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Nordic Energy Research

Nordic Energy Technologies

ENABLING A SUSTAINABLE NORDIC ENERGY FUTURE

CONTENTS

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Nordic Energy Research

LIST OF ABBREVIATIONS

CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
COP15	UN Climate Summit in Copenhagen 2009
DTU	Technical University of Denmark
EPO	European Patent Office
ERA	European Research Area
ERA-NET	European Research Area Network
EU	European Union
EUDP	Danish Energy Development and Demonstration Programme
GDP	Gross Domestic Product
GHG	Green House Gasses
IEA	International Energy Agency
IPCC	UN International Panel on Climate Change
IPR	Intellectual Property Rights
KTH	Royal Institute of Technology
NCM	Nordic Council of Ministers
NER	Nordic Energy Research
NIAS	Nordic Institute of Asian Studies
Nord Pool Spot	Nordic Power Exchange
Nordel	Former organisation of the Nordic Transmission System Operators, now ENTSO-E
Nordreg	Nordic Energy Regulators Association
NORIA	Nordic Research and Innovation Area
NTNU	Norwegian University of Science and Technology
NUPI	Norwegian Institute of International Affairs
OECD	Organisation for Economic Cooperation and Development
PV	Photovoltaic
R&D	Research and Development
RD&D	Research, Development and Demonstration
RES	Renewable Energy Sources
RTD	Research and Technology Development
SET-Plan	EU Strategic Energy Technology Plan
TSO	Transmission System Operator
UN	United Nations
VTT	Technical Research Centre of Finland
WTO	World Trade Organisation

1 Introduction

Combating climate change, increasing energy security of supply and finding new sustainable ways of ensuring economic growth are paramount political objectives worldwide. The Nordic countries are all subject to ambitious targets to increase renewable energy generation, improve energy efficiency and reduce greenhouse gas emissions. Achieving these targets, and their overarching political objectives, will require substantial changes in society's approach to energy issue.

In Energy Technology Perspectives 2008, the International Energy Agency (IEA) outlined several possible scenarios for achieving a 50 percent GHG reduction by 2050 – a measure considered by the IPCC to be necessary to confine global warming between 2 and 2.4 degrees. Their conclusion was that a global energy technology revolution is needed – in terms of developing new technologies, and in terms of finding ways to get more mature technologies to market. According to the IEA's analysis it is evident that a diverse and multi-faceted new energy mix is needed – no single renewable energy source or carrier can replace petroleum, gas and coal. Rather, better ways of integrating several different energy technologies into a smarter energy system is necessary (International Energy Agency 2008a).

A global energy technology revolution will require greater funding and cooperation in energy research, development and demonstration. Cooperation between countries can unlock added value and avoid overlaps, enabling far greater progress than is possible as individual nations. The Nordic region offers a prime example of this cooperation, where a clear goal is to form an integrated Nordic Research and Innovation Area (NORIA) that can foster coordination and collaboration in energy research and innovation. The NORIA could also be a locomotive in internationalising Nordic energy research and innovation efforts. The Nordic region has a long-standing history of working together in energy research. Reaching the targets necessary to combat climate change and ensure energy security of supply will require that the region build on the positive experiences from the past and strengthen regional cooperation in energy RD&D.

Supporting the goal of forming the NORIA in the energy sector, Nordic Energy Research in 2007 commissioned a range of studies to describe and assess the energy research and innovation systems in the Nordic region. The aim was also to look for possible collaborative actions with neighbouring countries, as well as China and Russia. The projects provided an extensive mapping of the Nordic energy research and innovation systems, and gave recommendations for further action.[1] This document aims to briefly summarise the results from the projects, and serve as an introduction to the Nordic energy research and innovation system.

The structure of this document is as follows; the first section provides a description and assessment of the framework conditions, the performance of the system and the diffusion of energy technology in the region. The second section takes a closer look at the transnational cooperation in the region, as well as between the Nordic region and other countries. Section three offers concluding remarks.

1 See appendix 1 for more information on the individual projects.

2 Energy Research and Innovation Systems in the Nordic Region

This chapter paints a picture of the Nordic systems for knowledge creation and diffusion in the energy sector. It is divided into two parts, a description and an assessment. The description covers the diverse Nordic energy mix, and provides an overview of the key actors and structures of Nordic energy research and innovation systems. The assessment that follows looks at both framework conditions providing input to innovation, and output as innovation performance. The energy systems in the Nordic countries are highly diverse due to geographical, topographical, political, and economical reasons – leading to different innovation systems and different approaches to solving energy issues. These differences increase the potential synergies from cooperation in areas of common interest, as demonstrated by the founding of Nordic Energy Research in 1985. Nordic cooperation extends across a wide range of energy technologies, but is limited to areas of common interest, leaving nuclear power outside the scope of official cooperation at the Nordic level.

2.1 DESCRIBING NORDIC ENERGY INNOVATION SYSTEMS

2.1.1 THE NORDIC ENERGY MIX

The energy mix in the Nordic region is a composite of both renewable sources, such as hydropower, wind and bioenergy, and non-renewable sources, including oil, natural gas, coal and nuclear energy.

The total energy consumption in the Nordic region is displayed in Table 1, where energy for transportation is also included. The share of clean energy in the energy mix is closely linked to climate change mitigation, but also to the concepts of energy security of supply and economic growth. Table 1 highlights differences in the share of energy dependency for the various countries. Increasing the share of indigenous renewable energy production in the energy mix reduces import dependency, and reduces the liability of the economy to rapid changes in the price of imported energy. Energy security of supply has been one of the main arguments behind the goal of a common European Energy Policy (European Commission 2008b).

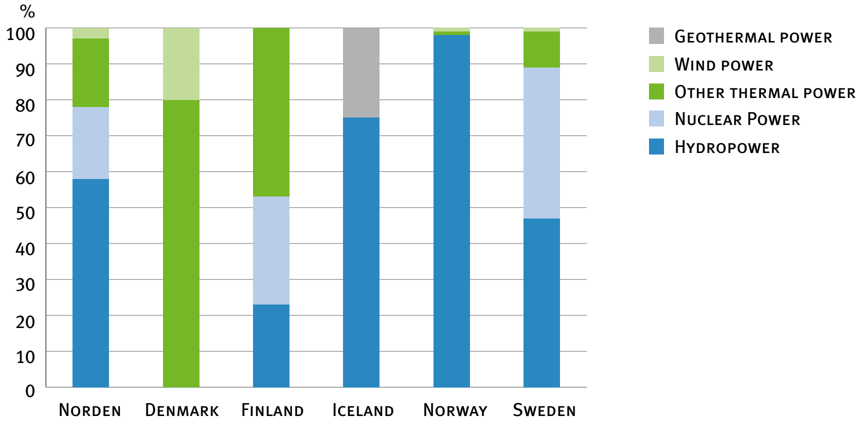
TABLE 1 TOTAL PRIMARY ENERGY SUPPLY, NORDIC REGION AND EU-15

Country	Indigenous production	Total primary energy supply							Energy dependency % in 2005
	Total energy production in 1000 toe	Total, in 1000 toe	% generated from source						
			Oil & Gas	Coal	Nuclear power	Hydro power	Wind power	Other	
Denmark	29,511	21,505	59.4	25.5	0	0	2.4	12.7	-51.6
Finland	17,787	36,785	40.4	20.2	16.1	2.7	0	20.6	54.7
Iceland	3,259	4,248	23.3	0	0	14.8	0	62	28.8
Norway	223,650	24,943	50.5	2.9	0	41.2	0.2	5.3	-609.1
Sweden	32,275	50,251	30.8	5.4	34.4	10.6	0.2	18.7	37.2
EU-15	693,947	1,537,627	63.6	14.2	15	1.5	0.5	5.2	57.7

(Nordic Council of Ministers 2008)

The electricity sector in the Nordic countries is fairly clean, with over 60 percent of electricity being generated from renewable energy sources (figure 1). Hydropower is located mainly in Norway and Sweden, and its high share in the energy mix makes the Nordic energy system vulnerable to weather changes. If the reservoirs in Norway and Sweden go dry, the Nordic system must import a significant amount of electricity, increasing prices dramatically. Most of the Combined Heat and Power (CHP) in the region is located in Denmark and Finland. Finland and Sweden both have a significant share of nuclear power in their energy mixes. Finland is currently building a new nuclear plant, with more planned. In Iceland, the main forms of electricity production are hydropower and geothermal.

FIGURE 1 NORDIC ELECTRICITY GENERATION 2008



Source: Nordel 2009

In the Nordic electricity market, the largest companies are Swedish Vattenfall, Norwegian Statkraft and Finnish Fortum. Respectively, the three companies produce 16.8 percent, 13 percent and 11.2 percent of the total electricity production in the Nordic region. All the three companies have government ownership to various degrees (Nordreg 2009).

Denmark, Finland, Norway and Sweden are joined in a common electricity market, and the Nordic region shares a range of cooperative measures in the energy area. Energy cooperation under the auspices of the Nordic Council of Ministers has existed since the early 1980s. Today, more than 60 percent of wholesale electricity in the Nordic region is traded at the Nordic electricity exchange NordPool Spot, which has had membership from all four participating countries since 2000. The Nordic region has the worlds most integrated and harmonised cross-border electricity market. All four participating Nordic countries have had more or less fully liberalised electricity markets since 2000, and since 2004 the annual meetings of the Nordic energy ministers has been the political driving force in increasing the level of harmonisation in the market.[2]

2 See the annual status memo of the Nordic Council of Ministers Electricity Market Group for updated information on the state of harmonisation and integration in the market.: http://www.norden.org/no/nordisk-ministerraad/ministerraad/nordisk-ministerraad-for-naering-energi-og-regionalpolitikk-mr-ner/institusjoner-samarbeidsorganer-grenseregioner-og-arbeidsgrupper/arbeidsgrupper/elmarkedsgruppen/rapporter-og-notater.

