



**NORDIC ENERGY  
TECHNOLOGY SCOREBOARD  
2010 / CONCISE VERSION**



# Nordic Energy Technology Scoreboard

CONCISE VERSION

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This report is available in both a concise and full version. The concise version is available in hard copy.  
Both versions can be downloaded from [www.nordicenergy.net](http://www.nordicenergy.net)

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# Preface

This is the concise version of the Nordic Energy Technology Scoreboard 2010. This first edition demonstrates and proposes a set of indicators to measure the conditions and performance of clean energy technology development in the Nordic region.

Effective policy and investment decisions require accurate information. This is especially true of clean energy technology development, a systemic and rapidly-developing sector of increasing political and economic significance. Equipped with an accurate picture of the conditions and performance of technology development, public and private decision-makers will be better able to contribute to achieving a more sustainable, secure and competitive energy system.

Various indicators and benchmarking reports already provide pieces to the puzzle. But differences in methodology, scope and data availability mean that these pieces do not fit together well. To provide a more complete picture, comparable across country, technology and by year, a more comprehensive energy technology scoreboard is needed.

The Nordic Energy Technology Scoreboard answers this call, and has been developed to meet three interconnected aims: Firstly, to provide a tool, equipping decision-makers with an understanding of the nature and state of clean energy technology development, and therefore insight into how to influence this development. Secondly, to act as a pilot study, utilising a limited geographic and technological scope to develop sound methodologies that can be adapted to more comprehensive scoreboards in the future. And lastly, to be a vehicle to promote better data collection, by demonstrating indicators where data is available and proposing indicators where data gaps exist.

The scoreboard was commissioned by Nordic Energy Research and developed by Antje Klitkou, Eric Iversen and Lisa Scordato of NIFU STEP. The project is indebted an international expert group that was established to help guide the development, consisting of: Estathios Peteves (JRC-IE, EU), Roberto Lacal-Arantequi (JRC-IE, EU), Karel-Herman Haegeman (JRC IPTS, EU), Christopher Palmberg (Avansis, Finland), Svein Olav Nås (Research Council of Norway), Charlotte Kjeldsen (FORA, Denmark), Birte Holst Jørgensen (Risø DTU, Denmark), and Carrie Pottinger (IEA).

It is our hope that this scoreboard will inform decisions, inspire development, and incite discussion.

Anne Cathrine Gjørde  
Director, Nordic Energy Research

Oslo, July 2010



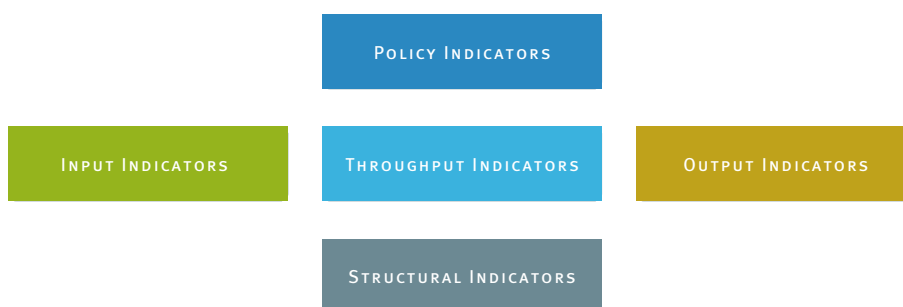
# Executive Summary

The Nordic Energy Technology Scoreboard provides a tool for understanding the state of low-carbon energy technology development in the Nordic region.

It assesses the five Nordic countries of Denmark, Finland, Iceland, Norway and Sweden, alongside reference countries and regions including: The United Kingdom, Germany, Spain, Portugal, France, Italy, the Netherlands, Austria, USA, Japan and the EU 27. It focuses on five low-carbon energy technologies: Wind, photovoltaic (PV) solar, bio-fuels, geothermal, and carbon capture and storage (CCS).

The scoreboard comprises a selection of indicators categorised into five interrelated groups. These groups are presented in the simplified model below which depicts the innovation process in the middle with factors external to the process above and below. The original version of the model can be found as Figure 3 later in the report.

**FIGURE 1: SIMPLIFIED SCHEMATIC OVERVIEW OF INDICATORS**



The key findings of the indicators are presented below, according to the structure of the model above. Due to the fact that this scoreboard was developed as a pilot project, key lessons learned from this exercise are presented at the end of this summary.

