latvia. Source: Cordis

Organisations	Number of projects
INSTITUTE OF PHYSICAL ENERGETICS, LATVIAN ACADEMY OF SCIENCES	7
EKODOMA	4
RIGA TECHNICAL UNIVERSITY	3
LATVIA DEVELOPMENT AGENCY ENERGY DEPARTMENT	2

Table 21: Lithuania. Source: Cordis

Organisations	Number of projects
LITHUANIAN ENERGY INSTITUTE	9
SAULES ENERGIJA - CLOSE JOINT STOCK COMPANY	2
UZDAROJI AKCINE BENDROVE NAMU PRIEZIUROS CENTRAS	2

Share of collaborating countries

In 419 projects Nordic and Baltic institutions have been involved. These projects have been based on collaboration with institutions from allover Europe and the rest of the world (Figure 17). Most important collaboration partners were Germany, the UK, the Netherland, France, Italy, Spain, Greece, Belgium and Austria.

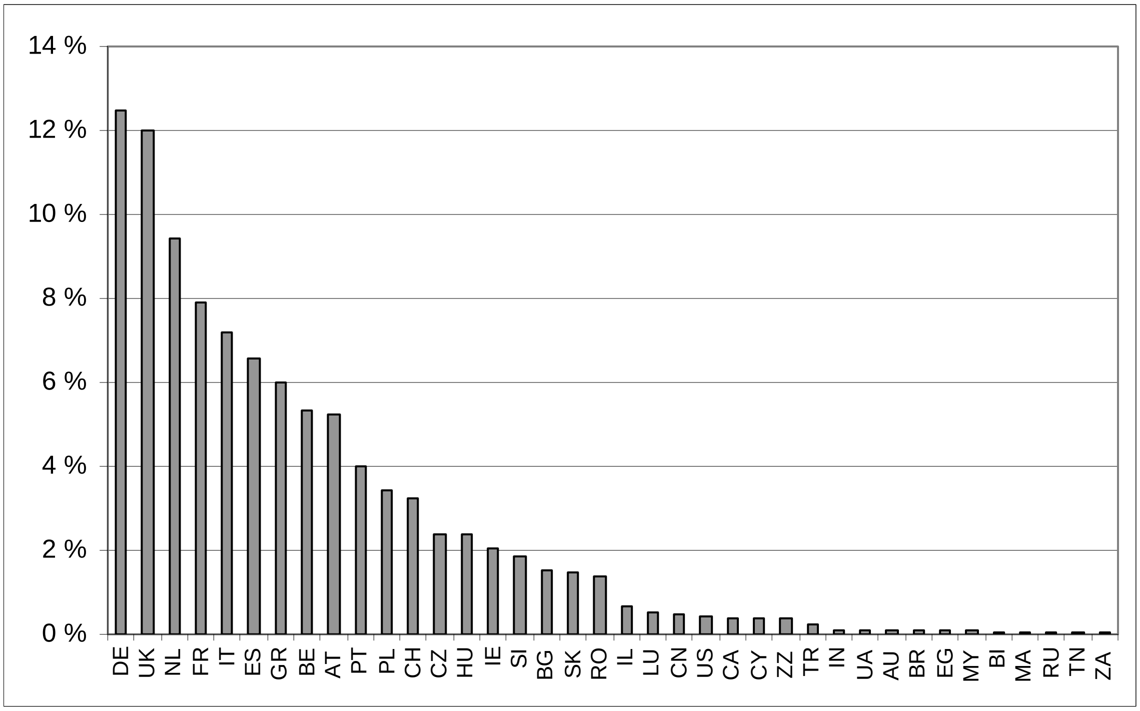

Figure 17: Projects of the Nordic and Baltic countries (N=419): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

The following figures give an indication on the collaboration partners of the different Nordic and Baltic countries (Figure 18 to Figure 25, Table 22). What can be concluded from these figures? Denmark and Sweden follow the same pattern of collaboration as described above, and the collaboration between these countries is rather important, but the collaboration with Norway is less important. Finland follows a similar pattern as Denmark and Sweden and has rather limited collaboration with Norway. For Norway the UK is most important, but the collaboration with Sweden and Denmark is quite high. The Baltic countries have different collaboration patterns. They collaborate to a higher degree with East European countries than the Nordic countries. They have a rather good collaboration with Denmark, Sweden and Finland, but almost no collaboration with Norway.

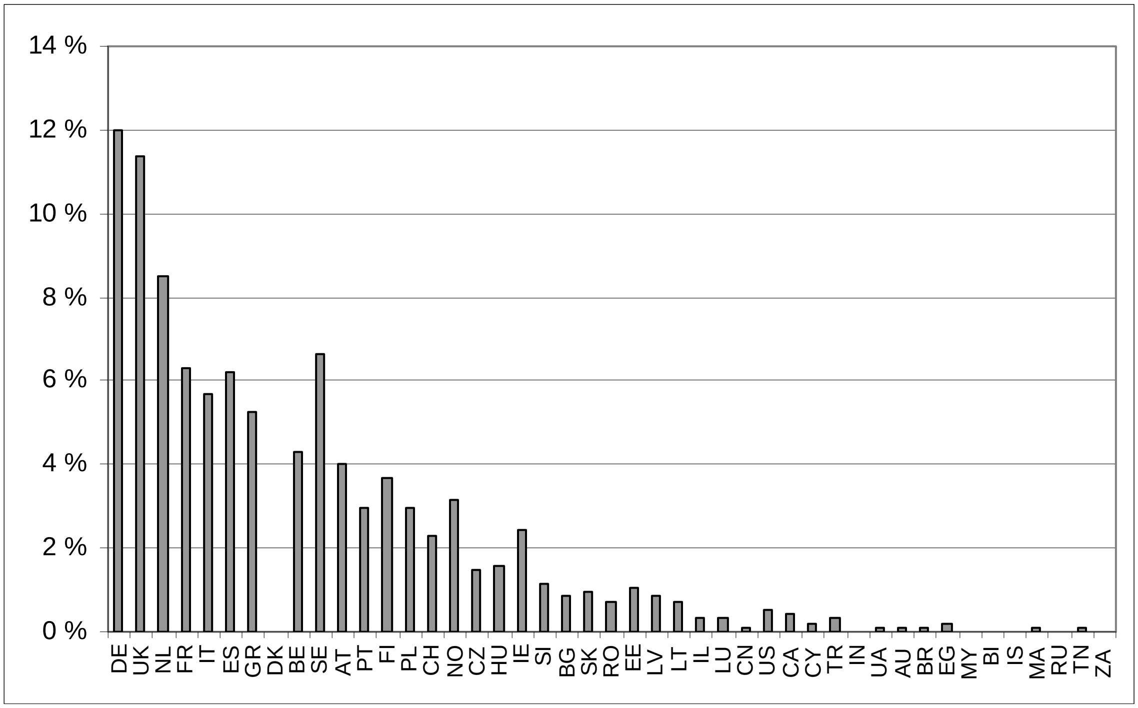

Figure 18: Danish projects (N=195): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

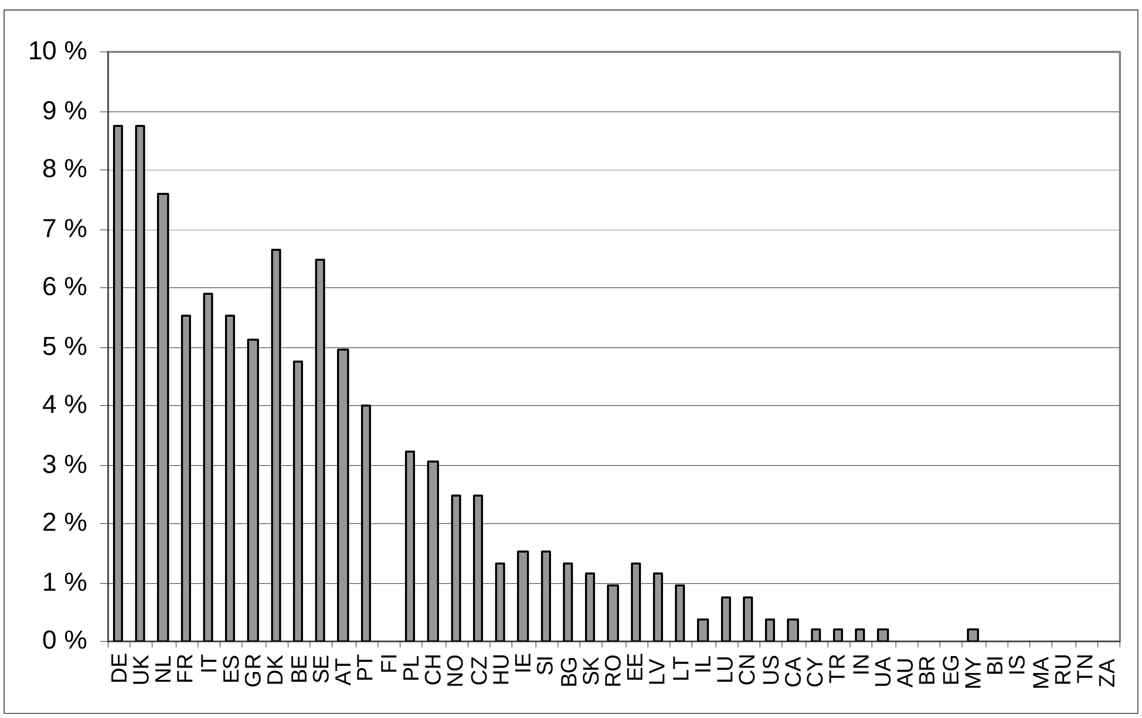

Figure 19: Finnish projects (N=86): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

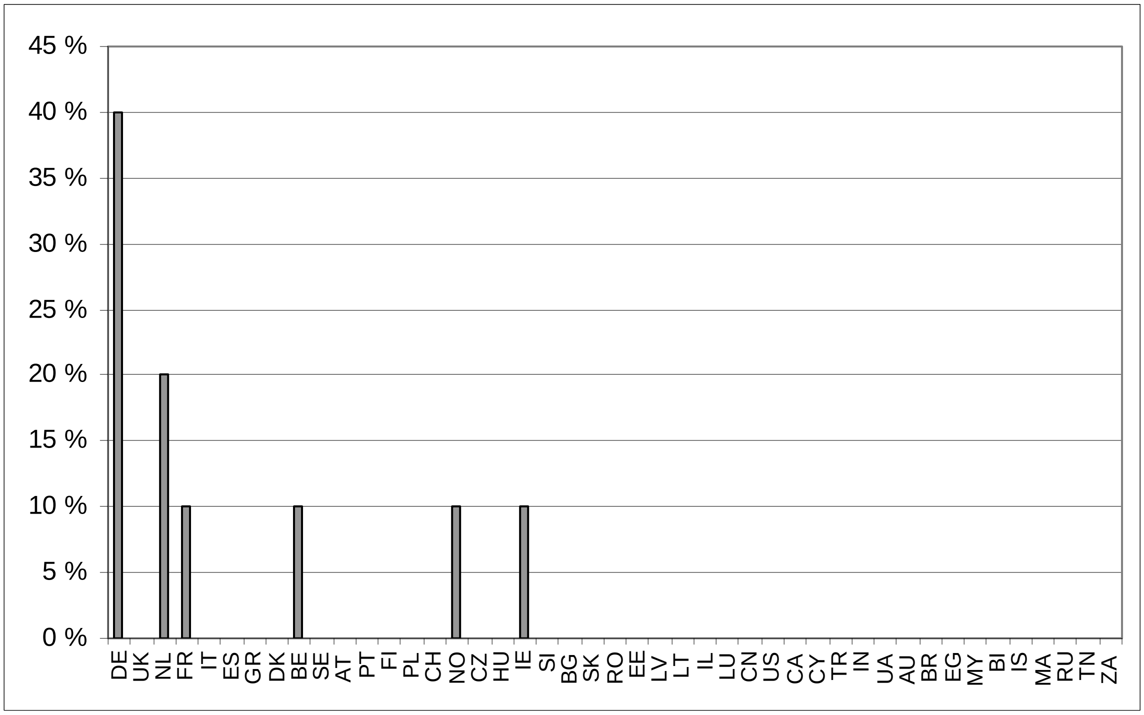

Figure 20: Icelandic projects (N=4): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

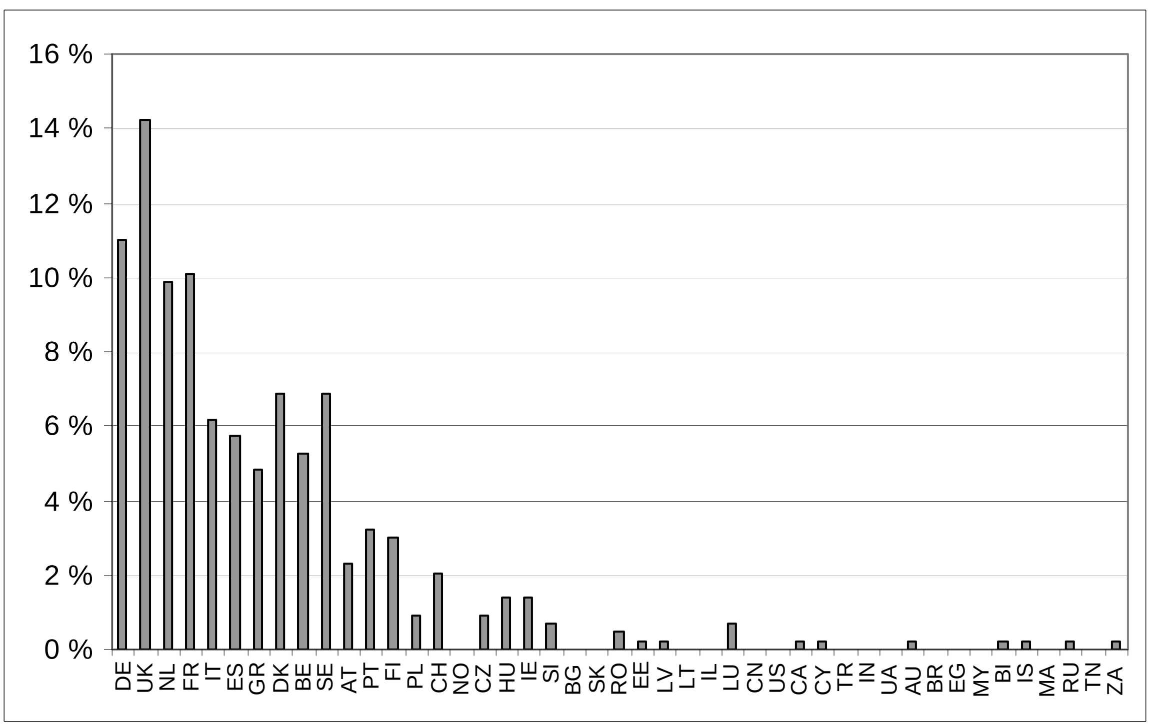

Figure 21: Norwegian projects (N=103): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

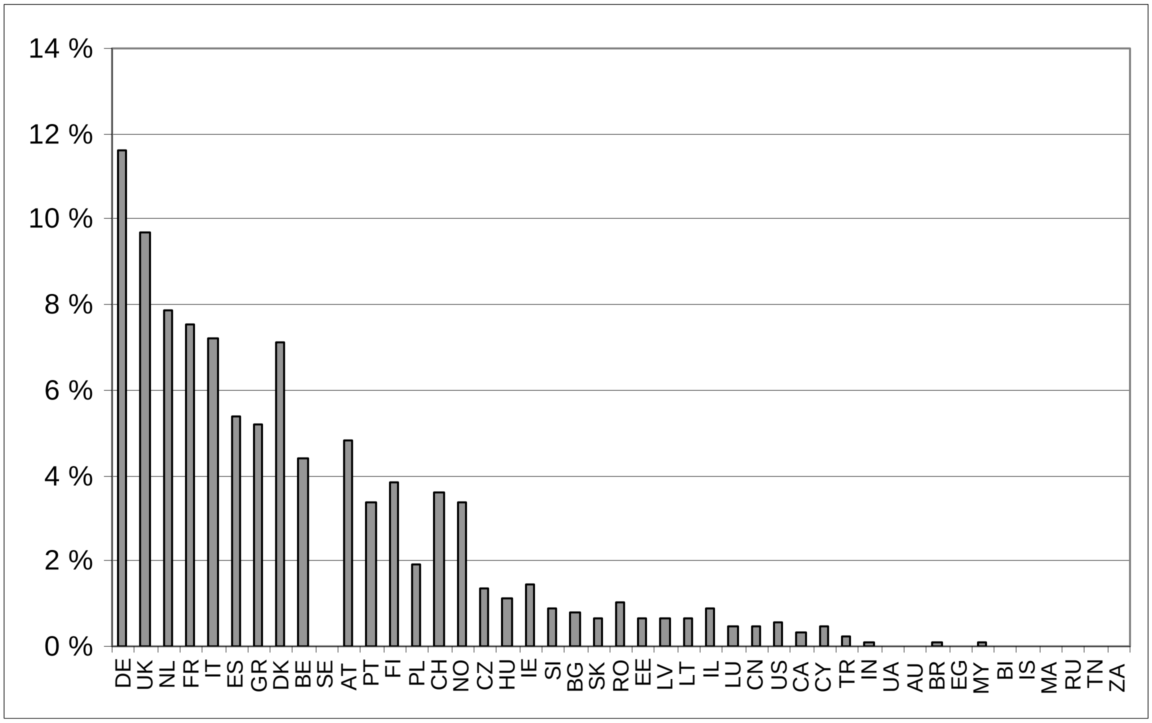

Figure 22: Swedish projects (N=176): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

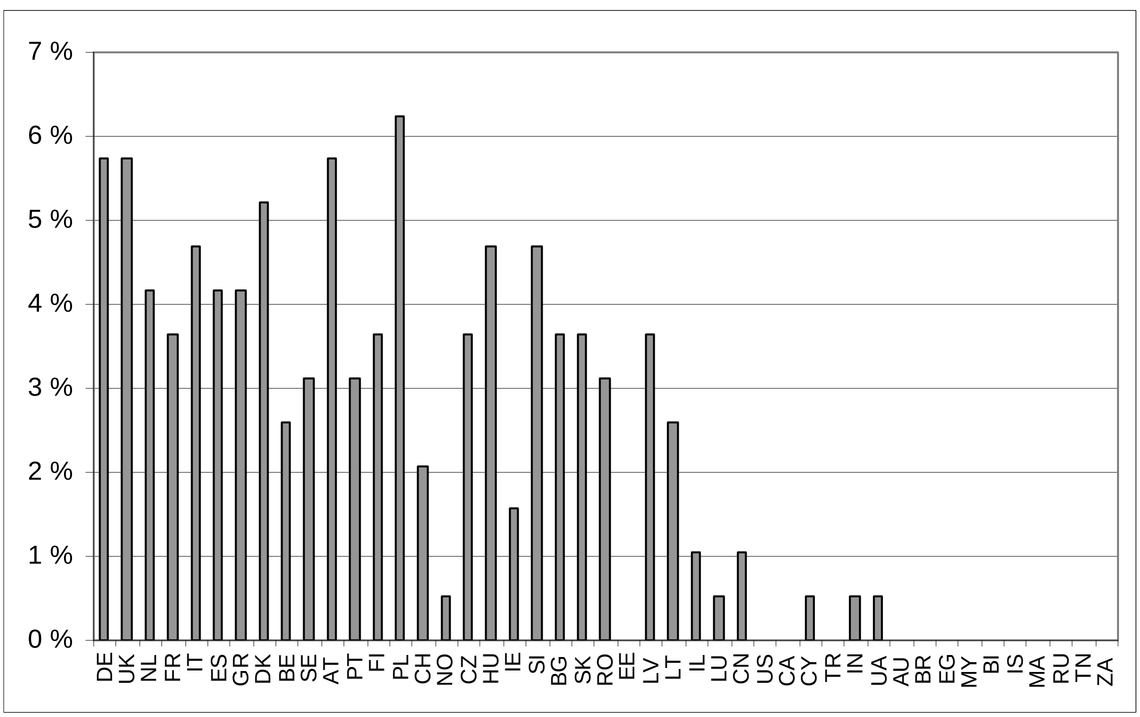

Figure 23: Estonian projects (N=22): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

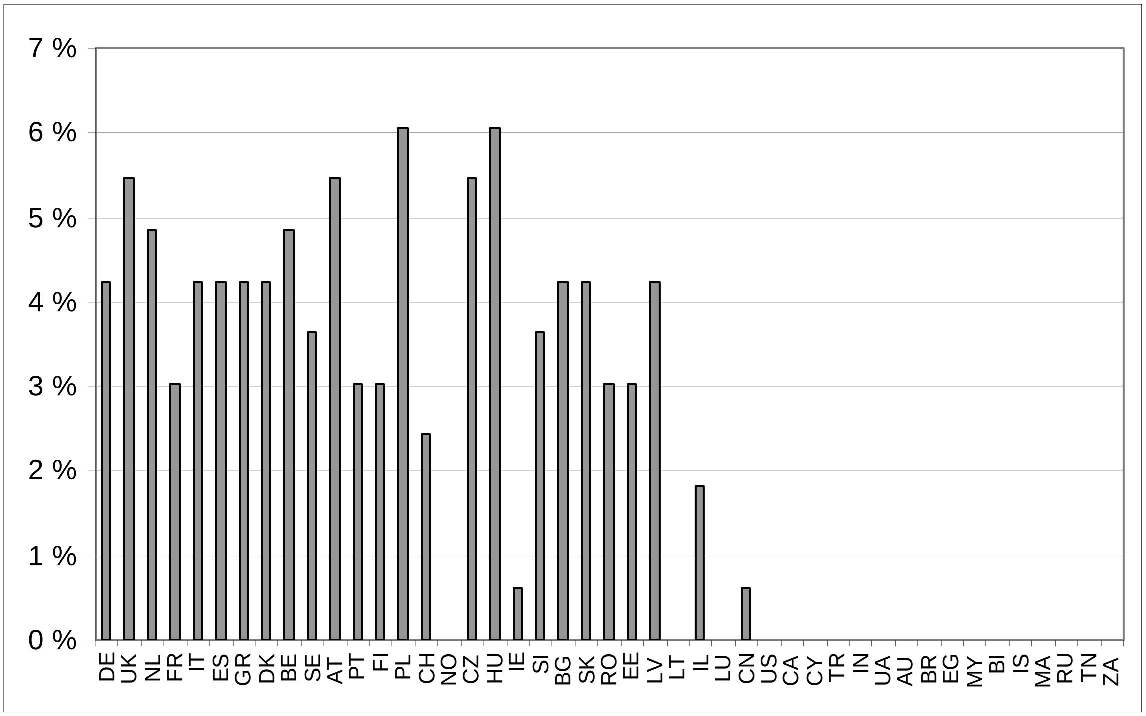

Figure 24: Lithuanian projects (N=17): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

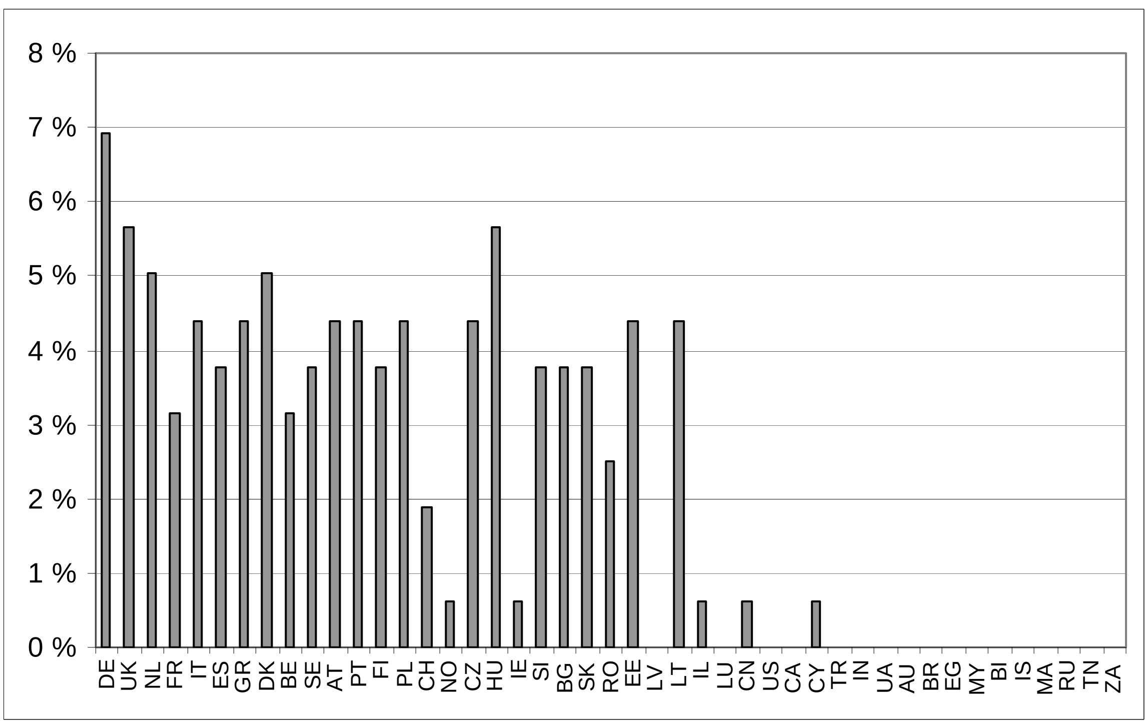

Figure 25: Latvian projects (N=16): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

Table 22: Nordic and Baltic projects (N=419): Share of collaborating countries in non-nuclear energy projects under EU FP5. Source: Cordis

	All Nordic & Baltic	DK	EE	FI	IS	LT	LV	NO	SE
N=	*419*	*195*	*22*	*86*	*4*	*17*	*16*	*103*	*176*
DE	10%	12%	6%	9%	40%	4%	7%	11%	12%
UK	10%	11%	6%	9%	0%	5%	6%	14%	10%
NL	8%	9%	4%	8%	20%	5%	5%	10%	8%
FR	7%	6%	4%	6%	10%	3%	3%	10%	8%
IT	6%	6%	5%	6%	0%	4%	4%	6%	7%
ES	5%	6%	4%	6%	0%	4%	4%	6%	5%
GR	5%	5%	4%	5%	0%	4%	4%	5%	5%
DK	5%	-	5%	7%	0%	4%	5%	7%	7%
BE	4%	4%	3%	5%	10%	5%	3%	5%	4%
SE	4%	7%	3%	6%	0%	4%	4%	7%	-
AT	4%	4%	6%	5%	0%	5%	4%	2%	5%
PT	3%	3%	3%	4%	0%	3%	4%	3%	3%
FI	3%	4%	4%	-	0%	3%	4%	3%	4%
PL	3%	3%	6%	3%	0%	6%	4%	1%	2%
CH	3%	2%	2%	3%	0%	2%	2%	2%	4%
NO	2%	3%	1%	2%	10%	0%	1%	-	3%
CZ	2%	1%	4%	2%	0%	5%	4%	1%	1%
HU	2%	2%	5%	1%	0%	6%	6%	1%	1%
IE	2%	2%	2%	2%	10%	1%	1%	1%	1%
SI	2%	1%	5%	2%	0%	4%	4%	1%	1%
BG	1%	1%	4%	1%	0%	4%	4%	0%	1%
SK	1%	1%	4%	1%	0%	4%	4%	0%	1%
RO	1%	1%	3%	1%	0%	3%	3%	0%	1%
EE	1%	1%	-	1%	0%	3%	4%	0%	1%
LV	1%	1%	4%	1%	0%	4%	-	0%	1%
LT	1%	1%	3%	1%	0%	-	4%	0%	1%
IL	1%	0%	1%	0%	0%	2%	1%	0%	1%
LU	0%	0%	1%	1%	0%	0%	0%	1%	0%
CN	0%	0%	1%	1%	0%	1%	1%	0%	0%
US	0%	1%	0%	0%	0%	0%	0%	0%	1%
CA	0%	0%	0%	0%	0%	0%	0%	0%	0%
CY	0%	0%	1%	0%	0%	0%	1%	0%	0%
TR	0%	0%	0%	0%	0%	0%	0%	0%	0%
IN	0%	0%	1%	0%	0%	0%	0%	0%	0%
UA	0%	0%	1%	0%	0%	0%	0%	0%	0%
AU	0%	0%	0%	0%	0%	0%	0%	0%	0%
BR	0%	0%	0%	0%	0%	0%	0%	0%	0%
EG	0%	0%	0%	0%	0%	0%	0%	0%	0%
MY	0%	0%	0%	0%	0%	0%	0%	0%	0%
BI	0%	0%	0%	0%	0%	0%	0%	0%	0%
IS	0%	0%	0%	0%	-	0%	0%	0%	0%
MA	0%	0%	0%	0%	0%	0%	0%	0%	0%
RU	0%	0%	0%	0%	0%	0%	0%	0%	0%

TN	0%	0%	0%	0%	0%	0%	0%	0%	0%
ZA	0%	0%	0%	0%	0%	0%	0%	0%	0%

Duration of Nordic and Baltic projects

Most of the projects have duration of three years (Figure 26).

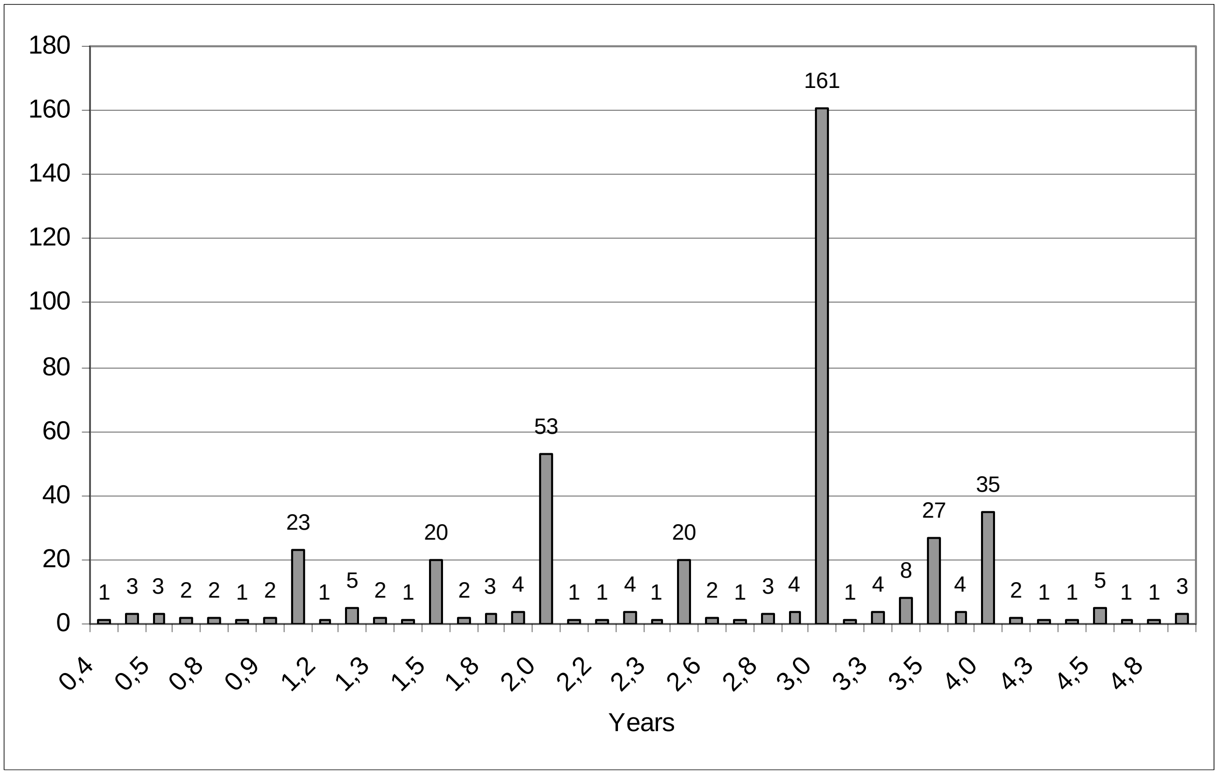

Figure 26: Duration of Nordic and Baltic EU FP5 projects in non-nuclear energy (N=419). Source: Cordis

Centrality–importance of co-ordination

Most of the projects are rather large projects – with four to ten participants, while non-collaborative projects are more common in the Baltic countries (Figure 28 and Figure 27). The share of large network projects with more than ten participants is 12 per cent.

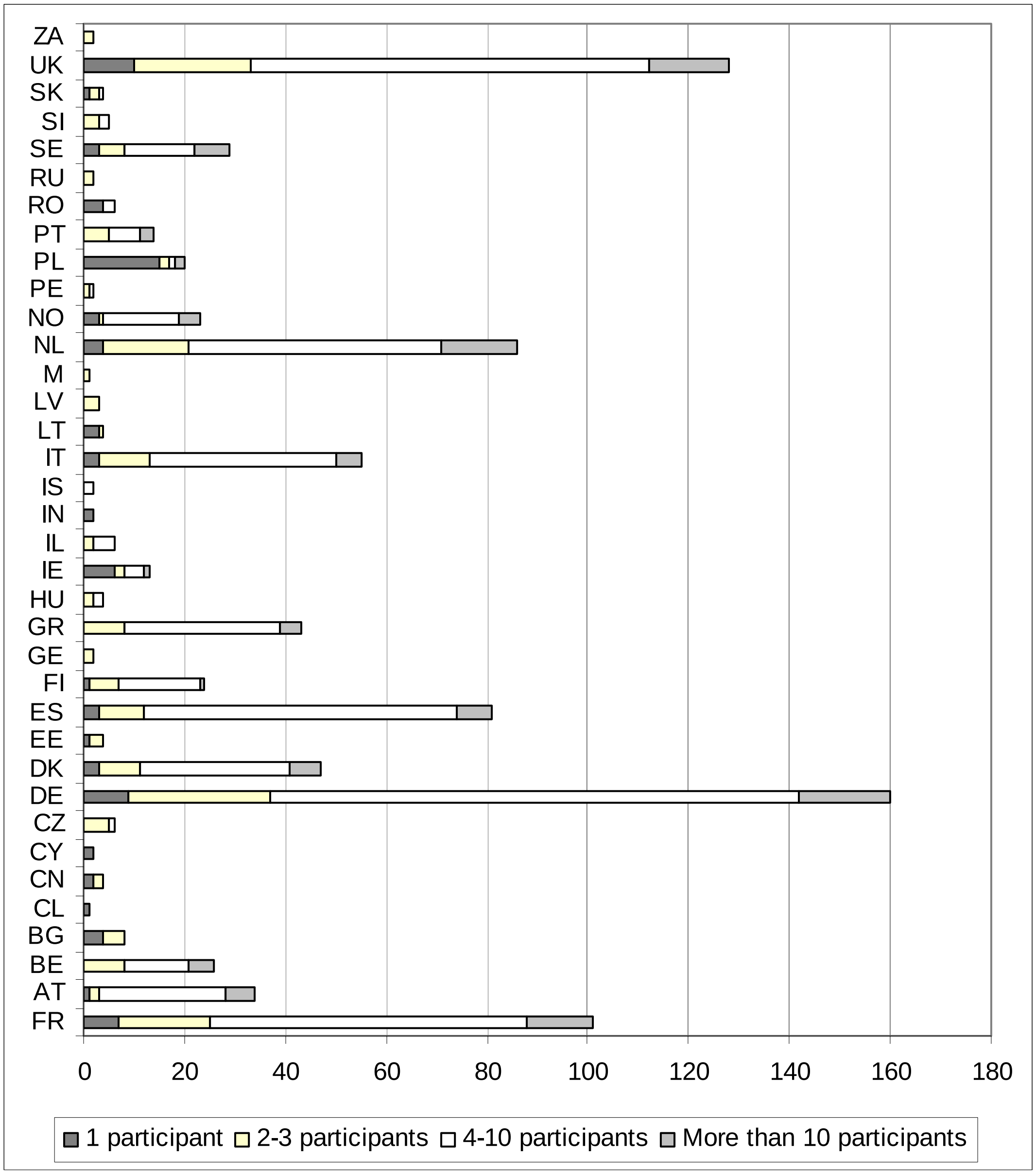

Figure 27: Size of the EU FP5 project networks for non-nuclear energy research (N=954). Source: Cordis

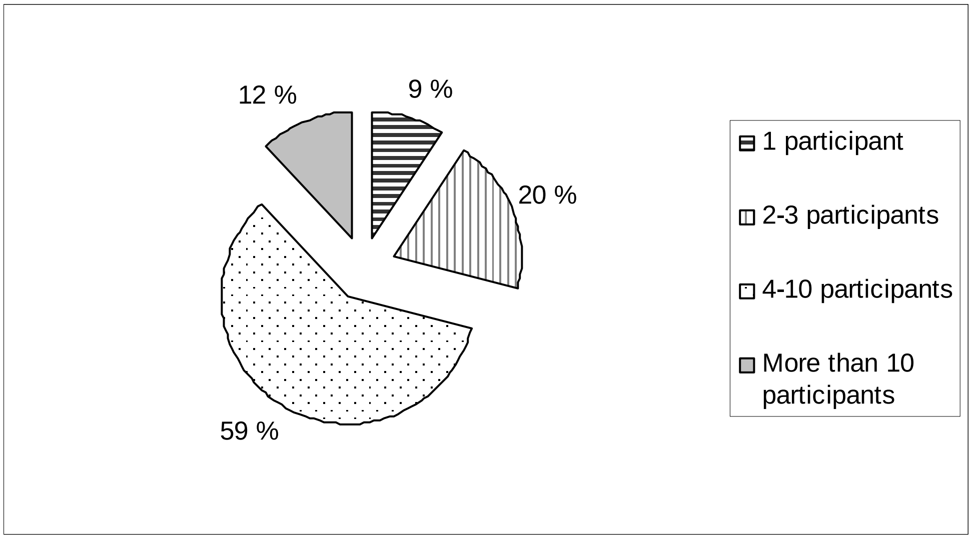

Figure 28: Size of the EU FP5 project networks for non-nuclear energy research (N=954). Source: Cordis

When analysing just the projects with a Nordic or Baltic coordinator, the share of projects with 4 to 10 participants decreases to 49 per cent; the share of large network projects with more than ten participants increases to 24 per cent.

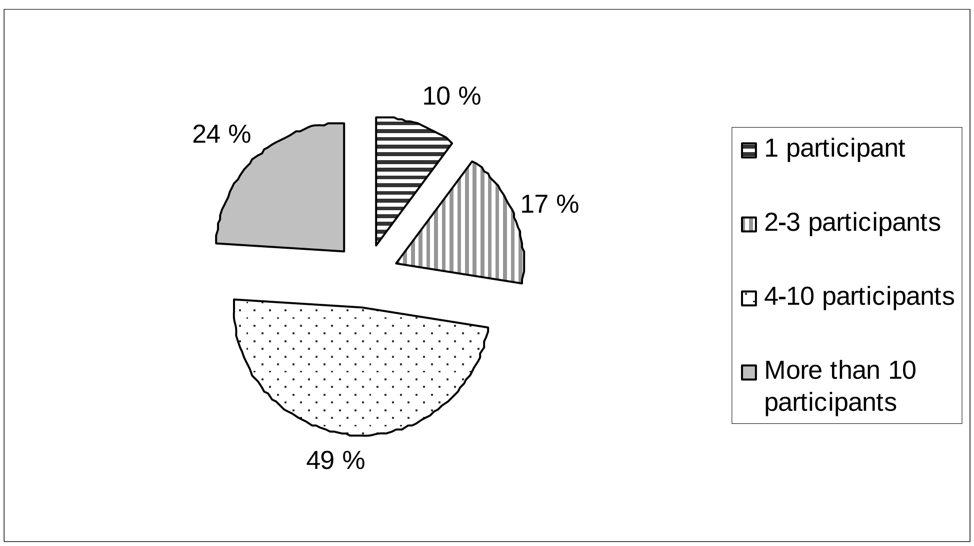

Figure 29: Size of the Nordic and Baltic coordinated EU FP5 project networks for non-nuclear energy research (N=136). Source: Cordis

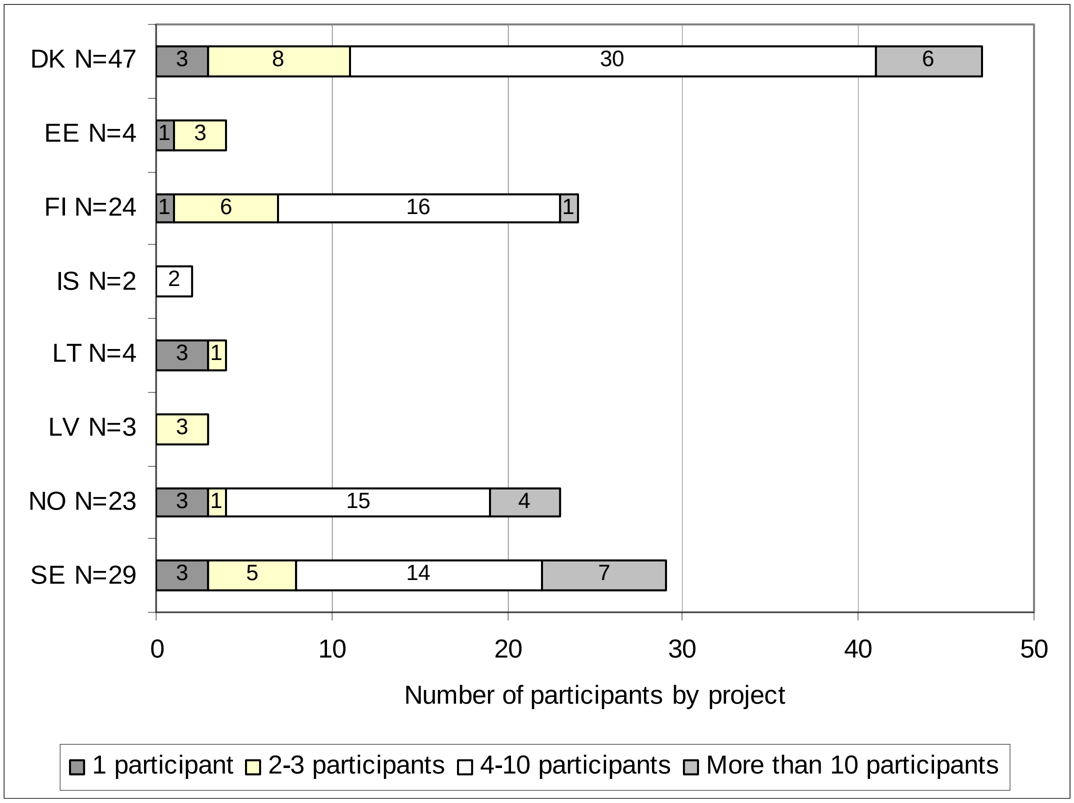

Figure 30: Size of the Nordic and Baltic coordinated EU FP5 project networks for non-nuclear energy research (N=136). Source: Cordis

Conclusions

Collaboration under the EUFP5 has been an important driver for Nordic energy research. This is especially the case for Denmark and Sweden, and to some extent also for Norway. The involvement of the Baltic countries is still minor, but could be improved by including these countries in existing Nordic collaboration networks. The collaboration of Norwegian institutions with Baltic institutions is still rather limited, while the strong involvement of industry actors in the Norwegian projects is noteable.