Much of the political and commercial efforts to meet the requirements in the EU Renewable Energy Directive (RES Directive) will come from the electricity production sector. The Nordic countries are all bound by the EU RES Directive. Based on resources and current performance, the Nordic countries are able to meet their individual obligations. However, recent studies indicate that obtaining the goals though a common Nordic approach and optimising the location of the installations in the region might be more cost efficient, and lead to a faster realisation of the targets (Ruokonen et al 2008).

2.1.2 ENERGY RESEARCH AND INNOVATION SYSTEMS IN THE NORDIC REGION

Differences in industrial competencies and resource bases have shaped different energy research and innovation systems in the Nordic countries. This complicates the concept of a common Nordic system, but also provides potential benefits through cooperation in energy policy and technology areas of common interest

Nordic efforts to create an integrated research and innovation area play on both the common and complementary strengths of the Nordic countries. Through increasing Nordic coordination, increasing the quality of research education in the region and heightening the level of researcher mobility, the NORIA aims to create a world-leading research and innovation area that can complement efforts at the European level. Through a well-functioning NORIA, joint actions with other leading research and innovation areas such as North America and the European Research Area (ERA) will grow and be strengthened (Björkstrand 2004).

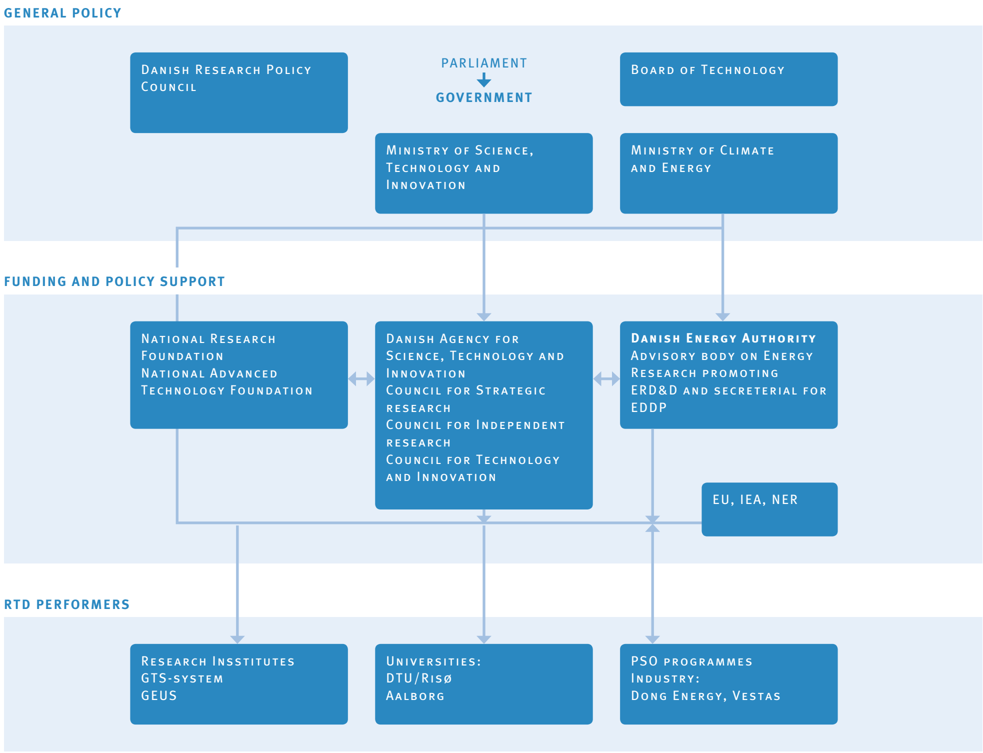
However, despite the converging forces of globalisation and efforts to increase international cooperation, energy innovation systems emerge primarily at the national level. Most of the interactions within research and innovation systems take place between companies and other actors within the borders of each individual country. One of the reasons for this is the close connection between the energy research and innovation system and the industry, knowledge networks, energy systems and policies of that country (Borup et al 2008). In all countries, the energy innovation systems are a consequence of both deliberate political choices, and historical accidents and events. The combination of a new challenge being presented and the existing resource base dealing with it often determine future energy pathways (Klitkou et al 2008a):

> **"The different paths of energy policy in the Nordic countries have resulted in the establishment of country-specific organisation of energy policy and energy R&D funding systems. Different technological domains have been prioritised and different types of support systems have been set up in terms of planning, concessions regulation and different types of subsidies."**
>
> (KLITKOU ET AL 2008a)

The national energy research and innovation systems consist of a range of different actors and institutions. These institutions play different roles in the makeup of the national systems, and provide funding and other support to researchers and companies that drive innovation and research forward. There are variations between the Nordic countries in both political and bureaucratic set up. This section looks at these national system structures.

DENMARK

FIGURE 2 KEY ACTORS AND INSTITUTIONS IN THE DANISH ENERGY POLICY SYSTEM



(Klitkou et al 2008a: 27)

The Danish policy system for energy (outlined in figure 2) is characterised by a strong link between energy policy and climate policy. The political leadership of the energy issue is placed under the Ministry of Climate and Energy.

In terms of energy research funding this is largely the prerogative of the Strategic Research Council under the Danish Research and Innovation Agency and the EUDP programme under the Danish Energy Agency. In addition, the Danish Transmission System Operator, energinet.dk, also funds energy research related to power, as does the Danish National Advanced Technology Foundation. There is a high degree of coordination in the Danish energy research funding sector (Klitkou et al 2008a: 26ff).

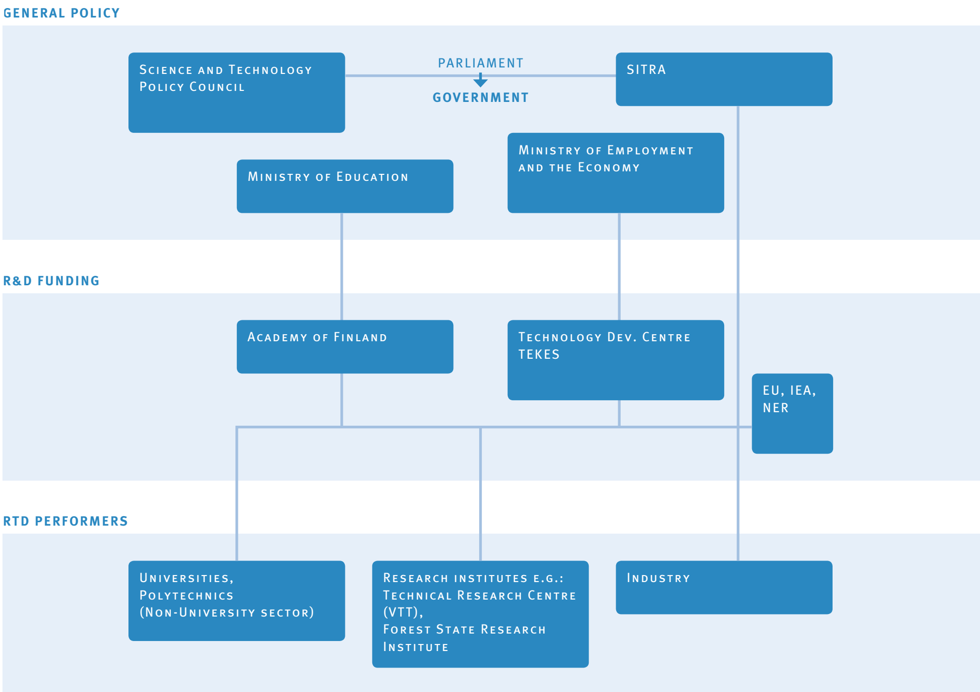
The innovation systems and levels of maturity of individual energy technologies vary considerably in Denmark. These differences in innovation systems consist of – among other things – the actor set-up, the industrial structure, the degree of interaction in the existing energy systems and existing energy companies.

Existing competencies in other sectors often shape the technology innovation systems in the energy area. For example, in Denmark wind energy and bioenergy innovation build on competencies stemming from the machinery and agricultural sector, respectively.

For energy technology areas that have seen significant growth in innovation, such as wind, policy efforts have been driving force. The Danish government launched a new energy technology legislation package in 2008, where the aim was to continue to provide long-term support to renewable energy technology development in businesses. The focus is especially on increasing the share of wind power in the energy mix. As this legislation is relatively new, it remains to be seen to what extent it will bear fruit (Klitkou et al 2008b).

FINLAND

FIGURE 3 KEY ACTORS AND INSTITUTIONS IN THE FINNISH ENERGY POLICY SYSTEM



(Klitkou et al 2008a: 57)

The political control over energy and innovation in Finland (outlined in figure 3) is placed under the "super" Ministry of Employment and the Economy.

While TEKES under the Ministry of Employment and the Economy is responsible for energy innovation and technology development, the Academy of Finland under the Ministry of Education is the key funding agency for basic research.

Today much of the energy research and innovation in Finland is organised through the so-called SHOKs. These are the Finnish Strategic Centres for Science, Technology and Innovation. The centres are organised as public-private partnerships. Finland has numerous firms active in research and innovation in the energy sector. As exemplified in the SHOKs, Finland has good experiences with public-private partnerships and cooperation with industry.

"A large business participation in the programme activities is ensured as many programmes are targeted and weighted towards business actors and designed with requirement of clear business participation. Other actor types are usually not to the same extent systematically prioritised in the programmes."