1. **Structural Indicators** offer an initial baseline of influential factors that are external to the innovation process. The Nordic countries have relatively high per capita GDP and R&D intensity for example, which facilitates inputs to energy technology development. Sweden and Finland in particular show a high R&D intensity, and when looking at the prioritisation of energy R&D from the total R&D budgets we see that both countries have a strong but declining focus on energy compared to other sectors.

The Nordic countries exhibit a high share of renewable sources in the energy mix. Denmark has seen the largest growth in recent years thanks to wind power, while Iceland is the only country with a notable share of geothermal power. Finland, Sweden and to a lesser extent Denmark all have a significant shares of biomass in their energy mixes compared to other industrialised countries. Hydropower is the key to the Nordic region's overall share of 66% renewable electricity, contributing all of Norway's, most of Iceland's, half of Sweden's and a decent share of Finland's electricity gen-

eration. Norway generates more electricity than it consumes thanks to the common Nordic electricity market in which a considerable amount of electricity is traded across Nordic borders.

Norway also produces many times more primary energy than it consumes due to oil and gas extraction. When comparing the value-added to the economy from these activities to the prioritisation of R&D in fossil-fuel-related technologies, Norway scores significantly higher in both variables than any other country in the scoreboard. Denmark is the only other Nordic country exhibiting a relatively high share of value-added due to oil and gas extraction but does not prioritise fossil-fuel-related R&D. These metrics offer insight into the importance and prioritisation of fossil-fuels in different economies.

Human resources are another structural indicator, where we see very large shares of R&D personnel involved with resource extraction in Norway, with the manufacture and refining of fuel (including nuclear fuel) in Sweden, and with the supply of electricity, gas and water in Iceland.

Lastly it is important to note that individually the Nordic countries make up a very small percentage of the total energy RD&D expenditure as measured by the IEA. This underlines the need to cooperate internationally in energy technology development.

**2. Input indicators** measure the investment of resources into the innovation process. The key indicator here is public RD&D budgets, where data going back to the 1970s shows a development trend common to most industrialised countries: A strong surge in low-carbon energy RD&D funding in the early 1980's as a reaction to the oil crises, followed by a prolonged decline until recent increases in the first decade of this century.

Some low-carbon energy technologies in some countries have received prolonged and consistent support. Wind power in Denmark is a prominent example, contributing to the development of world-class competencies. Wind power was also the most supported renewable energy technology during Sweden's notable increase in RD&D funding in the early 1980s, but since then has dwindled to become overtaken by other more highly prioritised low-carbon energy technologies.

When comparing the prioritisation of wind RD&D with the production of electricity from wind turbines, a cluster of countries including Denmark, Germany, Spain and Portugal exhibit high shares in both variables. Sweden has seen a relative decline in both variables over the last decade compared to the average of the reference countries, while Norway and Finland have increased their relative focus on wind RD&D without increasing their relative share of electricity generated from wind turbines.

PV solar has also received funding over a long time in some Nordic countries but in lesser amounts than wind energy. Recently Denmark, Finland, Sweden and especially Norway have increased their funding of PV solar R&D. Support for geothermal and hydro-power have been less notable and more sporadic over the last decades.

Recent ‘big movers’ have been biofuels in Denmark and Sweden, and CCS in Norway, both technologies grabbing a significant share of low-carbon energy RD&D funding in these countries in only a few years.

3. **Throughput Indicators** measure intermediate outcomes of the innovation process such as scientific publishing and patent filing.

Looking at scientific publishing, Denmark and Sweden are most prolific of the Nordic countries in wind technologies, while Sweden published most in PV solar and biofuel technologies. Both Norway and Sweden lead the other Nordics in publishing on CCS.

Patents on the other hand show Denmark ahead in wind and biofuels, while Norway leads the other Nordic countries in PV solar and CCS.

4. **Output Indicators** capture the desired end results of inputs into the innovation system. This category has significant potential for development but is most hampered by data gaps. Taking wind power as an example, we can see that Danish exports of wind energy technology have exhibited strong growth over recent years and that Denmark is the world’s largest exporter of this technology.

5. **Policy Indicators** attempt to measure the quantifiable aspects of energy technology policies. By looking at the types of policies and their longevity, it becomes evident that Nordic countries first introduced R&D support measures in the 1970s, followed by investment incentives and other measures. More recently Nordic countries have introduced quantity obligations and tradable permits.

## LESSONS LEARNED

This scoreboard was developed as a pilot project with a limited scope of technologies, countries and indicators. In addition to providing a tool for decision-makers, it aimed to act as a catalyst for the future development of scoreboards and a vehicle to promote better data collection. Key lessons learned from the development of this scoreboard are presented below.