3.3 Collaboration in ERA-NETs related to renewable energy

The Nordic countries are well represented in the ERA-NETs related to renewable energy technologies (Table 23).

Sweden participates in ERA-NETs for bioenergy, hydrogen and fuel cells, photovoltaic's (PV) and for innovative energy research. In Sweden, the Swedish Energy Agency is the main partner organisation in all ERA-NETs related to the energy field.

Tekes, the Finnish funding Agency for Technology and Innovation, is a partner in the ERA-NETs for bioenergy and hydrogen and fuel cells.

Norway, with the Norwegian Research Council as a partner organisation, participates in ERA-NETs on hydrogen and fuel cells, innovative energy research and the ERA-NET for clean fossil energy technologies. Despite considerable research efforts on PV in Norway, we find that Norway does not participate in the ERA-NET on PV. Denmark is represented in ERA-NETs on hydrogen, PV and clean fossil energy technologies.

Iceland participates in the HY CO ERA-NET on hydrogen, with the National Energy Authority of Iceland as partner.

Among the Baltic countries, Estonia and Latvia participate in the ERA-NET for clean fossil energy technologies, both countries having respective Ministry of Economics as partner organisations.

Table 23: ERA-NETs on Renewable Energy Technologies for Nordic and Baltic States

ERA- NET on energy technologies	Nordic/Baltic countries	Name of participating Nordic/Baltic organisation
ERA-NET BIOENERGY: The goal of this network is to strengthen national bioenergy research programmes through enhancing cooperation and coordination between the national agencies.	Finland	Tekes
	Sweden	Swedish Energy Agency
HY CO ERA- NET on Hydrogen and Fuel Cells: The HY-CO network is establishing coordination and cooperation between national and regional ministries of Member States and Associated Countries as well as their research agencies across all aspects of research, development and trial in the area of hydrogen as a fuel and the related fuel cell technologies.	Norway	Research Council of Norway
	Sweden	Swedish Energy Agency
	Finland	Tekes
	Iceland	The National Energy Authority of Iceland
	Denmark	Danish Energy Authority
	Nordic countries	Nordic Energy Research
PV ERA-NET:	Denmark	Danish Energy Authority

Its overall objective is to strengthen Europe’s position in photovoltaic technology through increasing cooperation and coordination of these fragmented research efforts.	Sweden	The Swedish Energy Agency and the Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (Formas)
	Nordic countries	Nordic Energy Research
INNER ERA-NET Innovative Energy Research: The aim is to improve co-operation between national research programmes that seek to nurture emerging energy technologies.	Norway	Research Council of Norway
	Sweden	Swedish Energy Agency
	Nordic countries	Nordic Energy Research
FENCO ERA-NET for clean fossil energy technologies: The overall aim of FENCO-ERA is to network the national R&D activities in the field of fossil energy conversion and CO2 capture and storage in order to construct a durable ERA-Net	Denmark	Energinet.dk
	Norway	Research Council of Norway
	Estonia	Ministry of Economics and Communication
	Latvia	Ministry of Economics

4. R&D output in selected energy technology fields

4.1 Patenting in selected energy technology fields

Methodology

The gaol of the patent study was to compare the patenting activities in selected technology fields. Following technologies have been covered:

- Solar photovoltaic energy
- Wind energy
- Hydropower
- Wave energy
- CO_2 capturing and storage
- Hydrogen technology
- Second Generation Bioenergy.

The patent database provided by Delphion© Thomson has been the main source.[28] The search has been restricted to the period 1998–2005, based on the priority date for the patent applications.

Combined search strings have been applied:

- Relevant IPC classes and sub-groups
- Keywords
- Firm names for Assignees
- Search for country in the inventor field.

The results of the patent studies are presented in tables for each technology summarizing the findings by country and year, a diagram, and tables of assignees by country. An overview of the main search strings is given in the appendix.[i]

The analysis is based on EPO Patent Applications (in this report shortened to "patents"), national patent applications or granted patents have not been covered. This has been done as the study should be comparative.

Knowing that the Baltic countries, Iceland and Norway just recently became members of the European Patent Organisation, it must be clear that an analysis of the national patenting could, in some cases, reveal other priorities than the study of EPO patenting.

The countries in the study had following entry dates for the EPO:

Denmark	1 January 1990
Estonia	1 July 2002
Finland	1 March 1996
Iceland	1 November 2004

[28] http://www.delphion.com/

Latvia	1 July 2005
Lithuania	1 December 2004
Norway	1 January 2008
Sweden	1 May 1978

One of the countries in our study has been an EPO member state before 1990: Sweden. Denmark followed in 1990 and Finland in 1996. The other countries also became member states of the EPO commencing with Estonia in 2002, Iceland and Lithuania in 2004, Latvia in 2005. Norway did not become an EPO member state until 2008.

Comparing the number of EPO patent applications (Table 24) Sweden has been identified as clearly leading, followed by the Finland and Denmark. Among the new EPO members achieved only Norway reasonable high numbers, but still far less than the other Scandinavian countries.

Table 24: Number of Patent applications to the EPO by priority year at the national level. Total number. 1998–2004. Data: EUROSTAT

	1998	1999	2000	2001	2002	2003	2004
Denmark	771	835	931	884	902	979	1 082
Estonia	5	7	6	10	6	11	:
Finland	1 172	1 398	1 355	1 233	1 233	1 245	1 154
Iceland	24	35	36	21	36	33	:
Latvia	5	2	7	4	6	8	:
Lithuania	1	3	5	3	3	13	10
Norway	327	371	395	351	371	336	287
Sweden	2 077	2 182	2 265	2 075	1 962	1 939	2 172

Normalising the number of patent applications by million labour force (Table 25) we get a different picture: Finland and Sweden in a leading position, followed by Denmark. The value for Iceland in 2003 is surprisingly high, probably due to the rather low number of labour force on Iceland. Other values are not given for Iceland in the EUROSTAT statistics. The normalised values for the Baltic countries are also here rather low, confirming the results from the absolute counts.

Table 25: Patent applications to the EPO by priority year at the national level. By million labour force. 1998–2004. Data: EUROSTAT

	1998	1999	2000	2001	2002	2003	2004
Denmark	274	293	328	308	316	342	373
Estonia	8	11	9	15	9	16	:
Finland	466	547	536	520	472	479	445
Iceland	:	:	:	:	:	206	:
Latvia	0	2	3	2	2	8	6
Lithuania	4	2	7	4	6	7	:
Norway	:	:	169	149	157	142	121
Sweden	470	490	504	457	431	424	474

The aim for this comparison was to show that the different countries in this study have different priorities regarding EPO patenting. If the patent analysis of the different energy technologies reveals strong positions for countries that normally do not patent extensively in the EPO framework, then it may be concluded that these are core technology areas for these countries.

In the following tables we summarise the results for the four Nordic countries–Denmark, Finland, Norway and Sweden. The other four countries had almost no EPO patent applications in the selected technology fields.

Table 26: Summary on EPO patent applications for Denmark, Finland, Norway and Sweden. Absolut numbers of patent applications

	PV	Wind	2nd Biofuel	CCS	Hydropower	Hydrogen
Denmark	0	107	52	3	1	14
Finland	3	5	12	1	1	0
Norway	18	8	7	9	10	16
Sweden	4	13	14	0	3	2

The comparative analysis reveals that Denmark has a very high activity level in two of the selected technology fields – both wind and second generation biofuels – and in addition also in hydrogen there is a high level of activity.

Finland and Sweden have a high level of activity in second generation biofuels, but in the other fields are not very active. Considering the high volume of EPO patenting in both countries, this means that these fields are not in the core technology areas.

Norway has a high activity level in several fields – photovoltaics, CCS, hydropower and hydrogen, only in wind and second generation biofuels there is a low activity level. Considering the low number of Norwegian EPO patent applications it is possible to conclude that energy technology is one of the core technology areas in Norway.

As a question remains whetgher it is possible to have a top level of activity in all fields, or if the countries could gain more advantage by collaborating more closely in the Nordic region.

Table 27: Summary on EPO patent applications for Denmark, Finland, Norway and Sweden. Rating based on comparison between countries*

	PV	Wind	2nd generation Biofuel	CCS	Hydropower	Hydrogen
Denmark	-	+++	+++	+	-	++
Finland	+	+	++	-	-	-
Norway	++	+	+	++	++	++
Sweden	+	+	++	-	+	-

* Explanations for rating:
- Almost no activities
+ Low activity level
++ High activity level
+++ Very high activity level

In the following subsections we show the analyses in more detail. For each technology field the development of patenting is given, the shares of patenting and the patenting organisations. The search strings are given in the Appendix.

Solar photovoltaic energy

Table 28: Nordic patenting in solar photovoltaic energy technology. 1998–2005. Source: Delphion

	Denmark	Finland	Iceland	Norway	Sweden	Estonia	Latvia	Lithuania
1998	0	0	0	0	0	0	0	0
1999	0	0	0	3	0	0	0	0
2000	0	0	0	2	0	0	0	0
2001	0	0	0	3	0	0	0	0
2002	0	1	0	2	0	0	0	0
2003	0	1	0	3	2	0	0	0
2004	0	1	0	4	2	0	0	0
2005	0	0	0	1	0	0	0	0
	0	*3*	*0*	*18*	*4*	*0*	*0*	*0*

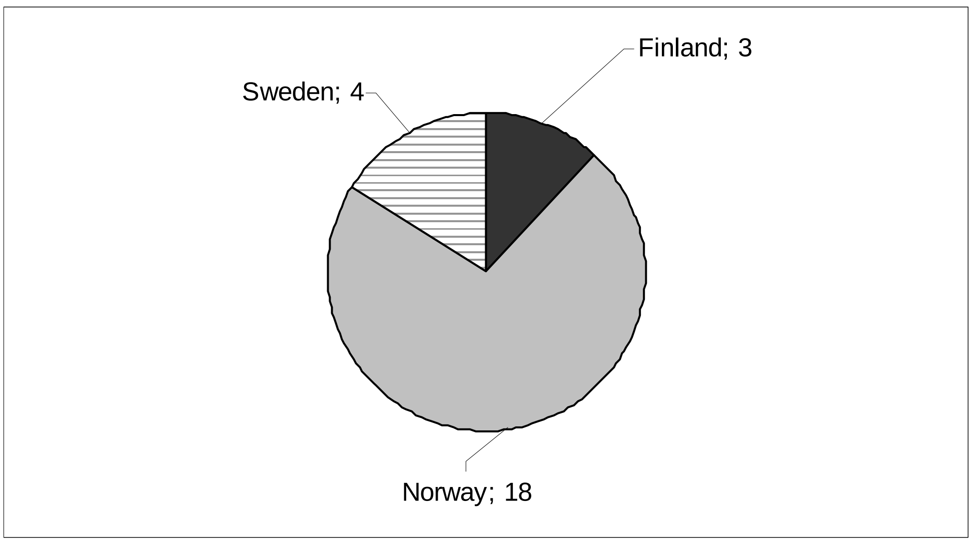

Figure 31: Nordic patenting in solar photovoltaic energy technology. 1998–2005. Source: Delphion

The patent analysis revealed a high activity level in the field of patenting on photovoltaics in Norway. This is consistent with the industrial specialisation of Norway (compare 2.1 Solar photovoltaic energy). The activities in Norway are concentrated on silicone-based solar cells, while the patenting in Sweden is specialised in second-generation photovoltaics.

Table 29: Nordic patenting organizations in solar photovoltaic energy technology. Source: Delphion

Norway:	
ELKEM ASA, Norway	7
ELKEM SOLAR AS	1

INSTITUTT FOR ENERGITEKNIKK, Norway	1
Metallkraft AS	1
Promeks AS Langeland Gaard, 5110 Frekhaug, Norway	1
REC ScanWafer AS	2
REC SILICON, INC.	1
Scatec AS	1
SensoNor asa	1
Solarnor AS	2

Finland:

SILECS OY Finland	3

Sweden

Solibro AS	3
SANDVIK INTELLECTUAL PROPERTY AB	1

Wind energy

Table 30: Nordic and Baltic patenting in wind energy technology. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	7	0	0	0	0	0	0	0
1999	11	0	0	0	0	0	0	0
2000	6	0	0	0	0	0	0	0
2001	5	0	0	0	1	0	0	3
2002	18	0	0	0	0	0	1	4
2003	26	0	0	0	0	0	3	4
2004	31	0	2	0	0	0	2	2
2005	3	0	3	0	0	0	2	0
	107	*0*	*5*	*0*	*1*	*0*	*8*	*13*

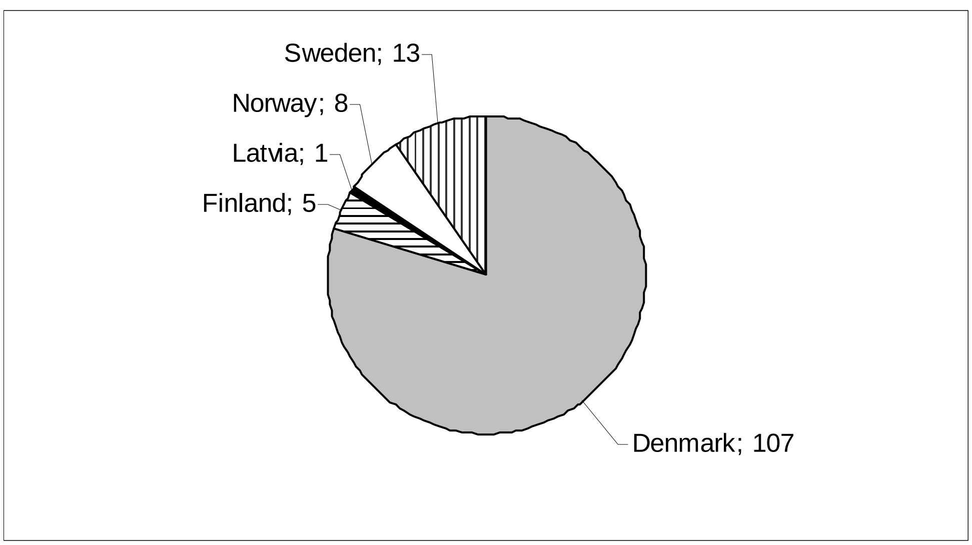

Figure 32: Nordic and Baltic patenting in wind energy technology. 1998–2005. Source: Delphion

Patenting in wind energy is a clear domain for Danish companies. This is consistent with the industrial specialisation of Denmark (compare the the first chapter and section in the country report on Denmark). Danish patenting covers the whole value chain of the wind energy industry and has many actors in this field, while Norwegian and Swedish patents are more specialised and have relatively few actors. Norwegian patenting is more concentrated on offshore wind power, in clear tradition to offshore competencies acquired in the oil and gas industry. .

Table 31: Nordic and Baltic patenting organizations in wind energy technology. Source: Delphion

Denmark	
A2SEA AS Denmark	1
Bonus Energy A/S	1
Elsam A/S, 7000 Fredericia, Denmark	2
Forskningscenter Risø, 4000 Roskilde, Denmark	6
Gamesa Wind Engineering, APS; 8600 Silkeborg, Denmark	1
JOHANSEN, ARNE Denmark	1
LM GLASFIBER A/S Denmark	29
Logima V/Svend Erik Hansen, 2660 Brondby Strand, Denmark	1
Mita-Teknik A/S	1
NEG Micon A/S, 8900 Randers, Denmark	13
NORDEX ENERGY GMBH Germany	1
PP ENERGY APS Denmark	3
SIEMENS AKTIENGESELLSCHAFT Germany	1
SSP Technology A/S, 5672 Broby, Denmark	3
VAMDRUP SPECIALTRANSPORT APS Denmark	1
Vestas Wind System A/S, 6950 Ringkobing, Denmark	42
Finland:	
ABB Oy, 00380 Helsinki, Finland	1
MOVENTAS OY Finland	1
Winwind Oy, 00210 Helsinki, Finland	3
Latvia	
Latekols, Sia, 1056 Riga, Latvia	1
Norway:	
Haugsoen, Per Bull (in collaboration with Gunnar Foss from the Netherlands	1
MPU ENTPR AS Norway	1
NORSK HYDRO ASA Norway	2
OWEC TOWER AS Norway	2
Sway AS, 4006 Stavanger, Norway	3
Sweden:	
AB SKF	9
Deltawind AB, 187 28 Täby, Sweden (in collaboration with Nordic Windpower AB, Sweden	2
Oldin, Karin, 903 22 Umeå, Sweden (in collaboration with Mohammad Golritz, Canada)	1

Second Generation Bioenergy

Table 32: Nordic patenting in second-generation bioenergy technology. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	15	0	1	0	0	0	2	1
1999	15	0	0	0	0	0	3	1
2000	6	0	0	0	0	0	0	1
2001	1	0	1	0	0	0	1	0
2002	6	0	3	0	0	0	0	5
2003	4	0	3	0	0	0	0	2
2004	5	0	4	0	0	0	0	3
2005	0	0	0	0	0	0	1	1
	52	*0*	*12*	*0*	*0*	*0*	*7*	*14*

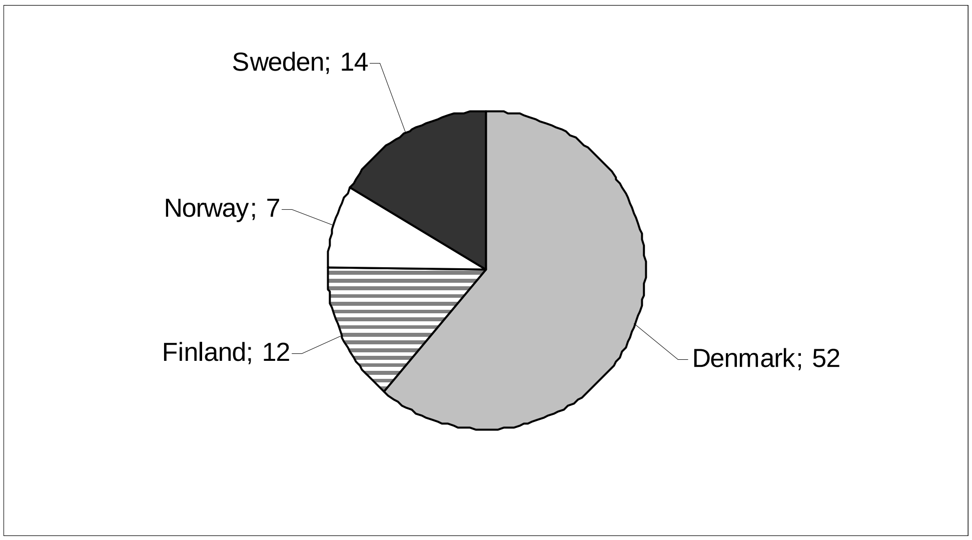

Figure 33: Nordic patenting in second-generation bioenergy technology. 1998–2005. Source: Delphion

Patenting in second-generation biofuels is an important domain for Danish companies in true tradition with strong competencies in biotechnology and a strong food sector. There we find both strong industrial actors and SME's specialised in this field. Patenting in Finland and Sweden is clear continuation of a strong focus on bioenergy in general in both countries, while Norway is still more in a starting position here.

Table 33: Nordic patenting organizations in second-generation bioenergy technology. Source: Delphion

Sweden	
Bernhardsson, Sven	1
Forskarpatent i Syd AB	9
SWEDISH BIOFUELS AB Sweden	1
SWETREE TECHNOLOGIES AB	1
Tekniska Verken i Linkoeping AB	3

Finland	
Fortum Oil Oy	2
FRACTIVATOR OY Finland	1
Lassila & Tikanoja Oyj, 00441 Helsinki, Finland	1
Neste Oil Oyj, 00095 Neste Oil, Finland	1
PRESECO OY Finland	2
VERDERA OY Finland	1
VTT	4
Denmark	
BIO-CIRCUIT APS Denmark	2
Biocontractors A/S	1
Bioscan A/S	1
ELSAM ENGINEERING A/S	1
FORSKNINGSCENTER RISO	1
Green Farm Energy A/S, 8370 Hadsten, Denmark	2
Haldor Topsoe A/S	31
INVENSYS APV A/S Denmark	1
Novo Nordisk A/S Denmark	1
NOVOZYMES A/S Denmark	10
Samson Bimatech I/S	1
Norway	
CAMBI AS	1
NORSK HYDRO ASA	2
Statoil	2
Thermtech AS	1

CO_2 capturing and storage (CCS)

Table 34: Nordic patenting in CO_2 capturing and storage. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	0	0	0	0	0	0	2	0
1999	0	0	0	0	0	0	2	0
2000	0	0	0	0	0	0	0	0
2001	1	0	1	0	0	0	0	0
2002	0	0	0	0	0	0	0	0
2003	1	0	0	0	0	0	1	0
2004	1	0	0	0	0	0	4	0
2005	0	0	0	0	0	0	0	0
	3	*0*	*1*	*0*	*0*	*0*	*9*	*0*

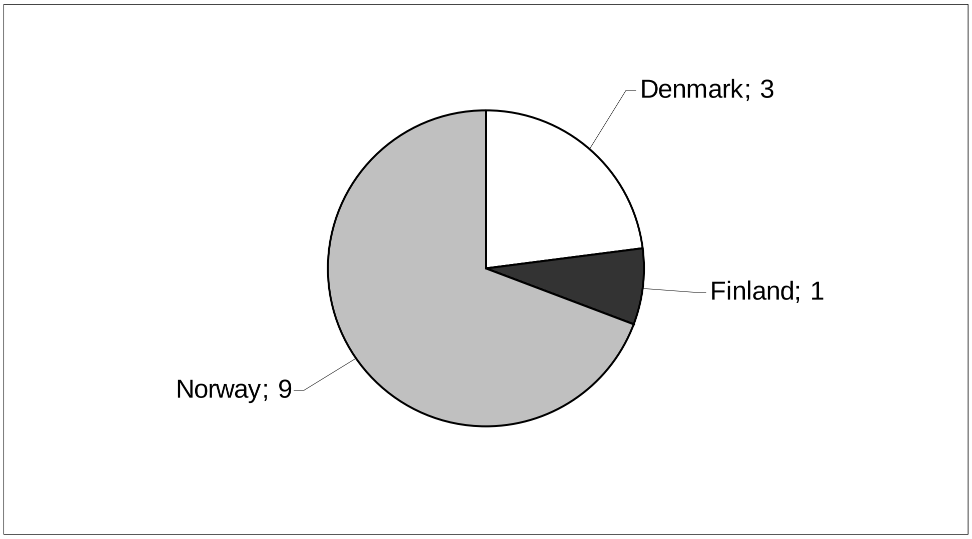

Figure 34: Nordic patenting in CO_2 capturing and storage. 1998–2005. Source: Delphion

Patenting in the field of CCS is concentrated in Norway, consistent with the industrial specialisation in this field (see chapter 2.4). Parts of the patenting activities are a result of collaboration with a public research institute, Sintef.

Table 35: Nordic patenting organizations in CCS. Source: Delphion

Denmark	
UNION ENGINEERING A/S	3
Norway	
AKER ENGINEERING A/S	1
Aker Clean Carbon (According to information provided by Aker Clean Carbon has the company filed 7 patent applications under the PCT in 2008)	7
STATOIL ASA (In cooperation with: SINVENT AS Norway, ORKLA ENGINEEERING Norway and TEEKAY NORWAY AS Norway)	2
STATOIL ASA	1
Norsk Hydro ASA	3
NTNU Technology Transfer AS	1
Naturkraft AS	1
Finland	
Cuycha Innovation Oy Finland	1

Wave energy

Table 36: Nordic patenting in wave energy technology. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	2	0	0	0	0	0	1	0
1999	0	0	0	0	0	0	0	0

2000	2	0	0	0	0	0	0	0
2001	0	0	1	0	0	0	5	0
2002	0	0	0	0	0	0	1	2
2003	0	0	1	0	0	0	2	3
2004	0	0	0	0	0	0	5	0
2005	0	0	0	0	0	0	0	0
Sum	*4*	*0*	*2*	*0*	*0*	*0*	*14*	*5*

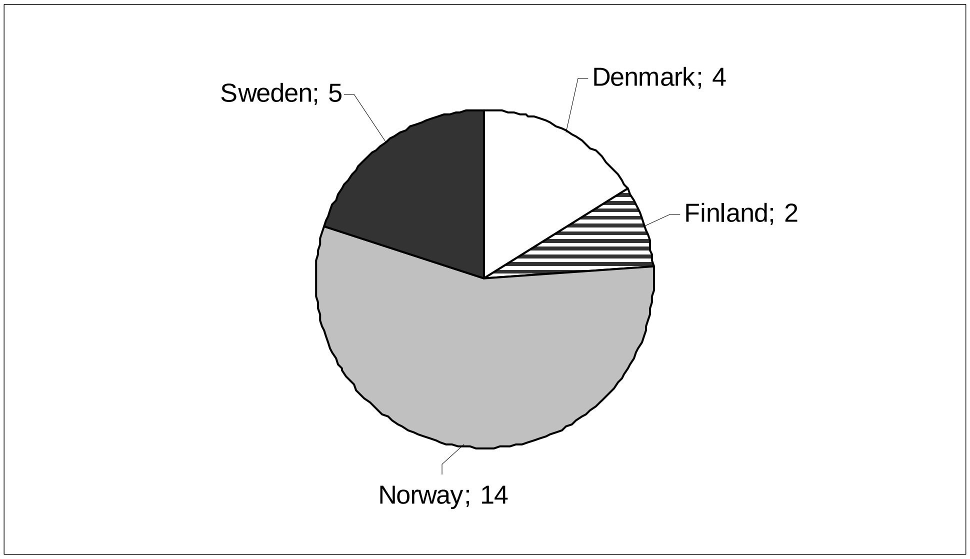

Figure 35: Nordic patenting in wave energy technology. 1998–2005. Source: Delphion

Wave energy is a technological field that has received much attention in Norway over a long period because of the natural conditions for developing wave and tidal energy. There are several smaller industrial companies that try to find applicable solutions. In the other Nordic countries these activities have been more concentrated in few companies.

Table 37: Nordic patenting organizations in wave energy. Source: Delphion

Finland	
AW-Energy Oy, 00560 Helsinki, Finland	2
Sweden	
Swedish Seabased Energy AB Sweden	5
Denmark	
Christensen, Henrik Frans, Lemvig, Denmark	1
Hansen, Niels, Arpe; Hansen, Keld	1
Waveplane International A/S Denmark	2
Norway	
Hammerfest Ström AS	1
Hydra Tidal Energy Technology AS	5
Miljø-Produkter AS Norway	1
NAVAL DYNAMICS AS	1

OTTERSEN, HANS-OLAV Norway	2
POWER VISION AS	1
SKOTTE, ASBJOERN	1
TIDETEC AS	1
WAVE ENERGY AS Norway	1

Hydropower

Table 38: Nordic patenting in hydropower technology. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	0	0	1	0	0	0	1	0
1999	0	0	0	0	0	0	1	1
2000	0	0	0	0	0	0	2	0
2001	1	0	0	0	0	0	1	0
2002	0	0	0	0	0	0	2	0
2003	0	0	0	0	0	0	1	1
2004	0	0	0	0	0	0	2	1
2005	0	0	0	0	0	0	0	0
	1	*0*	*1*	*0*	*0*	*0*	*10*	*3*

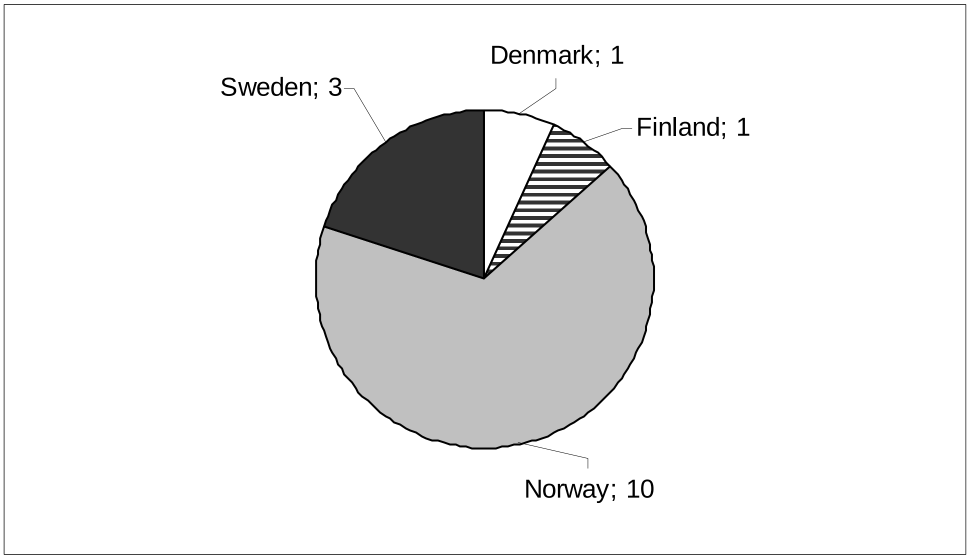

Figure 36: Nordic patenting in hydropower technology. 1998–2005. Source: Delphion

Hydropower has a long tradition in Norway, but there are rather few new patents in this field. Norway nevertheless has a strong position here, partly based on the contributions of strong research groups at SINTEF and the NTNU.

Table 39: Nordic patenting organizations in hydropower technology. Source: Delphion

Norway:	
Hammerfest Stroem AS	3
Leiv Eiriksson Nyfotek AS	2

NORPROPELLER AS	1
SINVENT AS	1
Small Turbine Partner AS	1
TROMS KRAFT PRODUKSJON AS	1
Water Power Industries AS	1
Finland:	
ABB Azipod Oy	1
Sweden:	
CURRENT POWER SWEDEN AB	1
GE Energy (Sweden) AB	1
Vind- och Vattenturbiner	1
Denmark:	
JK Turbine APS	1

Hydrogen technology

Table 40: Nordic patenting in hydrogen technology. 1998–2005. Source: Delphion

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden
1998	2	0	0	0	0	0	6	0
1999	0	0	0	0	0	0	1	0
2000	3	0	0	0	0	0	2	0
2001	0	0	0	0	0	0	2	0
2002	1	0	0	0	0	0	1	2
2003	5	0	0	0	0	0	3	0
2004	3	0	0	0	0	0	1	0
2005	0	0	0	0	0	0	0	0
	14	*0*	*0*	*0*	*0*	*0*	*16*	*2*

Patenting in the field of hydrogen is especially strong in Norway and Denmark, but there are some interesting differences. While these activities are concentrated in one company in Denmark, there are many Norwegian actors – companies, research institutes and persons – engaged in this field.

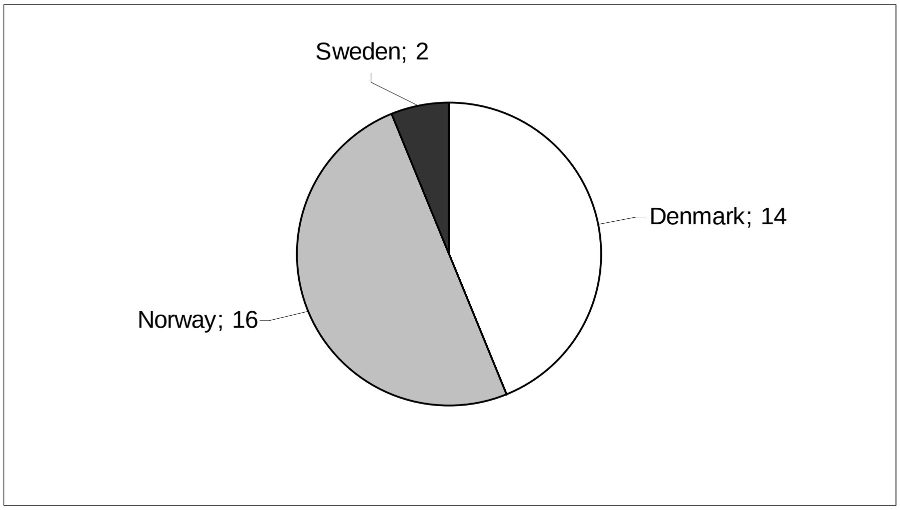

Figure 37: Nordic patenting in hydrogen technology. 1998–2005. Source: Delphion

Table 41: Nordic patenting organizations in hydrogen technology. Source: Delphion

Denmark	
Haldor Topsoe A/S, 2800 Kgs. Lyngby, Denmark	11
FORCE TECHNOLOGY Denmark	1
Norway	
Aker Kvaerner Technology	2
Andersen, Erling Reidar; Andersen, Erling Jim, Norway	1
Carbontech Holding AS Norway	1
INSTITUTT FOR ENERGITEKNIKK	1
NORSK HYDRO ASA Norway (in collaboration with University of Newcastle upon Tyne, UK)	1
NORSK HYDRO ASA Norway	2
Prototech AS	1
REVOLT TECHNOLOGY AS Norway	1
STATOIL ASA Norway	6
Sweden	
VOLVO, 405 08 Gøteborg, Sweden	2

4.2 Bibliometric evidence for selected technologies

Methodology

Bibliometric data have been retrieved from ISI Web of Science for 1998 to 2006. The following categories of publication have been included: article, letter, meeting abstract, note and review. The technologies have been defined by keywords. The search string is given for every technology field. For analysing the data we applied the analysing tool provided by Web of Science®.
We calculated absolute numbers of publications and did not weight co-authorship.