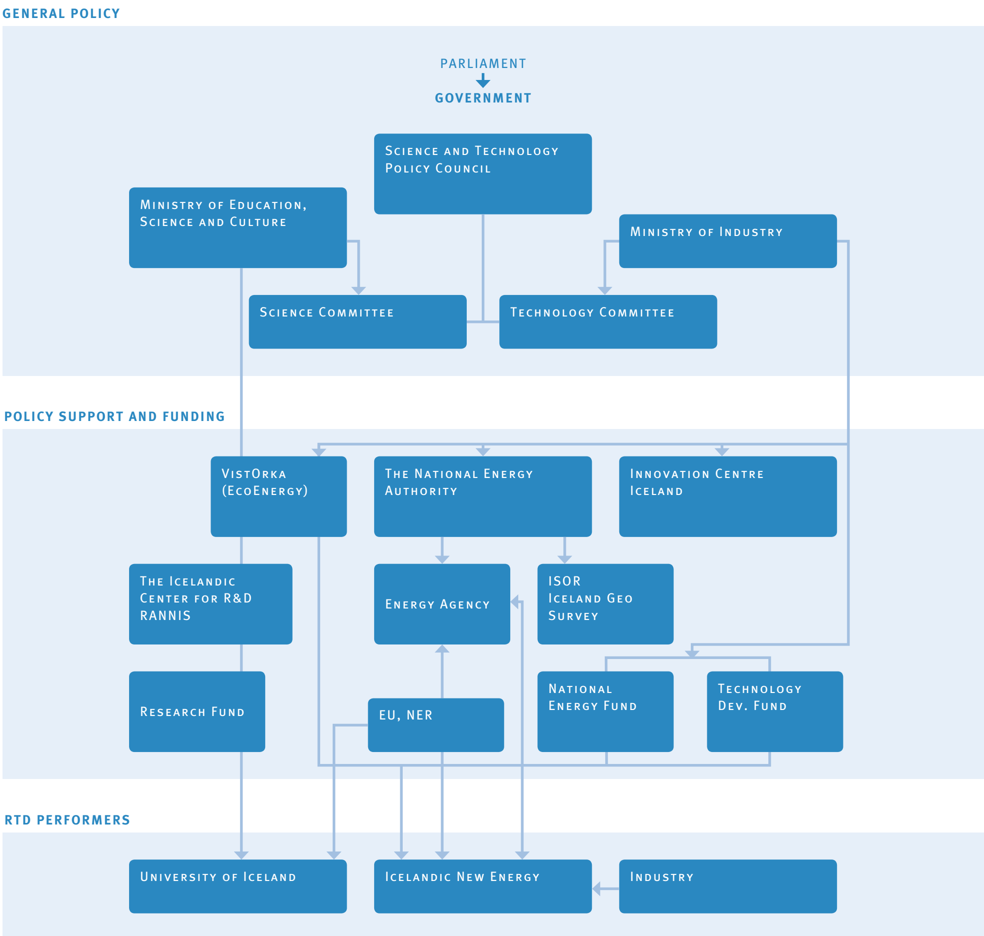
(BORUP ET AL 2008)

While the energy sector itself has not been considered a key innovation sector in Finland, the parallel environmental field has received increasing attention in the form of national policies, sustainability strategies, clean tech investment studies, and public R&D. This will most likely spill over to the energy area in the coming years (Borup et al 2008).

The Finnish Ministry of Employment and the Economy has recently proposed that wind power in Finland will have a guaranteed price, a feed-in tariff that should help foster the development of more wind power in the Finnish system. According to the proposal, this feed-in tariff should be introduced in the beginning of 2010.

ICELAND

FIGURE 4 KEY ACTORS AND INSTITUTIONS IN THE ICELANDIC ENERGY POLICY SYSTEM



(Klitkou et al 2008a: 89)

In Iceland, the political control over the energy issue (the energy policy system in Iceland is outlined in figure 4) lies with the Ministry of Industry and Commerce. Under the Ministry, the Department of Energy and Environmental Affairs is tasked with promoting better use of energy resources. The government agencies responsible for the energy area are ORKUSTOFNUN (the Icelandic National Energy Authority) and the Orkusetur (the Energy Agency). Orkusetur is mainly tasked with increasing energy efficiency in households and industry whereas ORKUSTOFNUN has been involved with energy policy and research for decades, including:

- Conducting research on energy issues, accumulating information, and maintaining a database of knowledge on energy resources.
- Collecting basic data on hydrological conditions, on the hydrological budget of Iceland's freshwater and geothermal resources, as well as data on various natural and environmental processes.
- Disseminating knowledge on the exploration and exploitation of geothermal resources to developing nations.
- Executing administrative functions on behalf of the Icelandic government, and serve as a governmental advisor on energy issues (Klitkou et al 2008 82ff).

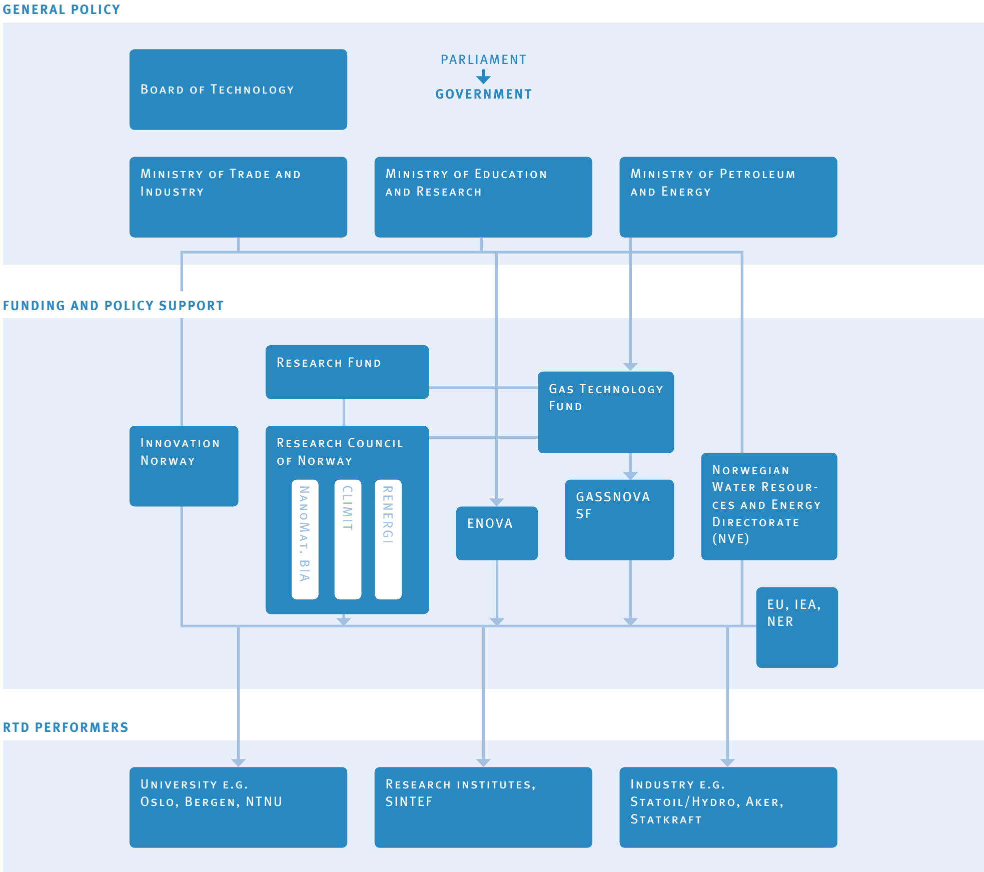
Energy R&D in Iceland is also funded through RANNIS, The Icelandic Centre for Research. RANNIS is under the auspices of the Icelandic Ministry of Education, Science and Culture.

The rich natural resources in Iceland, especially hydropower and geothermal energy, are clearly visible in the energy innovation system, which has strong international linkages to Europe and North America.

The Icelandic energy innovation system exhibits end-user-oriented learning as an important cornerstone. The number of R&D projects and the research community are of course much smaller than in the other Nordic countries, but they manage to integrate a wide range of actors. Another issue of central importance is the considerable development in education in the energy area that has occurred in recent years (Borup et al 2008; Klitkou et al 2008a).

NORWAY

FIGURE 5 KEY ACTORS AND INSTITUTIONS IN THE NORWEGIAN ENERGY POLICY SYSTEM



(Klitkou et al 2008a: 74)

The Norwegian energy sector is highly influenced, both in practice and in institutional set-up by the strong position of the petroleum industry. From the mid 1970's petroleum-related taxes and activities have been the key source of income for the Norwegian government. The political control over energy issues in Norway is with the Ministry of Petroleum and Energy, while environmental and climate issues lie with the Ministry of the Environment (outlined in figure 5).

The research and technology section in the Ministry is responsible for research and technology development in energy. Almost all public research funds are channelled through the Research Council of Norway. The energy research portfolio in the Research Council of Norway is financed by amongst others the Ministry of Petroleum and Energy, the Ministry of the Environment and the Ministry of Education and Research.

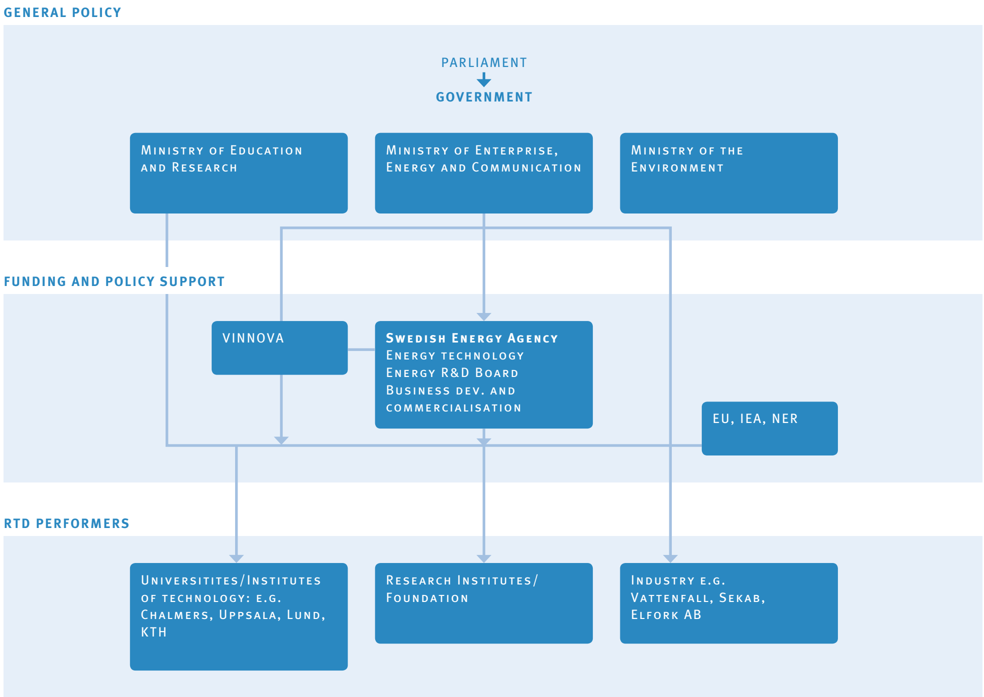
In addition to the Research Council, other government agencies such as Innovation Norway, Enova and Gassnova fund and support pre-market activities. Enova is tasked with giving investments support and devising strategies for increased implementation of renewable energy whereas Gassnova ensures the implementation of the government's interests in the area of Carbon Capture and Storage (CCS).

Much of the Norwegian R&D strategy for renewable energy is rooted in the Energi 21 strategy that was presented in 2008. The strategy was developed in cooperation between Norwegian energy companies, research actors and representatives from public institutions. The strategy has led to the formation of eight Research Centres for Environmentally Friendly Energy in Norway.

Norway has a predominantly corporate-funded innovation system, where the petroleum sector has been able to sustain long-term innovation strategies. Compared to the petroleum innovation system, the renewable energy innovation system in Norway is relatively small. Innovation in the Norwegian hydroelectric sector has been of low priority during the last decades. There has however, been positive developments in solar cell technologies in Norway in recent years, which has utilised competencies from existing metallurgy industries (Borup et al 2008).

SWEDEN

FIGURE 6 KEY ACTORS AND INSTITUTIONS IN THE SWEDISH ENERGY POLICY SYSTEM



(Klitkou et al 2008a: 41)

Energy policy on government level in Sweden is the responsibility of the Ministry of Enterprise, Energy and Communication (outlined in figure 6). Together with the Ministry of Education and Research and the Ministry of the Environment these three ministries form the political leadership for energy research funding in Sweden.

Swedish energy research is primarily organised through the Swedish Energy Agency and Vinnova. The Swedish Energy Agency has a mandate to "create conditions for an efficient and sustainable energy use and a cost-effective Swedish energy supply" (Swedish Energy Agency 2009).

"The Swedish Energy Agency is a government agency under the Ministry of Enterprise, Energy and Communications27 and is responsible for Sweden's national energy research programmes for the national energy restructuring process in Sweden"

(KLITKOU ET AL 2008a: 40FF).

The Agency is responsible for Sweden's national energy research programmes. Vinnova is the state's innovation funding agency. The main purpose of Vinnova is to:

"...fund the needs-driven research required by a competitive business and industrial sector, and to strengthen the networks that are such a necessary part of this work. Vinnova collaborates with the Swedish Energy Agency especially on transport sector specific programmes, such as vehicle research"

(KLITKOU ET AL 2008a: 40FF).

The expansion of nuclear power in Sweden in the 1980s has, combined with low energy prices, made energy innovation in Sweden slumber for a number of years. An external regulatory change – the introduction of green certificates – was influential in reinvigorating the innovation system for renewable energy technologies to make it what it is today.

Today Sweden exhibits strong innovation in biomass and biofuels. Much of the development of the innovation system around these technologies could be linked to existing industrial bases in forestry and paper and pulp.

2.2 ASSESSING NORDIC ENERGY RESEARCH AND INNOVATION SYSTEMS

This section provides an assessment of the Nordic energy innovation systems, both in terms of framework conditions providing input to the system, and the output of the system measured in innovation performance.

2.2.1 FRAMEWORK CONDITIONS

Relevant framework conditions for energy innovation include energy R&D expenditure, private investment and support mechanisms as well as stakeholder cooperation and involvement. These are elements of the framework conditions that shape energy research and innovation performance. With strong financial support, favourable regulatory and market conditions, and a high level of cooperation between stakeholders, an energy innovation system is more likely to achieve stronger innovation performance.

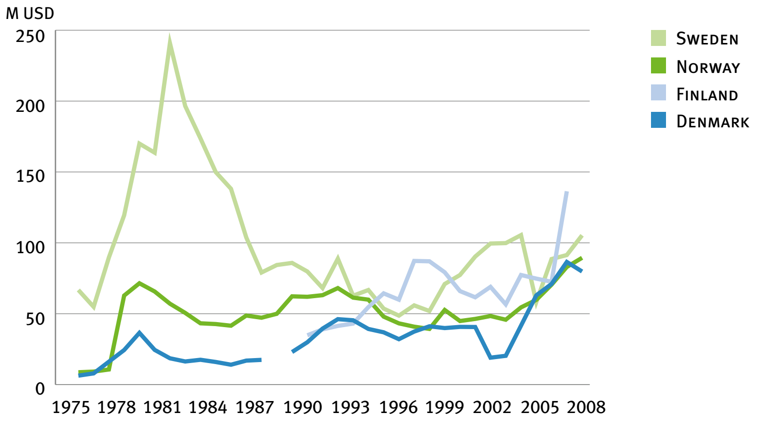
ENERGY R&D EXPENDITURE

The energy sector is unique in its low R&D intensity compared to other industries, as less is invested in R&D per unit of turnover. Energy R&D has also typically relied on public funding to a far greater extent than other industries (Stern 2006: 352). A recent report indicates that Nordic energy companies' investment in energy R&D is relatively healthy, even under the economic downturn. However, statistically there has been a problem with properly identifying R&D and innovation funding in the private sector, as most of the innovation takes place within the energy technology companies.

Public spending on energy research peaked in most OECD countries during the oil crisis in the late 1970s, and has seen a steady decline in the entire OECD area since that time. This picture is no different when the scope is limited to include just the Nordic countries (see figures 7 and 8 for a graphical presentation of the development in energy research funding). From 2006 and onwards spending has started to increase again, yet still the governments allocate less money to energy research today in absolute terms than in the late 1970s. The IEA firmly states in their energy technology perspectives 2008 that a substantial increase in energy research is crucial in order to solve the climate and energy crises (International Energy Agency 2008a). Stern (2006) seconds this view. In order avoid this dangerous temperature rise, the IEA estimates that annual average investment in the low-carbon sector between now until 2030 must increase 4-fold relative to that offered by the fiscal packages for the 2008 financial crisis (International Energy Agency 2009). The IEA also notes the urgency to increase public investments in cleaner energy technologies to come out of the present economic hardships in a better position than when the crisis began (International Energy Agency 2008b).

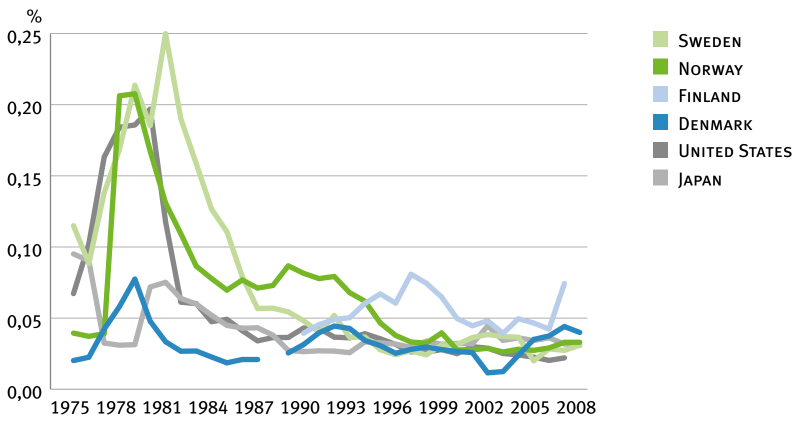
When looking at energy RD&D as a share of GDP, Sweden exhibited a strong lead in the 1980s with research into bioenergy, and to a slightly lesser extent solar and wind. However by the 1990s Sweden's RD&D to GDP ratio had dropped significantly to be surpassed by Denmark, that continued to show the highest ratio throughout the 1990s with a focus mainly on wind, but also bioenergy, and to a lesser extent solar. After 2000 the picture is less clear, with ratios for Sweden, Denmark and Finland fluctuating considerably. While Finland's ratio of renewable energy RD&D to GDP exhibited a pronounced rise since 1990, the Norwegian figure has gone in the opposite direction.

FIGURE 7 NON-NUCLEAR PUBLIC ENERGY RD&D SPENDING, MILLION USD



Source: IEA, OECD
Note: RD&D Budget in USD 2008 prices and PPP

FIGURE 8 NON-NUCLEAR PUBLIC ENERGY RD&D SPENDING AS SHARE OF GDP



Source: IEA, OECD
Note: RD&D Budget in USD 2008 prices and PPP, GDP in USD 2009 prices and PPP

PRIVATE INVESTMENT AND MARKET-BASED INSTRUMENTS

Private investment in energy R&D is tied to a perception of future markets of technologies. Market-based instruments can make markets more attractive and stimulate private investment in energy assets and R&D, building competencies and bringing technologies to market. Market-based policy instruments are regulatory moves that encourage certain behaviour in firms or people through market signals, instead of using explicit directives. Examples of market-based policy instruments are green certificates, “cap and trade” schemes, and taxes of certain products or behaviours (Stavins 2006).

In Norway and Finland today the instrument of choice is investment support, although Finland is considering implementing a feed-in tariff. In Denmark there is a feed-in tariff in place, and in Sweden the government has implemented a green certificate system.