Every sub-study is structured as following:

- Development of Scientific publishing 1998–2006–Table
- Scientific publishing 1998–2006 in three years periods–Figure
- Search String for Web of Science query are given in the Appendix[ii]
- Articles with international co-authorship–shares of countries–Figure
- Ranking of countries by number of articles–Tables are given in the appendix
- Scientific publishing in the World–shares of countries–Figure
- International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006–Tables are given in the appendix
- The 100 most visible institutions in the Nordic-Baltic sample of articles–Tables are given in the appendix

Solar photovoltaic energy

Table 42: Solar photovoltaic energy - Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	Denmark	Estonia	Finland	Iceland	Lithuania	Latvia	Norway	Sweden	World
1998	17	1	10	0	1	0	6	41	2215
1999	7	5	20	0	5	2	15	39	2347
2000	14	0	26	0	3	0	9	74	2537
2001	15	3	20	0	4	1	13	72	2617
2002	15	1	29	0	4	0	11	54	2735
2003	10	5	34	1	2	0	7	59	3158
2004	13	3	31	0	10	2	14	86	3490
2005	27	10	38	0	12	1	10	77	4024
2006	30	12	43	0	11	0	20	80	4183
Sum	*148*	*40*	*251*	*1*	*52*	*6*	*105*	*582*	*27306*

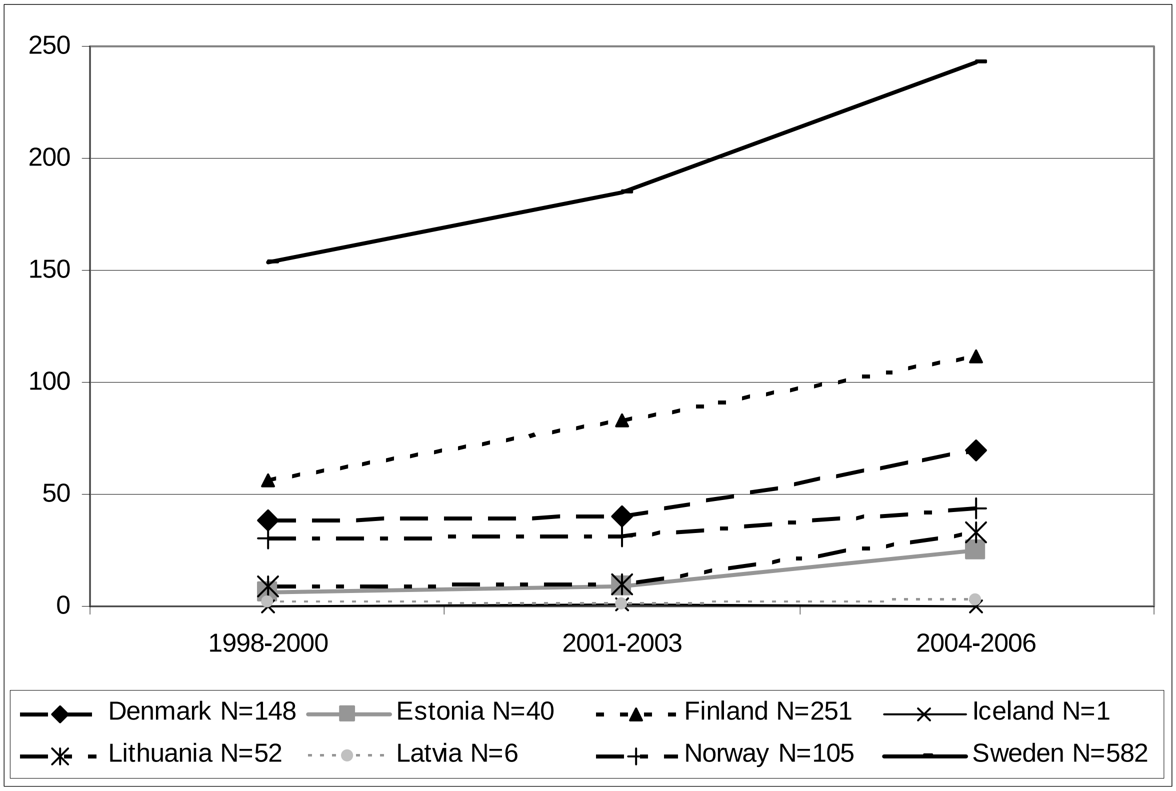

Figure 38: Solar Photovoltaic energy - Scientific publishing 1998–2006 (N=1082). Source: ISI Web of Science

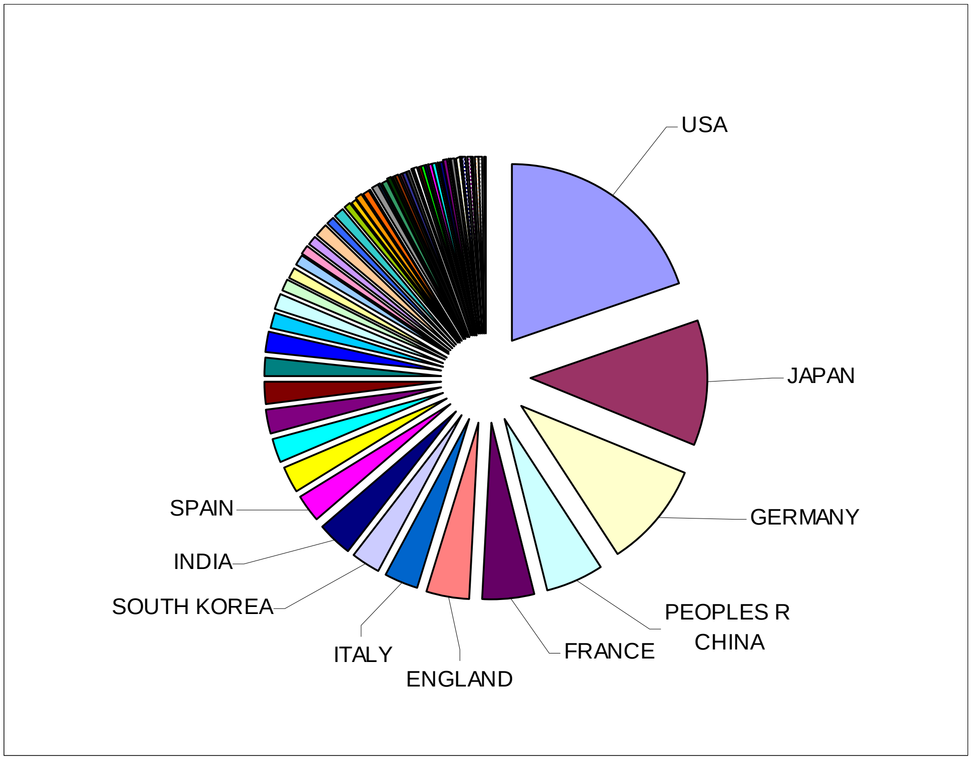

Figure 39: Solar Photovoltaic energy - Scientific publishing in the World. Shares of countries. 1998–2006. N=24976. Source: ISI Web of Science

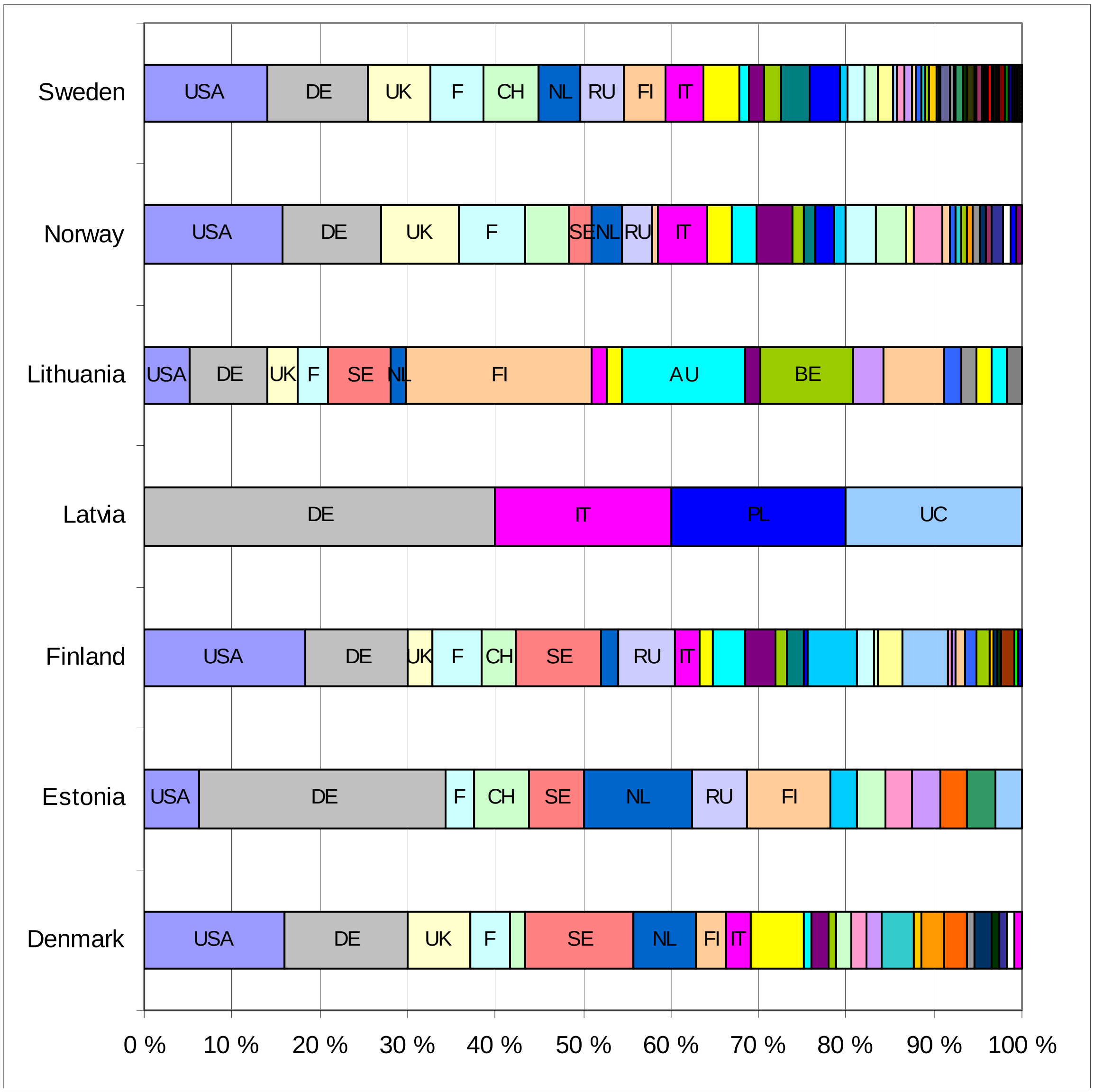

Figure 40: Solar Photovoltaic energy - Articles with international co-authorship - share of countries. Source: ISI Web of Science

Wind energy

Table 43: Wind - Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	Denmark	Estonia	Finland	Iceland	Lithuania	Latvia	Norway	Sweden	World
1998	10	1	4	0	0	0	7	12	601
1999	20	2	6	2	0	0	12	24	637
2000	15	0	8	0	0	1	8	20	665
2001	18	1	5	0	1	0	6	22	750
2002	26	0	3	1	0	0	10	27	704
2003	35	0	10	1	1	0	12	20	838

2004	29	1	3	0	0	0	14	24	949
2005	46	4	10	1	1	0	13	28	972
2006	44	0	10	0	2	0	17	25	940
Sum	*243*	*9*	*59*	*5*	*5*	*1*	*99*	*202*	*7056*

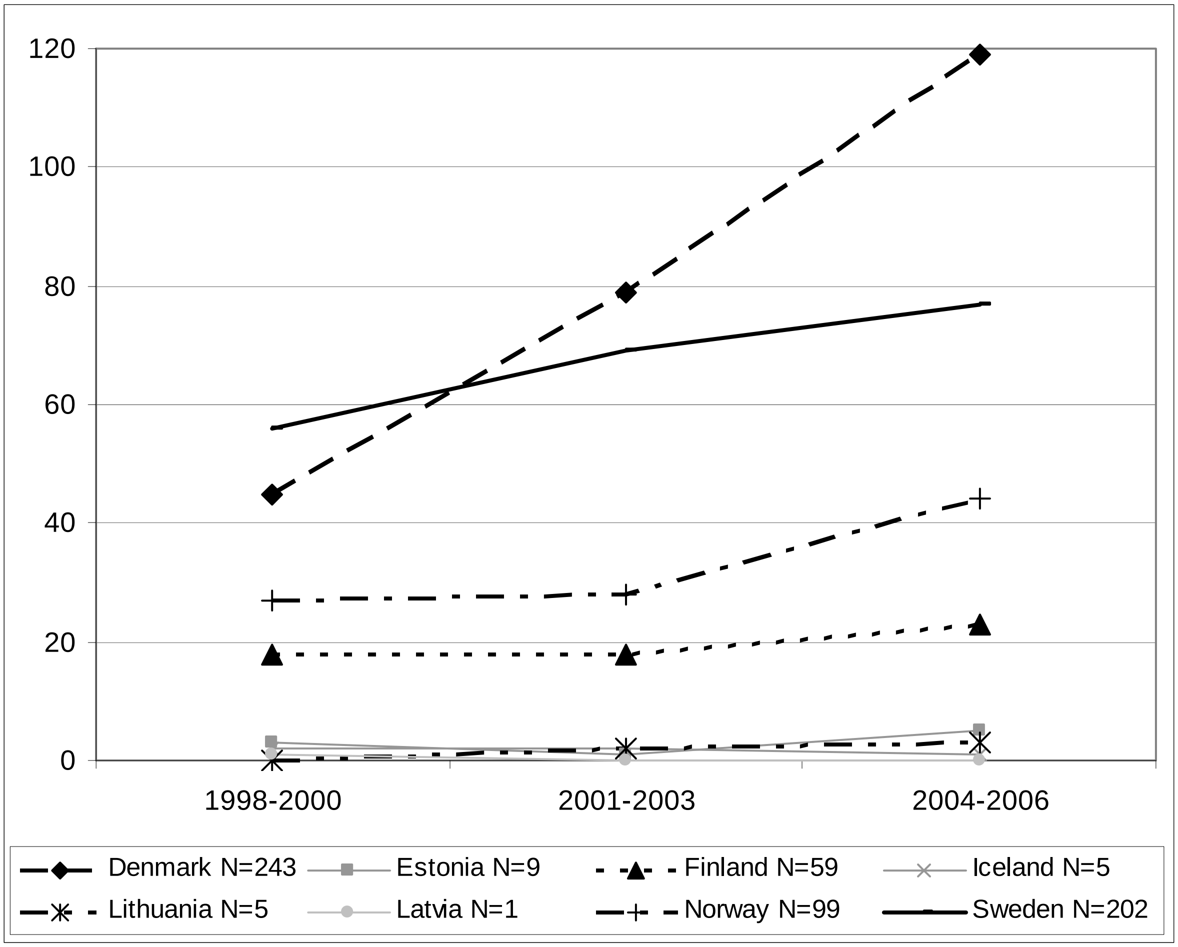

Figure 41: Wind energy - Scientific publishing 1998–2006 (N=564). Source: ISI Web of Science

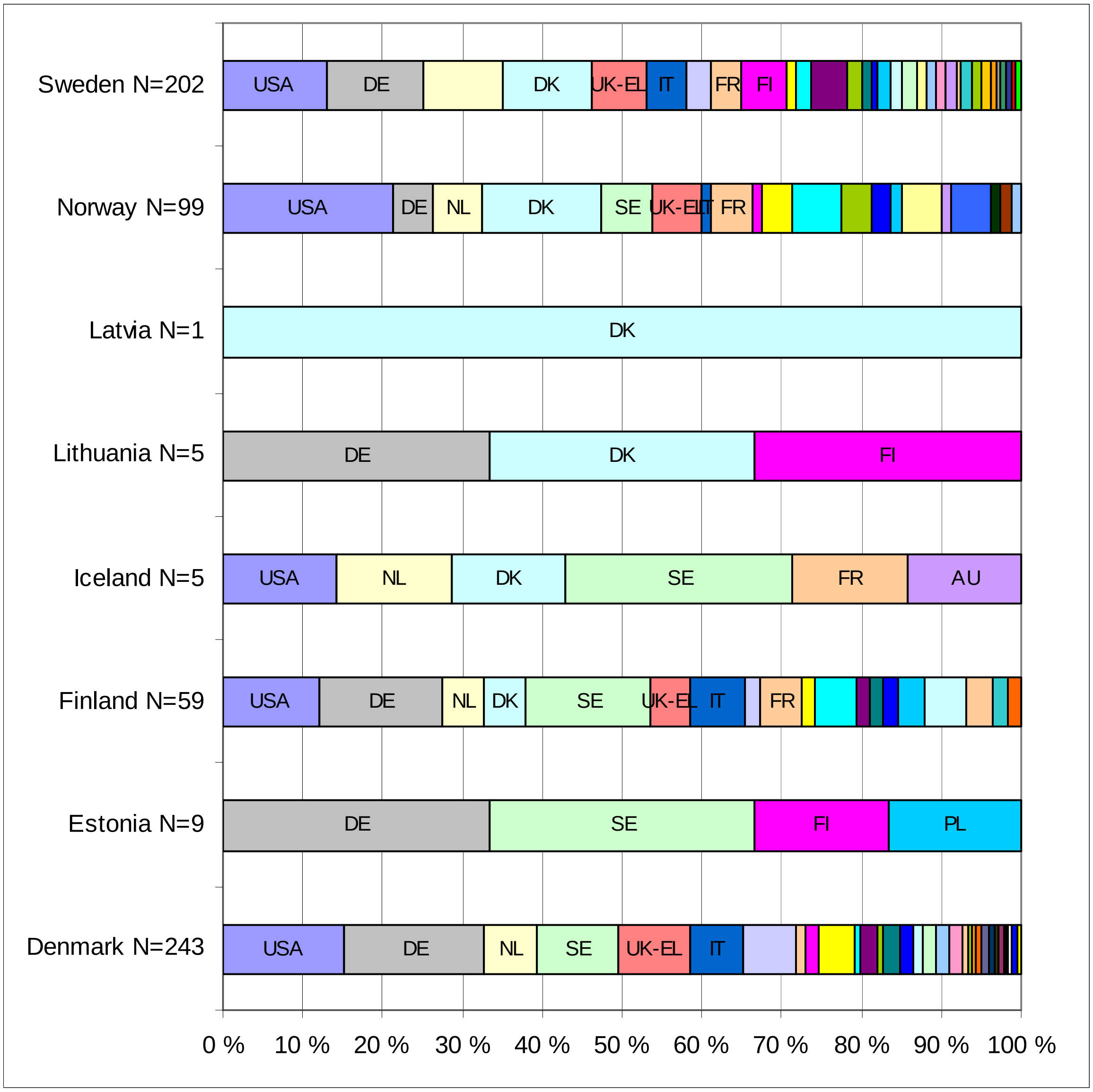

Figure 42: Wind energy - Articles with international co-authorship - share of countries. Source: ISI Web of Science

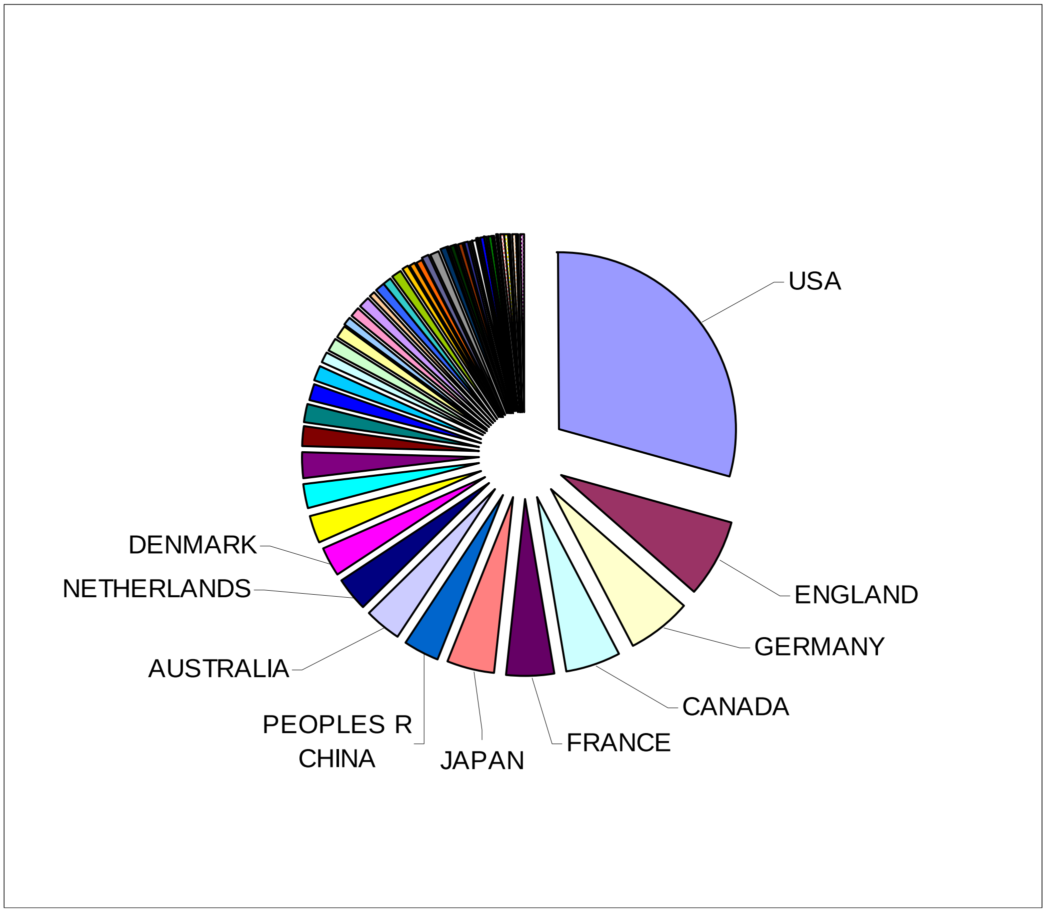

Figure 43: Wind energy - Scientific publishing in the World. Shares of countries. 1998–2006. N=24976. Source: ISI Web of Science

Second-generation Biofuels

Table 44: Second-generation Biofuels–Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	DK N=134	EE N=5	FI N=78	IS N=0	LT N=4	LV N=2	NO N=25	SE N=171	World N=5034
1998	8	0	4	0	0	0	1	11	395
1999	10	0	7	0	0	0	2	12	445
2000	8	0	4	0	0	0	5	15	490
2001	4	1	4	0	0	0	3	14	476
2002	16	0	16	0	1	0	1	19	511
2003	23	1	15	0	0	0	1	20	574
2004	16	2	8	0	0	2	4	23	652
2005	17	0	11	0	1	0	3	27	698
2006	32	1	9	0	2	0	5	30	793
Sum	*134*	*5*	*78*	*0*	*4*	*2*	*25*	*171*	*5034*

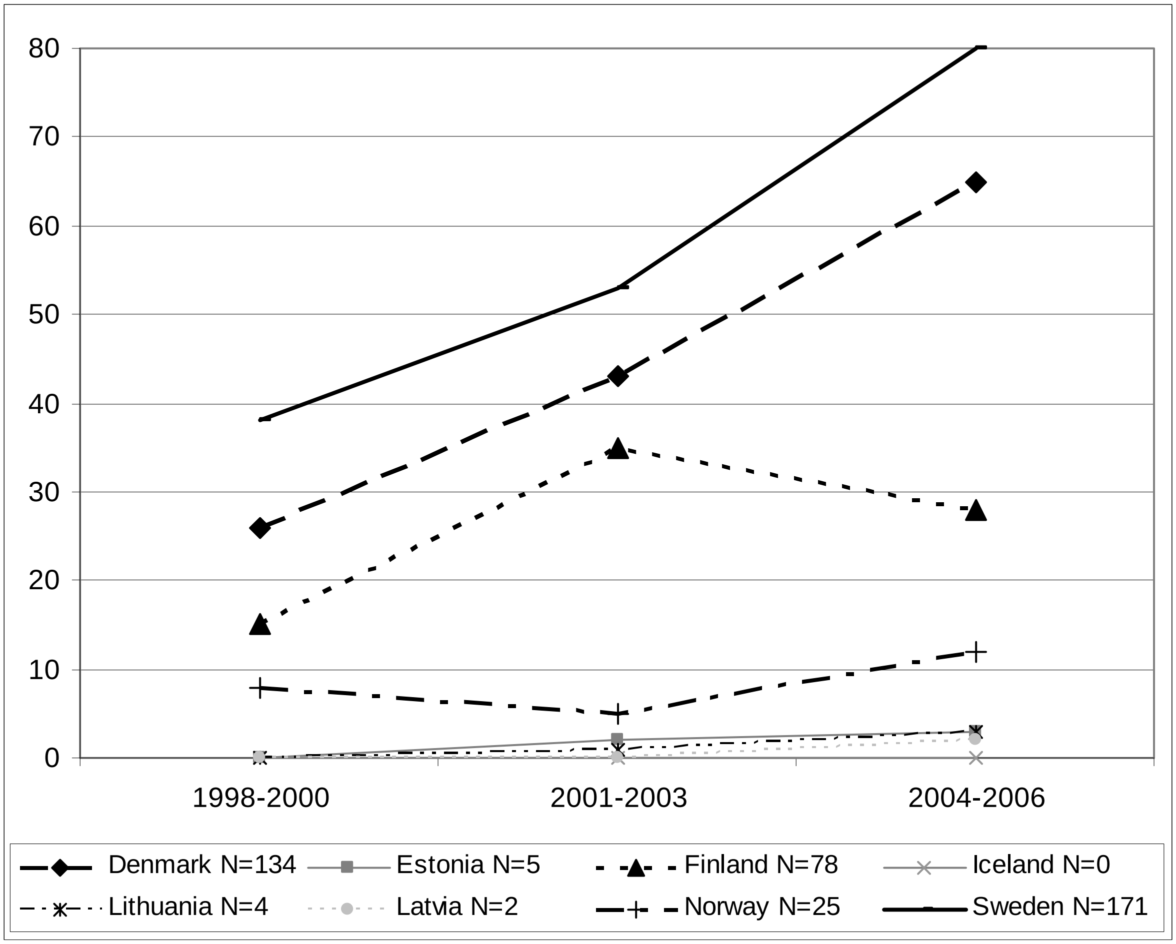

Figure 44: second-generation Biofuels - Scientific publishing 1998–2006 (N=396). Source: ISI Web of Science

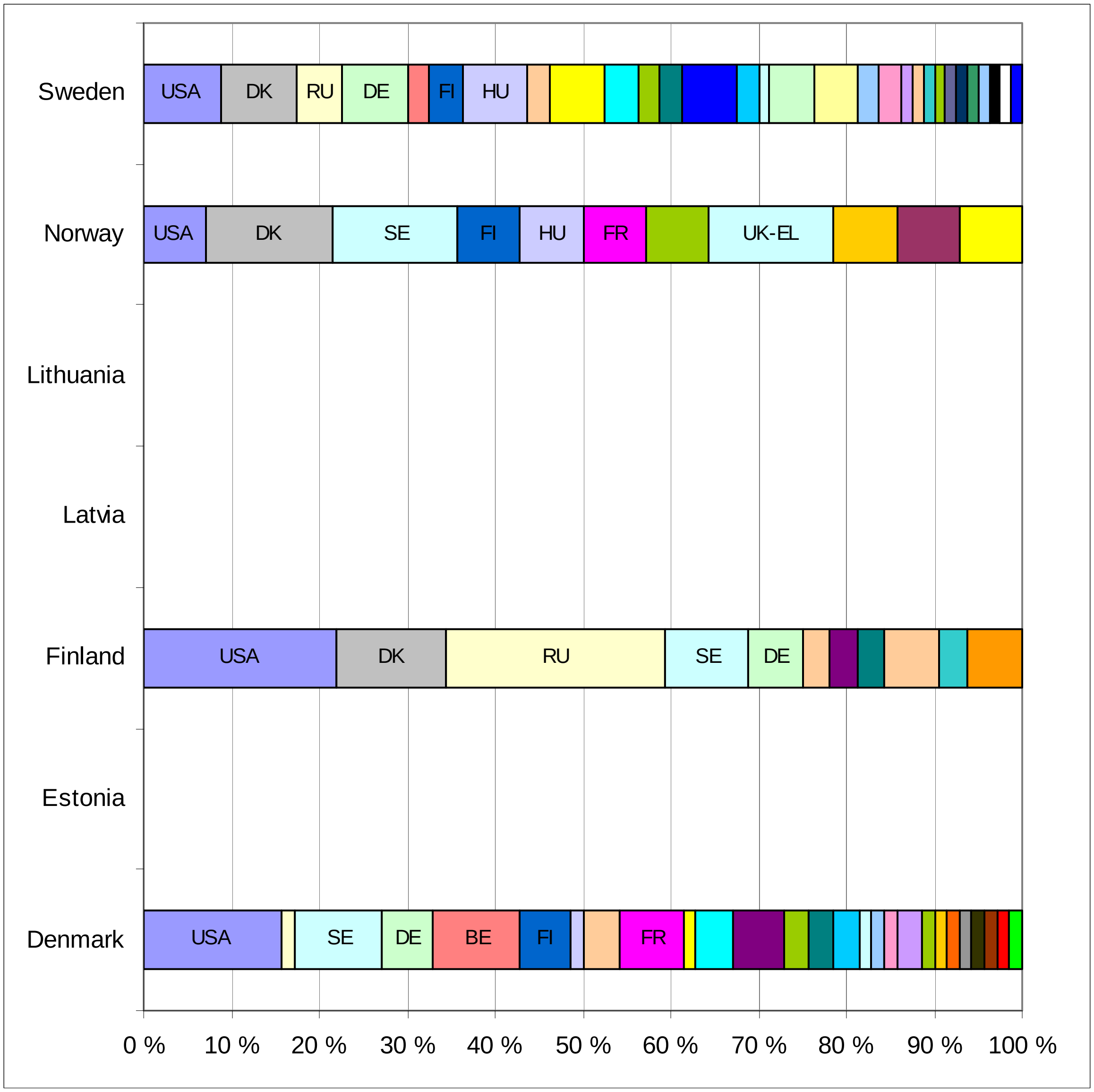

Figure 45: second-generation Biofuels - Articles with international co-authorship - share of countries. Source: ISI Web of Science

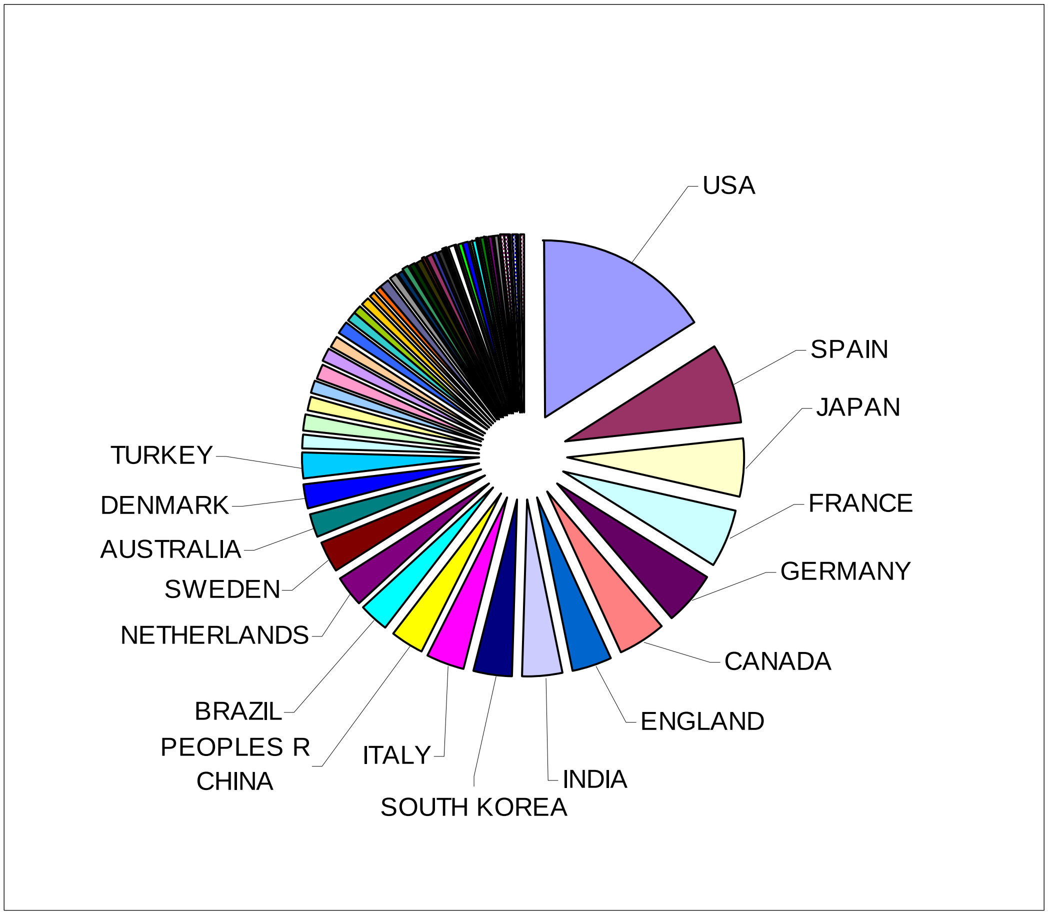

Figure 46: second-generation Biofuels - Scientific publishing in the World. Shares of countries. 1998–2006. N=5034. Source: ISI Web of Science

CO_2 technology

Table 45: CO_2 technology–Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	DK	EE	FI	IS	LT	LV	NO	SE	World
1998	3	1	1	1	0	0	4	4	130
1999	2	0	0	1	0	0	2	3	140
2000	3	0	1	0	0	0	2	7	164
2001	0	2	1	0	0	0	5	5	166
2002	1	0	2	0	0	0	2	2	198
2003	0	1	1	0	0	0	5	8	262
2004	3	1	1	0	0	0	15	8	307
2005	6	1	2	0	0	0	17	7	389
2006	4	0	4	0	0	0	19	18	408
Sum	*22*	*6*	*13*	*2*	*0*	*0*	*71*	*62*	*2164*

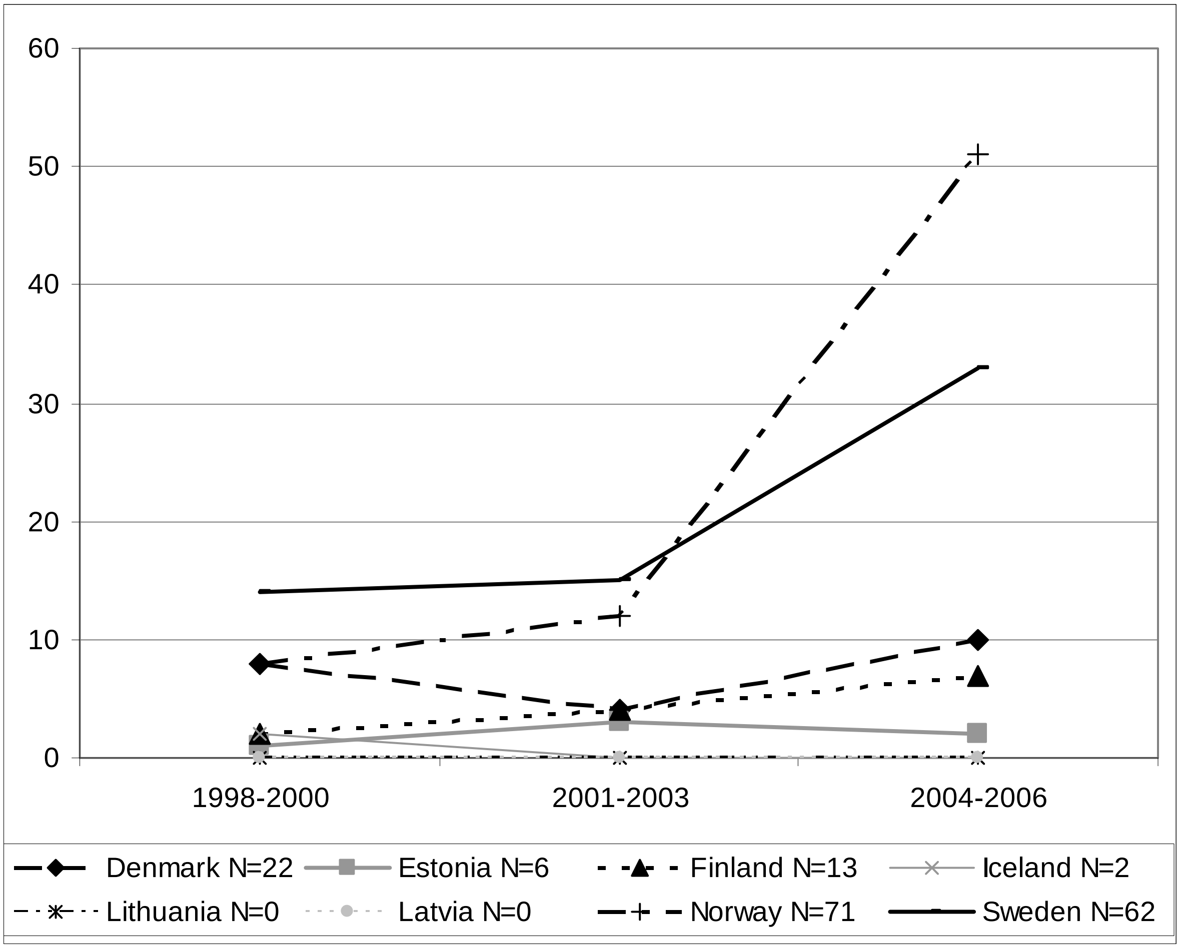

Figure 47: CO_2 technology - Scientific publishing 1998–2006 (N=165). Source: ISI Web of Science

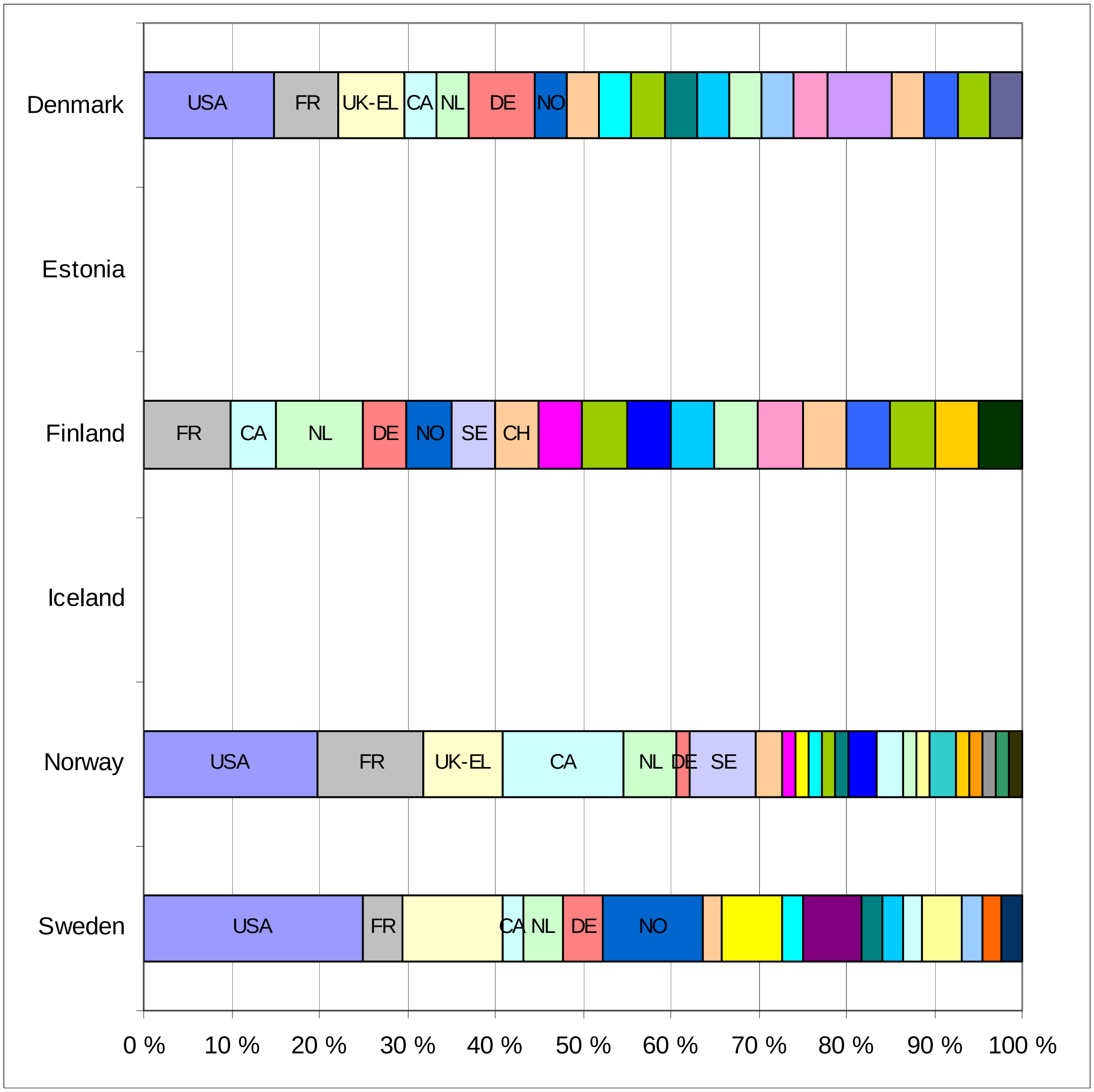

Figure 48: CO_2 technology - Articles with international co-authorship - share of countries. Source: ISI Web of Science

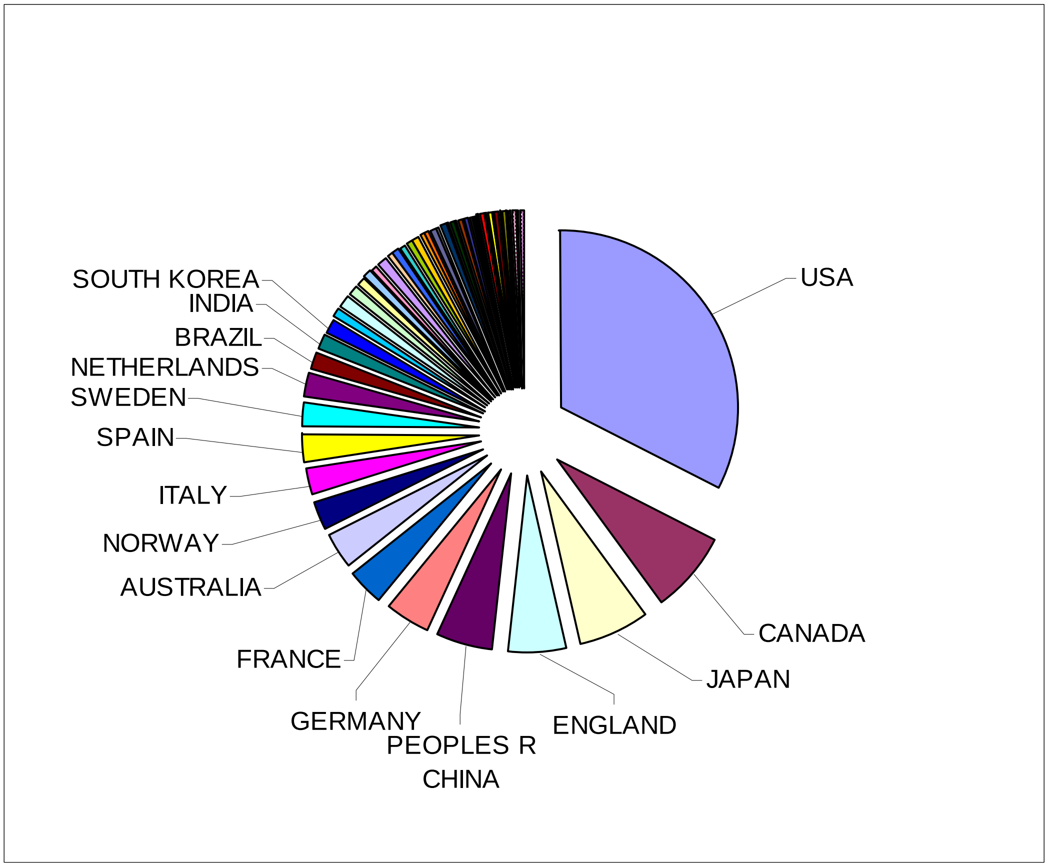

Figure 49: CO_2 technology - Scientific publishing in the World. Shares of countries. 1998–2006. N=34360. Source: ISI Web of Science

Hydropower

Table 46: Hydropower–Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	DK N=19	EE N=1	FI N=28	IS N=3	LT N=4	LV N=1	NO N=57	SE N=72	World N=2289
1998	0	0	1	0	0	0	1	5	188
1999	2	0	2	0	0	0	3	2	241
2000	2	0	0	1	0	0	1	4	223
2001	0	0	3	1	0	0	7	3	235
2002	3	0	8	1	1	1	4	10	256
2003	2	0	4	2	1	0	12	7	256
2004	1	0	1	0	0	0	8	14	285
2005	5	1	6	1	0	0	10	13	295
2006	4	0	3	3	2	0	11	14	310
Sum	*19*	*1*	*28*	*9*	*4*	*1*	*57*	*72*	*2289*