Although venture capital in the energy sector is not currently a significant source of funding, Norway comes out as the top Nordic country in this regard, with an internationally respectable level of venture capital in its energy sector. While venture capital is in fact increasing in the Nordic countries, Danish and Swedish energy companies have difficulty in attracting such funding due in part to the traditionally weak venture capital markets in those countries (Klitkou et al 2008b: 154).

STAKEHOLDER COOPERATION AND INVOLVEMENT

As energy systems modernise, liberalise and diversify, an increasing number of stakeholders become involved. Previously, change in the energy sector was the business of governments, now public authorities, industry, entrepreneurs, investors, universities, research institutions; NGOs, branch organisations and citizens groups all play important roles (Borup et al 2008).

The Nordic region exhibits a high level of stakeholder cooperation, with a variety of actors involved in the innovation system (Borup et al 2008). One stakeholder of crucial importance in energy technology is industry, whose involvement in applied research is critical in bridging the laboratory and market. The Nordic countries have well developed competencies in use-driven innovation, where industry collaboration plays an important role in providing the market pull to commercialise technologies (Borup et al 2008: 72). In addition, many of the largest companies in Nordic countries are energy-related, and energy technology in the region is estimated to have revenues of EUR 26 billion, 6.2% of total industry revenues (Trong 2008). Industry involvement in Nordic countries occurs through public R&D programmes, and in informal cooperation through networks and public debates and hearings (Borup et al 2008).

Innovation builds on pre-existing competence bases, which include key ingredients such as knowledge, infrastructure, and a network of stakeholders. Where new energy technologies have built on such pre-existing competence bases, they have been able to make use of pre-existing networks of stakeholders.

2.2.2 ENERGY RESEARCH AND INNOVATION PERFORMANCE

As different Nordic countries show differences in their framework conditions for energy innovation, they similarly exhibit differences in innovation performance – through strengths in different technologies. Furthermore, the Nordic countries position themselves on different levels of development within the same technology. For instance in solar power technology, Norway is dominant on first generation silicon based photovoltaic power, yet Denmark is more prominent in the publishing and patenting within second generation solar power systems.

The performance of an innovation system can be assessed through academic productivity, measuring bibliometric factors such as publications and citations. As a measurement of innovation patents are included as well as by assessing productivity in the market, measured in technology production and diffusion.

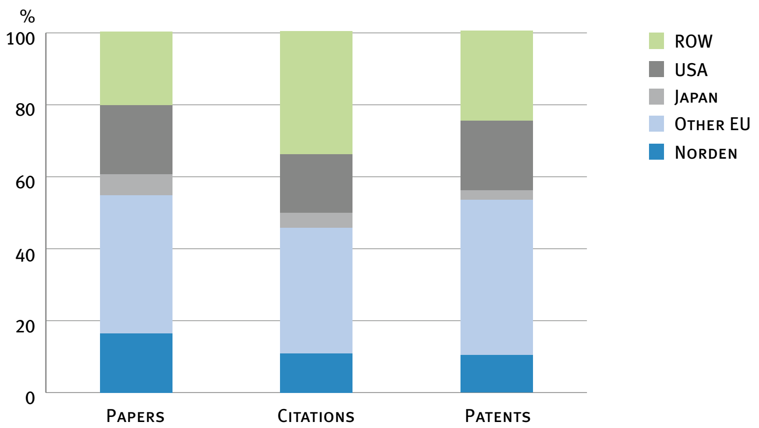
PUBLICATIONS, CITATIONS AND PATENTS

Bibliometric data refer to publications, citations of those publications, and patents filed. Considering its size, the Nordic region is relatively strong in its contribution to the scientific knowledge base for energy technology.

Wind

The Nordic countries together contribute an impressive 16% of the global scientific publications within wind energy as shown in figure 9 (Borup et al 2008: 107). While Sweden was the largest producer of scientific publications within wind energy until around the year 2000, Denmark has since led the Nordic countries in this field with even stronger growth in bibliometric output. The gap between Sweden and Norway is more pronounced, with Finland and Iceland exhibiting lower numbers of publications (Klitkou et al 2008b:121). Denmark is by far the most prolific in filing wind-based patents in Europe (Klitkou et al 2008a: 106).

FIGURE 9 WIND POWER BIBLIOMETRIC MEASUREMENTS

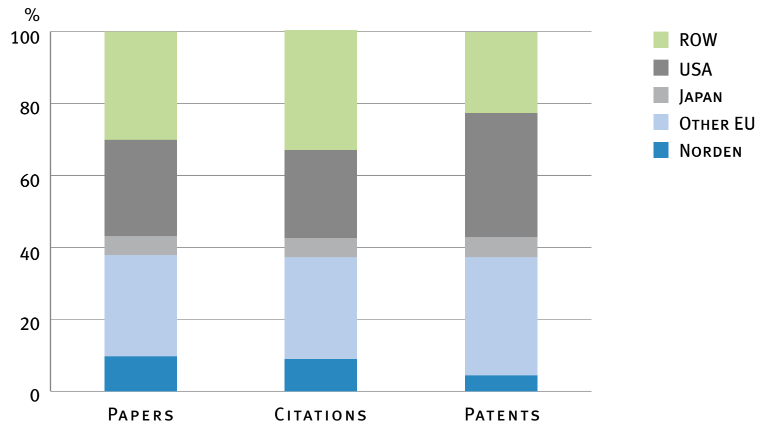


Source: Borup et al 2008: 107
Notes: Data from 1996-2006

Bioenergy

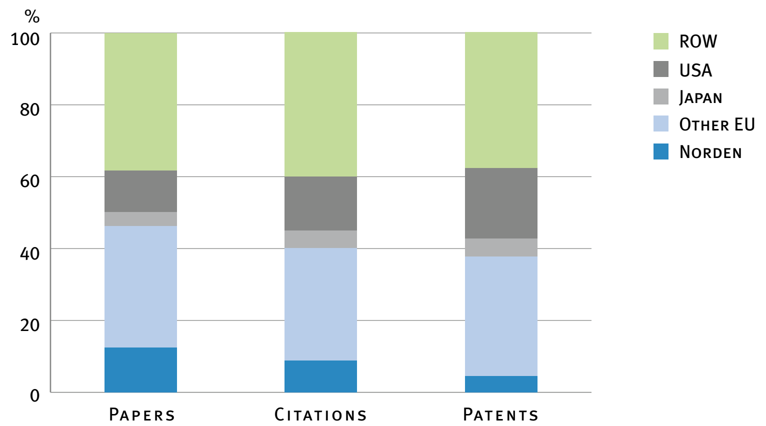
The Nordic region produces around 10% of the total global scientific knowledge on bioenergy, including both biofuels and bioenergy for Combined Heat and Power (CHP). A bibliometric study performed by Klitkou et al (2008:114) revealed that in second generation biofuels Sweden and Denmark were the Nordic countries that were the most active in publishing scientific studies. Finland has dropped in total publications over recent years, but maintains third place, with Norway in fourth. The Nordic performance on a range of measurements is portrayed in figure 10 and 11. The ENERGIA project cites the Danish food industry as a source of competencies for the bioenergy field, as a reason for the apparent Danish leadership in this technology area. Denmark, Sweden and Finland are all highly active in filing patents for second generation biofuels, which is not the case for Norway (Klitkou et al 2008b:106).

FIGURE 10 BIOFUELS BIBLIOMETRIC MEASUREMENTS



Source: Borup et al 2008: 114
Notes: Data from 1996-2006

FIGURE 11 BIOENERGY FOR COMBINED HEAT AND POWER BIBLIOMETRIC MEASUREMENTS



Source: Borup et al 2008: 119
Notes: Data from 1996-2006

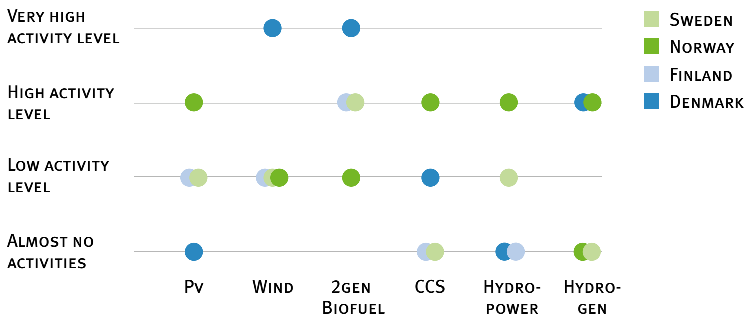
Solar

In the Photovoltaic (PV) field, the Nordic region contributes around 2.5% of global publications, far less than is evident in bioenergy and wind energy (Borup et al 2008: 110). Sweden holds a substantial lead in this area, followed by Finland, Denmark and Norway (Klitkou et al 2008b: 117). However, when patents are analysed, Norway is the most prominent of the Nordic countries (Klitkou et al b: 106), although Nordic patents only account for around 1% of the global total in PV (Borup et al 2008). Denmark is more prominent within the second generation solar power.

Other

For Hydropower, Sweden has overtaken Norway as the leading producer of publications, while the opposite has occurred with CCS, where Norway has shot past Sweden in recent years. For hydrogen, Sweden is the most prolific of the Nordic countries. Norway is the most active in filing patents in all three technologies, while the other Nordic countries are relatively inactive (Klitkou et al 2008b: 106)

FIGURE 12 COMPARATIVE RATING OF EUROPEAN PATENT APPLICATIONS



Source: Klitkou et al 2008b: 106

The figure above (figure 12) provides an overview of comparative strengths in six different clean energy technologies. A rating has been given to each country based on the distribution of their total EPO patent applications to date between the six technologies. Denmark for example, is rated as having very high activity within wind, due to a relatively large percentage of Danish EPO patent applications being within wind energy.

TECHNOLOGY DEPLOYMENT AND DIFFUSION

This section covers the technology produced in each country, and the installed capacity of energy technologies. The Nordic countries are key exporters of energy technologies, and all exhibit a substantially higher share of renewable energy capacity than the EU average.