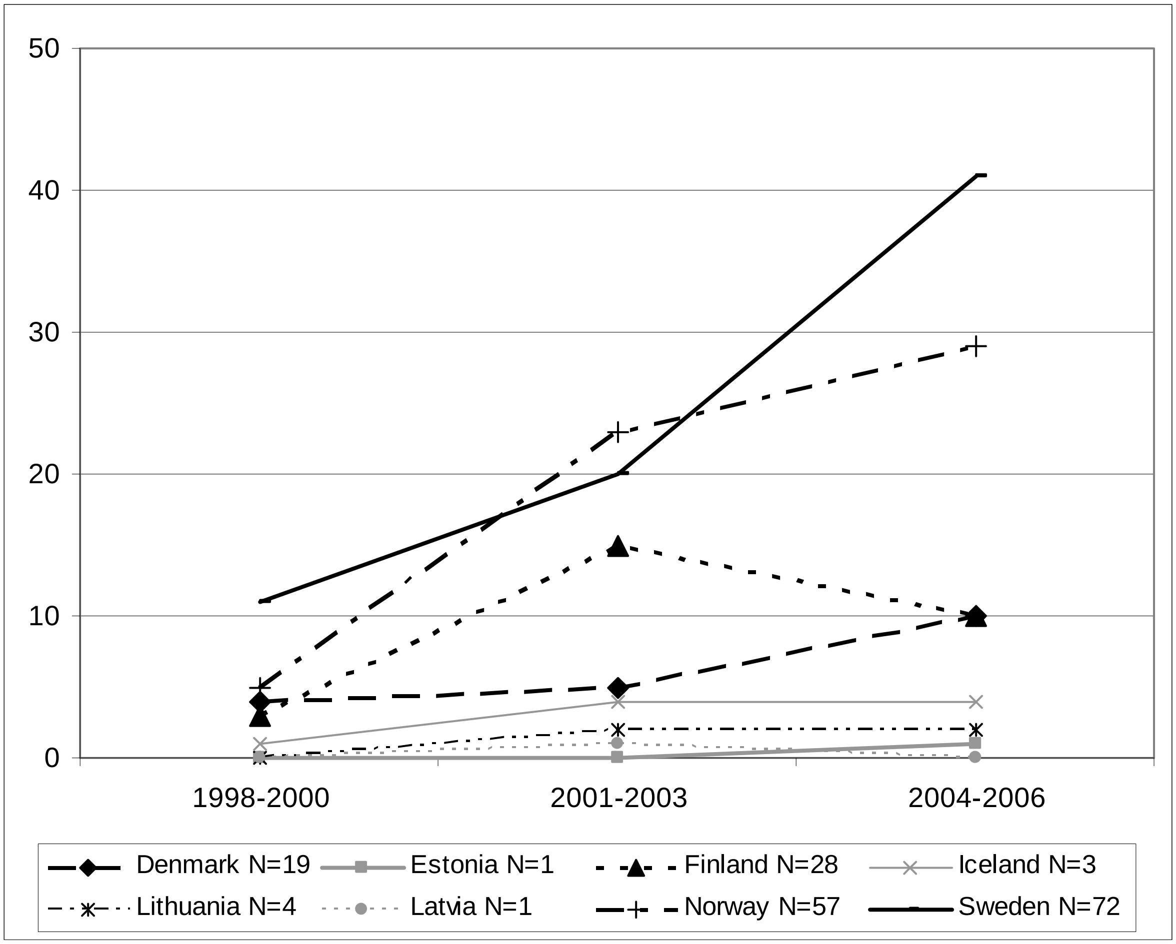

Figure 50: Hydropower - Scientific publishing 1998–2006 (N=175). Source: ISI Web of Science

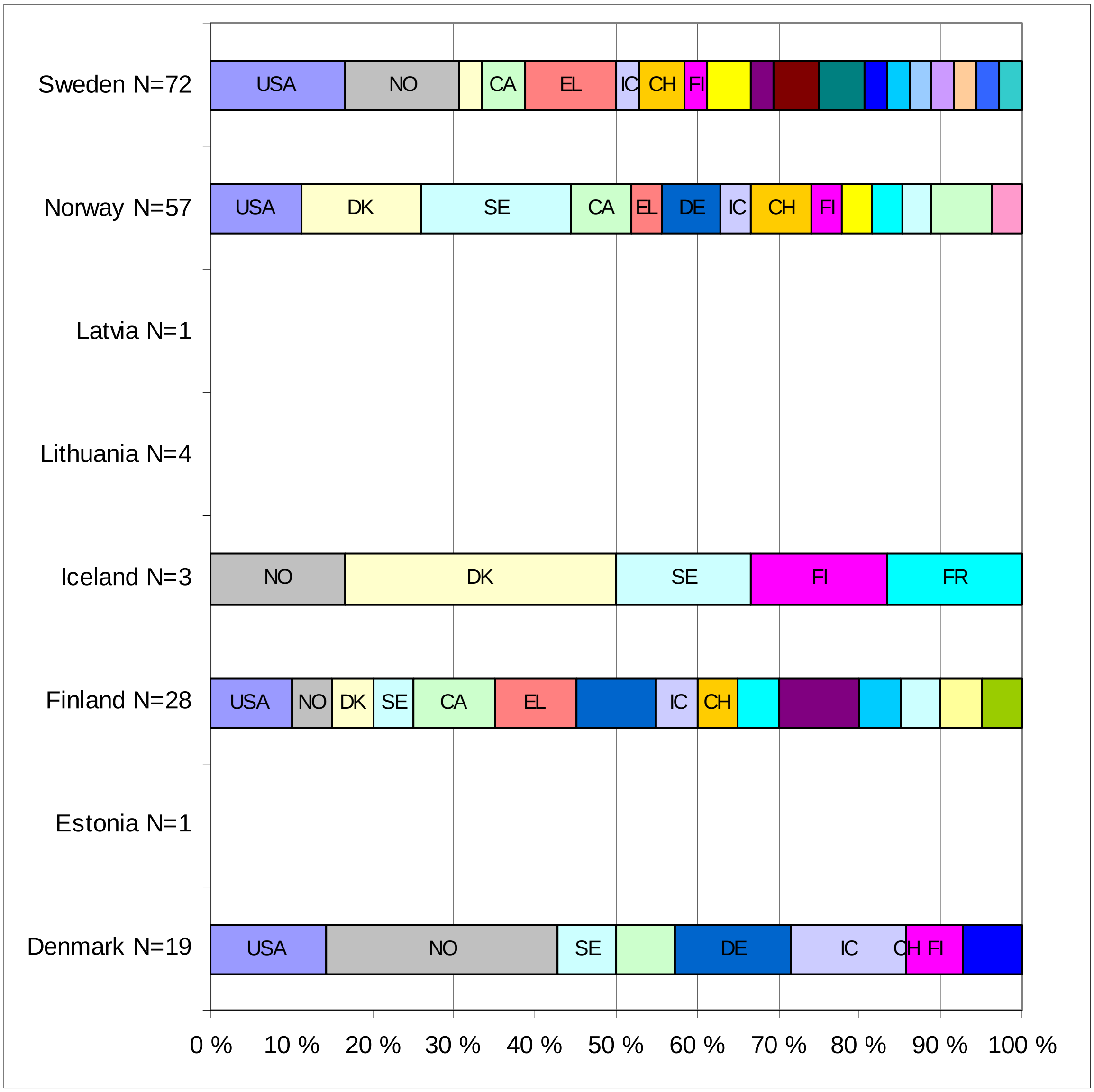

Figure 51: Hydropower - Articles with international co-authorship - share of countries. Source: ISI Web of Science

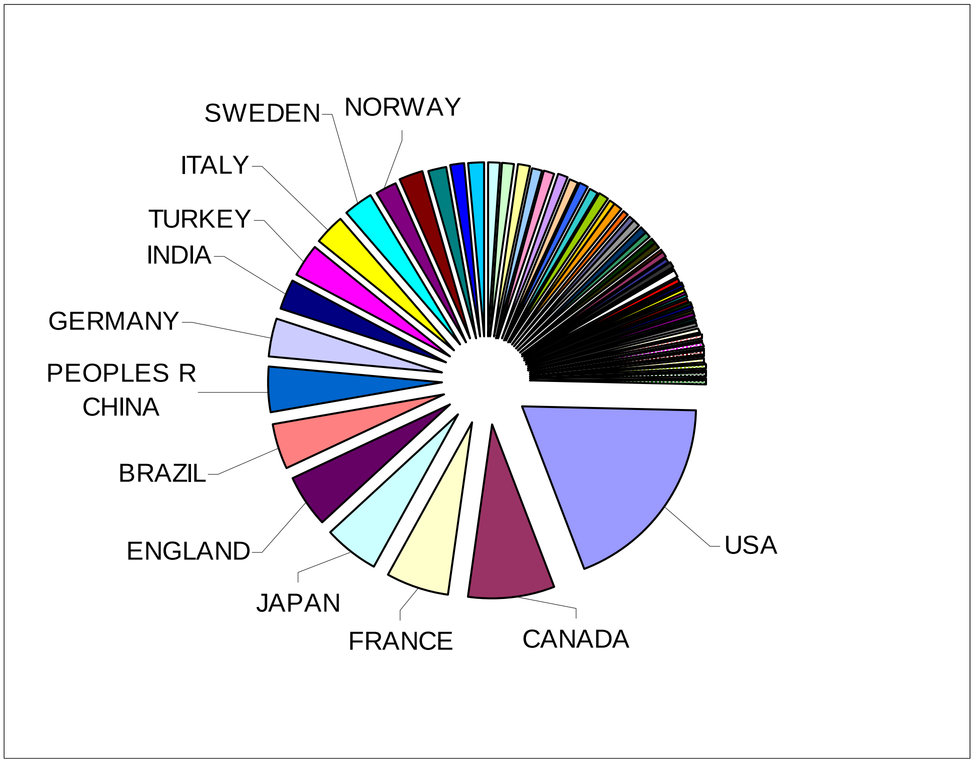

Figure 52: Hydropower - Scientific publishing in the World. Shares of countries. 1998–2006. N=2289. Source: ISI Web of Science

Hydrogen energy

Table 47: Hydrogen energy–Development of Scientific publishing 1998–2006. Source: ISI Web of Science

	DK	EE	FI	IS	LT	LV	NO	SE	World
1998	32	0	20	1	6	0	21	55	3297
1999	32	0	31	3	3	4	17	65	3352
2000	43	3	34	4	1	1	12	76	3355
2001	38	4	28	0	2	1	18	79	3432
2002	39	4	30	0	1	2	16	79	3711
2003	34	2	23	0	0	1	18	72	3882
2004	30	4	26	1	3	1	20	85	4189
2005	42	2	37	2	6	2	28	94	4694
2006	38	3	27	4	2	2	45	85	4448
Sum	*328*	*22*	*256*	*15*	*24*	*14*	*195*	*690*	*34360*

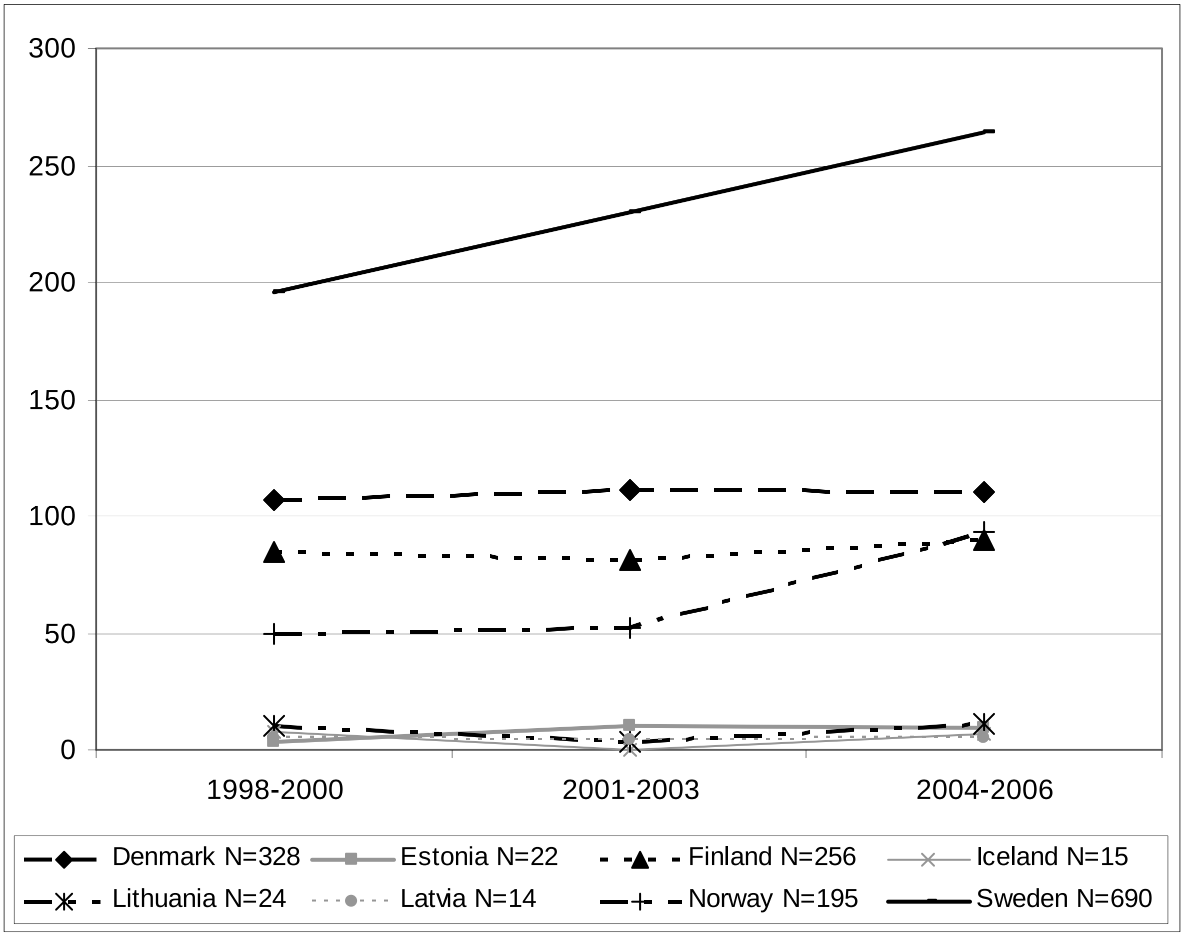

Figure 53: Hydrogen energy - Scientific publishing 1998–2006 (N=1449). Source: ISI Web of Science

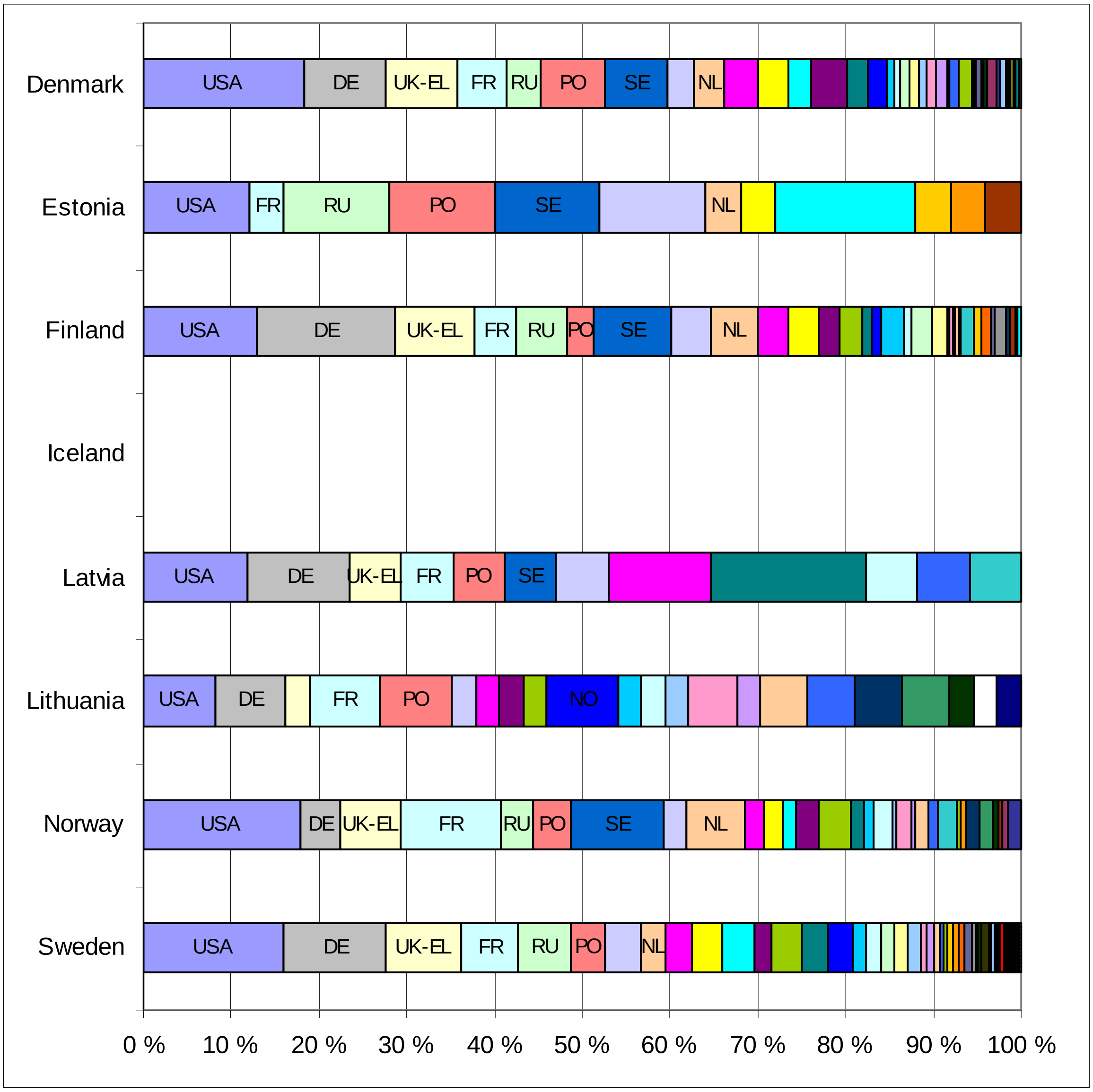

Figure 54: Hydrogen energy - Articles with international co-authorship - share of countries. Source: ISI Web of Science

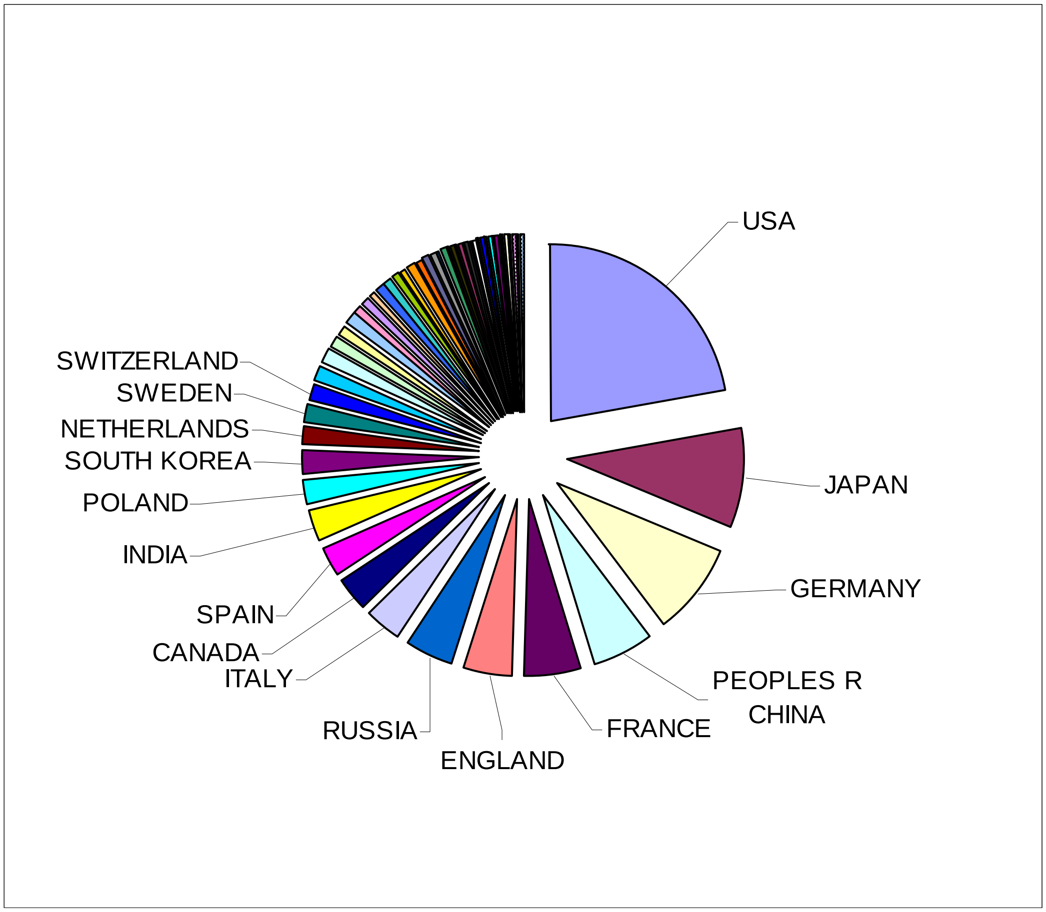

Figure 55: Hydrogen energy - Scientific publishing in the World. Shares of countries. 1998–2006. N=34360. Source: ISI Web of Science

5. Renewable energy by country

5.1 Ratio between the electricity produced from renewable energy sources and the gross national electricity consumption

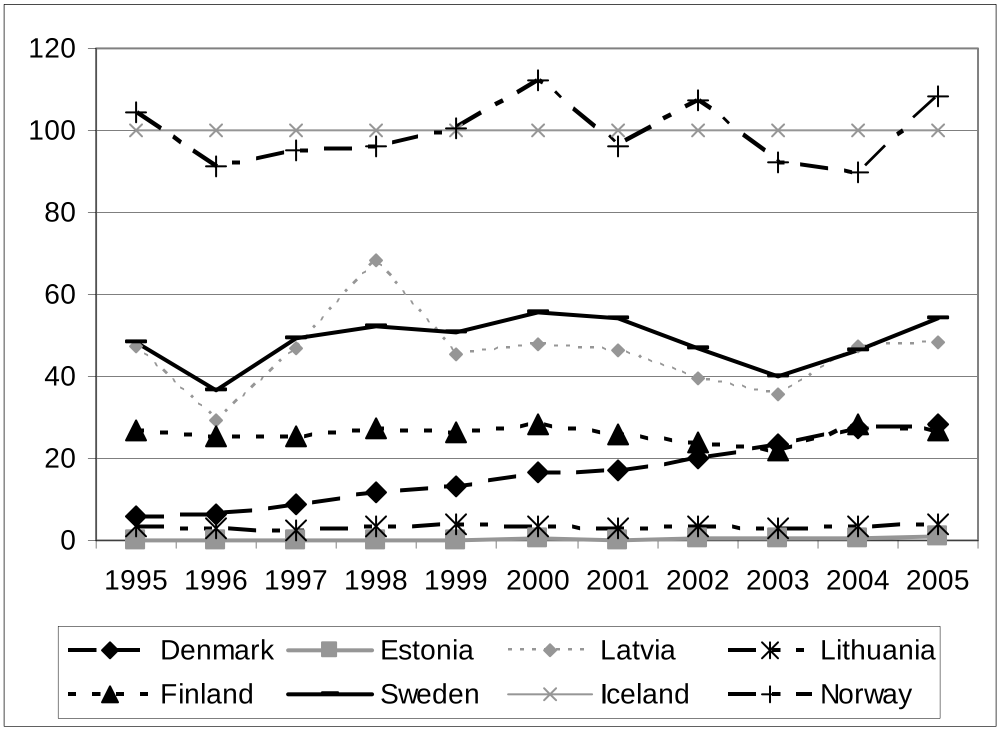

Figure 56: Ratio between the electricity produced from renewable energy sources and the gross national electricity consumption. 1995–2005. Source: Eurostat

The ratio between the electricity produced from renewable energy sources and the gross national electricity consumption for a given calendar year measures the contribution of electricity produced from renewable energy sources to the national electricity consumption (Figure 56 and Table 48). Electricity produced from renewable energy sources comprises the electricity generation from hydro plants (excluding pumping), wind, solar, geothermal and electricity from biomass/wastes.

Gross national electricity consumption comprises the total gross national electricity generation from all fuels (including auto production), plus electricity imports, minus exports.

The data have been compiled through annual questionnaires undertaken by Eurostat and the IEA. Time series are given from 1994 onwards. EU Member States have to report on the improvement of the ratio between the electricity produced from renewable energy sources and the gross national electricity consumption to reach the indicative targets by 2010.

All the Nordic countries and Latvia have a significant higher share of electricity produced by renewable sources than the average of the European Union (Figure 50 and Table 48). The highest share of electricity produced by renewable sources had Norway due to the extensive use of hydropower and Iceland due to the use of geothermal energy. The relatively high shares in Sweden, Latvia and Finland have remained fairly stable. The biggest changes can be reported for Denmark, where the share of electricity produced by renewable sources increased from from 5.8 per cent to 28.2 per cent. These countries will probably reach the targets for 2010.

The shares for Estonia and Lithuania are still on a very low level and demand a great effort to come on the envisaged target for 2010.

Table 48: Ratio between the electricity produced from renewable energy sources and the gross national electricity consumption. 1995–2005. Source: Eurostat

	Denmark	Estonia	Latvia	Lithuania	Finland	Sweden	EU27	Iceland	Norway
1995	5.8	0.1	47.1	3.3	27	48.2	13	99.8	104.6
1996	6.3	0.1	29.3	2.8	25.5	36.8	12.7	99.9	91.4
1997	8.8	0.1	46.7	2.6	25.3	49.1	13.1	99.9	95.3
1998	11.7	0.2	68.2	3.6	27.4	52.4	13.4	99.9	96.2
1999	13.3	0.2	45.5	3.8	26.3	50.6	13.4	99.9	100.7
2000	16.4	0.3	47.7	3.4	28.5	55.4	13.8	99.9	112.2
2001	17.3	0.2	46.1	3	25.7	54.1	14.4	100	96.2
2002	19.9	0.5	39.3	3.2	23.7	46.9	12.9	99.9	107.3
2003	23.2	0.6	35.4	2.8	21.8	39.9	12.9	99.9	92.1
2004	27.1	0.7	47.1	3.5	28.3	46.1	13.9	100	89.7
2005	28.2	1.1	48.4	3.9	26.9	54.3	14	99.9	108.4
Target 2010	29.0	5.1	49.3	7.0	31.5	60.0	21		

5.2 Electricity generation by origin: Wind (GWh)

Gross electricity generation in wind turbines is shown in Table 49. The gross electricity generation is measured at the outlet of the main transformers, i.e. the consumption of electricity in the plant auxiliaries and in transformers is included.

Table 49: Gross electricity generation in wind turbines (in GWh) 1994–2005. Source: Eurostat.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
EU 27	3494	4069	4846	7330	11278	14204	22250	26977	35710	44370	58814	70482
Denmark	1137	1177	1227	1934	2820	3029	4241	4306	4877	5561	6583	6614
Estonia	0	0	0	0	1	1	1	1	1	6	8	54
Latvia	0	0	1	1	2	2	4	3	11	48	49	47
Lithuania	-	-	-	-	-	-	-	-	-	-	-	-
Finland	7	11	11	17	24	49	78	70	64	93	120	170
Sweden	72	99	144	203	316	358	457	482	608	679	850	936
Norway	9	10	9	10	7	25	31	27	75	218	252	506

The electricity generation in wind turbines has been the main pathway for Denmark's strategy to expand the share of renewable based electricity production (Table 49 and Figure 57). The other countries have used this option to a much more limited degree. There are some efforts worth mentioning, like the increase in Swedish wind-based electricity generation or the efforts in Norway. Development in Estonia and Latvia is promising, while due to extensive use of nuclear power, Lithuania had not used this technology before 2005. A marginal increase can though be seen since 2006 when a total of 36 wind turbines were installed. According to the latest installation figures the total wind energy capacity for December 2007 in Lithuania was 52.3 MW.[29]

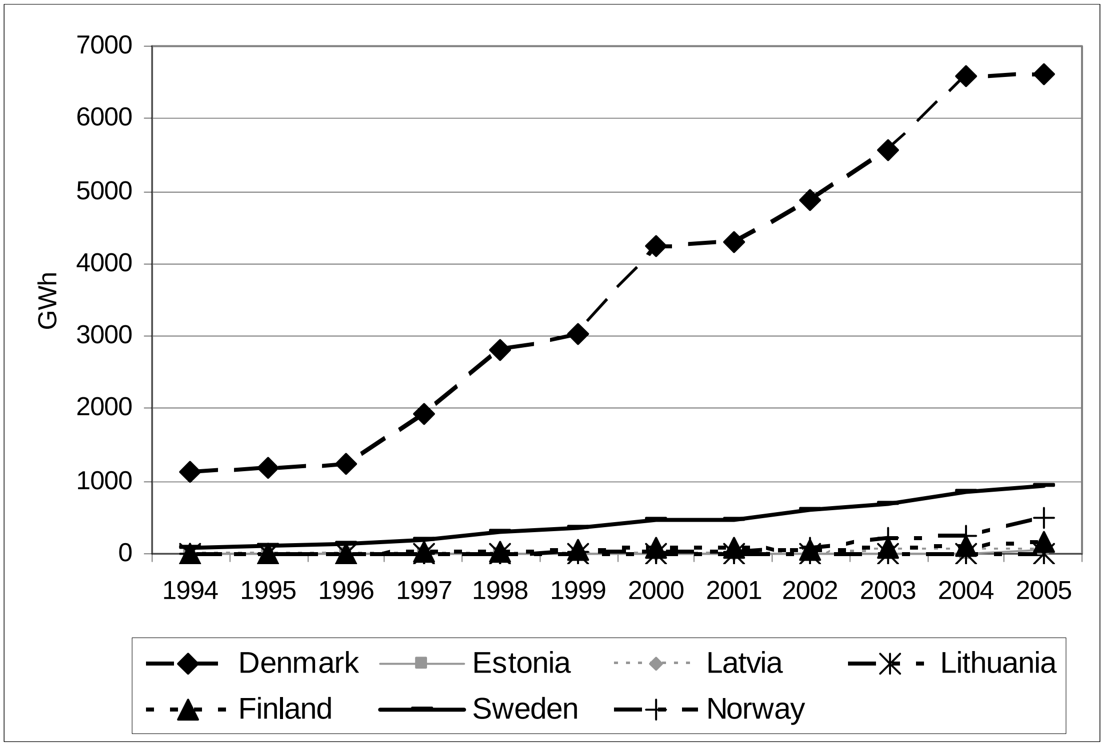

Figure 57: Nordic and Baltic gross electricity generation in wind turbines (in GWh) 1994–2005. Source: EUROSTAT

5.3 Renewable energy primary production: solar energy, biomass and wastes, geothermal and hydro power

In the following section we compare the countries in our sample according to following renewable energy sources based on data for 1994 to 2005 provided by Eurostat:

- Solar energy covers the solar radiation exploited for solar heat (hot water) and electricity production (Figure 58);
- Biomass and wastes (heat content of the produced biofuels or biogas; heat produced after combustion during incineration of renewable wastes) (Figure 59);

[29] Lithuanian Wind Energy Association

- Geothermal energy comprises energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam (Figure 60);
- Hydropower covers potential and kinetic energy of water converted into electricity in hydroelectric plants (the electricity generated in pumped storage plants is not included) (Figure 61).

The production of energy based on solar energy is fairly limited in all the Nordic and Baltic countries (Figure 58) and the modest contributions in some of the countries – especially Denmark and Sweden – are concentrated on solar heating and not on solar photovoltaic energy.

The production of energy based on biomass and wastes has especially high attention in Sweden and Finland and this type of energy production has still increased since 1994 (Figure 59). Important to mention are the efforts to increase the energy production based on biomass and wastes in Latvia and Denmark – Latvia achieved a doubling of the production of energy based on biomass and wastes and has passed Norway. The two other Baltic countries have also increased this energy production, while Norway has not put much effort into this. In Iceland this energy source is still not prioritised, but Iceland is also the only country in this study with large geothermal energy resources (Figure 60).

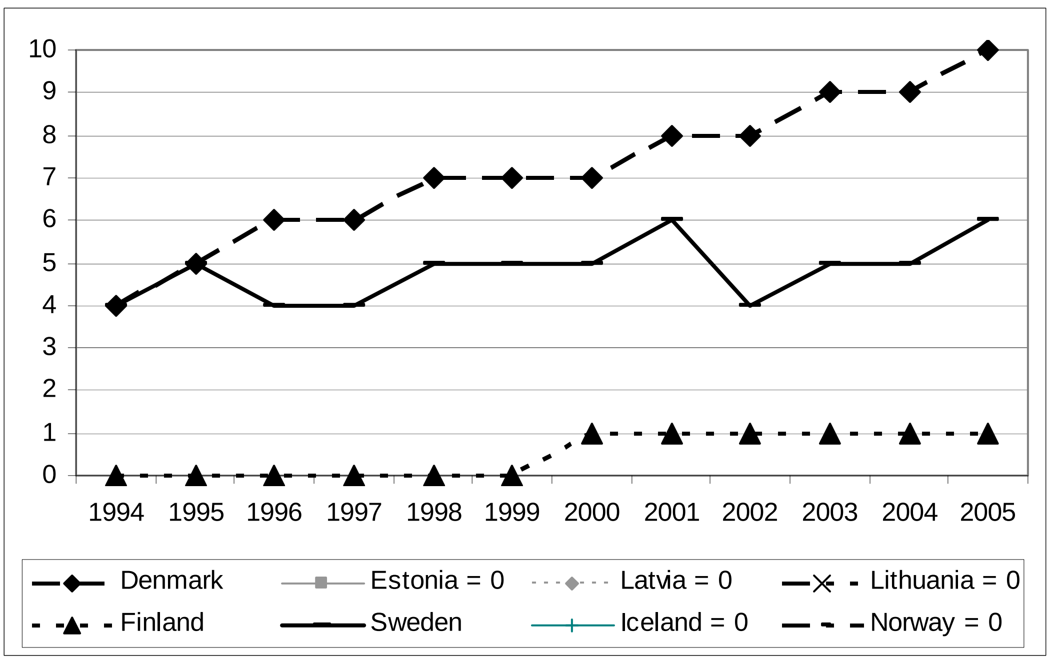

Figure 58: Renewable energy primary production: Solar energy (1000 toe) 1994–2005. Source: EUROSTAT

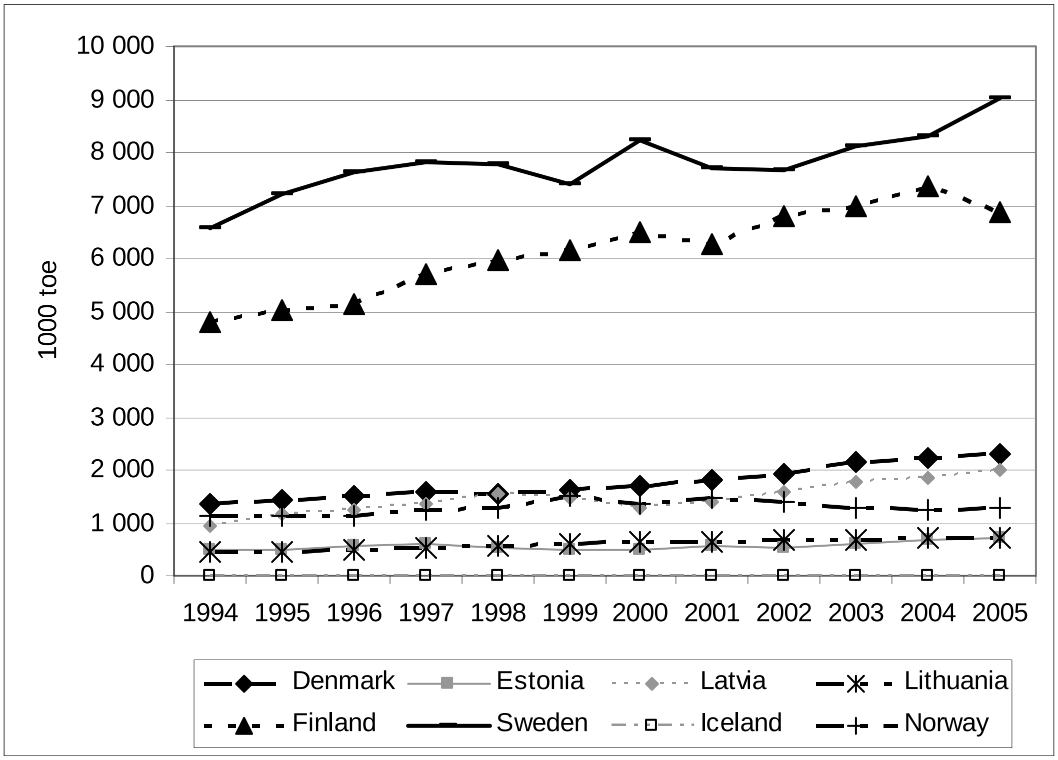

Figure 59: Renewable energy primary production: Biomass and wastes (1000 toe) 1994–2005. Source: EUROSTAT

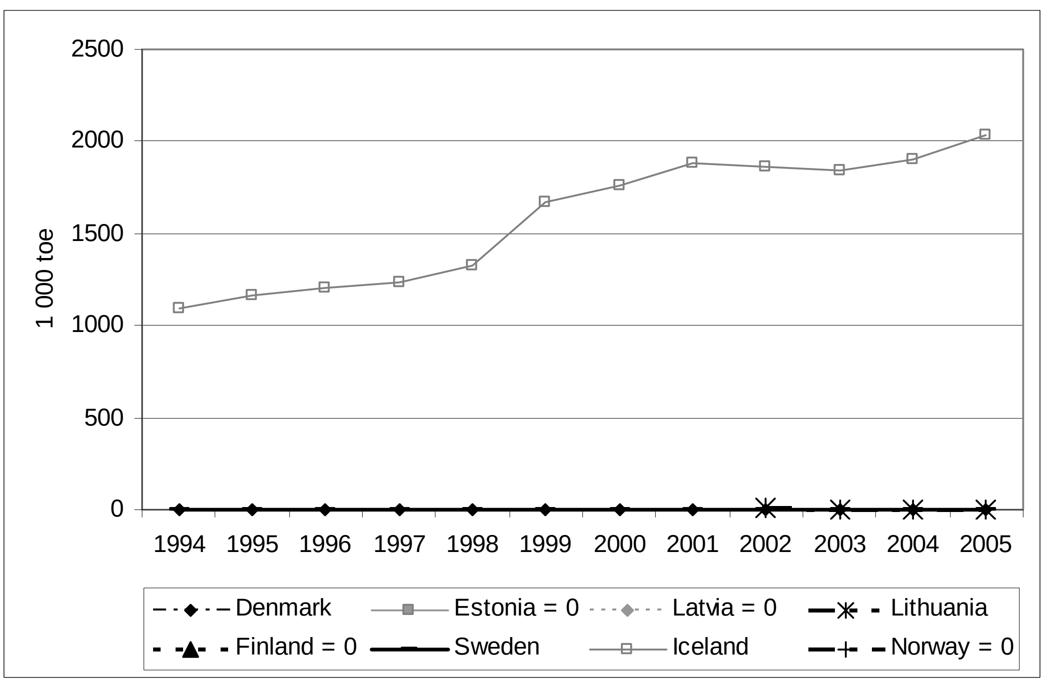

Figure 60: Renewable energy primary production: Geothermal energy (1000 toe) 1994–2005. Source: EUROSTAT

The primary energy production based on hydropower has been important for Norway and Sweden, and the volume has still increased since 1994 (Figure 61). Differences from year to year can be explained by climatic variations which have an impact on the water level in the reservoirs. Finnish and Latvian hydropower production has also been important, but fairly stable. The volume of hydropower in Iceland has increased by more than 50 per cent.

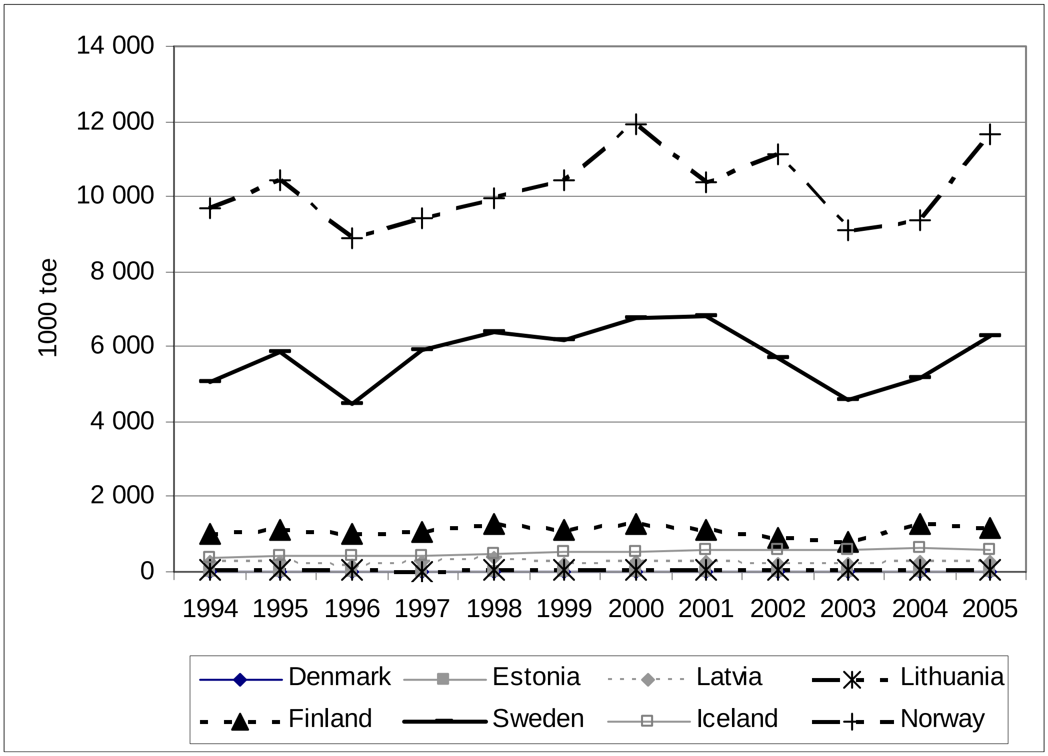

Figure 61: Renewable energy primary production: Hydropower primary production (1000 toe) 1994–2005. Source: EUROSTAT

6. RD&D expenditures on renewable energy technologies in the Nordic countries

6.1 Data by country

This section presents data from the International Energy Agency (IEA), which publishes time series between 1974 and 2005 of RD&D budget data for the energy sector. The data for Norway, Sweden, Finland and Denmark is presented country by country before some comparisons of the RD&D budgets are done. The aim of the section is to uncover the peculiarity of each country's energy RD&D configuration, and to bring that lesson on into the comparison of RD&D efforts across countries.

Norway

Norway's structure of RD&D in the energy sector is strongly influenced by oil and gas. Figure 62 shows the development of oil and gas RD&D compared to the renewable energy RD&D. In 2005 almost €49m were allocated to oil and gas RD&D. The same year renewable energy RD&D totalled €6.3m, i.e. only about one-eighth of that of oil and gas. But, the figure illustrates, the two RD&D domains were previously more similar in terms of RD&D. In 1992 Norwegian renewables RD&D amounted to €20m while the oil and gas RD&D effort was at an almost historically low level around €30m.

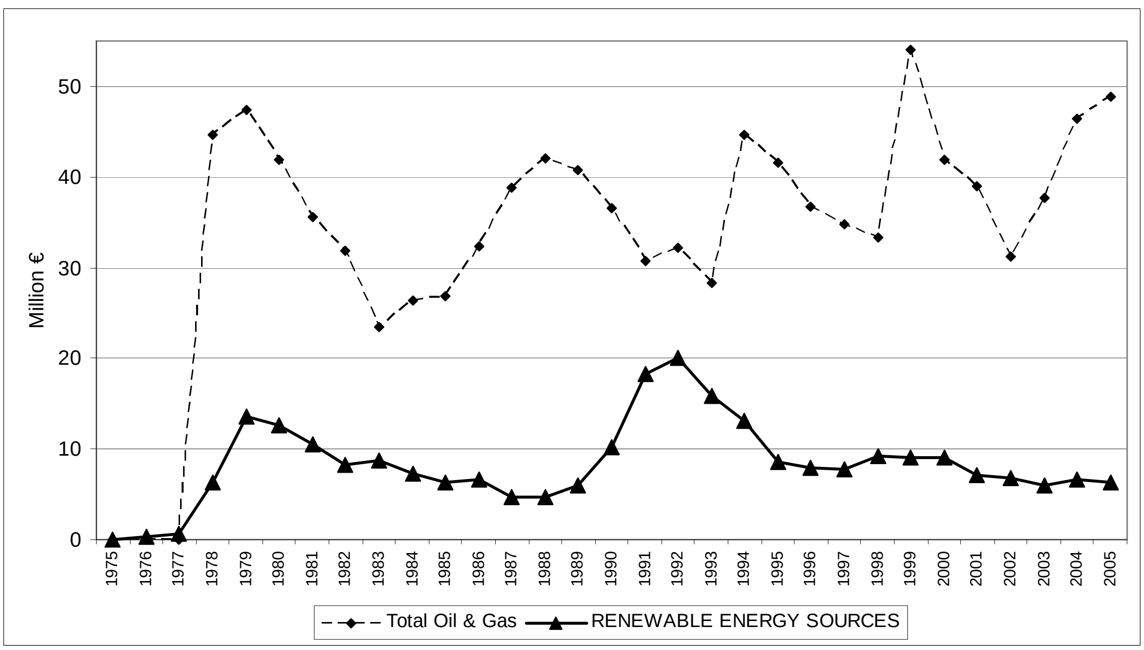

Figure 62: RD&D Budgets, Norway, Fossil fuel and Renewable Energy, 1975–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

The next figure (Figure 63) displays the details of the renewables energy RD&D in Norway which, as mentioned, had its peak in the early 1990s. The main contribution to this peak is hydropower RD&D. Hydropower RD&D has experienced a steady decline but stayed dominant until around the turn of the millennium, when solar energy research took over. The picture in 2005 revealed fewer differences. Most of the RD&D domains had a volume of between €1 and €2m. The overall trend of Norwegian renewable energy RD&D shows a slight increase but the absolute level of this type of RD&D is not impressive.

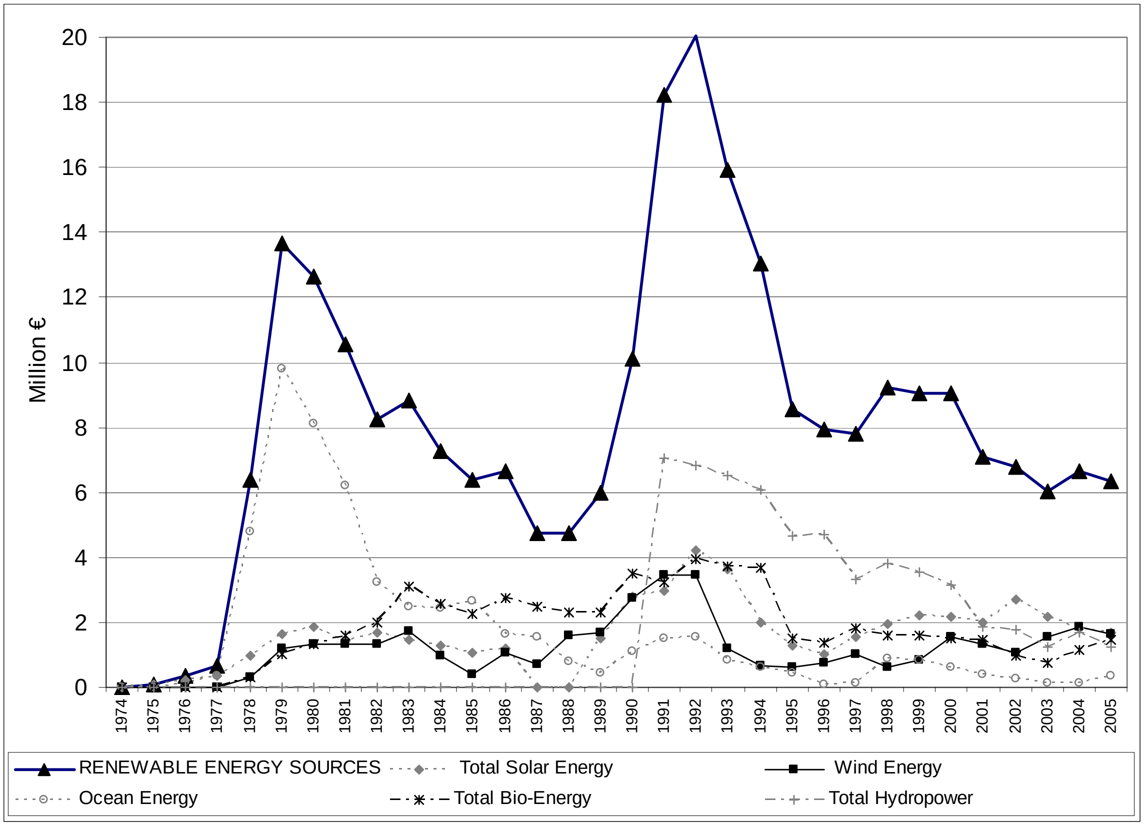

Figure 63: RD&D Budgets, Norway, Renewable Energy, 1974–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

Sweden

Sweden has an energy RD&D configuration that, over time, has been dominated by the renewable energy domain, as seen in the figure below. Figure 64 compares the level of RD&D resources allocated to the three largest domains – fossil fuels, renewable energy and nuclear energy.

Figure 65 depicts the renewables domain in more detail. Bioenergy RD&D is structurally the largest area of energy RD&D. RD&D in the other renewable energy domains has been stable and relatively low over the last 30 years. A specific feature in the Swedish case is the relatively strong RD&D effort in solar heating during the 1980s. In general, the early 1980s was a period in which the total renewable energy RD&D peaked at around €100m annually.

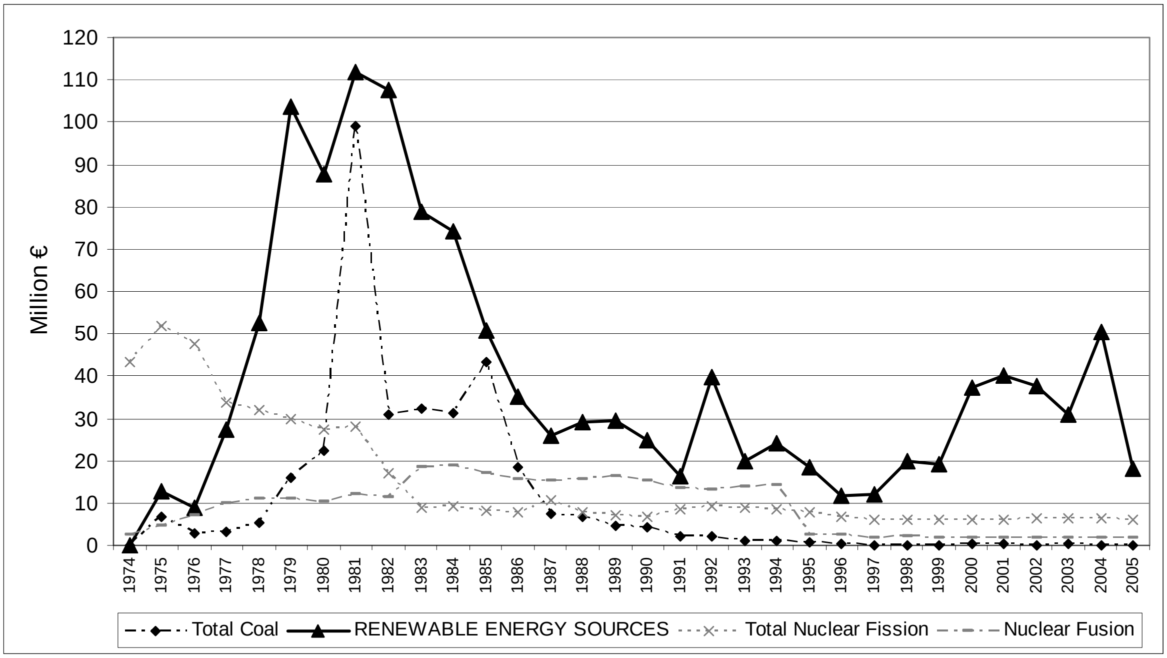

Figure 64: RD&D Budgets, Sweden, Fossil fuel, Renewable Energy and Nuclear Fission/Fusion, 1974–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

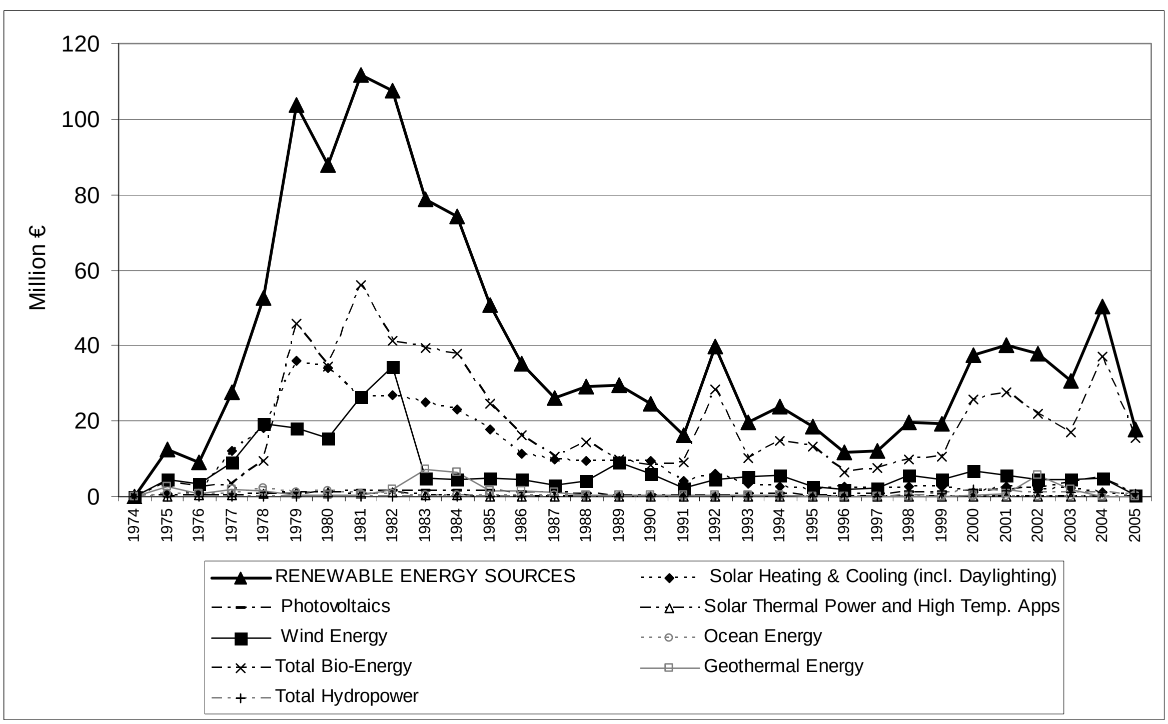

Figure 65: RD&D Budgets, Sweden, Renewable Energy, 1974–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

Finland

Energy research data from Finland has a more limited time span. IEA holds data of Finnish energy RD&D between 1990 and 2003 (Figure 66). Finnish energy RD&D has two domains with a relatively high level of input, the nuclear energy domain and the renewable energy domain, and two domains with a relatively low level of effort; oil and gas, and coal. This was the main pattern throughout the period 1993–2003. The trend in terms of Finnish non-renewable energy RD&D up until 2003 is that of a steady and slightly declining effort in the nuclear domain. Oil and gas and coal RD&D was relatively stable during the first half of the 1990s (zero for oil and gas and around €5m annually for coal), the last then moving slowly towards marginal amounts in 2003.

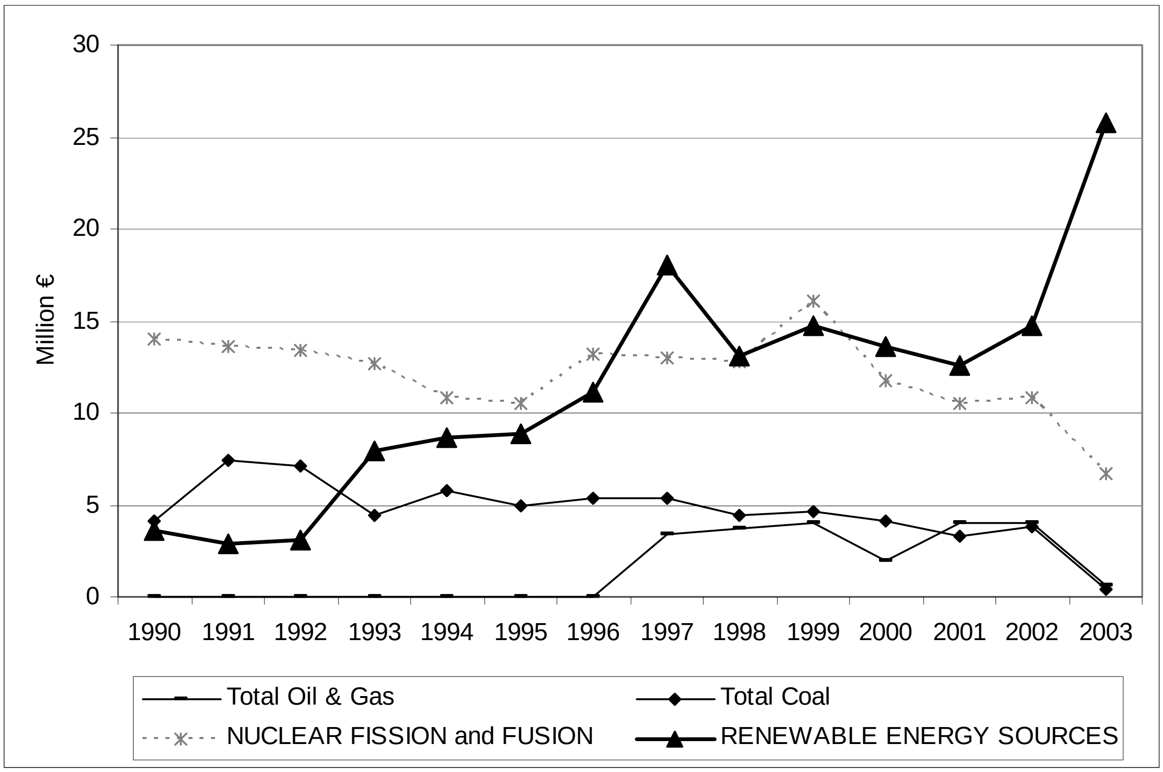

Figure 66: RD&D Budgets, Finland, Fossil fuels, nuclear energy, renewable energy, 1990–2003, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

Figure 67 provides details of the Finnish renewable energy RD&D effort between 1993 and 2003. The total renewable energy RD&D level increased from about €4m in 1990 to about €26m in 2003. This main contribution to this development is from the bioenergy RD&D. The last year of observation, 2003, hydropower contributes significantly to the total Finnish renewable energy RD&D. Hydropower RD&D is up from zero in 2002 to about €13m in 2003. The other renewable energy RD&D domains, solar energy and wind energy, are marginal, even though RD&D in the latter amounts to about €3m.

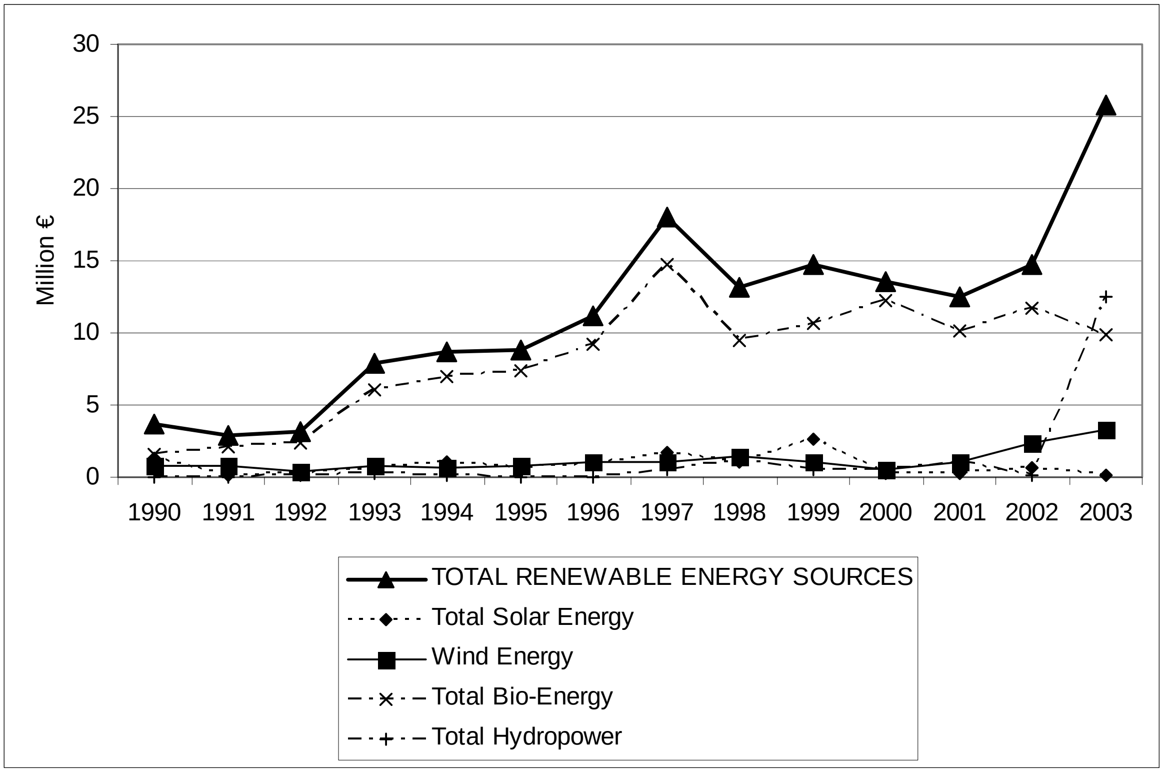

Figure 67: RD&D Budgets, Finland, Renewable Energy, 1990–2003, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

Denmark

As Figure 68 indicates, the Danish pattern of energy RD&D has been dominated by renewable energy ever since the 1980s. Between 1974 and 1980 nuclear energy RD&D dominated in Denmark. Since 1985, nuclear energy research has been around €5m. The annual RD&D efforts for oil and gas research peaked in 1995 (€5m) and for coal research in 1992 (€10m). The last years' development in RD&D in the domain of fuel cells deserves a comment when fuel cells research experienced a strong growth from zero in 2003 to about €20m in 2005.

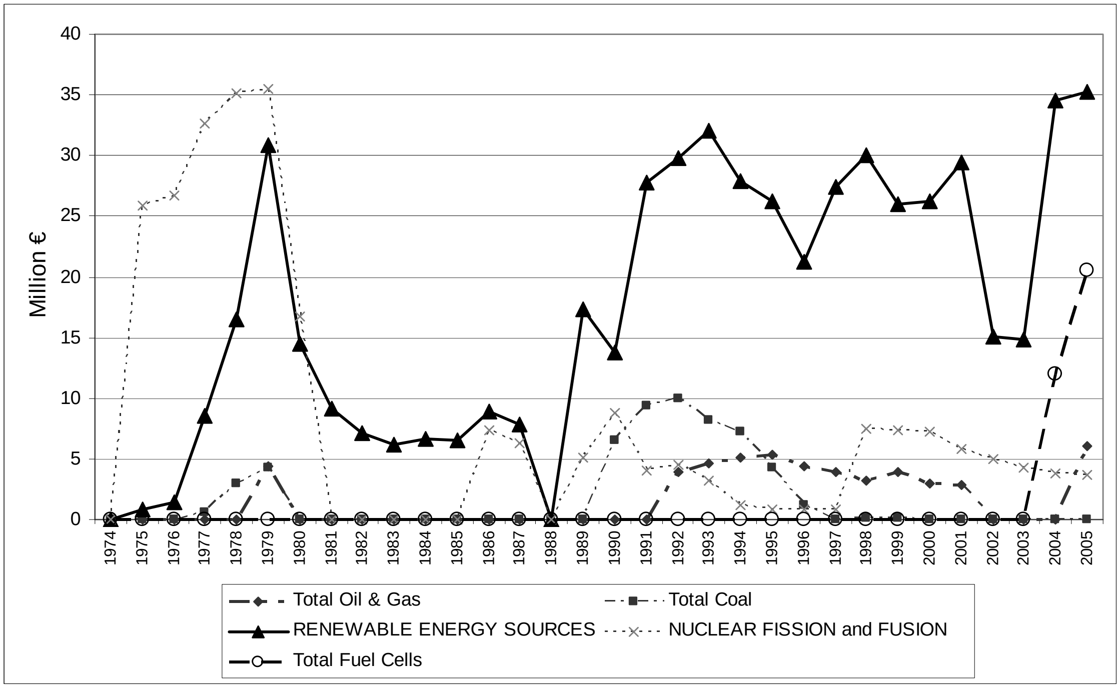

Figure 68: RD&D Budgets, Denmark, Oil and Gas, Renewable Energy, Fuel Cells, Coal, Nuclear, 1974–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

Figure 69 below shows the details of Danish renewable energy research between 1975 and 2005. The peak in 1979 for renewables in total is caused by an unusual increase in expenditures for geothermal energy R&D to €22.25m (in 1978 €5.67m, in 1980 €1m).

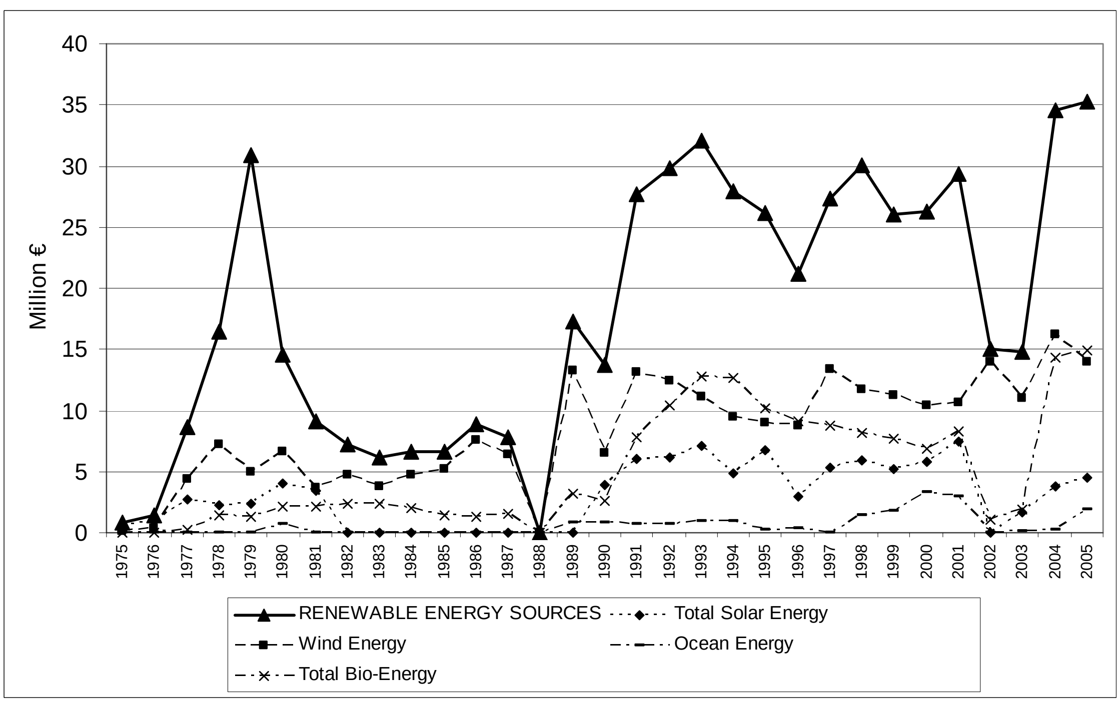

Figure 69: RD&D Budgets, Denmark, Renewable Energy, 1974–2005, million euro (2005 prices and exchange rates). Source: International Energy Agency, IEA

6.2 Comparison of countries based on normalized data

In the previous section the structure and development of country's energy research in each country was described, without that attention was given to comparisons between countries. With the normalized data in this section, we calculate the RD&D effort as share of GDP and per inhabitant. It enables a historical comparison of the countries' RD&D efforts in the renewable energy domain.

RD&D in renewable energy as share of GDP

The comparison in Figure 70 shows that Sweden had the strongest RD&D input within renewables in the 1980s by far. Remembering Sweden's detailed distribution of renewable energy research in the previous section, this strong performance is the sum of bioenergy, wind energy and solar energy research. In the 1990s Denmark basically takes over the "hegemony" of renewable energy research as percentage share of GDP. After the new millennium the picture is varied. In Sweden, Denmark and Finland the renewable energy RD&D effort is varies considerably. The Norwegian input is declining all the time with levels below the other countries. Finland's renewable energy RD&D share of GDP has significantly increased over the period.

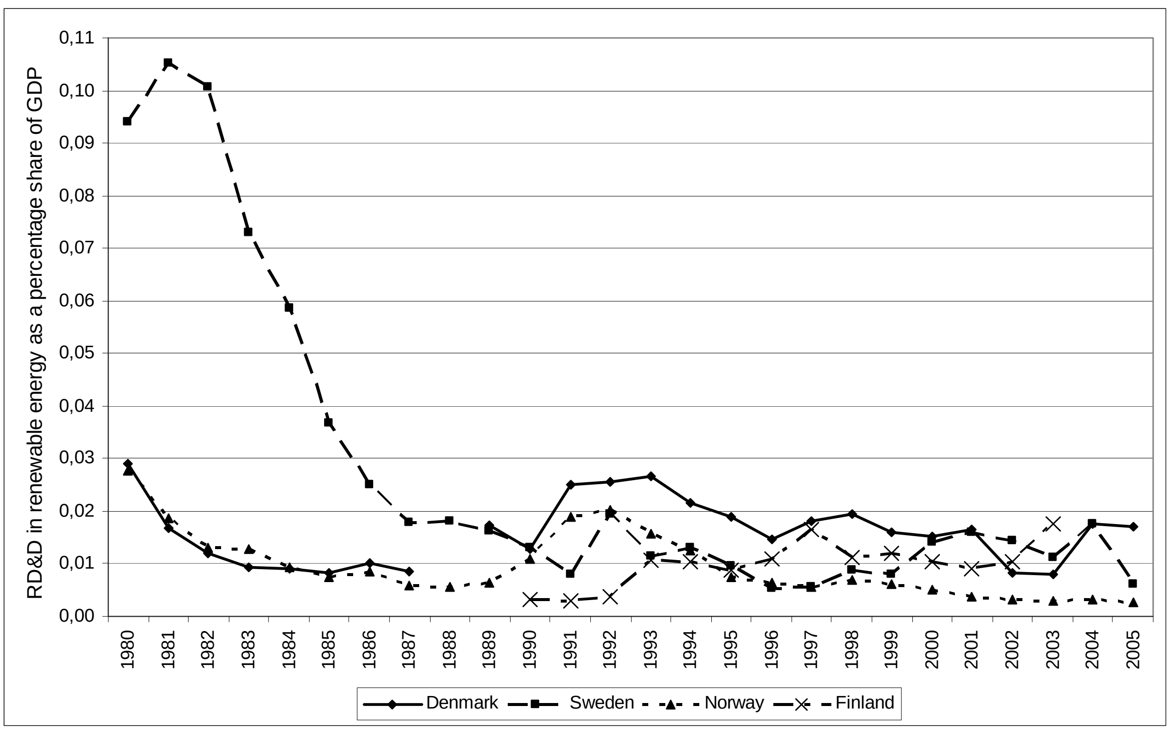

Figure 70: RD&D in renewable energy as a percentage share of GDP, 1980–2005. Source: International Energy Agency, IEA and Eurostat

The table below (Table 50) shows the numbers on which the figure above is based, however not the whole time series, only between 1993 and 2005.

Table 50: RD&D in renewable energy as a percentage share of GDP, 1993–2005

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Denmark	0.027	0.022	0.019	0.015	0.018	0.019	0.016	0.015	0.016	0.008	0.008	0.018	0.017
Sweden	0.011	0.013	0.010	0.005	0.005	0.009	0.008	0.014	0.016	0.014	0.011	0.017	0.006
Norway	0.016	0.012	0.008	0.006	0.006	0.007	0.006	0.005	0.004	0.003	0.003	0.003	0.003
Finland	0.011	0.010	0.009	0.011	0.017	0.011	0.012	0.010	0.009	0.010	0.018	n/a	n/a

RD&D in renewable energy per inhabitant

Calculating the countries' renewable energy research effort per inhabitant provides another indicator permitting comparison between countries (Table 51 and Figure 71). This indicator, also calculated for the period 1975–2005, generally shows the same picture as RD&D as a proportion of GDP. Sweden dominates in the 1980s, Denmark in the 1990s, and a more complex picture in the first half of the millennium's first decade. In the last year of observation, 2005, Denmark is highest and Norway lowest regarding renewable energy research effort per inhabitant.

Table 51: RD&D in renewable energy per inhabitant, 1992–2005

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Denmark	5.8	6.2	5.4	5.0	4.0	5.2	5.7	4.9	4.9	5.5	2.8	2.8	6.4	6.5
Sweden	4.6	2.3	2.7	2.1	1.3	1.4	2.2	2.2	4.2	4.5	4.2	3.4	5.6	2.0
Norway	4.7	3.7	3.0	2.0	1.8	1.8	2.1	2.0	2.0	1.6	1.5	1.3	1.4	1.4
Finland	0.6	1.6	1.7	1.7	2.2	3.5	2.5	2.9	2.6	2.4	2.8	4.9	n/a	n/a

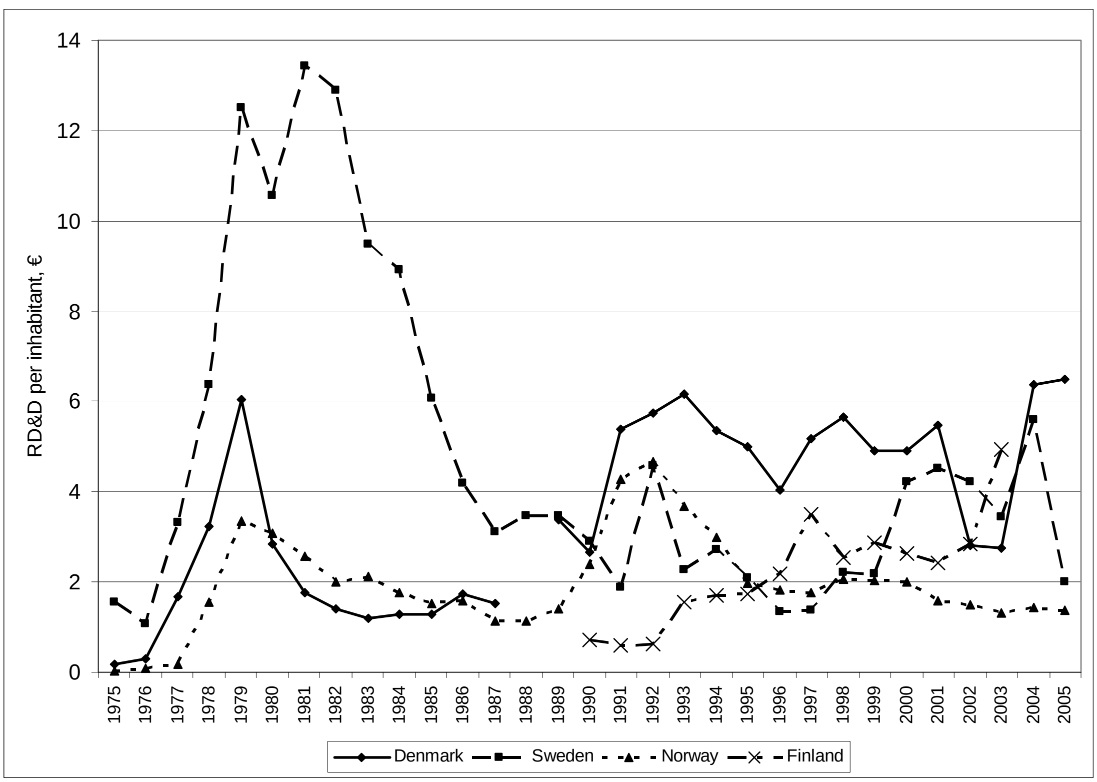

Figure 71: RD&D in renewable energy per inhabitant, €, 1975–2005. Source: International Energy Agency, IEA and Eurostat

7. Venture Capital Investments in Energy

Public concerns about the impact of energy production on the environment have increasingly forced governments to set ambitious targets to reduce CO_2 emissions through increased use of renewable energy sources. High carbon-based energy prices, global resource competition and increasingly favourable policy frameworks provide stronger than ever fundamental drivers for investment in renewable energy companies. The international tendencies show that venture capital (VC) investors have increased their focus towards alternative energy during the last couple of years. Around 40 per cent of all VC investments in energy in 2006 were in alternative energy (Figure 72).

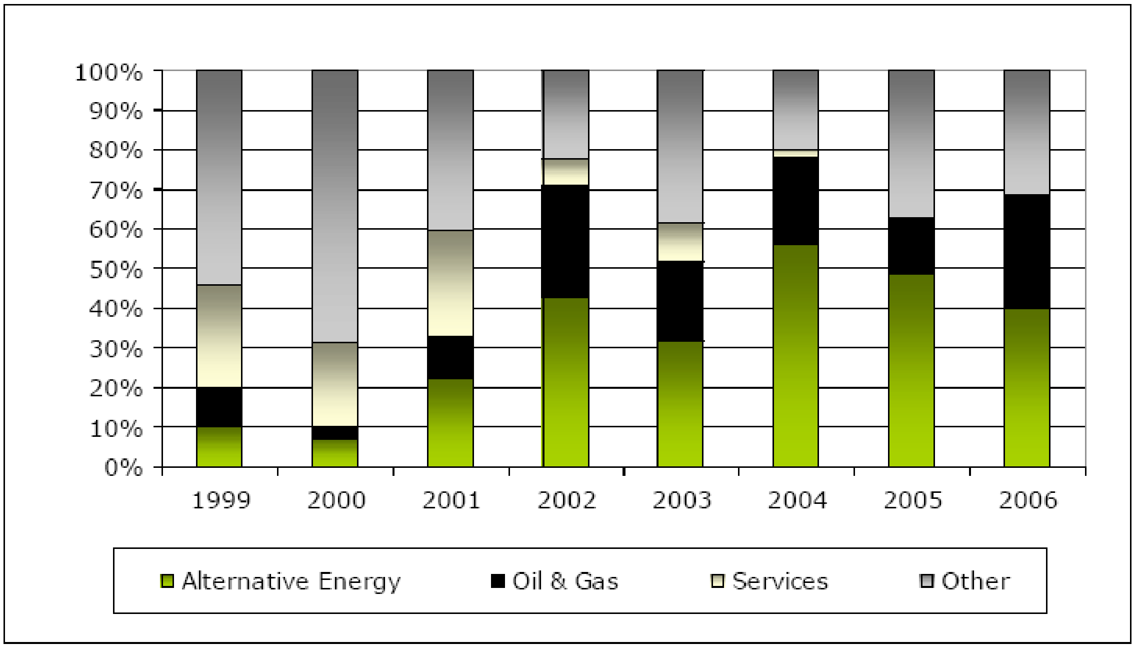

Figure 72: Global venture capital investments, by energy segments. Source: Vækstfonden (2006)

Norway is one of the highest-ranking countries in the world for attracting VC investments in energy (Figure 74). In 2006, the US market attracted more than 80 per cent of the World's VC investments in energy, which can be explained by the favourable conditions of the deregulated energy market in some US States. The same trend is visible when analysing the distribution of the number of exits: the US companies lead with 55% (Figure 73). For the Nordic countries Vækstfonden reported Norway 6%, Sweden, Denmark and Finland each 1% of all VC investments.[30]

[30] The energy industry in Denmark: perspectives on entrepreneurship and venture capital. Vækkstfonden. (2006) Hellerup

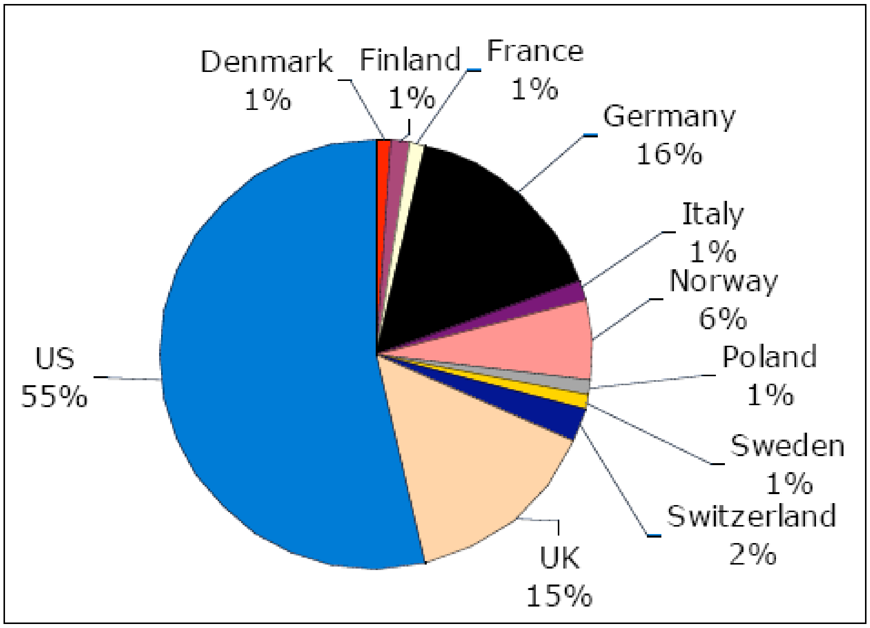

Figure 73: Energy exits in the period 2000–2006 distributed by country. Source: Vækstfonden (2006)

In spite of the strengths of the Danish energy sector and the increasing share of venture capital going into energy in other countries, Danish energy start-ups continue to attract only a limited amount of venture capital (VC) according to a report about Danish energy industry. Energy investments in Danish start-ups constitute only 1.5% of all VC investments in 2005 (Figure 75). This must be considered low compared to the strong global role of the Danish wind energy sector. The low level of investment has its roots in a sector has been characterised by regulation and monopolistic behaviour for decades. As a consequence, the deregulated market of today still suffers from a weak entrepreneurial culture and a very low level of start-ups, with a yearly average of only 2 or 3 energy starts-ups (Vaekstfonden, 2006).