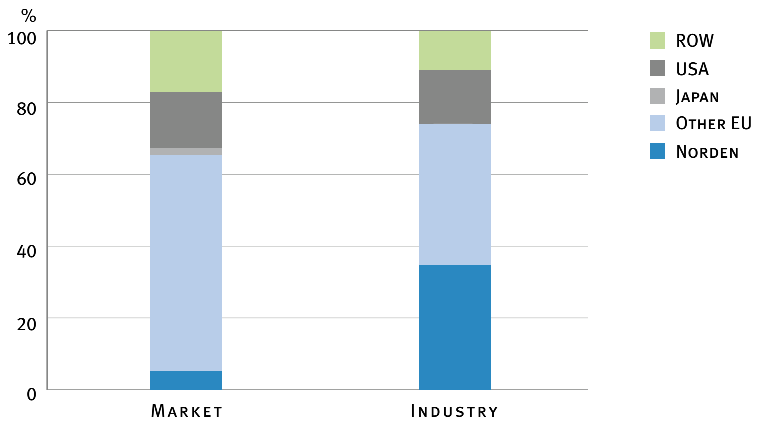
Energy technology exports from the four largest Nordic countries in 2006 amounted to 140 billion DKK in 2006. Sweden and Denmark had the largest share of this with exports between 45 and 50 billion DKK. In total, the energy technology exports from the Nordic countries amounted to 5 percent of total exports in 2006. Given the substantial increase in focus on energy and climate issues since 2006, there is reason to believe that these numbers are even higher today than in 2006 (Trong 2007).

Norway and Iceland lead the Nordic countries due to their extensive use of hydropower and geothermal energy. Sweden and Finland have maintained relatively high shares of renewable energy, while Denmark – without installing the hydropower, geothermal or nuclear energy of other Nordic countries – has increased its share of renewable energy generation from 5.8 to 28.2% (Klitkou et al 2008b).

Wind

Of the world market for wind turbines, the Nordic share is a massive 30% (figure 13). This is due to the thriving turbine industry in Denmark, and most notably Vestas. Recent developments in Norway indicate the engagement of the North Sea petroleum cluster in offshore wind development. In addition to being the leading exporter of wind technology, the Nordic region has significant installed capacity, with over 5% of global installations in 2008 (Klitkou et al 2008b). In Denmark, wind energy appeared as alternative to the mainstream systems but is now fully accepted and integrated. Today, with over 3000 MW installed, wind power produces 17% of the Danish total demand. Sweden, Norway, Finland and Iceland all have wind power ratios at one percent or lower.

FIGURE 13 WIND POWER DIFFUSION MEASUREMENTS



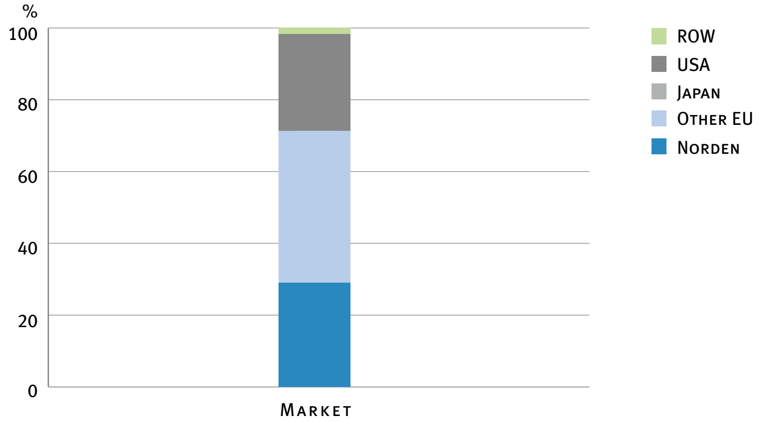
Source: Borup et al 2008: 107

Notes: Market defined as accumulated installed capacity in GW by the end of 2006. Industry defined as MW supplied in 2006 by the 10 leading manufacturers (96% of global market), home country of manufacturer used as the indicator.

Bioenergy

The region is also home to leading international suppliers of bioenergy technology and equipment, and accounts for nearly 30% of the world's biomass-based CHP generation, as seen in figure 14. In Denmark, bioenergy is a relatively mature technology with significant industrial activity, and is closely related to the existing energy companies and mainstream energy systems. This is also the case in Finland and Sweden, where bioenergy plays an important role. In Finland bioenergy accounts for 20 percent of the primary energy consumption, making Finland the Nordic country that uses the most bioenergy. Finland has also seen growth in its export of bioenergy technologies. For biofuels, Sweden had made significant ground in terms of consumption, while other Nordic countries have yet to see notable diffusion in this area (Klitkou et al 2008b; Borup et al 2008).

FIGURE 14 BIOENERGY FOR COMBINED HEAT AND POWER DIFFUSION



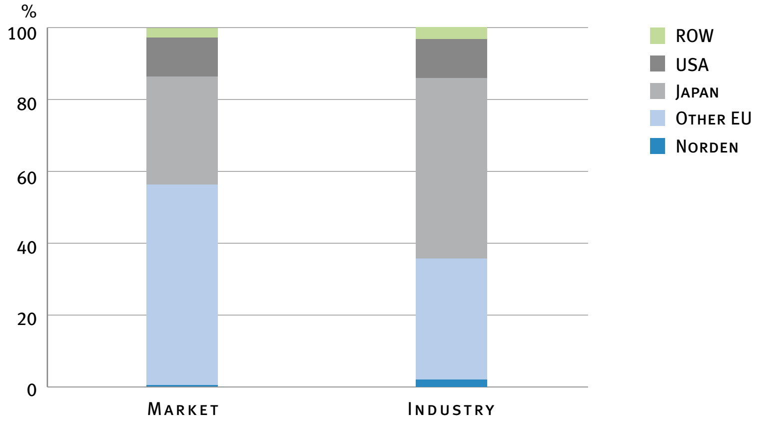
Source: Borup et al 2008: 119

Notes: Market defined as the production of electricity and heat based on biomass (Wood, Wood-waste, Municipal waste, Biogas) in TJ during 2006. Only includes OECD member countries.

Photovoltaic Solar

The most common technology for harvesting solar energy is the wafer based solar cell. According to the Environmental and Energy Study Institute, the global markets for wafer based solar cell technology is said to increase annually by 25 percent (Klitkou et al 2008b: 20). As figure 15 illustrates, Nordic solar cell companies represent 2% of the world market (Borup et al.: 2008:110). The Norwegian company Renewable Energy Corporation (REC) is one of the large actors in this field, which is primarily export-driven in the Nordic region where there is very low installed capacity. The key to the success of REC is the intelligent use of engineering knowledge from the metallurgy industry in Norway, this knowledge allowed REC to make silicon based wafer production much more efficient. In the solar energy sector, a number of actors are trying to replace the wafer technology; witch has both economic and environmental constraints with a newer more cost efficient technology. A number of actors in Denmark are experimenting with a paint based solution.

FIGURE 15 PHOTOVOLTAIC SOLAR DIFFUSION



Source: Borup et al 2008: 110

Notes: Market defined as accumulated installed capacity measured in MWp by the end of 2006. Industry defined as PV cell production in MW during 2006 by country.

Summing up, this section has provided an overview of the status of energy innovation systems in the five Nordic countries, detailing both framework conditions for innovation as well as innovation performance. The resource bases, existing industrial competencies, energy policies, research funding, stakeholder involvement and other factors that vary between the Nordic countries have forged different framework conditions. These differences have consequently led to differences in energy innovation performance - the output of the innovation system.

Countries who wish to increase the effectiveness of their own innovation system, and hence make their economy more innovative should increase international research cooperation. Increasing the innovativeness of economies is a clearly stated goal of both the Nordic region and EU. The countries should import more R&D as well as building on it through national efforts (Johansson 2007). Increased internationalisation in research can lead to the performance of participating economies improving, moving them closer to acquiring the technologies and solutions needed to meet future challenges in climate and energy issues.

Nordic exports of renewable energy technology are increasing. Much of the increase is in exports to the emerging economies of China, Brazil and Russia, while the US remains the largest single market. In 2006 the total energy technology export to the US from the Nordic countries was worth 1.8 billion (Trong 2008).

3 Transnational Cooperation

International cooperation in energy RD&D is crucial. The Nordic countries have been in the very forefront in this regard – especially through the work of the Nordic Council of Ministers and Nordic Energy Research. Much of the international cooperation in energy research today is linked to either the European Union or the International Energy Agency. International energy research cooperation can unlock great potential in innovation, reduce redundancies and duplication, and add significant value to national efforts.

Finding a viable solution to the threat of climate change and increasing energy security of supply are ambitious goals. The development of new, paradigm-changing energy technologies will be instrumental in achieving these goals. Getting there require leveraging international resources and expertise both for development, deployment and diffusion. In order to advance the Nordic, European and global energy RD&D efforts, emphasis should be put on finding forms of international multilateral collaboration beyond the cooperation and information sharing mechanisms in use today. This must of course play out on the premise of increased RD&D budgets in general (IEA Expert Group 2008).

3.1 NORDIC COOPERATION

Nordic Energy Research orchestrates transnational energy research cooperation among the five Nordic countries – Denmark, Finland, Iceland, Norway and Sweden. Nordic Energy Research cooperation started in 1985 to add value to the relatively small and fragmented national energy research communities within energy technology areas of common interest. Activities are organised in four-year strategic programmes for five priority areas: Renewable energy, energy efficiency, hydrogen economy, liberalised energy markets and the impact of climate change on the energy system. National energy research entities such as Danish Energy Authority, Finnish TEKES, The Icelandic energy Authority, the Swedish Energy Authority and the Norwegian Ministry of Petroleum and Energy allocate approximately 5 million EUR annually to common Nordic research projects.