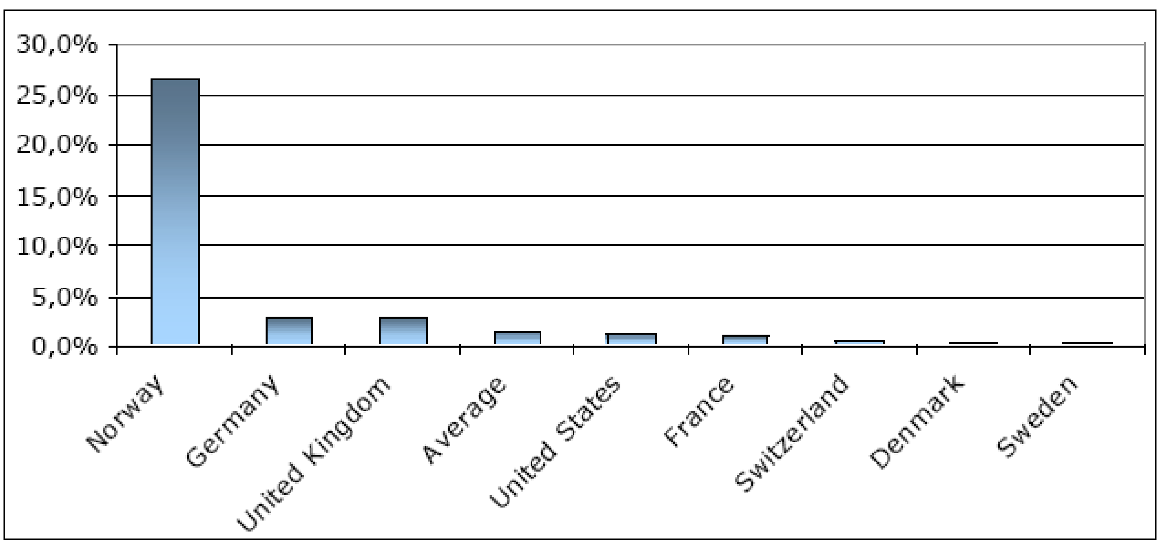

Figure 74: Percentage of Venture Capital allocated to energy, calculated as yearly average from 2000–2006. Source: Vækstfonden (2006)

The Danish Venture Fund P/S BI New Energy Solutions (NES) invests in companies commercialising renewable and distributed energy technologies with potential for a high return. The Fund was established in 2002 and has invested in early and expansion stage companies. However, the latest investments are more weighted towards later stage companies (P/S BI New Energy Solutions, 2006).

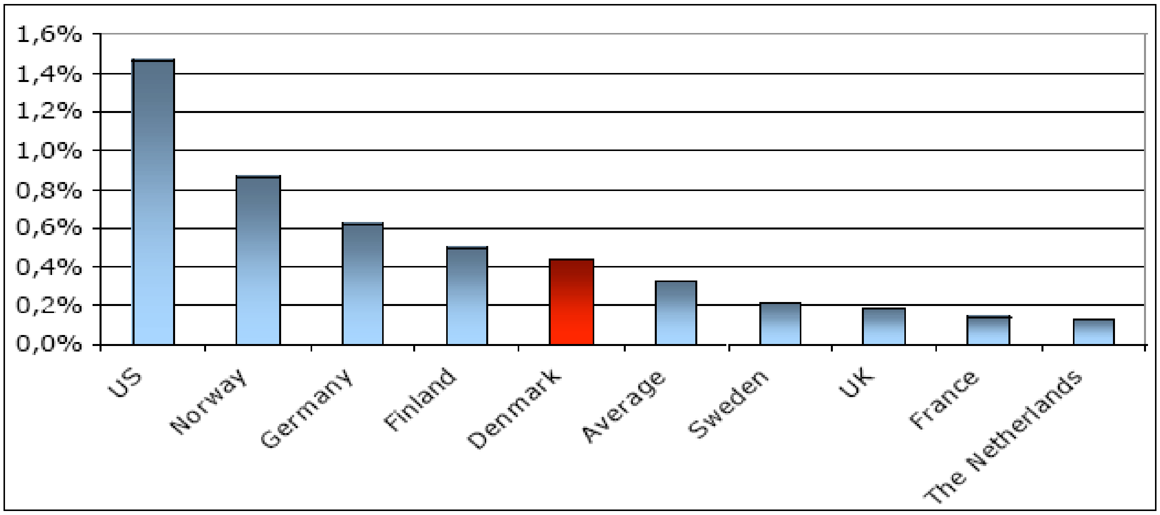

Figure 75: Percentage of energy start-ups in all start-ups. Source: Vækstfonden (2006)

Germany is a market that predominantly invests in alternative energy from 1999 to 2006. Denmark experienced a large progress from 0% in the period 1999–2002 to nearly 40% in the following three years. By contrast, Norway experienced a sharp decline in investments in alternative energy compared to the pervious period 1999–2002 (compare Figure 76).

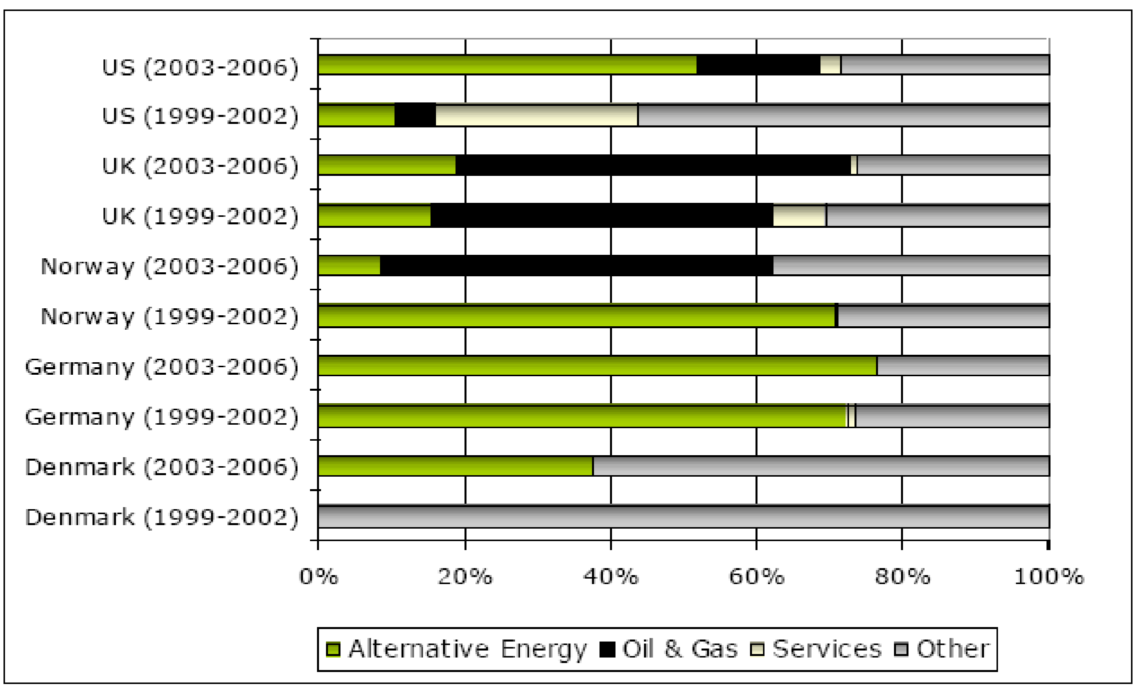

Figure 76: Energy investments, selected countries, by segment. Source: Vækstfonden (2006)

In 2006, the Swedish Energy Agency evaluated the quality of the venture capital system in the Swedish energy market. According to the findings, the venture capital market in the energy sector leaves room for improvement. Private equity investments in the energy field are traditionally small and few. The energy field attracts in average 0.18 per cent of total venture capital. As an indicator of the level of venture investment in Sweden, the business plan competition Venture Cup was used in the evaluation. In the period 2005-2006, approximately 47 plans out of 1154 participating business plans were to some extent related to the energy sector, which was considered to be a quite low number. A paradox seems to be that although the energy sector is characterised by low human resource intensity in relation to GDP, private equity investments are underrepresented considering that sectors with low human recourse intensity often are interesting targets for investors (Energimyndigheten, 2007).

In the Swedish 2007 Fiscal Policy Bill, the government stated that the measures for early stages venture capital in the energy sector should be strengthened both organisationally and financially. It remains to be seen what specific measures and initiatives here will be taken.

In 2007, the Finnish Innovation Fund, Sitra, jointly with Provider Venture Partners AB, a leading Swedish venture capital firm, launched a venture capital fund for Nordic cleantech companies. The target is to create a €100–160m fund investing in Nordic cleantech enterprises.

There is a growing interest in Iceland by banks and financially strong companies to invest in export of Icelandic know-how in energy technologies, especially in geothermal and hydropower technologies.

In the Baltic States the venture capital markets are still in the development stage. According to a University of Tartu paper, the Estonian venture capital market is still in its infancy (Kõomägi and Sander, 2006). There is neither a public venture capital fund nor a venture capital association. The market is small, and therefore there are few venture capital funds. Five of the largest Estonian venture capital funds were analyzed in the article refered to here.

BaltCap Management is the leading private equity investor in the Baltic States providing equity capital for growth-oriented companies. Since 1995 this frim have invested over €50m in over 35 different companies out of which 21 are now fully exited. Over 12 years BaltCap has raised four funds, Baltic Investment Fund I and II; Baltic Investment Fund III and the Baltic SME Fund.

BaltCap have offices in the capitals of all three Baltic States and in Finland. BaltCaphas following investors: Finnish National Fund for Research and Development (SITRA), European Bank for Reconstruction and Development (EBRD), European Investment Fund and a number of Finnish, Norwegian and British financial institutions.

According to the RIS Latvia projectm Venture Capital activities are still undeveloped in Latvia (RIS Latvia, 2004). There are funds that have some focus on energy-related issues:

EEF–Energy Efficiency Fund
The Latvian Development Agency–Energy Efficiency Fund is sponsored by PHARE and provides loan for energy efficiency projects at good interest rates.
CEEF–Commercializing Energy Efficiency Finance
Since 2003 the, CEEF programme–Commercializing Energy Efficiency Finance–is under implementation in Latvia. It is a guarantee program for energy efficiency projects and third party financing. The guarantee fund is USD90m. The program includes technical assistance activities as well as training of commercial bank on EE projects.

LEIF–Latvian Environmental Investment Fund
The Latvian Environmental Investment Fund (LEIF) was established under the Ministry of Environmental Protection and Regional Development in order to strengthen Latvian collaboration with international organisations supporting environmentally friendly projects. LEIF is sponsored by PHARE. The main objective of the Fund isb to finance private and public environmentally friendly projects, by granting long-term loans on favourable conditions for projects through combining local financial and foreign resources. The major cooperation partners are LVAF (Latvian Environmental Protection administration Fund) and NEFCO (Nordic Environmental Finance Corporation).

NIB–Nordic Investment Bank
The Nordic Investment Bank (NIB) is a multilateral finance institution that finances private and public projects in and outside the Nordic countries, offering long-term loans and guarantees on competitive market terms. The bank finances up to half of the costs of a project. Environmental investments have a high priority. The bank grants loans to public and private environmental investment projects in Northwest Russia and in the Baltic Sea area. The projects contribute to reduce emissions and cross-border pollution.

Summary
Generally, we see that more venture capital investment in the energy sector is needed in the Nordic countries and in particular the Baltic States. In recent years investments have increased but those directed to the energy sector remain relatively small. Among the Nordic countries Norway is that country with highest VC investments in the energy sector. Also when compared internationally, Norway does quite well. Swedish and Danish energy companies struggle to attract venture capital, which can be explained by a traditionally weak venture capital market.

8. Market regulations

Market regulations comprise the set of conditions that actors in a market must operate within. The energy sector is historically a more regulated market than other markets, mainly because the production of energy implied exploitation of what can be considered public resources, and because the output of energy production, power, is considered a basic infrastructural good that should be assured by public authorities. Today, liberalization of energy markets has come far in the sense that in many countries it is now open for several suppliers to compete on price in supply to their customers. Currently, the most important market regulations in the energy sector are based on the political intention to support renewable energy. This includes the use of concessions, which are there to make sure that entry to the market is made in compliance with political intention and in compliance with other laws in society, such as environmental and security laws. Moreover, and perhaps most importantly, market regulations include supporting mechanisms for access of the relatively more expensive renewable energy to a market that is dominated by cheaper fossil fuels. The following describes the regulatory regimes in the Nordic and Baltic countries.

Denmark

In Denmark, renewable energy has high priority in government policy. Finance for support schemes is collected through network tariffs. There is a large consensus in favour of continuing renewable energy policies. Support mechanisms have recently become more market- based. Wind generation is exposed to market process and incentives are created for CHP generators to participate in balancing the market (European Commission (2007a).

The electricity market was liberalised in accordance with a decision of the Danish Parliament at the end of the 1990s. Measures included:

- Production and trading in electricity is subject to competition.
- The electricity grid and its operation are subject to public price regulation, and all users of the system may make use of this infrastructure.

Since 2003, all electricity costumers may purchase electricity in the open market and choose the supplier they prefer (Danish Ministry of Economic and Business Affairs, 2002). "Electricity from Danish electricity producers is sold on market conditions via bilateral agreements, via Nord Pool (the Nordic power exchange) or other power exchanges. The larger power stations will usually be expected to sell electricity based on market conditions whilst the transmission system operator (TSO) will to a large degree sell production from small plants and RE-based production on the Nord Pool spot market" (DEA).[31]

According to the Danish Energy Authority it is necessary to diversify support mechanisms for renewable energy technologies. The Danish experiences show that it is positive to develop several such mechanisms:

[31] DEA: Market electricity prices. http://www.energistyrelsen.dk/sw23597.asp

- Investment grants
- Fixed feed in tariffs
- Market based tenders.

It is important not to over-subsidise mature technologies because costs are constantly falling. Therefore subsidies should be reduced gradually, but this has to be clear from the start.

An important lesson for the deployment of renewable energy technologies is the need for transparency and confidence-building measures for attracting investors.

Market-based systems should be considered in the long term, especially when the technology is more mature. This is also consistent with the recommendations of the IEA in the last review of the Danish energy policy.

Sweden

In the Energy Bill 2002, the electricity certificate system was proposed by the government. The electricity certificate system, introduced in May 2003 and still in use today, has the purpose of increasing the share of electricity from renewable sources. The system has been extended and improved and the target for production of electricity from renewable sources has increased as can be seen in the Government Bill for 2005/06 (Ministry of Sustainable Development, 2006).

The electricity certificate is a market-based support system for electricity from renewable energy sources. The principle of the system is that there are sellers and purchasers of certificates and market to bring them together. The objective of the electricity certificate system is to increase the production of renewable electricity with 17 TWh by year 2016 compared to year 2002. The system replaces earlier public grants and subsidy systems.

Electricity produced from the following energy sources is entitled to certificates:

- Wind power
- Solar energy
- Wave energy
- Geothermal energy
- Biofuels, as defined in the Ordinance (2003:120) Concerning Electricity Certificates
- Peat, when burnt in combined heat and power production (CHP) plants
- Hydro power:
  - Small scale hydro power which, at the end of April 2003, had a maximum installed capacity of 1500 kW per production unit
  - New plants
  - Resumed operation from plants that had been closed
  - Increased production capacity from existing plants
  - Plants that can no longer operate in an economically viable manner due to decisions by the authorities or to extensive rebuilding (Swedish Energy Agency, 2007).

During the last few years the Nordic countries have discussed the possibility to establish a common Nordic market for Tradable Green Certificates (TGC). However the interest for such a common system has been traditionally low. Other countries in the EU using a TGC system are the United Kingdom and the Netherlands (Chapter 10 in Rydén, B., 2006).

Finland

Finland has taken the following regulatory/investment related measures to encourage use of renewable energy sources in energy consumption (RES-E):[32]

- *Tax subsidies:* RES-E has been made exempt from the energy tax paid by end users.
- *Discretionary investment subsidies*: New investments are eligible for subsidies up to 30% (40% for wind).
- *Guaranteed access to the grid* for all electricity users and electricity-producing plants, including RES-E generators (Electricity Market Act–386/1995).

Biofuels benefit from tax exemptions under certain conditions. Biogas used as motor fuel, for example, is exempt from excise duty. Taxes imposed on heat, are calculated on the basis of the net carbon emissions of the input fuels and are zero for renewable energy sources. Further encouragement of renewable energy for heating and cooling (RES-H) takes the form of direct biomass investment support.

Renewable energy power plants may get investment aid. The level of aid differs between various technologies and depends on the size of the power plant. As mentioned, investments in wind energy power plants are supported by 40%. Large wood combustion power plants may typically receive 5 to 10% investment. New, large hydro power plants exceeding 10 MW, do not receive investment support at all. In 2004, total investment support amounted to €24.5m.

Electricity produced from renewable energy may receive direct support (tax refund). There is a specific tax that has to be paid for fossil fuels used in heat production. This makes bio energy more competitive in the market.

Norway

Market regulation of power supply in Norway is based on the 1990 Energy Act. This framework for the organisation of the power supply system in Norway is in terms of general regulation and principles administered by the Ministry of Petroleum and Energy. The detailed regulation is the responsibility of the Norwegian Water Resources and Energy Directorate (NVE). Close to 100 per cent of the oil extracted on the Norwegian continental shelf is exported. Literally nothing is used to produce electricity. Hence, around 95% of electricity production comes from hydropower which, accordingly, is regulated by NVE.

- The energy market in Norway has been restructured during recent years. This restructuring has included changes in the regulation of the transmission and

[32] The information about regulatory regime is taken from the European Commission's Renewable energy fact sheet, see http://ec.europa.eu/energy/energy_policy/facts_en.htm

distribution networks including:, Establishing market access and conditions for the network utilities

- Clarify ingthe role and responsibility of the Transmission System Operator
- Establishing a power exchange–Nord Pool
- Establish competition between suppliers
- Establish an efficient power exchange with neighbouring countries.

The main objective of the Ministry and NVE is to ensure that all producers and consumers have access to the network and the market on non-discriminatory conditions. Statnett SF is the Transmission System Operator (TSO) with responsibility for system operation and transmission system investments and market-based instruments. Neutrality and independency are important properties playing this role. The Norwegian TSO shall invest according to socio-economic criteria. The TSO is a 100 per cent state-owned company with a monopoly, and regulated by the directorate (NVE). Statnett is also co-owner of the Nordic power exchange Nord Pool, which is the Nordic market actor owned by the Nordic Transmission System Operators. Nord Pool is central in price-setting and is the basis for power exchange between the Nordic countries. Moreover, it offers physical and financial markets and clearing services, and is independent of economic interests in power trade. Nord Pool is regulated by energy and financial authorities. Nord Pool also provide the market with information about future market price expectations.

In Norway, the producers of electricity to the grid and Nord Pool are many small utilities with different activities. The majority of the actors are wholly or partly-owned by municipalities, regional authorities and the state. They are mostly organised as limited companies. Nord Pool has shown that privatisation is not necessarily central as a condition for market reforms.

All actors that produce energy and want to deliver to the Norwegian grid (and Nord Pool) need to have a concession to operate. This, of course also, applies to new producers/suppliers, for example those with other types of energy technologies. Wind power technology is the most common currently developed alternative to hydropower in Norway. The table below gives an overview of concessions within the regulator’s (NVE) system and the corresponding capacity in MW.

Table 52: Norwegian wind power concessions. Source: NVE.

Concessions	Number	Capacity MW
Concessions in operation	15	333
Concessions given, but not in operation	18	1407
Concessions applied for	44	5460
Concessions, application under consideration	86	
Concessions refused	6	

Lack of incentive systems

Even though it is a prioritized Norwegian policy target to support new renewable energy production into the market, there is currently no concrete incentive system that addresses this, except for certain possibilities for investment support. There is room for speculation about whether the lack of a specific incentive system, such as a green certificate market or feed-in tariffs, contributes to the hesitant investment behaviour in wind power in Norway. An electricity certificate is a market-based support system for electricity from renewable energy sources. The principle of the system is that there are sellers and purchasers of certificates and a market to bring them together. The objective of the electricity certificate system is to increase the production of renewable electricity. The system has replaced earlier public grants and subsidy systems in Sweden. Recently, however the Norwegian government has re-entered into discussions with Sweden about establishing a common electricity certificate market.[33]

Iceland

There are currently no support mechanisms for electricity generation in Iceland (Rydén, 2006). In 2003, the Icelandic parliament passed Acts on the deregulation of the electricity market in Iceland in accordance with the European Union's directive. The supervision of the deregulated market is under the responsibility of Orkustofnun, the National Energy Authority of Iceland.

Baltic States

The Baltic States and Baltic regulators cooperate on energy issues. The Baltic Council of Ministers adopted a Baltic Energy Strategy in 1999 A resolution by the prime ministers and an agreement between regulators was concluded in 2002 in order to establish a Common Baltic Electricity Market (CBEM) (European Commission, 2007a).

Estonia

The key legislative provisions regarding electricity in general and electricity production from renewable energy sources in Estonia are set out in the Electricity Market Act as amended and in the Grid Code. On 15 February 2007 the Parliament adopted a set of amendments to the EMA which significantly altered the support system of RES-E. Most of these amendments entered into force on 1 May 2007. The perspectives and goals of the Estonian energy and electricity sector are set forth by the Long-term Public Fuel and Energy Sector Development Plan until 2015 (adopted by Parliament) and the Development Plan for the Electricity Sector 2005–2015 (adopted by the government) (Jürgen, 2007).

The functions of the regulator of the Estonian energy market are performed by the Estonian Energy Market Inspectorate. Overall responsibility for the energy sector lies with the Ministry of Economic Affairs. The regulation policy as it was on 1 May 2007, proclaims that the producers of RES-E are entitled to sell as a fixed supply to a seller appointed by the transmission system operator (TSO) and the latter has a corresponding obligation to buy the RES-E at the price of EEK 1.15 (approximately €0.073) per kWh.

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[33] See press briefings: "Nye samtaler med Sverige om grønne sertifikat (07.12.07) and "Arbeidet med grønne sertifikat fortsetter" (23.05.08). Ministry of Petroleum and Energy, Norway.

The appointed seller buying the RES-E is entitled to request from the TSO compensation for additional costs borne due to the obligation to buy the RES-E.

The obligation to buy shall no longer be limited to the amount of network losses. The RES-E producers whose generation installation in total does not exceed 1 MW shall be entitled to sell the RES-E at the same fixed prices as open supply. As an alternative, the producers of RES-E shall be entitled to sell and apply for a subsidy in the amount of EEK 0.84 (approximately €0.053) per 1 kWh of electricity released to the grid and sold. The subsidy shall be paid by the TSO. The system of subsidies should encourage the RES-E producers to be active in selling the RES-E themselves as it should be significantly more profitable than to sell the RES-E by using the obligation to buy. It is noteworthy that the feed-in tariffs and the subsidy tariffs are both set forth by the EMA and any alterations to these tariffs need approval of the Parliament of Estonia.

The obligation to buy, and the obligation to pay a subsidy shall only be applicable if the net capacity of the generation installation of the RES-E generated and sold does not exceed 100MW. In addition, the producers and the generation installation of RES-E must meet certain regulatory requirements (operation licence, registration and information obligations, balance liability, etc.). The producers may not cross-subsidise production of RES-E at the expense of other production and vice versa.

It should be noted that the obligation to buy and the obligation to pay a subsidy shall also be applicable to electricity produced by means of cogeneration or CHP. The price and subsidy tariffs are lower than in the case of RES-E. It is stipulated that the costs deriving from the obligation to buy and the payment of subsidies shall be borne by final customers pursuant to the amount of consumed network services.

Particular features of wind energy
There are certain particularities stipulated in the EMA for the producers which use wind energy as the source of electricity. As of January 1, 2009 such producers may sell RES-E at fixed tariffs until the total annual amount of electricity generated from wind in Estonia is up to 200GWh, and receive a subsidy until the total annual amount of electricity generated from wind in Estonia is up to 400GWh. Such restrictions have been justified by the technical particularities of the Estonian electricity system—there is a lack of power stations which could be regulated quickly to balance the instability of supply of wind energy.
For the purposes of stabilisation, additional measures are required. If more electricity is produced than the Estonian consumers are able to consume, the overproduction has to be sold to neighbouring systems at the price of balance energy and Estonian consumers cannot be asked to cover the costs of production of such RES-E. Another reason for such restrictions is the necessity to vary the sources of renewable energy in order to secure a steady supply of electricity production. The construction and installation of equipment for generation of electricity from other renewable sources (such as landfill gas, hydropower and biomass) usually takes longer than the installation of wind farms. The restrictions to support wind energy should encourage the use of other sources of renewable energy.

Latvia

The amendment of the *Energy Law* in 2002 included several issues relevant for the energy market regulation:

- Requirements for CHP stations and the procedure to set the price for the purchase of excess electricity: a higher power purchase price is set if domestic energy sources (including peat as a local energy source) are used.
- Regulations on total installed capacities for each type of electricity generation if renewable energy sources are utilized.
- Regulations for the installation and dislocation of electricity production capacities if renewable energy sources are used for the production of electricity.

The Lisbon Programme of Latvia stated that vertically integrated monopolies exist in the energy sector (see also Section 2.2.2 of the Lisbon Programme), therefore prices for electricity and gas supply services and end sale tariffs for connected customers are regulated. In addition, heat and electricity generation prices for combined heat and power stations are regulated. Competition exists in the market of primary energy resources.

The creation of market conditions in the sector of electrical energy is one of the priorities of the government. The state company JSC Latvenergo is still playing a dominant role in the energy supply for Latvia, providing more than 90 per cent of all electricity generated in Latvia and ensuring imports, transmission, distribution and supply to consumers. There are also more than 100 small power plants and 10 licensed distribution and sales companies. Although interconnection capacities of Latvia exceed electricity consumption several times, their further development, especially providing connections with Nordic and Central European countries, is necessary in order to increase the security of electricity supply and foster development of the electricity market (compare also the description of the Latvian electricity market provided the Austrian Energy Agency).

In the Lisbon Programme of Latvia it was planned for the energy sector in 2005–2008 to continue the development of the electricity market by developing the secondary legal acts required for the Electricity Market Law by 2007 and by establishing an independent distribution system’s operator by July 1, 2007.

The Electricity Market Law (2005) shall determine incentive measures for producing electricity by using renewable energy sources. Sections 29 and 30 deal especially with this issue. “A definite share of the total consumption of the electricity end users in Latvia shall be mandatorily covered by electricity produced from renewable energy resources. The Cabinet shall determine such a share for each type of the renewable energy resources for a period of five years, beginning with 1 January 2006.” The law defined a goal for 2010: the share of electricity produced from renewable energy sources in relation to the total electricity consumption shall not be less than 49.3 per cent.

Lithuania

The Act on Energy, Article 12, relates to the use of renewable and secondary energy resources. By shaping taxation policy, granting soft credits, extending grants, the State (municipality) shall promote the efficient use of renewable and secondary energy resources. Consumers who use renewable energy sources shall be able to feed surplus energy generated by their autonomous equipment into the electric grid. Accounts with such consumers shall be based on negotiated prices and tariffs. The Ministry of Economy is responsible for the procedures, terms and conditions of their connection to the electric grid.

The Resolution No. 443 On the approval of the national energy efficiency programme for 2006–2010 (2006) pointed out that the tax policy does not stimulate the use of renewable and waste energy resources.

Rules for market players (producers, public and independent suppliers, eligible customers, grid operators, market operator) have been defined–in 2001 the Ministry of Economy introduced rules for public service obligations (PSO), and in 2003. Rules for electricity trading at auctions (Renewable Energy Policy Review Lithuania, 2004). Since 2002 the activities within the electricity sector have been unbundled and the sector has been restructured into separate companies. The electricity market started in 2002, but is still dominated by the electricity supply from Ignalina Nuclear Power Plant. The electricity market is supervised and regulated by the National Control Commission for Prices and Energy and by the Ministry of Economy.

In January 2004, the Ministry of Economy defined the quantities of electricity based on renewable energy sources for 2004–2009 to be supported by the PSO instrument on two levels:

- Purchase price
- Subsidy for connection of RES-electricity plants to the power grid.

Conclusions

The Nordic and Baltic countries have organised market regulation of their energy sectors quite differently. A common feature is that most countries have opened up their markets in terms of production and supply to the national grids, and consumers are free to choose their supplier. Another resemblance between the Nordic and Baltic countries is that political intentions are strongly pro renewable energy. However this political intention is followed up rather differently from country to country when it comes to concrete regulatory schemes and mechanisms. Denmark has feed-in tariffs, as do the Baltic countries; Sweden has green certificates, Finland and Norway have investment aid. Iceland has no measures. The differences in regulatory mechanisms between the countries make it less financially attractive to enter the market. There is an observation from Norway that wind power concession tenders are obstructed because of lack of personnel capacity. Detailed information from all Nordic and Baltic countries is leacking, but there is reason to believe that potential entrants in most countries experience obstructions for different reasons.

9. Social concerns

Social concerns related to the energy sector are visible in public debates and channelled through interest groups and political groups that influence decision-making in the bureaucracy, and in political decision making locally, regionally and at the national level.

Denmark

One of the main organisations involved in public debates covering energy research is the Danish Board of Technology. After 2001, Denmark expefrienced a liberalisation of the energy marked and the government reduced its level of involvement. This provoked reactions by the Danish industry. Representatives from Danish energy technology firms– Flemming Nissen (Elsam A/S) and Helge Østed Pedersen (now Ea) came to the Danish Board of Technology and asked them to open a public debate. It was stated by experts from the Danish Board of Technology that private firms need government support in order to plan long-term R&D. If important milestones, goals and supportive framework conditions are not stated, it is not possible for the firms to plan R&D. The transition to the hydrogen society cannot be achieved by private means only; it is necessary to develop infrastructure, standards and norms. Private firms will not accept the risks if the framework conditions are not clear.

The Technology Board organised expert panels and public hearings about the further development of Danish energy policy in general in parliament. A main goal of these activities was to develop an open debate involving politicians without hidden agendas and to achieve a common understanding of the needs of all political parties. Denmark now has energy policy negotiations in the Parliament.

The main stakeholders in the policy process are the Danish Board of Technology (DBT), the Danish Society of Engineers, IDA and the industry associations the Confederation of Danish Industries - Dansk Industri (DI), the Association of Danish Energy Companies - Dansk Energi and the Danish Hydrogen Association.

In 2003, The Ministry for Science, Technology and Innovation published a foresight study on eco technology also covering flexible energy systems and wind technology (Ministeriet for Videnskab, Teknologi og Udvikling, 2003).

An important foresight study was Scenarios for the exploitation of hydrogen as an energy carrier in the future energy system of Denmark under DEA's Hydrogen Programme (Sørensen, 2001). The project analysed total energy scenarios for introducing hydrogen as an energy carrier, storage medium and fuel. The project studied ways of handling large deficits and surpluses of electricity from wind energy. Another goal has been system aspects of the choice of hydrogen technologies. The study was not followed up because of the change of government.

For 2030, two scenarios were developed

1. Using hydrogen primarily in the transportation sector
2. Using hydrogen as a storage option for the centralised power plants

For 2050 two scenarios were developed:

1. Complete decentralisation of the use of hydrogen, converting and storing electricity surpluses into hydrogen in individual buildings
2. Centralised infrastructure is retained (hydrogen cavern stores and a network of vehicle hydrogen filling stations).

Sweden

In Sweden, as in many other countries, the environment and energy debate has been increasingly affected by concerns over climate change. For instance, the public opinion on nuclear power, traditionally against an expansion, has rapidly shifted towards a more positive standpoint. According to a recent opinion poll (DN/Synovate January 2008), every second Swedish citizen is now in favour of expanding nuclear power.

Within the research community, concerns about the unpredicatability and instability of state funded energy research have been expressed in recent years. The malcontent was particularly manifest in late 2004 after the Swedish government's decision to significantly reduce the allocations for energy research and to make the Energy Agency the sole agency managing state energy research funds. The research allocations for energy research were reduced by half from SEK807m in 2004, to SEK440m in 2005. The earmarked funds for basic energy research administered by the Swedish Research Council were eliminated. Since 2005, the Swedish Energy Agency has the main responsibility for allocating funds for energy research. The initiative raised concerns for diminished attention and resources for basic research.[34] At the same time the Swedish Energy Agency expressed worry that research activities might adapt to the low level of funds, with the risk of seeing parts of important research activities disappear. In the case of continued cuts in the research allocations Swedish basic research in energy, and the possibility for Swedish researchers to participate in international research project, could be hampered. However, after pressure from the research community the government allocation for energy research has increased during last two years.

Norway

In Norway, societal concerns about issues of energy production and consumption are strongly rrelated to the domains of sustainable development, industrial development and value creation. Societal concerns related to energy policy are therefore politically a matter for severalministries. While the Ministry of the Environment has a particular responsibility for carrying out the environmental policies of the government, the Ministry of Petroleum and Energy, the Ministry of Trade and Industry, and not the least the Ministry of Finance, are all actors that have strong interests in energy policy and relevant domains. Reflecting these strong interests, the Norwegian civil society is characterised by intense public debates on energy policy, policy for sustainable development and industrial development.

[34] Article in *Forska*, nr. 3, 2005, "Få ljuspunkter för energiforskningen". Swedish Research Council.

The continuously expanding Norwegian oil and gas extraction activity is one of the main topics in public debates. Literally all oil and gas extraction is off-shore in rough waters. Of current interest is the expansion into arctic waters, potentially threatening the nature around the North Pole. The debate is polarised, but there seem to be consensus when it comes to protection of local waters in the northern parts of Norway.

Another topic is wind power and investment in onshore and offshore windmills along the coast. There is strong resistence towards this in the local democratic municipalities in coastal Norway. This applies to both onshore and offshore wind technology solutions.

A third area of dispute is further investments in hydropower. Here the debate is polarised again. The interest groups that are in favour of protection of the environment are strong.

Iceland

The debates in Iceland concerning energy issues are essential in relation to the further construction and expansion of hydropower plants. Environmentalists have expressed their concern regarding eventual plans of the government to expand and utilise further inland areas for hydropower. On a political level there is concern about the high CO_2 emissions from the transport sector in Iceland. As a response to these concerns the government launched a Forum for environmentally friendly fuels associated with the climate change strategy 2007–2050, and which has submitted reports on how to increase the use and consumption of environmentally friendly fuels.

Finland

The energy debate in Finland is also concerned about climate change as one of a wide range of issues. The controversy about the risks of nuclear power has abated, and earlier concerns about issues such as the price and availability of energy have retreated into the background. The following main issues presently dominate the debate.

- Issues relating to the new gas pipeline between Russia and Germany, crossing Finland
- Sustained exploitation of traditional forms of “slowly regenerating biofuel”, such as peat, which is important to regional policy considerations in peripheral areas
- New innovative development of solid biomass based heating systems for new housing areas, which are now being successfully implemented on a broad basis.

In general, public documents and media reports reflect a high awareness of the challenges of global warming, the need for more renewable energy consumption, energy conservation, and compliance with the targets set through the Kyoto Protocol, and EU environmental policies. Public and policy debate seems to pragmatically accept the development of new nuclear reactors as a relevant instrument to meet the challenge of global warming. But the Finnish public’s feelings about nuclear power have always been fairly evenly balanced between approval and disapproval. Among the public as well as MPs, women are more doubtful about nuclear power than men. Compared to the situation in Norway, where local communities are fighting wind farm projects, the exploitation of wind generated energy has not met serious resistance in public debate.

Estonia

According to a study made by the Swedish Trade Council environmental public awareness in Estonia is low but growing. Perhaps because of the country's size and small population, civil society appears to be very flexible in its continuous adjustments in relation to both western values and political and regulatory requirements (from EU), and in relation to the economic and cultural heritage from the Soviet period. The strategy document "Sustainable Estonia 21" referred to in the environmental laws and regulations paragraph above, is a document that incorporates and considers societal concerns, civil society and the policy debate into the framework of Sustainable development.

Latvia

In 2006 the final draft of Energy guidelines – the sector policy planning document – was developed. The document was widely discussed at all levels and has been approved by the government. The Guidelines outline the following important aims for the Latvian energy sector:

1. Overcome the isolation of the Baltic energy market from the rest of Europe
2. Need for a diversification of energy resources because Latvia is dependent on gas imports from Russia–only 36% of the total consumption is covered by local resources.
3. Promotion of different types of renewable energy resources, such as bio-mass, water and wind. By 2010 renewable energy resources shall generate 49.3% of the total consumed energy in Latvia.
4. Increased generating capacity by at least 700 MW, including building of a new hard fuel operated electrical power station with the capacity of about 400 MW. 80% of the consumed electricity must be generated locally in 2012 and increasing to 100% by 2016.
5. Improved energy efficiency in all energy supply chains, but priorities have heat supply and thermal energy consumption.

A major topic in the public debate regarding energy issues is the new European energy policy. Latvia supports the majority of EC policy statements such as proposals for more effective use of fossil fuel, nuclear safety and security, new trends regarding priorities, development of research and energy technologies.

There are several issues that have raised controversy:[35]

- EU's aim to unbundled distribution and transmission of electricity from generation;
- Latvia'' potential for further reducing CO_2 emission and which might affect the development of industrial production and the energy sector, leading to unavoidable price rises for electricity and heating.
- Each member state should be able to choose its own objectives and to define the sectors with greater potentials for energy saving (heating, supply, consumption, transportation)

[35] Compare the debates in EnergoForum: Survey of the energy industry news, discussions, analysis no. 1(5) in February 2007.

- Each member state should be given maximum freedom in deciding the electricity volume generated by renewable resources, the ratio of this energy on the balance of primary resources and the ratio of biofuel in transport.

A major issue in the public debate is the plan to build a new nuclear power plant in Lithuania close to the Latvian border. Latvian ecological non-government organisations oppose both Latvia's participation in the project and its implementation in principle (Raguzina, 2007).

Lithuania

The Law on the establishment of the National Investor, LEO LT that will have the responsibility to build the new nuclear power plant was approved in parliament in February 2008. There is however still an intensive debate on the decision to prolong the Ignalina Power Plant's life span and on what will happen when the plant will terminate its electricity production at the end of 2009. Today, Ignalina provides 75% of all electricity in Lithuania. In the debate concerns have been made public that the construction of the nuclear power plant will divert Lithuania's attention away from developing the renewable energy capacity.[36]

Conclusions

Social concerns clearly reflect the different problems and challenges that the Nordic and Baltic countries face as a result of their specific energy sector configurations. The more interesting and perhaps surprising observations include the recent reversal of public opinion in Sweden and Finland in favor of nuclear power, and the severe oppositon to wind power along the Norwegian coast.

[36] The Lithuanian President gives his blessing to the LEO LT. A busy week in the Lithuanian energy sector. (February 2008): http://irzikevicius.wordpress.com/

10. Infrastructural challenges

The European Commission calls for urgent improvements in the electrical network connecting the European countries (compare in detail on the map in Figure 77). The Commission has highlighted the four most critical projects; two of these are located in the Nordic-Baltic region (European Commission, 2007b):

- The power-link between Germany, Poland and Lithuania
- Connections to offshore wind power in Northern Europe–both Denmark and Norway.

Also important in the European context are the links between Estonia and Finland, and between Finland and Sweden.

Denmark

Denmark has still a large number of coal-based power plants. A big challenge is to handle the CO_2 emissions from these plants. Costs for CCS have to be reduced and the feasibility of new technologies has to be proved in demonstration projects.

The existing traditional biomass solutions have to be replaced by second-generation biofuel plants. The technology is still in the trial and not commercial stage.

The electricity market is divided into two parts, East and West. They have no direct physical link between them, but it is planned to link the two parts by 2010.

Sweden

Uppsala University, Dept of Engineering Sciences, Division for Electricity and Lightning Research is developing the Ångström Energy Park. The facilities are being planned for large-scale studies of energy conversion with solar, wind and hydro power as well as energy storage.