In 2008 the Nordic Prime Ministers met in Riksgränsen in Sweden, where they reaffirmed their commitment to finding common Nordic solutions to the challenges facing the region. Their declaration read that:

> **"Globalisation and climate change present the Nordic countries with issues that challenge our societies in fundamental ways. These include increasingly fierce international competition, and require that we look at our way of life in order to shape a sustainable future that does not imperil our environment. Irrespective of the challenges we face, progress will only be made if we act together at Nordic and international level."**
>
> NORDIC COUNCIL OF MINISTERS 2008

The Nordic countries all have ambitious emission reduction targets and need to fulfil the EU Directive on Electricity Production from Renewable Energy Sources (RES Directive) targets for renewable energy. As we have seen, finding the solution to the energy puzzle requires a complex mix of instruments. Prominent among these instruments is a long-term ambitious energy R&D policy. Building on the successes of a long-standing cooperation in energy R&D, the Nordic countries can achieve far more together than alone. Coordinating research priorities and pooling funding across borders and professional disciplines can unlock great potential. One such example is the recently launched Nordic Top-Level Research Initiative on energy, climate and the environment. It is the largest ever Nordic research programme, with 400 Million DKK over five years. The Initiative is administered in collaboration between Nordic Energy Research, Nordic Innovation Centre and Nordforsk. Emphasis is placed on six sub themes: Adaptation to climate change, climate change's interaction with the cryosphere, integration of large-scale wind power, sustainable biofuels, nanotechnology and energy efficiency, and carbon capture and storage.

3.2 COOPERATION WITH ADJACENT AREAS

3.2.1 COOPERATION WITH THE BALTIC COUNTRIES

Nordic Energy Research aims to maximise the results of energy-related research and development in the Nordic region and its adjacent areas. Since the year 2000, funds have been earmarked to strengthen cooperation with researchers from Northwest Russia and the Baltic countries – Estonia, Latvia and Lithuania. The current project portfolio includes a number of projects with Baltic and Russian partners and PhD students.

Nordic cooperation with the Baltic countries stretches back beyond their independence in 1991. Nordic parliamentarians have expressed a clear will to assist the Baltic countries in their development since the mid 1980s. As they gained autonomy, cooperation across the Baltic Sea took on a new pace, with the Nordic Council of Ministers setting up offices in the three capital cities and Baltic Ministers of Parliament being invited to attend various Nordic sessions. Cooperation has entered a new phase with the three Baltic countries achieving accession to the EU in May 2004.

Another positive step in the further development of this cooperation is the implementation of the Baltic Sea Strategy during the Swedish presidency of the EU in 2009. The aim of this strategy is to strengthen and further regional cooperation around the Baltic Sea, as well as fostering economic development.

3.2.2 EUROPEAN RESEARCH AREA (ERA)

The EU's main instrument for international research cooperation is the 7th Framework Programme of the Strategic European Framework Programme of International Science & Technology Cooperation. Both member countries (27) and associated countries (11) take part in this programme. One of the central themes in the 7th Framework Programme is energy, with a budget of 2.35 billion Euro.

As the majority of European research activities take place at the national level, and only a minor fraction at the EU level, there are a number of open coordination mechanisms aiming at avoiding overlap and creating synergies across national borders. One such mechanism is the European Research Area Networks (ERA-NETs). The aim of the ERA-NETs is to provide bottom-up contributions to the creation of an internal market for knowledge in Europe.

Nordic Energy Research ERA activities

Nordic Energy Research participates in EU projects under the ERA-NET umbrella. Currently Nordic Energy Research coordinates the North European Innovative Energy Research Programme (N-INNER), which has developed through the INNER ERA-NET, consisting of national energy research funding agencies from several countries.

Nordic Energy Research is also actively engaged in the Smart Grid ERA-NET. The Smart Grid ERA-NET aims at developing research activities to speed up the development of a Smart European Electrical Infrastructure, which is necessary for a successful realisation of the European Action Plan "Energy Policy for Europe". Grid-related challenges in the future are especially related to large-scale supplies of renewable electricity, strong consumer response and high levels of distributed generation.

For more information on Nordic Energy Research activities in the ERA, please see: www.nordicenergy.net/era

The ERA-NETs for Energy focus on research and cooperation between energy research financiers. While the development of a common EU energy policy may yet be in the future, the development of the Strategic Energy Technology Plan (SET-Plan) could be a step in that direction. The EU SET-Plan aims at accelerating the development and deployment of cost-effective low-carbon technologies. In the plan the European Commission covers policy measures to improve the EU's performance on planning, implementation and cooperation in energy technology. For the Nordic countries this represents an opportunity to coordinate efforts with the EU, and share Nordic expertise in the area. Planning, implementation, resources and international cooperation are included in the plan.

"...the SET plan makes provision for intensified international cooperation, in order to promote the development, marketing, deployment and accessibility of low carbon technologies worldwide"

(KÖNNÖLA ET AL 2009:45).

The SET-Plan is, according to Könnöla (et al 2009) mostly a coordinating and integrating tool for the European Commission. The aim is to contribute to the internal and external integration and coordination of the European Energy Policy.

"...the plan proposes to increase research targeted to reduce costs and improve performance of existing technologies, as well as encouraging the commercial implementation of these technologies. The efforts should in particular involve second-generation biofuels, capture, transport and storage of carbon, integration of renewable energy sources into the electricity network and energy efficiency in construction, transport and industry"

(KÖNNÖLA ET AL 2009:45).

Analyses of various transition management frameworks find that the system transition platform applied by the Commission in forming the SET-Plan yields an opportunity for the Nordic countries to introduce and apply a renewed transition management platform in the region (Eerola and Loikanen 2009).

> **"Nordic participation in the European and international prospective work is of importance, and GoReNEST study encourages Nordic actors to proactively participate in the global and regional energy systems transition processes. Nordic actors´ proactive role in the global energy transition means that (1) sustainable energy technologies are actively searched for and adopted in the Nordic countries, (2) Nordic actors actively participate in developing new energy technologies and services that support sustainable developments, (3) Nordic countries take an active role in facilitating sustainable developments also globally (including the emerging economies and developing countries), and (4) Nordic actors actively utilise new business opportunities related to the global energy transition"**
>
> (EEROLA AND LOIKKANEN 2009).

With the 7th Framework Programme, the ERA-NETs and the SET-Plan, the development of a market for research in the EU will be important in the internationalisation of Nordic research in energy, and will most certainly add value to Nordic cooperation in research. This also includes opening up cooperation to third countries, especially emerging economies. The following is a discussion on how to increase the energy research and innovation cooperation with China and Russia.

3.3 EMERGING ECONOMIES

3.3.1 RUSSIA

The Nordic region has had earmarked funds for research cooperation with the north-western part of Russia since the year 2000. Notably, Russia is a part of the Baltic Sea region as well. The cooperation with Russia in energy research has however remained small. The focus of this section is to discuss the possibility of establishing energy research cooperation or collaboration with Russian partners on a larger scale than the current projects in Northwest Russia.

While the issue of climate change may be high on the political agenda in the Nordic region, this is not the case in Russia. Prominent scientists and politicians in Russia are openly sceptical of the idea of anthropogenic climate change. This creates an additional barrier to the development and implementation of renewable energy technology (Øverland 2008).

The low focus on climate change does not mean that Russia is uninterested in energy issues and the development of renewable energy. Security and economic growth remain important energy political drivers. Russia is a huge exporter of natural gas to Europe, and uses a lot of gas for domestic purposes. If Russia can increase the share of electricity and renewable energy in the domestic market, more of the produced gas can be sold to international customers that pay much more for their gas than domestic ones. Russian politicians have pledged to reduce subsidies for domestic gas, but the resulting price increase for gas is coming at a much slower rate than agreed. The low focus on climate issues in Russia increases the importance of the Kyoto flexible mechanisms (Øverland 2008).

"Despite the country's natural abundance in petroleum resources and nuclear energy, there are several reasons why renewable energy is relevant for cooperation with Russia. First of all, it is clear that Russia can benefit economically from prioritising renewable energy sources, since this will boost its opportunities for energy exports by decreasing the domestic use of fossil fuels. Secondly, Russia can attract significant investment by using mechanisms in the global climate regime that require increased production of renewable energy. Thirdly, fossil fuels are exhaustible resources, whereas renewable energy sources are not. This means that developing renewable energy sources will be necessary sooner or later."

(ØVERLAND 2008)

Russia has one of the world's least energy efficient economies. The energy efficiency potential in industry alone is huge; the same can be said for both the energy sector and the housing sector. The Russian electricity sector is under reform, and moving towards a liberalised or at least deregulated electricity sector. Old state monopolies are being split up and sold. Increasing the efficiency of the energy sector is high on the political agenda, as is increasing energy efficiency in general. According to Øverland (2008) the same can not be said for renewable energy sources.

Reforming the electricity sector in Russia is expected to help the increase of renewable energy to some extent. For now the renewable energy potential in Russia appears overshadowed by petroleum development. As a part of Russia's adoption of World Trade Organisation (WTO) rules, subsidies on gas for domestic consumption should be phased out by 2011 – this could help level the playing field for producers of renewable energy. The phase out however, is going much slower than scheduled, so slow in fact that observers are having doubts as to whether they will meet their target.

Despite the lack of political support for harvesting renewable sources, Russia has access to a large amount of indigenous renewable energy.

In Russia science and technology are strong professional disciplines with long histories, and cooperation would benefit both Nordic and Russian partners The NUPI study outlined a number of possible steps for increased Nordic-Russian Cooperation in energy research. The top recommendations were:

- Coordinate and pool funding among Nordic institutions supporting cooperation with Russia.
- Both top–down and bottom–up calls can work, depending on the content of the calls.
- Seek joint financing by Russian research funding institutions if possible.
- Work with the best Russian institutes and build a brand.
- Seek out complementarities between Nordic and Russian actors.
- Focus on basic science in Russia.