The Nordic TSOs are cooperating in transmission planning. There are currently five projects forming a Nordic Master Plan, of which three projects relate to Sweden. Of primary importance are the overhead transmission lines designed to relieve the bottlenecks in Southern Sweden and the capacity allocation between Sweden and Eastern Denmark (European Commission (2007a).

One of the current major infrastructural plans is the construction of the Southwest Link. The new electricity transmission grid will be constructed using new technology that will double capacity and provide a new link to Norway. This will be the most powerful electricity transmission system in the world. The decision to construct the Southwest link is a step towards adapting the Swedish and Nordic transmission grids to the European energy and environmental politics of the future. The growth in wind power generation will create a particular need for increased capacity and flexibility in the electricity transmission grids. The technique that will be applied combines HVAC (high voltage alternating current) and new so-called HVDC technology (high voltage direct current). The establishment of new transmission lines is being monitored by Svenska Kraftnät, the

Swedish transmission system operator for electricity (Press Release 1717 2008 from Svenska Kraftnät).

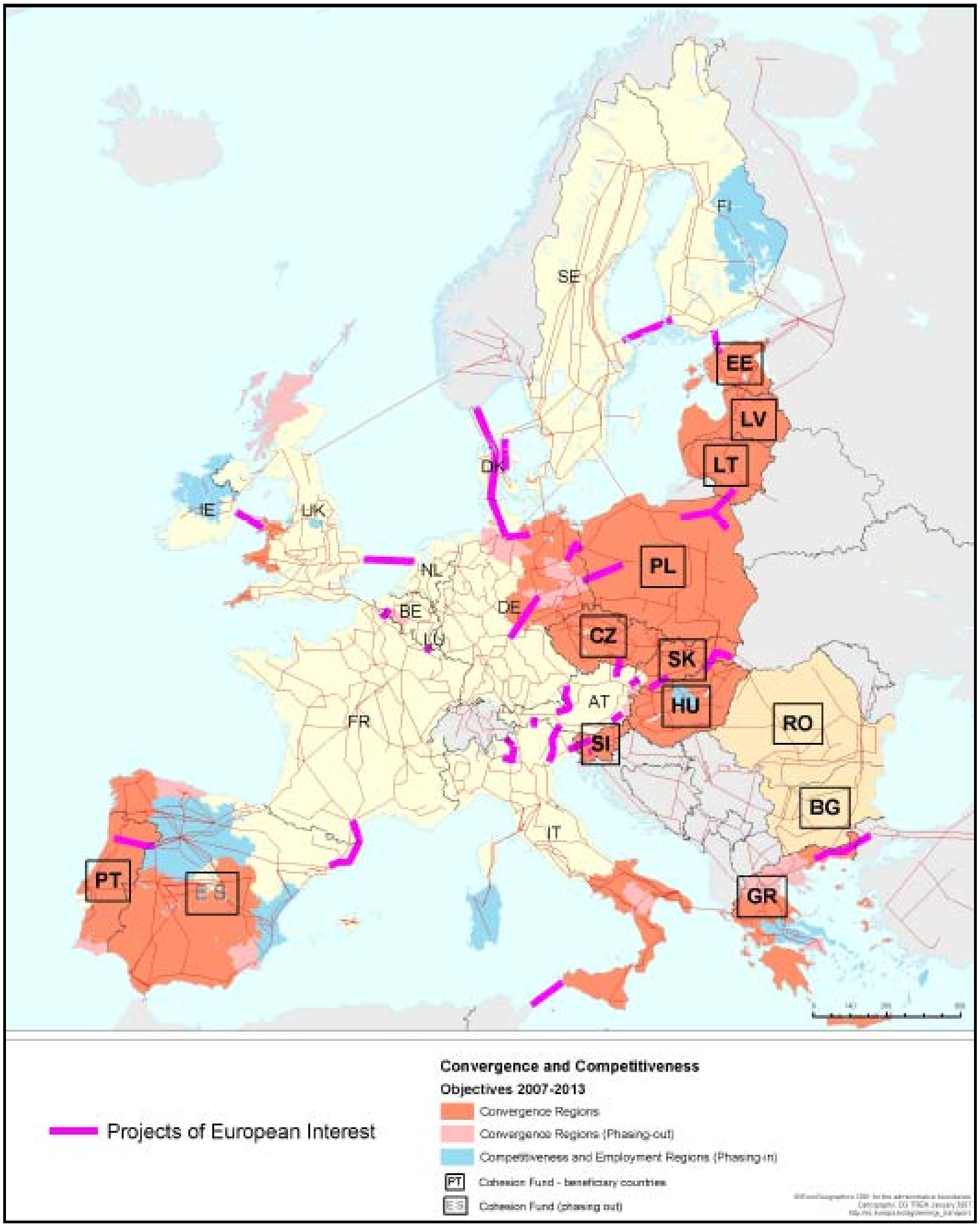

Figure 77: Trans-European networks: electricity projects of European interest. Source: European Commission (2007b)

Finland

Efficient use of solid biomass depends on the development of infrastructures for long-distance heating of housing areas. This issue is addressed in the energy and climate policy of Finland as an infrastructural challenge (Ministry of Trade and Industry, 2006). Other infrastructural issues include the new gas pipeline between Russia and Germany, which traverses Finland.

There was not much debate about Finland's first nuclear power plants, but especially after the accidents at Harrisburg and Chernobyl, the debate about the safety of atomic energy gathered pace in Finland in the 1980s. On the other hand, people began blaming fossil fuels, especially coal, for the greenhouse effect and contamination of the soil and lakes by acid rain. The reasoning of both Finnish opponents and supporters of nuclear power has varied over the years. A dramatic increase in the use of natural gas has been put forward as an alternative to the new nuclear power plant — in addition to energy conservation, of course. But natural gas is also a fossil fuel, and increasing its use would increase Finland's dependence on Russian energy sources. Extending a gas pipeline from Norway or Western Europe via Sweden to Finland has been on the drawing board since the 1970s, but has not been seroulsy considered as yet.

The Germans and Russians are planning to extend a gas pipeline from Viipuri, near the present Finnish border, under the Baltic Sea to Western Europe. The pipeline has met with heavy opposition in Sweden and Poland, but Finland has adopted a neutral attitude as long as the environment, that is the sensitive ecosystem of the Baltic Sea, is protected. Extending a branch pipeline to Finland has been discussed, but so far is not included in the programme. A branch would link Finland to the western European network — and gas can travel in both directions.

The Russians also offered Finland a new undersea cable that would carry electricity to Finland from nuclear power plants in the St Petersburg area, but in 2006 the government rejected this project because it would have required a large amount of additional investment in the Finnish national grid. There were also doubts about the reliability of Russian electricity supply, for example in periods of extremely cold weather when Russia has its own great need for electricity.

Norway

Norway has a range of infrastructural challenges related to both new and existing energy production. The Norwegian Energi21 R&D-strategy process (Energi21–a unifying R&D-strategy for the energy sector, Norges Forskningsråd 2008) identified five overall domains that are in need of accelerated R&D efforts. They include efficient energy consumption, climate friendly energy, CO_2-neutral heating, an energy system adapted to future needs, and attractive framework conditions for R&D. There are infrastructural challenges related to all these five domains.

In terms of efficient energy consumption, housing technology, household consumption and industrial energy consumption are the central areas. This is related to consumer behaviour but technological solutions and infrastructure investments (buildings) are also required. Special challenges are related to petroleum and hydropower energy. On the one hand, as Norway is heavily relaint on energy production based on offshore oil and gas, there are specific infrastructural challenges related to electrification of the activities on the Norwegian continental shelf. On the other hand, Norway has a positive reputation due to the predominant share of hydro power production, but this has had its implications for other types of climate-friendly energy technologies that have received little attention from policy makers. There are specific challenges related to more innovation and industrial development in the areas wind, wave and solar energy. All require considerable infrastructure investment. On shore wind technologies require more land area. Additionally, existing hydropower production facilities have huge potentials in terms of increased efficiency. There is a general challenge related to the electricity grid and transmission equipment, which is outmoded if energy production is to increase according to predictions. The grid is already almost 100 per cent utilised in terms of capacity. Hence, in addition to the mere technological and innovation-related challenges concerning industrial development of wind power, wave power and solar photovoltaic, Norway is in need of large infrastructural investment in energy system capacity, including transformation and transportation.

Norway is currently (2008) experiencing a challenge with roots in what can be called institutional infrastructure. The Norwegian regulator NVE, with responsibility for concessions for hydropower and wind power production, has limited capacity to manage applications for new wind power investments. This is a fundamental bottleneck to climate-friendly energy investment. NVE is in charge of the transmission infrastructure investment. It is many times more costly to invest in underground cable compared to overhead transmission lines. But new methods, for example camouflage of high-tension masts, are giving better reasons for choosing lines in masts. This is however not an option when it comes to offshore windmills, which require costly underwater cables.

Investment in CO_2-cleaning and storage technology for the gas power plants in Norway has become a prestigious project for the Norwegian authorities. The new gas power plants and Liquefied Natural Gas (LNG) production facilities in Norway are contributing considerably to CO_2-emmissions. It is a problem that the technological infrastructure for CO_2-cleaning and storage is not yet in place. Delay in the development process of CO_2 cleaning and storage technology is due to both financial costs and technical issues. CO_2 cleaning and storage can definitively be characterised as a complex product system.

Summing up, it is in particular a challenge to establish systems with flexibility to combine hydropower and other renewable energy, including Europe’s thermal power. Norway has Europe’s best wind conditions. The potential is vast, but it is demanding in technological and economic terms. Ocean energy (wavepower) also has a large potential. The technology is still immature and involves high costs. We have mentioned the potential of being able to store CO_2, which is costly and has experienced technical bottlenecks (2008). Within bioenergy there is need for infrastructural development along the whole chain from collection to storage and heating and cooling technology.

Iceland

The infrastructural needs in energy are mostly related to geothermal and hydropower plants. There is also a need for development of hydrogen stations and electricity plug-in stations for cars. In the case of further expansion of energy intensive companies being established in Iceland the electricity grid will have to be strengthened.

Estonia

The Estonian Power Station and the Baltic Power Station, both fuelled by oil shale, together make up nearly 95 per cent of Estonia's electricity production. The remaining 5% is generated by other oil shale plants and combined heat and power plants. This strong reliance on oil shale as energy source and the two power stations that supply nearly all energy in the country, represent an infrastructural challenge when the objective is to move in the direction of less dependence on fossil fuels. The reliance in oil shale is a challenge that is also incorporated into the education and research system. However, more recently are universities offering courses on how to get from oil shale based products to more environmentally friendly technologies. The current objective to reach a 5% energy production from renewable energy sources by the year 2010, from a marginal share close to zero in 2003.

The main issue is the lack of adequate connection between the Baltic market and the rest of the EU. The Estlink project connecting Estonia to Finland, with a capacity of 350MW, commenced commercial operation at the end of 2006. The Estlink connects the Nordic transmission grid to the IPS system including Russia and the Baltic states. Other projects connecting the Baltic market to the rest of the EU are still in feasibility study stage (European Commission, 2007a).

Latvia

Currently, the High Voltage Electricity Network has fourteen 330 kV voltage sub stations; a 1248 km 330 kV current electric transmission line; a 3925 km, 110 kV current overhead line, a 26 km, 110 kV current cable line and 113 110 kV current substations. The combined installed capacity is 6783.5 MVA.

The Baltic Dispatching Center (DC Baltija) was founded in 1991 by energy specialists from the Baltic countries. DC Baltija successfully manages the Baltic electricity union and its operations. The Latvian energy grid has been successfully integrated into a joint Russia–Baltic–Belarus energy grid, helping prevent system failures.

BALTREL (The Baltic Ring Electricity Co-operation Committee), established in 1998, is an association of energy companies in the Baltic region. It is a discussion forum analyzing issues and problems of common interest to these countries. The aim is to undertake the "Baltic Ring" project, to develop a common electiricity market in the Baltic Sea Region.

The ESTLINK project which commenced in 1998 has the aim to build a sub-sea electricity link between Estonia and Finland across the Bay of Finland. Latvenergo has been participating in ESTLINK as a partner since 2001. In the Latvian Lisbon Programme for the period 2005–2008 it is planned for the energy sector to develop interconnections between electricity networks of the Baltic, Nordic and Central European countries by participating in the NORDIC ENERGY LINK project. The NORDIC ENERGY LINK is an underwater electricity cable connecting Estonia and Finland across the Finnish Gulf. The cable was planned to be laid by November 2006. In December 2006, Estlink – the direct current underwater cable connecting Estonia with Finland – was put into operation. This is the first connection between the Nordic and Baltic power systems and the first step towards integrating the electricity markets of the regions. Estlink will provide Latvenergo with opportunities of selling electricity in the Nordic market.

In the framework of *EU Structural Funds* for 2004–2006, LVL14.96m (€21.83m) were allocated for the modernisation of heat supply systems according to environmental requirements and improvement of energy efficiency of heat supply systems both in production and distribution and for end-consumers. From the *Cohesion Fund in the current Structural Funds utilisation period of 2007–2013* it is planned to allocate approximately €116m in the energy sector. This will be made available for measures aimed at increasing the efficiency of district heating systems and for the development of cogeneration plants that use biomass (Ministry of Economics (2006a).

Lithuania

In 2005, several large investment projects were completed implementing the National Energy Strategy. In 2006, the Ministry of Economy ordered a scientific research study, titled “Comparison of Natural Gas Reserve Storage Projects”. For the period 2007–2009 there are not foreseen investments to increase Lithuania’s natural gas import capacity. Taking into consideration the decommissioning of the Ingalina Nuclear Power Plant and Lithuania’s obligation to increase electricity generation based on renewable energy resources, construction of private power stations and power stations using renewable energy resources, mostly biomass and wind energy, is planned (European Commission, 2007a).

The updated National Energy Strategy, which became effective on 27 January 2007, stated that it is necessary to ensure the succession, continuity and development of safe nuclear energy and to start operation of a new nuclear power plant in the region — to cover the demand of the Baltic States and the region — no later than 2015. In June 2007, the Seimas (the Lithuanian Parliament) passed the Act on Nuclear Power Plant of the Republic of Lithuania, and gave its approval for the construction of a new nuclear power plant.

Resolution No. 443, “On the approval of the national energy efficiency programme for 2006–2010” (2006)[37] pointed out that municipalities have only limited investment capacity for contributing to financing renewable energy projects. The improvement of the investment environment for renewable and waste energy sources and the use of EU structural funds for supporting projects related to the use of renewable and waste energy sources therefore offer good opportunities for the energy sector.

Lithuanian Lietuvos Energija and its Swedish counterpart, Svenska Kraftnat, completed a feasibility study on linking the energy systems of Lithuania and Sweden and will continue the cooperation on this project.

[37] http://www3.lrs.lt/pls/inter3/dokpaieska.showdoc_e?p_id=305634&p_query=&p_tr2=

Conclusions

In sum, infrastructural challenges in the Nordic and Baltic region can be divided into two domains. On the one hand there is need for large-scale investment in order to link up the Nordic and Baltic countries with their largest energy sector business partners. This work has already commenced. A related challenge is the required investment in flexible transmission and transformation equipment. On the other hand an infrastructural challenge is to ensure that there is capacity in local, regional and national grids to handle the planned increase in renewable energy. This challenge calls for long-term commitment in infrastructure investment.

Appendix

Tables from the bibliometric study

1. Scientific publishing–Ranking of countries by number of articles 1998–2006

The position of the Nordic and Baltic countries is highlighted in the tables.

Table 53: Solar Photovoltaic energy–Scientific publishing–Ranking of countries by number of articles 1998-2006. Source: ISI Web of Science

Rank	Country	Number of articles
1	USA	6813
2	JAPAN	3880
3	GERMANY	3366
4	PEOPLES R CHINA	1806
5	FRANCE	1616
6	ENGLAND	1281
7	ITALY	1066
8	SOUTH KOREA	1010
9	INDIA	1000
10	SPAIN	882
11	RUSSIA	814
12	NETHERLANDS	797
13	SWITZERLAND	746
14	AUSTRALIA	676
15	CANADA	611
16	SWEDEN	582
17	TAIWAN	529
18	BELGIUM	470
19	ISRAEL	365
20	BRAZIL	334
21	MEXICO	327
22	POLAND	314
23	TURKEY	310
24	GREECE	307
25	AUSTRIA	303
26	SINGAPORE	272
27	FINLAND	251
28	EGYPT	188
29	PORTUGAL	169
30	CZECH REPUBLIC	165
31	SCOTLAND	160
32	UKRAINE	149
33	DENMARK	148
34	ROMANIA	140
35	HUNGARY	115
36	ARGENTINA	111
37	NORWAY	105
38	TUNISIA	100
39	BULGARIA	96
40	IRELAND	93
41	SOUTH AFRICA	90
42	ALGERIA	89
43	SLOVENIA	83
44	SAUDI ARABIA	78
45	SRI LANKA	73
46	BYELARUS	68
47	NEW ZEALAND	68
48	NORTH IRELAND	65
49	JORDAN	61
50	MOROCCO	58
51	THAILAND	58
52	MALAYSIA	56
53	SLOVAKIA	54
54	LITHUANIA	52
55	CUBA	45
56	WALES	43
57	CROATIA	42
58	ESTONIA	40
59	COLOMBIA	38
60	IRAN	36
61	NIGERIA	35
62	KUWAIT	33
63	CYPRUS	32
64	CHILE	29
65	ARMENIA	27
66	HONG KONG	26
67	U ARAB EMIRATES	24
68	UZBEKISTAN	23
69	VENEZUELA	22

70	OMAN	21
71	PAKISTAN	21
72	YUGOSLAVIA	20
73	IRAQ	19
74	MOLDOVA	19
75	AZERBAIJAN	18
76	KENYA	17
77	BANGLADESH	16
78	INDONESIA	15
79	LEBANON	15
80	ETHIOPIA	14
81	SYRIA	14
82	URUGUAY	13
83	BAHRAIN	12
84	REP OF GEORGIA	11
85	TANZANIA	11
86	PERU	10

Table 54: Wind energy–Scientific publishing–Ranking of countries by number of articles 1998–2006. Source: ISI Web of Science

Rank	Country	Number
1	USA	2625
2	ENGLAND	602
3	GERMANY	514
4	CANADA	455
5	FRANCE	389
6	JAPAN	385
7	PEOPLES R CHINA	297
8	AUSTRALIA	296
9	NETHERLANDS	270
10	DENMARK	243
11	ITALY	221
12	SWEDEN	202
13	SPAIN	190
14	INDIA	176
15	GREECE	139
16	RUSSIA	137
17	SCOTLAND	118
18	NORWAY	99
19	NEW ZEALAND	93
20	TURKEY	93
21	SWITZERLAND	87
22	SOUTH KOREA	81
23	BRAZIL	76
24	PORTUGAL	73
25	ISRAEL	72
26	TAIWAN	69
27	FINLAND	59
28	BELGIUM	56
29	MEXICO	55
30	CHILE	54
31	SOUTH AFRICA	54
32	WALES	52
33	ARGENTINA	49
34	POLAND	32
35	AUSTRIA	28
36	UKRAINE	28
37	IRELAND	27
38	EGYPT	21
39	SAUDI ARABIA	21
40	CROATIA	20
41	SINGAPORE	17
42	NORTH IRELAND	16
43	NIGER	15
44	JORDAN	13
45	SRI LANKA	11
46	IRAN	10
47	ROMANIA	10
48	ESTONIA	9
49	HUNGARY	9
50	KENYA	9
51	TUNISIA	8
52	BULGARIA	7
53	CZECH REPUBLIC	7
54	INDONESIA	7
55	MALAYSIA	7
56	COLOMBIA	6
57	ECUADOR	6
58	MALTA	6
59	TANZANIA	6
60	THAILAND	6
61	ALGERIA	5
62	BANGLADESH	5
63	ICELAND	5
64	LITHUANIA	5
65	NIGERIA	5
66	OMAN	5
67	PANAMA	5
68	PERU	5
69	HONG KONG	4
70	KUWAIT	4
71	LEBANON	4
72	MOROCCO	4
73	NAMIBIA	4

74	SLOVENIA	4
75	VIETNAM	4
76	BRUNEI	3
77	CAMEROON	3
78	FIJI	3
79	FR POLYNESIA	3
80	LAOS	3
81	NEW CALEDONIA	3
82	PAKISTAN	3
83	SUDAN	3
84	SYRIA	3
85	BERMUDA	2
86	COTE IVOIRE	2
87	CYPRUS	2
88	ERITREA	2
89	GUADELOUPE	2
90	SENEGAL	2
91	SERBIA MONTENEG	2
92	SLOVAKIA	2
93	TRINID & TOBAGO	2
94	UGANDA	2
95	YEMEN	2
96	ZIMBABWE	2
97	BAHRAIN	1
98	BENIN	1
99	BOSNIA & HERCEG	1
100	CONGO	1
101	DOMINICAN REP	1
102	ETHIOPIA	1
103	GREENLAND	1
104	GUYANA	1
105	JAMAICA	1
106	LATVIA	1
107	LIBYA	1
108	MADAGASCAR	1
109	MALAWI	1
110	MAURITIUS	1
111	NEPAL	1
112	NORTH KOREA	1
113	PAPUA N GUINEA	1
114	PHILIPPINES	1
115	QATAR	1
116	REP OF GEORGIA	1
117	TOGO	1
118	UZBEKISTAN	1
119	VENEZUELA	1
120	YUGOSLAVIA	1

Table 55: second-generation Biofuels–Scientific publishing–Ranking of countries by number of articles 1998–2006. Source: ISI Web of Science

Rank	Country	Number of articles
1	USA	985
2	SPAIN	441
3	JAPAN	329
4	FRANCE	326
5	GERMANY	292
6	CANADA	256
7	ENGLAND	234
8	INDIA	220
9	SOUTH KOREA	210
10	ITALY	208
11	PEOPLES R CHINA	180
12	BRAZIL	175
13	NETHERLANDS	172
14	SWEDEN	171
15	AUSTRALIA	143
16	DENMARK	134
17	TURKEY	126
18	MEXICO	85
19	TAIWAN	85
20	BELGIUM	83
21	FINLAND	78
22	GREECE	77
23	SOUTH AFRICA	70
24	SWITZERLAND	70
25	RUSSIA	63
26	PORTUGAL	60
27	EGYPT	46
28	POLAND	44
29	IRELAND	41
30	SCOTLAND	40
31	AUSTRIA	39
32	MALAYSIA	36
33	HUNGARY	34
34	SINGAPORE	34
35	ARGENTINA	33
36	CHILE	33
37	CUBA	28
38	TUNISIA	28
39	CZECH REPUBLIC	26
40	IRAN	26
41	NORWAY	25
42	THAILAND	25

43	ISRAEL	23
44	NEW ZEALAND	21
45	WALES	20
46	SLOVAKIA	16
47	NORTH IRELAND	14
48	COLOMBIA	13
49	MOROCCO	13
50	NIGERIA	13
51	URUGUAY	13
52	BULGARIA	11
53	PAKISTAN	11
54	VENEZUELA	11
55	TANZANIA	10

Table 56: CO_2 technology–Scientific publishing–Ranking of countries by number of articles 1998–2006. Source: ISI Web of Science

Rank	Country	Number
1	USA	864
2	CANADA	199
3	JAPAN	166
4	ENGLAND	141
5	PEOPLES R CHINA	134
6	GERMANY	109
7	FRANCE	93
8	AUSTRALIA	84
9	NORWAY	71
10	ITALY	67
11	SPAIN	64
12	SWEDEN	62
13	NETHERLANDS	60
14	BRAZIL	35
15	INDIA	35
16	SOUTH KOREA	35
17	SCOTLAND	27
18	SWITZERLAND	26
19	RUSSIA	25
20	DENMARK	22
21	KUWAIT	19
22	AUSTRIA	18
23	POLAND	18
24	TURKEY	18
25	BELGIUM	16
26	SINGAPORE	16
27	TAIWAN	15
28	FINLAND	13
29	U ARAB EMIRATES	12
30	VENEZUELA	12
31	MEXICO	11
32	HUNGARY	10
33	PORTUGAL	10

Table 57: Hydropower–Scientific publishing–Ranking of countries by number of articles 1998–2006. Source: ISI Web of Science

Rank	Country	Number of articles
1	USA	501
2	CANADA	214
3	FRANCE	156
4	JAPAN	139
5	ENGLAND	129
6	BRAZIL	114
7	PEOPLES R CHINA	111
8	GERMANY	93
9	INDIA	80
10	TURKEY	76
11	ITALY	75
12	SWEDEN	72
13	NORWAY	57
14	SWITZERLAND	57
15	SPAIN	45
16	SCOTLAND	40
17	GREECE	34
18	AUSTRALIA	32
19	FINLAND	28
20	PORTUGAL	28
21	SOUTH KOREA	26
22	RUSSIA	25
23	NETHERLANDS	24
24	TAIWAN	24
25	BELGIUM	22
26	NEW ZEALAND	22
27	DENMARK	19
28	SLOVENIA	19
29	AUSTRIA	18
30	MEXICO	16
31	CROATIA	15
32	POLAND	15
33	TANZANIA	15
34	ARGENTINA	14
35	SAUDI ARABIA	14
36	SLOVAKIA	13
37	SOUTH AFRICA	13
38	CZECH REPUBLIC	12
39	CHILE	11
40	FRENCH GUIANA	11
41	ISRAEL	11
42	IRAN	10

Table 58: Hydrogen energy–Scientific publishing–Ranking of countries by number of articles 1998–2006. Source: ISI Web of Science

Rank	Country	Number
1	USA	10109
2	JAPAN	4052
3	GERMANY	3741
4	PEOPLES R CHINA	2534
5	FRANCE	2309
6	ENGLAND	2050
7	RUSSIA	2020
8	ITALY	1489
9	CANADA	1321
10	SPAIN	1307
11	INDIA	1183
12	POLAND	1062
13	SOUTH KOREA	934
14	NETHERLANDS	822
15	SWEDEN	690
16	SWITZERLAND	675
17	TAIWAN	641
18	AUSTRALIA	637
19	BRAZIL	504
20	ISRAEL	411
21	AUSTRIA	403
22	BELGIUM	399
23	MEXICO	351
24	UKRAINE	340
25	DENMARK	328
26	HUNGARY	325
27	ARGENTINA	316
28	CZECH REPUBLIC	299
29	TURKEY	286
30	PORTUGAL	272
31	FINLAND	256
32	SINGAPORE	215
33	GREECE	199
34	NORWAY	195
35	SCOTLAND	174
36	EGYPT	138
37	IRAN	131
38	BULGARIA	116
39	NORTH IRELAND	107
40	ROMANIA	105
41	SLOVAKIA	104
42	SOUTH AFRICA	99
43	WALES	98

44	YUGOSLAVIA	93
45	IRELAND	92
46	THAILAND	83
47	CHILE	75
48	SLOVENIA	72
49	BYELARUS	59
50	CROATIA	57
51	SAUDI ARABIA	57
52	NEW ZEALAND	55
53	ARMENIA	47
54	ALGERIA	44
55	TUNISIA	43
56	PAKISTAN	39
57	MOROCCO	38
58	VENEZUELA	38
59	HONG KONG	33
60	MACEDONIA	28
61	MALAYSIA	28
62	LITHUANIA	24
63	VIETNAM	24
64	COLOMBIA	22
65	CUBA	22
66	ESTONIA	22
67	REP OF GEORGIA	22
68	U ARAB EMIRATES	22
69	PHILIPPINES	21
70	UZBEKISTAN	21
71	KAZAKHSTAN	20
72	SERBIA MONTENEG	20
73	BANGLADESH	17
74	JORDAN	16
75	NIGERIA	16
76	BARBADOS	15
77	ICELAND	15
78	INDONESIA	14
79	LATVIA	14
80	AZERBAIJAN	12
81	SERBIA	11
82	URUGUAY	11

2. International co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006

Table 59: Solar Photovoltaic energy–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

Country	Denmark N=148	Estonia N=40	Finland N=251	Iceland N=1	Latvia N=6	Lithuania N=52	Norway N=105	Sweden N=582	Total	Share
USA	18	2	39			3	23	62	147	14.6%
GERMANY	16	9	25		2	5	16	51	124	12.3%
ENGLAND	8		6			2	13	31	60	6.0%
FRANCE	5	1	12			2	11	27	58	5.8%
SWITZERLAND	2	2	8				7	28	47	4.7%
SWEDEN	14	2	21			4	4		45	4.5%
NETHERLANDS	8	4	4			1	5	21	43	4.3%
RUSSIA		2	14				5	22	43	4.3%
FINLAND	4	3				12	1	21	41	4.1%
ITALY	3		6		1	1	8	19	38	3.8%
SPAIN	7		3			1	4	18	33	3.3%
AUSTRIA	1		8			8	4	5	26	2.6%
JAPAN	2		7			1	6	7	23	2.3%
BELGIUM	1		3			6	2	9	21	2.1%
DENMARK			4				2	14	20	2.0%
POLAND			1		1		3	15	20	2.0%
LITHUANIA		1	12				2	4	19	1.9%
CANADA			4				5	9	18	1.8%
AUSTRALIA	2	1	1				5	6	15	1.5%
PEOPLES R CHINA			6				1	8	15	1.5%
IRELAND			11					2	13	1.3%
SCOTLAND	2	1	1				5	4	13	1.3%
NORWAY	2	1	1			2		4	10	1.0%
CZECH REPUBLIC			2			4	1	2	9	0.9%
ESTONIA			3			1	1	2	7	0.7%
GREECE	4						1	2	7	0.7%
HUNGARY			3				1	2	6	0.6%
NORTH IRELAND	1		1					4	6	0.6%
BRAZIL	3						1	1	5	0.5%

BULGARIA	3	1						1	5	0.5%
ETHIOPIA								5	5	0.5%
INDIA	1					1	1	2	5	0.5%
WALES	2		1				1	1	5	0.5%
BYELARUS		1						3	4	0.4%
ISRAEL	1		1					2	4	0.4%
KENYA								4	4	0.4%
PORTUGAL			3					1	4	0.4%
SLOVENIA							1	3	4	0.4%
ARGENTINA	1						2		3	0.3%
UKRAINE		1			1			1	3	0.3%
COSTA RICA								2	2	0.2%
NEW ZEALAND	1						1		2	0.2%
PERU								2	2	0.2%
SLOVAKIA			1					1	2	0.2%
SOUTH AFRICA			1				1		2	0.2%
SOUTH KOREA						1		1	2	0.2%
TANZANIA	1							1	2	0.2%
THAILAND						1		1	2	0.2%
TURKEY								2	2	0.2%
URUGUAY								2	2	0.2%
ZAMBIA								2	2	0.2%
CHILE								1	1	0.1%
ROMANIA							1		1	0.1%
SINGAPORE								1	1	0.1%
SRI LANKA								1	1	0.1%
TAIWAN						1			1	0.1%
TUNISIA								1	1	0.1%
ZIMBABWE								1	1	0.1%

Table 60: Wind energy–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden	Total	Share
USA	27		7	1			17	21	73	14.8%
GERMANY	31	2	9		1		4	19	66	13.4%
NETHERLANDS	12		3	1			5	16	37	7.5%
DENMARK			3	1	1	1	12	18	36	7.3%
SWEDEN	18	2	9	2			5		36	7.3%
ENGLAND	16		3				5	11	35	7.1%
ITALY	12		4				1	8	25	5.1%
NORWAY	12		1					5	18	3.7%
FRANCE	2		3	1			4	6	16	3.2%
FINLAND	3	1			1		1	9	15	3.0%
CANADA	8		1				3	2	14	2.8%
RUSSIA	1		3				5	3	12	2.4%
SWITZERLAND	4		1					7	12	2.4%
AUSTRALIA	1						3	3	7	1.4%
GREECE	4		1					2	7	1.4%
PEOPLES R CHINA	3		1				2	1	7	1.4%
POLAND		1	2				1	3	7	1.4%
SPAIN	2		3					2	7	1.4%
CHILE	3							3	6	1.2%
JAPAN							4	2	6	1.2%
BELGIUM	3							2	5	1.0%
SCOTLAND	3							2	5	1.0%
AUSTRIA				1			1	2	4	0.8%
PORTUGAL	1		2					1	4	0.8%
UKRAINE							4		4	0.8%
ESTONIA			1					2	3	0.6%
ICELAND	1							2	3	0.6%
CROATIA								2	2	0.4%
ISRAEL	1							1	2	0.4%
LATVIA	1		1						2	0.4%
ROMANIA	2								2	0.4%

BOSNIA & HERCEG								1	1	0.2%
BRAZIL	1								1	0.2%
CZECH REPUBLIC								1	1	0.2%
ETHIOPIA							1		1	0.2%
GREENLAND	1								1	0.2%
INDONESIA							1		1	0.2%
LITHUANIA	1								1	0.2%
NEW ZEALAND								1	1	0.2%
SERBIA MONTENEG							1		1	0.2%
SOUTH AFRICA	1								1	0.2%
SOUTH KOREA	1								1	0.2%
SUDAN								1	1	0.2%
TANZANIA								1	1	0.2%
TURKEY	1								1	0.2%
VIETNAM	1								1	0.2%

Table 61: second-generation Biofuels–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

Co-country	Denmark N=134	Estonia N=5	Finland N=78	Latvia N=2	Lithuania N=4	Norway N=25	Sweden N=171	Totalt	Share
USA	11		7			1	7	26	12,9%
DENMARK			4			2	7	13	6,4%
RUSSIA	1		8				4	13	6,4%
SWEDEN	7		3		1	2		13	6,4%
GERMANY	4		2				6	12	5,9%
BELGIUM	7						2	9	4,5%
FINLAND	4				1	1	3	9	4,5%
HUNGARY	1					1	6	8	4,0%
CANADA	3		1				2	6	3,0%
FRANCE	5					1		6	3,0%
ITALY	1						5	6	3,0%
SPAIN	3						3	6	3,0%
GREECE	4		1					5	2,5%
NETHERLANDS	2					1	2	5	2,5%
NORWAY	2		1				2	5	2,5%

ZIMBABWE							5	5	2,5%
AUSTRALIA	2						2	4	2,0%
ENGLAND	1					2	1	4	2,0%
IRAN							4	4	2,0%
TANZANIA							4	4	2,0%
CUBA	1						2	3	1,5%
CZECH REPUBLIC	1						2	3	1,5%
MEXICO	2						1	3	1,5%
SWITZERLAND			2				1	3	1,5%
BRAZIL		1		1				2	1,0%
LITHUANIA			1				1	2	1,0%
SLOVENIA	1						1	2	1,0%
SOUTH AFRICA	1					1		2	1,0%
SOUTH KOREA			2					2	1,0%
ARGENTINA	1							1	0,5%
BOLIVIA							1	1	0,5%
BULGARIA	1							1	0,5%
ECUADOR							1	1	0,5%
EGYPT							1	1	0,5%
ESTONIA				1				1	0,5%
GHANA	1							1	0,5%
JAPAN	1							1	0,5%
KUWAIT						1		1	0,5%
LATVIA		1						1	0,5%
PEOPLES R CHINA							1	1	0,5%
POLAND							1	1	0,5%
PORTUGAL							1	1	0,5%
THAILAND	1							1	0,5%
TURKEY	1							1	0,5%
VENEZUELA							1	1	0,5%
WALES						1		1	0,5%

Table 62: CO_2 technology–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

Co-country	Denmark	Estonia	Finland	Iceland	Norway	Sweden	Total
USA	4				13	11	28
FRANCE	2		2		8	2	14
ENGLAND	2				6	5	13
CANADA	1		1		9	1	12
NETHERLANDS	1		2		4	2	9
GERMANY	2	1	1		1	2	7
NORWAY	1		1			5	7
SWEDEN			1		5		6
SWITZERLAND	1		1		2	1	5
DENMARK			1	2	1		4
SPAIN					1	3	4
AUSTRALIA	1				1	1	3
AUSTRIA						3	3
BELGIUM	1		1		1		3
FINLAND	1				1	1	3
INDONESIA			1		2		3
ITALY	1		1			1	3
PEOPLES R CHINA					2	1	3
PORTUGAL	1		1		1		3
RUSSIA					1	2	3
BRAZIL	1					1	2
CZECH REPUBLIC	1		1				2
ICELAND	2						2
IRELAND	1		1				2
ISRAEL	1		1				2
JAPAN					2		2
SCOTLAND	1		1				2
VENEZUELA			1		1		2
HUNGARY					1		1
INDIA						1	1
NEW ZEALAND	1						1

PAKISTAN					1		1
POLAND						1	1
SINGAPORE					1		1
SUDAN			1				1
TURKEY					1		1

Table 63: Hydropower–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

Country	Denmark N=19	Estonia N=1	Finland N=28	Iceland N=3	Lithuania N=4	Latvia N=1	Norway N=57	Sweden N=72	Total	Share in%
USA	2		2				3	6	13	12.6%
NORWAY	4		1	1				5	11	10.7%
DENMARK			1	2			4	1	8	7.8%
SWEDEN	1		1	1			5		8	7.8%
CANADA	1		2				2	2	7	6.8%
ENGLAND			2				1	4	7	6.8%
GERMANY	2		2				2		6	5.8%
ICELAND	2		1				1	1	5	4.9%
SWITZERLAND			1				2	2	5	4.9%
FINLAND	1			1			1	1	4	3.9%
AUSTRALIA							1	2	3	2.9%
FRANCE			1	1			1		3	2.9%
TANZANIA			2					1	3	2.9%
BRAZIL								2	2	1.9%
INDIA								2	2	1.9%
ITALY	1							1	2	1.9%
JAPAN			1					1	2	1.9%
RUSSIA			1				1		2	1.9%
SINGAPORE							2		2	1.9%
HUNGARY			1						1	1.0%
NETHERLANDS								1	1	1.0%
PAKISTAN							1		1	1.0%
PEOPLES R CHINA								1	1	1.0%
POLAND								1	1	1.0%
SCOTLAND								1	1	1.0%

SOUTH AFRICA								1	1	1.0%
SPAIN			1						1	1.0%

Table 64: Hydrogen energy–International Co-authorship in Scientific publishing in the Nordic-Baltic sample 1998–2006. Source: ISI Web of Science

Country	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden	Totalt	Share
USA	61	3	38	2	2	3	34	112	255	15,9%
GERMANY	31		46		2	3	9	82	173	10,8%
ENGLAND	27		27		1	1	13	61	130	8,1%
FRANCE	19	1	14	2	1	3	22	46	108	6,7%
RUSSIA	13	3	17				7	43	83	5,2%
POLAND	24	3	9		1	3	8	26	74	4,6%
SWEDEN	24	3	26		1		20		74	4,6%
ITALY	10	3	13		1	1	5	29	62	3,9%
NETHERLANDS	11	1	16				13	21	62	3,9%
SPAIN	13		10		2	1	4	21	51	3,2%
SWITZERLAND	12	1	10				4	24	51	3,2%
FINLAND	8	4					3	26	41	2,6%
CANADA	14		7			1	5	13	40	2,5%
DENMARK			8			1	7	24	40	2,5%
JAPAN	8		3		3		3	22	39	2,4%
NORWAY	7		3			3		20	33	2,1%
BELGIUM	3		8			1	2	10	24	1,5%
AUSTRALIA	2		2		1	1	4	13	23	1,4%
PORTUGAL	4		7					10	21	1,3%
HUNGARY	3		5					11	19	1,2%
PEOPLES R CHINA	3		1			1	1	11	17	1,1%
BRAZIL	4		1			2	3	4	14	0,9%
AUSTRIA	4		1			1	1	6	13	0,8%
INDIA	1		1			2	3	5	12	0,7%
ISRAEL	3		1		1	2	2	2	11	0,7%
UKRAINE			4		1		4	1	10	0,6%
GREECE	5						1	3	9	0,6%
SCOTLAND	1	1	3					4	9	0,6%

CZECH REPUBLIC	1	1					1	5	8	0,5%
IRELAND			3					5	8	0,5%
SLOVENIA	2		1					5	8	0,5%
ESTONIA			4					3	7	0,4%
NEW ZEALAND	1		1			2	3		7	0,4%
SOUTH AFRICA						2	3	2	7	0,4%
CHILE	1					1	1	3	6	0,4%
SLOVAKIA								6	6	0,4%
TURKEY		1	2				1	2	6	0,4%
WALES	4						1		5	0,3%
LITHUANIA	1						3		4	0,2%
MEXICO	2							2	4	0,2%
REP OF GEORGIA								4	4	0,2%
YUGOSLAVIA						1		2	3	0,2%
BYELARUS								2	2	0,1%
COLOMBIA								2	2	0,1%
CROATIA			1					1	2	0,1%
NORTH IRELAND								2	2	0,1%
ROMANIA								2	2	0,1%
URUGUAY	1		1						2	0,1%
ALBANIA								1	1	0,1%
ARGENTINA	1								1	0,1%
ARMENIA						1			1	0,1%
BULGARIA	1								1	0,1%
COSTA RICA	1								1	0,1%
HONG KONG	1								1	0,1%
INDONESIA	1								1	0,1%
LATVIA								1	1	0,1%
MACEDONIA								1	1	0,1%
SINGAPORE								1	1	0,1%
SOUTH KOREA								1	1	0,1%
THAILAND								1	1	0,1%
VENEZUELA								1	1	0,1%

3. The 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006

The results of companies from the Nordic and Baltic countries are highlighted in the tables.

Table 65: Solar Photovoltaic energy - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006. N=1919. Source: ISI Web of Science

	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden	Total	Share
UNIV UPPSALA	4	2	3				2	229	240	8.3%
ROYAL INST TECHNOL KTH			3			1	1	94	99	3.4%
LINKOPING UNIV	1		4					83	88	3.0%
CHALMERS UNIV TECHNOL	2		2			1		80	85	2.9%
HELSINKI UNIV TECHNOL		1	77					2	80	2.8%
LUND UNIV	4		8					66	78	2.7%
RISO NATL LAB	52		2					5	59	2.0%
VTT	3		51					2	56	1.9%
UNIV HELSINKI		1	46			3	1	3	54	1.9%
UNIV OSLO			1			1	42	2	46	1.6%
VILNIUS STATE UNIV			11			29	2	2	44	1.5%
TALLINN TECH UNIV		37	3			1		2	43	1.5%
TECH UNIV DENMARK	36							2	38	1.3%
UNIV STOCKHOLM								29	29	1.0%
UNIV COPENHAGEN	20		2					2	24	0.8%
ABO AKAD UNIV			12			9		2	23	0.8%
FINNISH METEOROL INST	1		20					2	23	0.8%
UNIV JYVASKYLA	1		14				1	5	21	0.7%
NORWEGIAN UNIV SCI & TECHNOL							19	1	20	0.7%
UNIV TURKU			15			3		2	20	0.7%
NASA	1		7				3	7	18	0.6%
RUSSIAN ACAD SCI			6				3	9	18	0.6%
SINTEF	2						15	1	18	0.6%
TAMPERE UNIV TECHNOL			18						18	0.6%
OKMET OYJ			12					5	17	0.6%
SWEDISH INST SPACE PHYS			2					15	17	0.6%
JOHANNES KEPLER UNIV			7			7		2	16	0.6%

CERN			7				6	1	14	0.5%
UNIV GOTHENBURG	3							11	14	0.5%
UNIV CALIF SAN DIEGO			8				1	4	13	0.4%
CNR	1				1	1	4	5	12	0.4%
UNIV CALIF BERKELEY			5				3	4	12	0.4%
UNIV OULU			12						12	0.4%
VATTENFALL UTVECKLING AB								12	12	0.4%
DUBLIN CITY UNIV			9					2	11	0.4%
SWEDISH UNIV AGR SCI								11	11	0.4%
UNIV CAMBRIDGE	2						5	4	11	0.4%
CNRS	2		3				2	3	10	0.3%
IMEC			3			6		1	10	0.3%
KAUNAS UNIV TECHNOL			1			8		1	10	0.3%
RUTHERFORD APPLETON LAB			1				3	6	10	0.3%
AF IOFFE PHYS TECH INST			5					4	9	0.3%
GOTHENBURG UNIV	1							8	9	0.3%
KAROLINSKA INST			1					8	9	0.3%
UNIV AALBORG	9								9	0.3%
ACAD SCI CZECH REPUBL			2			3	1	2	8	0.3%
CSIC	3					1	2	2	8	0.3%
HAHN MEITNER INST BERLIN GMBH		4						4	8	0.3%
KONARKA AUSTRIA			4			4			8	0.3%
NATL RENEWABLE ENERGY LAB	2	1					1	4	8	0.3%
UNIV JOENSUU			8						8	0.3%
UNIV AARHUS	7							1	8	0.2%
DALARNA UNIV COLL								7	7	0.2%
INST SEMICOND PHYS		1				6			7	0.2%
KATHOLIEKE UNIV LEUVEN			1			4	1	1	7	0.2%
KYOTO UNIV			3				3	1	7	0.2%
LULEA UNIV TECHNOL								7	7	0.2%
PACIFIC NW NATL LAB		1	1				2	3	7	0.2%
UNIV LONDON IMPERIAL COLL SCI TECHNOL & MED								7	7	0.2%
WARSAW UNIV TECHNOL								7	7	0.2%

ABB AB								6	6	0.2%
BROOKHAVEN NATL LAB			4			2			6	0.2%
CHINESE ACAD SCI			1				1	4	6	0.2%
CIEMAT	2		2					2	6	0.2%
IMEGO AB								6	6	0.2%
INST MARINE RES							6		6	0.2%
IPP	2		2					2	6	0.2%
KARLSTAD UNIV								6	6	0.2%
LOS ALAMOS NATL LAB			6						6	0.2%
NORWEGIAN RADIUM HOSP						2	3	1	6	0.2%
STUDSVIK ECO & SAFETY AB	2		2					2	6	0.2%
TNO	2							4	6	0.2%
UNIV BERGEN							5	1	6	0.2%
UNIV GRONINGEN							1	5	6	0.2%
UNIV NEW HAMPSHIRE	1						3	2	6	0.2%
AEROSP CORP			2					3	5	0.2%
ARIZONA STATE UNIV			3				2		5	0.2%
CEA			2				1	2	5	0.2%
FRAUNHOFER INST SOLAR ENERGY SYST	2							3	5	0.2%
IST NAZL FIS NUCL			1					4	5	0.2%
POLISH ACAD SCI			1				1	3	5	0.2%
SENSONOR ASA							5		5	0.2%
TURKU UNIV			4			1			5	0.2%
UNIV CASTILLA LA MANCHA								5	5	0.2%
UNIV FLORENCE								5	5	0.2%
UNIV GLASGOW	1						1	3	5	0.2%
UNIV HAMBURG	1		2			2			5	0.2%
UNIV ILLINOIS								5	5	0.2%
UNIV KUOPIO			5						5	0.2%
UNIV MANCHESTER						1	2	2	5	0.2%
UNIV MARYLAND			3					2	5	0.2%
UNIV OXFORD							1	4	5	0.2%
UNIV TROMSO							5		5	0.2%

UNIV VALENCIA	1						1	3	5	0.2%
UNIV WAGENINGEN & RES CTR	3							2	5	0.2%
ACREO AB								4	4	0.1%
AGH UNIV SCI TECHNOL			1				1	2	4	0.1%
AGR UNIV NORWAY		1					3		4	0.1%
ANGSTROM LAB								4	4	0.1%

Table 66: Wind energy - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006. N=1919. Source: ISI Web of Science

Institution	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden	Total	Share
RISO NATL LAB	97		1				5	7	110	7.7%
LUND UNIV	3		3	2			1	51	60	4.2%
UPPSALA UNIV	3	1	3				2	37	46	3.2%
UNIV GOTHENBURG	2	1	1				2	31	37	2.6%
TECH UNIV DENMARK	31						1	2	34	2.4%
UNIV AALBORG	33		1						34	2.4%
NORWEGIAN UNIV SCI & TECHNOL	3		1				21	1	26	1.8%
CHALMERS UNIV TECHNOL								22	22	1.5%
ROYAL INST TECHNOL KTH	2		1					19	22	1.5%
UNIV COPENHAGEN	21							1	22	1.5%
STOCKHOLM UNIV	1		1				1	18	21	1.5%
INDIANA UNIV	13						1	3	17	1.2%
UNIV BERGEN	2						15		17	1.2%
NATL ENVIRONM RES INST	14			1				1	16	1.1%
UNIV HELSINKI			14					2	16	1.1%
SINTEF							13	1	14	1.0%
UNIV AARHUS	11							3	14	1.0%
VTT	1		9				1	2	13	0.9%
UNIV OSLO							11	1	12	0.8%
FINNISH INST MARINE RES			8					3	11	0.8%
HELSINKI UNIV TECHNOL	1		9					1	11	0.8%
NANSEN ENVIRONM & REMOTE SENSING CTR	2						8		10	0.7%
SWEDISH METEOROL & HYDROL INST	1							8	9	0.6%
INST MARINE RES	1	1					5	1	8	0.6%

NORWEGIAN METEOROL INST							8		8	0.6%
ABB	1		3					3	7	0.5%
DANISH INST FISHERIES RES	4		1		1			1	7	0.5%
DLR	5							2	7	0.5%
HERNING HOSP	4							3	7	0.5%
SWEDISH UNIV AGR SCI	1							6	7	0.5%
UNIV HAMBURG	5		1					1	7	0.5%
UNIV OLDENBURG	6							1	7	0.5%
UNIV TROMSO							7		7	0.5%
CONCEPCION UNIV	3							3	6	0.4%
DET NORSKE VERITAS	3						3		6	0.4%
FINNISH METEOROL INST			6						6	0.4%
ICELAND INST NAT HIST	1			3				2	6	0.4%
NEG MICON	5							1	6	0.4%
NORWEGIAN POLAR RES INST							5	1	6	0.4%
SWEDISH INST SPACE PHYS								6	6	0.4%
CIEMAT	1		2					2	5	0.3%
CNRS			1				1	3	5	0.3%
DANISH METEOROL INST	5								5	0.3%
ECOFYS	4							1	5	0.3%
GEOL SURVEY DENMARK & GREENLAND	5								5	0.3%
NORSK HYDRO AS							4	1	5	0.3%
ROSKILDE UNIV CTR	4						1		5	0.3%
STATKRAFT SF							4	1	5	0.3%
STATOIL			1				4		5	0.3%
TALLINN TECH UNIV		4	1						5	0.3%
UNIV UTRECHT				1			2	2	5	0.3%
BALT SEA RES INST WARNEMUNDE	2		1					3	4	0.3%
CARL BRO AS	4								4	0.3%
CEA			2					2	4	0.3%
CNR	2		1					1	4	0.3%
CTR RENEWABLE ENERGY SOURCES	2							2	4	0.3%
ENERGY RES CTR NETHERLANDS	4								4	0.3%

EURATOM			2					2	4	0.3%
FREE UNIV BRUSSELS	2							2	4	0.3%
LM GLASFIBER AS	3							1	4	0.3%
NATL TECH UNIV ATHENS	2							2	4	0.3%
NESA AS	4								4	0.3%
NORDITA	2						2		4	0.3%
PLANENERGI SI	4								4	0.3%
SWEDISH DEF RES AGCY	2							2	4	0.3%
UKAEA EURATOM FUS ASSOC			2					2	4	0.3%
UNIV GRONINGEN							1	3	4	0.3%
UNIV TURKU			4						4	0.3%
UNIV WASHINGTON	1		1				1	1	4	0.3%
VESTAS WIND SYST AS	3							1	4	0.3%
WOODS HOLE OCEANOG INST	2			1				1	4	0.3%
BJERKNES CTR CLIMATE RES							3		3	0.2%
BOLDING & BURCHARD HYDRODYNAM GBR	2							1	3	0.2%
CHINESE ACAD SCI	1						1	1	3	0.2%
COMMISS EUROPEAN COMMUNITIES	3								3	0.2%
COPENHAGEN SCH ECON & BUSINESS ADM	2					1			3	0.2%
CRES	2							1	3	0.2%
DEF RES ESTAB								3	3	0.2%
DELFT UNIV TECHNOL	3								3	0.2%
ELTRA	2						1		3	0.2%
ENERGI E2	2							1	3	0.2%
ETH	2							1	3	0.2%
FINNISH GAME & FISHERIES RES INST	1		1		1				3	0.2%
GARRAD HASSAN & PARTNERS LTD	2							1	3	0.2%
GEOL SURVEY NORWAY							3		3	0.2%
INST MEERESKUNDE	1		1		1				3	0.2%
INT CTR THEORET PHYS	2							1	3	0.2%
IST	1		1					1	3	0.2%
JOHNS HOPKINS UNIV	2							1	3	0.2%
LATVIAN FISHERIES RES INST	1		1		1				3	0.2%

MALARDALEN UNIV								3	3	0.2%
MAX PLANCK INST PLASMA PHYS	1		1					1	3	0.2%
MIT			1	1				1	3	0.2%
MOBIL EXPLORAT NORWAY INC							3		3	0.2%
NAGOYA UNIV							2	1	3	0.2%
NASA	1						1	1	3	0.2%
NATL CTR ATMOSPHER RES							1	2	3	0.2%
NATL RENEWABLE ENERGY LAB	1						1	1	3	0.2%
NETHERLANDS INST SEA RES								3	3	0.2%
OREGON STATE UNIV	2							1	3	0.2%

Table 67: second-generation Biofuels - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006. N=1919. Source: ISI Web of Science

Institution Name	Denmark	Estonia	Finland	Latvia	Lithuania	Norway	Sweden	Totalt
TECH UNIV DENMARK	93		2			2	5	102
LUND UNIV	5		3			1	90	99
UNIV JYVASKYLA	2		27			1	1	31
CHALMERS UNIV TECHNOL	2						19	21
SWEDISH UNIV AGR SCI							20	20
VTT	1		16				1	18
ROYAL VET & AGR UNIV	13		1				2	16
DANISH INST AGR SCI	14		1					15
RISO NATL LAB	12		1					13
RUSSIAN ACAD SCI	1		8				4	13
KTH					1		11	12
NORWEGIAN UNIV SCI & TECHNOL	1		1			9		11
UNIV CALIF LOS ANGELES	10							10
MTT AGRIFOOD RES FINLAND			9					9
UNIV GOTHENBURG							9	9
LINKOPING UNIV							8	8
BUDAPEST UNIV TECHNOL & ECON	1						6	7
SWEDISH PULP & PAPER RES INST							7	7
UNIV HELSINKI	1		5		1			7
ISFAHAN UNIV TECHNOL							6	6
TAMPERE UNIV TECHNOL			6					6

UNIV TURKU			5				1	6
KARLSTAD UNIV							5	5
LULEA UNIV TECHNOL							5	5
LUND INST TECHNOL							5	5
NATL VET INST							5	5
NOVOZYMES AS	5							5
TALLINN TECH UNIV		4		1				5
UNIV COPENHAGEN	5							5
UNIV PATRAS	4		1					5
UNIV ZIMBABWE							5	5
HELSINKI UNIV TECHNOL			4					4
NOVO NORDISK AS	3		1					4
STATOIL						4		4
UNIV DAR ES SALAAM							4	4
UNIV QUEENSLAND	2						2	4
BORREGAARD IND LTD	1					1	1	3
BURMEISTER & WAIN SCANDINAVIAN CONTRACTOR AS	3							3
FOSTER WHEELER ENERGIA OY			3					3
INRA	3							3
KATHOLIEKE UNIV LEUVEN	2						1	3
NATL ENVIRONM RES INST	3							3
SINTEF						3		3
STATE UNIV GHENT	2						1	3
STOCKHOLM UNIV							3	3
SWEDISH ENVIRONM RES INST						1	2	3
SWEDISH INST AGR ENGN							3	3
TRITONET LTD			3					3
UMEA UNIV							3	3
UNIV BAYREUTH	3							3
UNIV BERGEN						2	1	3
UNIV MATANZAS	1						2	3
UNIV AALBORG	3							3
BUR SANITAT	2							2
CAMBI AS NORWAY						2		2
CSIC	1						1	2

DANISCO	2							2
DANISH VET & FOOD ADM	2							2
ENVIRONM RES INST MICHIGAN						1	1	2
EUROPEAN SPACE AGCY						1	1	2
FINNMARK UNIV COLL						2		2
FOLKHALSAN RES CTR	1		1					2
INST CHEM TECHNOL	1						1	2
JOZEF STEFAN INST	1						1	2
KAUNAS UNIV TECHNOL					2			2
KRUGER AS	2							2
LATVIAN STATE INST WOOD CHEM		1		1				2
MALARDALEN UNIV							2	2
MALMO WATER & SEWAGE WORKS							2	2
MID SWEDEN UNIV							2	2
NANSEN ENVIRONM & REMOTE SENSING CTR						1	1	2
NUST							2	2
ODENSE UNIV	2							2
RDA			2					2
REATECH	1					1		2
TEKNISKA VERKEN LINKOPING AB							2	2
UNICAMP		1		1				2
UNIV BORAS							2	2
UNIV CALIF BERKELEY			2					2
UNIV FREIBURG			2					2
UNIV LONDON KINGS COLL						1	1	2
UNIV MICHIGAN						1	1	2
UNIV OSLO						2		2
UNIV TORONTO	1		1					2
UNIV UPPSALA							2	2
UNIV AARHUS	2							2
VILNIUS STATE UNIV					1		1	2
VOLVO							2	2
WARTSILA LTD			2					2
ABO AKAD UNIV			1					1
ACAD FINLAND			1					1

AGR CANADA	1							1
AGR RES STN							1	1
AGR UNIV NORWAY						1		1
AGRIFOOD RES FINLAND			1					1
ALIMETR LTD			1					1
ANOX AB							1	1
ARS							1	1
AS BIMKEMI EESTI		1						1
BIOSCAN ENGN AS	1							1

Table 68: CO_2 technology - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006. N=1919. Source: ISI Web of Science

Institution Name	Denmark	Estonia	Finland	Iceland	Norway	Sweden	Total
NORWEGIAN UNIV SCI & TECHNOL					25	3	28
CHALMERS UNIV TECHNOL					1	25	26
UNIV BERGEN					14		14
LUND UNIV					2	11	13
SINTEF	1				11		12
STATOIL					9		9
UNIV HELSINKI	1		7			1	9
UNIV COPENHAGEN	5			2			7
INST ENERGY TECHNOL					6		6
PRINCETON UNIV					5	1	6
VATTENFALL AB					2	4	6
ALSTOM POWER					3	2	5
MAX PLANCK INST	1		1		1	2	5
NORSK HYDRO OIL & ENERGY					3	2	5
ROYAL INST TECHNOL						5	5
TECH UNIV DENMARK	5						5
UNIV ALASKA					2	3	5
UPPSALA UNIV						5	5
AGR RES INST	2			2			4
AGR UNIV NORWAY			1		3		4
BRITISH GEOL SURVEY	1				3		4
DEMAG DELAVAL IND TURBOMACHINERY AB					2	2	4

GOTHENBURG UNIV						4	4
HELSINKI UNIV TECHNOL			4				4
INRA	2		2				4
INST FRANCAIS PETR					3	1	4
GEOL SURNEY DENMARK & GREENLAND	2				1		3
LINKOPING UNIV						3	3
LULEA UNIV TECHNOL						3	3
NATL CTR ATMOSPHER RES						3	3
RUSSIAN ACAD SCI					1	2	3
STOCKHOLM UNIV						3	3
TNO					2	1	3
UNIV NEWCASTLE UPON TYNE						3	3
UNIV OSLO					3		3
UNIV TARTU		3					3
UNIV WASHINGTON	1				1	1	3
ACAD SCI CZECH REPUBL	1		1				2
AGDER UNIV COLL					2		2
ALBERTA ENERGY & UTIL BOARD					2		2
ALTERRA	1		1				2
ARCO ALASKA INC					2		2
CANADIAN CTR CLIMATE MODELING & ANAL					1	1	2
CEFE			1		1		2
CNR	1		1				2
CSIC					1	1	2
CTR ECOL ALPINA	1		1				2
CTR ENERGET & PROCEDES					1	1	2
DEPT BIOL	1		1				2
ETH ZENTRUM	1		1				2
FINNISH METEOROL INST	1		1				2
FORSCHUNGSSTELLE POTSDAM					1	1	2
HALDOR TOPSOE RES LABS	2						2
ICRAF SE ASIA			1		1		2
INST SUPER AGRON	1		1				2

INST VENEZOLANO INVEST CIENT			1		1		2
INT INST APPL SYST ANAL						2	2
JOINT RES CTR	1		1				2
KVAERNER					2		2
MID SWEDEN UNIV						2	2
MIT						2	2
MONTEREY BAY AQUARIUM RES INST					2		2
NATL ENVIRONM RES INST	2						2
NATL MARITIME RES INST					2		2
NATL PUBL HLTH INST			1		1		2
NETHERLANDS INST FISHERY RES			1			1	2
POTSDAM INST CLIMATE IMPACT RES					1	1	2
RISO NATL LAB	1		1				2
TALLINN TECH UNIV		2					2
TECH UNIV DRESDEN	1		1				2
UMEA UNIV			1			1	2
UNIV BOLOGNA	1		1				2
UNIV BRITISH COLUMBIA					2		2
UNIV CAMBRIDGE					1	1	2
UNIV COLL DUBLIN	1		1				2
UNIV COLORADO					1	1	2
UNIV EDINBURGH	1		1				2
UNIV OREGON					1	1	2
UNIV PARIS 12			1		1		2
UNIV PETR BEIJING					2		2
UNIV ROUEN					2		2
UNIV TOULOUSE 3					2		2
UNIV TUSCIA	1		1				2
VL KOMAROV BOT INST					1	1	2
VRIJE UNIV AMSTERDAM			1			1	2
VTT			2				2
WEIZMANN INST SCI	1		1				2
ABISKO SCI RES STN						1	1

ABO AKAD UNIV			1				1
AIR LIQUIDE CRC D					1		1
AKF	1						1
ALBERTA GEOL SURVEY					1		1
AS NORSKE SHELL					1		1
BIONEER AS	1						1
BISPEBJERG HOSP	1						1
CHASNUPP					1		1
CHINESE ACAD SCI						1	1
CICERO					1		1
COLORADO SCH MINES					1		1
CRCD AIR LIQUIDE					1		1

Table 69: Hydropower - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998–2006. N=1919. Source: ISI Web of Science

Institution Name	Denmark	Estonia	Finland	Iceland	Latvia	Lithuania	Norway	Sweden	Total
ROYAL INST TECHNOL KTH								22	22
UNIV OSLO	1						15		16
NORWEGIAN UNIV SCI & TECHNOL							14		14
NORWEGIAN INST NAT RES	1						8		9
HELSINKI UNIV TECHNOL			8						8
SINTEF							8		8
SWEDISH METEOROL INST	1		1	1			1	4	8
LULEA UNIV TECHNOL								7	7
LUND UNIV								9	9
NORWEGIAN WATER RESOURCES & ENERGY DIRECTORATE							7		7
UNIV ICELAND	1			6					7
UPPSALA UNIV							1	5	6
DANISH METEOROL INST	1		1	1			1	1	5
FINNISH METEOROL INST	1		1	1			1	1	5
ISL METEOROL ORG	1		1	1			1	1	5
NORSK HYDRO AS							3	2	5
NORWEGIAN METEOROL INST	1		1	1			1	1	5
STOCKHOLM UNIV								5	5

ALSTOM POWER							1	3	4
DANISH INST FISHERIES RES	3						1		4
LINKOPING UNIV								4	4
NORWEGIAN INST WATER RES	1						2	1	4
TAMPERE UNIV TECHNOL			4						4
UMEA UNIV								4	4
VTT			4						4
AGR UNIV NORWAY							3		3
FINNISH GAME & FISHERIES RES INST			3						3
FISHERIES & OCEANS CANADA			1				2		3
GEOL SURVEY DENMARK & GREENLAND	2						1		3
MALARDALEN UNIV								3	3
RISO NATL LAB	3								3
TECH UNIV DENMARK	2			1					3
UNIV BERGEN	1						2		3
UNIV HELSINKI			3						3
ABB							1	1	2
AUSTRALIAN NATL UNIV							1	1	2
BAVARIAN ACAD SCI	1						1		2
CEA				2					2
CHALMERS UNIV TECHNOL								2	2
DEMAG DELAVAL IND TURBOMACHINERY AB							1	1	2
ELTRA	1						1		2
FINNISH ENVIRONM INST			2						2
FORSMARKS KRAFTGRP AB							1	1	2
FORTUM			2						2
GOTHENBURG UNIV							1	1	2
INT PAPER								2	2
KEMIJOKI OY			2						2
NATL INST HYDROL								2	2
NATL RENEWABLE ENERGY LAB							1	1	2
NORWEGIAN ELECT POWER RES INST							2		2
ORG ECON COOPERAT & DEV							1	1	2

PAUL SCHERRER INST			1					1	2
ROSKILDE UNIV CTR	1						1		2
STAT NORWAY							2		2
STATKRAFT SF							2		2
SUNATECH INC							1	1	2
SWEDISH UNIV AGR SCI								2	2
TELEMARK UNIV COLL							2		2
UNITED NATIONS UNIV				2					2
UNIV COPENHAGEN	2								2
UNIV KUOPIO			2						2
ABISKO SCI RES STN								1	1
ABS NOPON OY LTD			1						1
AGR UNIV LITHUANIA						1			1
ARGONNE NATL LAB			1						1
CARL BRO	1								1
CHASNUPP							1		1
CICERO							1		1
CLARKSON UNIV							1		1
COLUMBIA UNIV								1	1
COMISSARIAT ENERGY ATOM			1						1
COMSOL AB								1	1
CONVERS & RESOURCE EVALUAT LTD			1						1
CTR INT RECH ENVIRONM & DEV							1		1
CTY ADM BOARD NORRBOTTEN								1	1
DALARNA UNIV COLL								1	1
DANISH MED AGCY	1								1
DELFT UNIV TECHNOL								1	1
DEPT THERMO & FLUID DYNAM								1	1
DHI WATER & ENVIRONM	1								1
DIRECTORATE NAT MANAGEMENT							1		1
ECO TECH							1		1
ECON ANAL	1								1
ELECT FRANCE			1						1

EMT ASA							1		1
ENVIRONM IMPACT ASSESSMENT CTR FINLAND			1						1
ETH HONGGERBERG							1		1
FED RES CTR FORESTRY & FOREST PROD			1						1
FINNISH GEODET INST			1						1
FORESTRY RES INST SWEDEN SKOGFORSK								1	1
FORSCHUNGSZENTRUM KARLSRUHE			1						1
FRAMATOME ANP			1						1
GEORGIA INST TECHNOL								1	1
HEDMARK UNIV COLL							1		1
ICELAND NEW ENERGY				1					1
IEA			1						1
INDIANA UNIV	1								1
INST ENERGY TECHNOL							1		1
INT HYDROPOWER ASSOC			1						1

Table 70: Hydrogen energy - the 100 most visible institutions in the Nordic-Baltic sample of articles. 1998G40G–2006. N=1919. Source: ISI Web of Science

Institution Name	DK	EE	FI	IC	LV	LT	NO	SE	Total
UPPSALA UNIV	5	1	6				6	158	176
ROYAL INST TECHNOL KTH	3	1	5				7	120	136
STOCKHOLM UNIV	1		2				3	117	123
UNIV HELSINKI	2	2	102					7	113
LUND UNIV	7	1	3				5	88	104
UNIV OSLO	5					1	85	7	98
AARHUS UNIV	81		1				3	7	92
TECH UNIV DENMARK	80		1						81
CHALMERS UNIV TECHNOL	4		3					70	77
HELSINKI UNIV TECHNOL	2	1	52					9	64
UNIV GOTHENBURG	1						2	60	63
UNIV COPENHAGEN	54		2				3	3	62
EURATOM	12		16					22	50
LINKOPING UNIV	2							48	50
MAX PLANCK GESELL	8		20					18	46
RISO NATL LAB	34		2				1	6	43
RUSSIAN ACAD SCI	6	2	4				7	21	40
UNIV TROMSO	1		2			2	28	6	39
NORWEGIAN UNIV SCI & TECHNOL							30	2	32
KAROLINSKA INST			1		1			27	29
UNIV BERGEN	1		1			1	24	2	29
CEA	4	1	7	2		1		12	27
UNIV SO DENMARK	27								27
HALDOR TOPSOE RES LABS	22								22
UNIV JYVASKYLA	1		21						22
POLISH ACAD SCI	12		1					8	21
UNIV TURKU			19					2	21
UMEA UNIV								20	20
UNIV OULU	1		17				2		20
INST ENERGY TECHNOL							19		19
ABO AKAD UNIV			15					2	17
GOTHENBURG UNIV	3		1				1	11	16
KFA JULICH GMBH	5		3					8	16
UNIV CALIF BERKELEY	1		3				3	9	16
HARVARD SMITHSONIAN CTR ASTROPHYS	2		1				2	10	15
NASA	3		3			1	3	5	15
UKAEA EURATOM FUS ASSOC	1		7					7	15
UNIV COLORADO	5		3			1	1	5	15
UNIV PARIS 06	1		2				6	6	15
UNIV TARTU		11	2					2	15
CNRS	3	1	2				3	5	14
LULEA UNIV TECHNOL	2		1					11	14
SWEDISH INST SPACE PHYS			4					10	14
TAMPERE UNIV TECHNOL		1	13						14
UNIV ICELAND				14					14
UNIV TEXAS	1			1		2	3	7	14
AUSTRALIAN NATL UNIV	1				1	1	3	7	13
CERN	5	1	1					6	13
UNIV MANCHESTER	6		2				1	4	13

FINNISH METEOROL INST			8					4	12
ROSKILDE UNIV CTR	12								12
SINTEF							12		12
UNIV WROCLAW	2		7			1		2	12
CALTECH	2		2			1	3	3	11
LATVIAN STATE UNIV					10			1	11
NORDITA	8							3	11
ROYAL DANISH SCH PHARM	11								11
UNIV EXETER	2		1					8	11
UNIV KUOPIO			10				1		11
UNIV NEWCASTLE UPON TYNE	2		1				1	7	11
UNIV TORONTO	5		3					3	11
AF IOFFE PHYS TECH INST	1		5					4	10
CNR	3		1		1			5	10
CSIC	4		3					3	10
JAGIELLONIAN UNIV	3		1					6	10
JET JOINT UNDERTAKING			7					3	10
UNIV JOENSUU			10						10
UNIV MICHIGAN	1		3					6	10
VILNIUS STATE UNIV						8	2		10
EPFL			4					5	9
JOHNS HOPKINS UNIV			2				1	6	9
ROYAL VET & AGR UNIV	8		1						9
RUTHERFORD APPLETON LAB			3				1	5	9
STUDSVIK AB	3						1	5	9
BUDAPEST UNIV TECHNOL & ECON								8	8
CHINESE ACAD SCI	2		1			1	1	3	8
UNIV ARIZONA			2			1	2	3	8
UNIV COLL LONDON	2		4					2	8
UNIV GHENT	2		3					3	8
UNIV LEICESTER	1		2			1	1	3	8
UNIV TOKYO	4							4	8
UNIV WASHINGTON	1		1	2			2	2	8
UNIV AALBORG	8								8
VTT			8						8
ABB AB								7	7
JOHN INNES CTR PLANT SCI RES								7	7
MCMASTER UNIV	5		1				1		7
MICHIGAN STATE UNIV	2		2					3	7
TALLINN TECH UNIV		6	1						7
UNIV BERN			2					5	7
UNIV CALIF SAN DIEGO	3		2				2		7
UNIV TOULOUSE 3	1					1	2	3	7
UNIV UTRECHT	3		1				3		7
UNIV WISCONSIN	7								7
ALBANOVA UNIV CTR								6	6
ANGSTROM LAB								6	6
DANISH UNIV PHARMACEUT SCI	4							2	6
FOM	1		1					4	6
FREE UNIV BERLIN	1		1					4	6
IST NAZL FIS NUCL	2							4	6

Search strings for the patent and bibliometric analysis

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[i] Search strings for patent analysis

Solar photovoltaics Search string	*Nordic*	*World*
((((C01B 03300) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31)	9	809
(((((C01B 03312) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	2	186
(((((C30B 02100) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	1	11
(((((thin film*) <in> AB) AND ((H01G) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	56
(((((thin film*) <in> AB) AND ((H01L 03100*) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	57
(((((Dye-sensitized solar*) <in> AB)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	51
(((((Dye-sensitized photovoltaic*) <in> AB)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	5
(((((CIGS) <in> AB)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	4	82

Wind energy Search string

(((((Denmark) <in> IN) AND (((F03D)) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))

2nd generation biofuels Search string	*Nordic*	*World*
((((cellulosic bioethanol) <in> AB)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31)	0	
(((((biodiesel) <in> AB)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	21	
(((((C12P 00714) <in> IC)) AND (AD>=1998-01-01)) AND (AD<=2006-12-31))	1	12
((((((C12P 00700) <in> IC)) AND (AD>=1998-01-01)) AND (AD<=2006-12-31)))	2	62
((((((C12P 00500) <in> IC)) AND (AD>=1998-01-01)) AND (AD<=2006-12-31)))	3	75
((((((C12M 001107) <in> IC)) AND (AD>=1998-01-01)) AND (AD<=2006-12-31)))	4	128
((((((C12P 00702) <in> IC)) AND (AD>=1998-01-01)) AND (AD<=2006-12-31)))	23	473
(((((C02F 01100) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	8	148
(((((C02F 01104) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	9	113
(((((C10L 00102) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	4	188
(((((C11C 00300) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	1	309
(((((C11C 00310) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2006-12-31))	0	156

CO_2 capturing and storage Search string	*Nordic-*	*World*
(((((CO2 capturing) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	8
(((((carbon dioxide sequestration) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	1
(((((recovery of CO2) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	13
(((((storage of CO2) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	3
(((((seperation of carbon dioxide) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	0
(((((Carbon dioxide captur*) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	4
(((((Carbon dioxide storag*) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	7
(((((post-combustion separation) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	1
(((((pre-combustion separation) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	1
(((((((oxy-fuel combustion) <in> DESCRIPTION)) AND (CO2) <in> DESCRIPTION) AND (DP>=1998-01-01)) AND (DP<=2005-12-31)))	0	4
((((((((Depleted Oil and Gas Field*) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31)))))	0	0
(((((Enhanced Oil Recovery) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	41
(((((Enhanced Gas Recovery) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	7
(((((Saline aquifer*) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	4
(((((Un-mineable coal seam*) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	0
(((((CO2 sequestration) <in> DESCRIPTION)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	5
(((((((C01B 03120) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))))	3	89
(((((C01B 03120) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	2	96
(((((C01B 03122) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	0	20

Wave energy Search string	*Nordic*	*World*
(((((F03B 01314) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	8	36

Hydropower Search string	*Nordic*	*World*
((((((water power plant*) <in> TI) AND (AD>=1998-01-01)) AND (AD<=2005-12-31))))	0	1
((((((water turbin?) <in> AB) AND (AD>=1998-01-01)) AND (AD<=2005-12-31))))	2	15
(((((E02B 00900) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	2	22
(((((E02B 009??) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	3	31
(((((F03B 00306) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	1	8
(((((F03B 003??) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))	9	83

Hydrogen technology Search string	*Nordic*	*World*
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=1998-12-31)))	8	224
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=1999-01-01)) AND (DP<=1999-12-31)))	1	296
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2000-01-01)) AND (DP<=2000-12-31)))	6	338

(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2001-01-01)) AND (DP<=2001-12-31))) 2 340
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2002-01-01)) AND (DP<=2002-12-31))) 6 334
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2003-01-01)) AND (DP<=2003-12-31))) 6 267
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2004-01-01)) AND (DP<=2004-12-31))) 2 207
(((((((C01B 003<or>C01B 003??<or>C01B 003???<or>C01B 003????)) <in> IC)) AND (DP>=2005-01-01)) AND (DP<=2005-12-31))) 0 74
(((((((C01B 006<or>C01B 006??<or>C01B 006???<or>C01B 006????)) <in> IC)) AND (DP>=1998-01-01)) AND (DP<=2005-12-31))) 0 87

[ii] Search strings for the bibliometric study:

Solar photovoltaics

TS (title, abstract)	(solar energy* OR solar photovoltaic* OR (solar AND silicon*) OR solar cell* OR (silicon* AND wafer*)
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI
NOT	TS=(astronom* OR astrophysic* OR Space science* OR solar corona* OR CELL CARCINOMA OR medic*) OR SO=(Astronomy* OR ASTROPHYSICAL JOURNAL OR JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS OR ANNALES GEOPHYSICAE OR ASTRONOMISCHE NACHRICHTEN OR MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY OR SOLAR PHYSICS OR ASTROBIOLOGY OR ASTRONOMICAL JOURNAL OR ICARUS OR (JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS) OR (MERCURY, MARS AND SATURN) OR (NEW EYES TO SEE INSIDE THE SUN AND STARS) OR (POLAR CAP THERMOSPHERE/IONOSPHERE AND ITS ROLE IN SOLAR-TERRESTRIAL PHYSICS) OR (RECONNECTION AT SUN AND IN MAGNETOSPHERES) OR SPACE SCIENCE*)

2nd Generation Biofuels

TS (title, abstract)	(cellulosic bioethanol) OR (Biomass-to-liquids) OR (Fischer-Tropsch diesel) OR (Synthetic biodiesel) OR (Synthetic diesel) OR (Biomethanol) OR (Heavier alcohols) OR (Bio-DME) OR (Hydro-treated biodiesel) OR (Synthetic natural gas) OR (Lignocellulosic biomass*) OR (Lignocellulosic material*) OR (advanced hydrolysis) OR (advanced fermentation) OR (gasification AND synthesis) OR (anaerobic digestion) OR ((Hydrolysis) AND (fermentation)) OR (advanced biofuel*) OR (advanced bioenergy) OR (2nd generation biofuel*) OR (advanced bioethanol)
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI

Hydrogen

TS (title, abstract)	(Hydrogen AND (energy OR power)) OR (H2 AND energy)
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI

Wind energy

TS (title, abstract)	(Wind energ* OR Wind power OR wind turbin* OR wind mill* OR offshore wind* OR onshore wind* OR airborne turbine* OR near-shore turbine*)
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI
NOT	SO=((ASTROPHYSICAL JOURNAL) OR (JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS) OR (ASTRONOMY & ASTROPHYSICS) OR (ANNALES GEOPHYSICAE) OR (MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY) OR (SPACE SCIENCE REVIEWS) OR (ASTRONOMY AND ASTROPHYSICS) OR (PLANETARY AND SPACE SCIENCE) OR (SOLAR PHYSICS) OR (ASTROPHYSICS AND SPACE SCIENCE) OR (ICARUS) OR (ANNALES GEOPHYSICAE-ATMOSPHERES HYDROSPHERES AND SPACE SCIENCES) OR (ASTRONOMY LETTERS-A JOURNAL OF ASTRONOMY AND SPACE ASTROPHYSICS) OR (ASTRONOMICAL JOURNAL) OR (NUOVO CIMENTO DELLA SOCIETA ITALIANA DI FISICA C-GEOPHYSICS AND SPACE PHYSICS) OR (ASTRONOMY REPORTS) OR (ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES) OR (COORDINATED MEASUREMENTS OF MAGNETOSPHERIC PROCESSES) OR (HELIOSPHERIC COSMIC RAY TRANSPORT, MODULATION AND TURBULENCE) OR (COSMIC RESEARCH) OR (SOLAR SYSTEM RESEARCH) OR (SPACE WEATHER-THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS) OR (TO THE EDGE OF THE SOLAR SYSTEM AND BEYOND) OR (HELIOSPHERE AT SOLAR MAXIMUM) OR (YOUNG NEUTRON STARS AND THEIR ENVIRONMENTS) OR (ASTROPARTICLE PHYSICS) OR (PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF JAPAN) OR (COMPARATIVE MAGNETOSPHERES) OR (PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC) OR (SOLAR WIND-MAGNETOSPHERE-IONOSPHERE DYNAMICS AND RADIATION MODELS) OR (CHINESE JOURNAL OF ASTRONOMY AND ASTROPHYSICS) OR (ENERGY RELEASE AND PARTICLE ACCELERATION IN THE SOLAR ATMOSPHERE - FLARES AND RELATED PHENOMENA) OR (NEW ASTRONOMY REVIEWS) OR (PLASMA PHYSICS AND CONTROLLED FUSION))
NOT	TS=((Astronom*) OR (Astrophysic*) OR (SOLAR CORONA*) OR (SOLAR WIND*) OR (Heliosphere*))

Carbon Capppturing and Storage (CCS)

TS (title, abstract)	(Carbon dioxide captur*) OR (CO2 captur*) OR ("Carbon dioxide storag*") OR ("CO2 storag*") OR ("post-combustion separation") OR ("pre-combustion separation") OR ("oxy-fuel combustion") OR ("Oxy-fuel Firing") OR ("Depleted Oil and Gas Field*" OR "Enhanced Oil Recovery" OR "Enhanced Gas Recovery" OR "Saline aquifer*" OR "Un-mineable coal seam*") OR ("carbon dioxide sequestration" OR "CO2 sequestration") OR ("CO2 injection*" OR "carbon dioxide injection*")
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI

Hydropower

TS (title, abstract)	(Hydropower* OR hydroelectric* OR water turbine*)
PY	1998 OR 1999 OR 2000 OR 2001 OR 2002 OR 2003 OR 2004 OR 2005 OR 2006
CU	Denmark OR Estonia OR Finland OR Latvia OR Lithuania OR Norway OR Iceland OR Sweden
Time span	1998-2006
Doc Type	Article OR Letter OR Meeting Abstract OR Note OR Review
Language	All languages
Databases	SCI-EXPANDED, SSCI, A&HCI