However, the Russian economy has been hit very hard by the financial crisis, so the chances of finding substantial co-financing from Russian partners may have become slimmer. Despite this, there is good potential for increased cooperation with Russia in research on renewable energy, especially in territories other than the North Western area which has been the focus of Nordic cooperation until now.

3.3.2 CHINA

During the last three decades, China has seen phenomenal economic growth, with annual growth rates almost into double figures. This has led to a rise in primary energy demand, so that China is now the second largest energy consumer accounting for 17% of world primary energy consumption (IEA 2007).

China's annual increase in primary energy demand over this period of economic expansion has not been nearly as rapid as GDP growth, indicating a successful decoupling of economic growth and energy consumption. In 2003 and 2004 however, due to China's WTO entry and booming housing and transportation demand, heavy industry expansion led to a reversal of this trend in energy growth, forcing the Chinese authorities into taking a closer look at the domestic energy situation (Delman and Yong 2008).

Aiming to meet the increasing demand for energy the government increased the production of power from coal. In the six years from 2000 to 2006 the share of coal power in the Chinese energy mix increased from 72 percent to 76 percent. Both local and global environmental consequences of this increase in coal burning are substantial (Delman and Yong 2008).

In an attempt to limit environmental damage while continuing to meet growing demand, recent years have seen a greater emphasis on renewable energy. The government hopes to increase renewable sources to 10% by 2010 and 15% by 2020. Much of this will be traditional forms of renewable energy such as large-scale hydropower, but increases in newer forms, such as PV solar, wind, and biomass, are also prioritised (Delman and Yong 2008). Recent Chinese energy policies reflect these goals in a number of common priorities:

- Increased energy efficiency is the top priority.
- Increased energy demand should in principle be covered by national energy resources.
- The energy system should be exceedingly multi-pronged and diversified with a strong focus on the development of renewable energies.
- Environmental management should be strengthened both during production and use of energy.
- Mutually beneficial international collaboration within the energy sector should be sought.

China does not yet have the off-the-shelf solutions required to increase capacity in newer forms of renewable energy generation, and there is a strong political will in China to foster indigenous competencies in these areas. International cooperation is therefore crucial in both infrastructural and technological capacity-building, presenting a significant opportunity for energy technology providers and energy researchers in the Nordic region.

The following benefits from Nordic-Chinese energy R&D cooperation have been identified (Delman and Young: 2):

1. The world's future climate and energy security will rest on safer ground and the regional and local environmental quality will be improved by co-developing new generations of low-carbon energy technologies suitable for the Chinese contexts.

2. Given the relatively low salaries of high-quality researchers in China, the overall R&D budget could be reduced compared to the costs in the West. This has been a key driver in much cross university collaboration as well as in outsourcing of R&D centres to China in recent years.

3. There may be a swifter move from R&D to commercialisation in China's huge and promising market. The potential commercial returns are high as the Chinese energy sector is already large and growing rapidly; the huge markets with rapidly increasing demand and energy systems have to be upgraded and modernised and this will facilitate the commercialisation of more advanced energy technologies and be helpful in reaching the desirable scale of economy while reducing production costs.

4. New business opportunities are emerging for international actors to partner up with Chinese counterparts to expand into promising new or existing worldwide markets for new energy technologies.

There are substantial challenges in achieving a fruitful cooperation with China and Chinese actors. One of the biggest may be that of scale and coordination. There are a huge number of actors wanting to cooperate with and do business in China. Even within the Nordic countries there are competing national efforts. Another challenge is that of scale: China thinks big, Nordic countries think small and lack influence and weight compared to larger actors. Furthermore, there are notable issues with Intellectual Property Rights (IPR). IPR is not well enforced in China and actors looking to transfer core technologies must be well aware of these issues. Dealing with these challenges may benefit from cooperation through a common Nordic platform in addition to national efforts. Despite these challenges, China offers a considerable opportunity to the Nordic energy sector, which cannot be ignored.

To sum up, international research and development cooperation in energy is crucial in order to find the right solutions to the challenges facing us. There are many opportunities for in the Nordic countries for international cooperation and collaboration in energy research and innovation. This chapter has highlighted a number of these possibilities. The lessons from the discussion about European cooperation, as well as increasing cooperation with the emerging economies of China and Russia, is that more coordination of energy research and innovation policy is required.

4 Concluding Remarks

The main drivers behind recent developments in international energy policy and energy systems have been the threat of global climate change, the desire to ensure energy security of supply and ensuring continued and strengthened economic growth.

In 2007 the Nordic Prime Ministers met in Punkaharju, Finland. The declaration from their meeting emphasised the common challenges facing the region through globalisation. International politics are becoming more intertwined, international market competition, climate change and security issues affect all Nordic countries. The Prime Ministers decided that the Nordic region should aim to tackle these challenges together – building on the common strengths of the region.

The General Secretary of the Nordic Council of Ministers summed up the mood after the Prime Ministers meeting:

> **"Ambitious and relevant Nordic interventions are needed if we are to raise our profile as a strong region. The individual Nordic countries are capable of publicising their own accomplishments, but in certain areas of policy it is important that we work together and consciously pursue a strategy of Nordic synergy."**
>
> NORDIC COUNCIL OF MINSITERS 2009

When developing research and innovation policies and instruments for the Nordic region, variations in national innovation systems must be taken into consideration. Each of the Nordic countries has a distinctive set of framework conditions for energy research and innovation, and various combinations and structures of actors are involved in development and innovation processes in the different countries. Variations are also evident in technological strengths and weaknesses, which are typically rooted in existing industrial bases and natural resources. While this has led to the establishment of strong research and innovation environments in some areas, reliance on existing competencies may not be conducive to innovation in completely new fields and can lead to a technological lock-in.

Resulting in a series of ambitious and targeted Nordic projects, the Punkaharju declaration set the tone for a renewed spirit of Nordic cooperation to meet our common challenges. Sustainable development, reducing energy import dependency and creating a stable framework for future economic growth, involves finding joint solutions to Nordic energy challenges, creating better framework conditions for renewable energy production and continuing to strengthen the Nordic electricity market.

Policy makers need greater awareness and understanding of the differences in innovation systems and technological competencies when developing policies and R&D programmes. Greater awareness could lead to greater coordination of policies in the region, and could unlock significant benefits by bringing together the diverse energy innovation competences and exploring new areas of research not built directly on existing bases. Instruments or incentives must therefore stimulate coordination, collaboration and the creation of alternative spaces in which new technologies can thrive and develop. These instruments need to be integrated across national borders, and leverage the different

Nordic industrial- and natural resource bases facilitate the development of novel solutions and concepts. In addition, policies can potentially better harness the synergies presented through greater cooperation between private and public sector actors.

The Nordic region cannot escape the challenges related to global climate change, increasing international competition and concerns over energy security of supply. Furthering Nordic cooperation in energy research and innovation will in turn allow greater benefits from Nordic cooperation with other countries and regions. Nordic measures to promote international cooperation in this crucial area are an important step towards solving the challenges the region shares with the rest of the world.

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Appendix 1:
The NORIA-Energy project portfolio

Including the evaluation of Nordic Energy Research, 8 projects were commissioned as part of the NORIA portfolio. The projects were:

ENERGIA – Competitive Policies in the Nordic Energy Research and Innovation Area
(Project leader: Antje Klitkou et al, NIFU-STEP)
This project identified possibilities for coordinated Nordic policy interventions to develop and promote promising renewable energy production technologies in the Nordic/Baltic context.

Patterns of Need Integration and Co-operation in Nordic Energy Innovation Systems
(Project leader: Mads Borup, Risø-DTU)
This project analysed patterns of need integration and technological opportunities in the Nordic energy innovation systems.

Russian Energy Research and Innovation – Prospects for Co-operation on Renewables and Energy Efficiency
(Project leader: Indra Øverland, NUPI)
This study provided an overview of Russian energy efficiency and renewable energy research sectors, energy markets, energy science and innovation policy and international cooperation, highlighting opportunities for Nordic collaboration and technology export.

Nordic Opportunities for Collaboration with China in Energy Research and Innovation
(Project leader: Jørgen Delman, NIAS)
This project identified opportunities for Nordic energy technology companies and institutions to collaborate with Chinese stakeholders, and proposed ways to promote an energy-related R&D agenda between Nordic and Chinese governments and institutions.

Industrial Development and Export Opportunities for Nordic Energy Industry and Other Companies in the Energy Field – a research project within Nordic Energy Perspectives (NEP)
(Project leader: Anders Sandoff, Göteborg University)
This interdisciplinary project promotes stronger and sustainable growth and development in the Nordic countries, clarifying the consequences of political and strategic decisions by stakeholders and presenting ways for the Nordic region to improve the security and environmental impact of its energy supply in a cost efficient manner. The project will be finalised in late 2009.

How to Bring Renewable Energies Down their Learning Curves
(Project leader: Camilla Josephson, Lunds Universitet, and Cinzia Daraio, University of Pisa)
This project addresses the difficulties of research projects in attracting sufficient funding to bring about technical breakthroughs, and develops methods to assess returns in R&D investments within four renewable energy technologies. The project is not yet finalised.

Governance and Research of Nordic Energy System Transition (GoReNEST)
(Project leader: Annele Eerola, VTT)
The project developed an analytical framework for the governance of Nordic energy systems, and utilised this framework to determine the role of various research and policy instruments in strengthening Nordic support of a global transition towards more sustainable energy systems. The framework is designed to help stakeholders plan and execute energy R&D programmes.

In addition to the above mentioned projects is the evaluation of Nordic Energy Research carried out by Faugert & CO / Technopolis.

The results and findings from the projects have been discussed with international experts and key stakeholders in the Nordic energy sector at three different occasions: a kick off workshop for the portfolio in June 2007, a mid-term workshop on December 3rd 2007 and finally at a workshop in Oslo on December 1st 2008. The proceedings from the final workshop have been published by the administration as a conference report which can be downloaded from the Nordic Energy Research website.

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