Low-carbon energy technologies are not easy to measure. This is due to a variety of factors that much be kept in account when developing scoreboards for this purpose.

- Many low-carbon technologies are still at immature stages of development. Sound comparable data requires common definitions and standards to be adopted before collection can even take place. This process often lags behind the development of low-carbon technologies, and there are therefore considerable data availability and categorisation issues.
- The diversity of technologies and their different stages of development hamper comparability. The IEA classifies low-carbon technologies into three categories. The most mature includes hydro-power, onshore wind, biomass CHP, and geothermal energy, the second most mature includes PV solar and offshore wind power, while the least mature includes concentrating solar power, CCS and ocean energy. This is problematic as less mature technologies are underrepresented in later stages of the innovation system.

- Many low-carbon technologies are systemic, meaning progress in developing one technology may hinge on developments in a connected technology. Examples are hydrogen and fuel cells, or even intermittent renewable generation and smart grids.
- There is an inconsistent link between innovation activities and economic benefit. Due to the positive externalities created by mitigating environmental harm, increasing energy security and sustaining economic development, governments have interests in supporting technology development despite a lack of direct economic benefits from this support. This often occurs in the demonstration phase where a prime example is CCS. This hampers the ability of indicators of economic outcomes in assessing the impact of certain inputs to the innovation system.

## 10 RECOMMENDATIONS FOR BETTER SCOREBOARDS

With regard to the construction of a low-carbon energy technology scoreboard, the following ten areas were identified as needing further development in data collection and categorisation. These are presented in more detail in the summary.

1. **RD&D investment** – specifically addressing the data gap for private-sector RD&D budgets and improving collection of public RD&D demonstration budgets by the IEA, especially for demonstration.
2. **Industrial activities** – including value added from the manufacture of technologies, and improved categorisation and collection of export data.
3. **Licensing and private investment** – through venture capital, capturing activities closer to market.
4. **International technology transfer** – specifically the scope, type and direction.
5. **Technology standards** – measured for example by the development, existence and application of standards.
6. **Relationships between indicators** – how indicators of different aspects of the innovation system can be combined into composite indicators.
7. **Bibliometric and patent indicators** – specifically the categorisations and keywords used to sort this data.
8. **Monitoring carbon capture and storage** – with publicly available data.
9. **Political framework conditions** – improving the categorisation of measurable policy variables.
10. **Public acceptance** – improving the availability and comparability of data.

Comprehensive, consistent and well categorised data in the above areas will go a long way in facilitating the development of better scoreboards in the future. With scoreboards better able to paint a picture of where we are and how we got there, decision-makers will be better equipped to help steer us towards a sustainable, secure and competitive energy system in the Nordic region and beyond.

# Measuring low-carbon energy innovation

Different dimensions of human activities and conditions have long been subjected to measurement and comparison. In terms of innovation, cross-country comparisons can be used to posit an empirical relation between knowledge accumulation and growth of output or productivity.

Measurements should however be well-founded and one should be critical of their use – even straightforward measures, such as emissions, can pose difficulties. The measurement of innovation is a far more difficult area that poses significant challenges both in terms of the collection and the interpretation of data (OECD, 1992).

## CHALLENGES SPECIFIC TO LOW-CARBON ENERGY TECHNOLOGIES

The nature of low carbon energy technologies poses a number of particular measurement challenges in addition to the general issues mentioned above.<sup>1</sup> A number of low-carbon energy technologies which are interesting to track are still not mature (IEA, 2006). In addition, different levels of maturity are evident within these technologies – such as the maturity of their intermediate and end markets. This has clear implications for the degree to which input, through-put and output measures are applicable for the individual technologies. The IEA distinction between three generations of technologies is helpful:

- (i) First-generation technologies which have already reached maturity, such as hydropower, biomass combustion, onshore wind and geothermal energy;
- (ii) Second generation technologies which are undergoing rapid development such as solar energy, offshore wind power and modern forms of bio-energy;
- (iii) Third-generation technologies which are presently in developmental stages such as concentrating solar power, ocean energy, improved geothermal, CO<sub>2</sub> capture and storage and integrated bio-energy systems.

A further set of challenges arises in that low-carbon technologies can involve the deployment of large-scale experimental sites to demonstrate and test different modes of the technology (e.g. carbon capture and storage or offshore wind). These deployment/ demonstration sites can require large allocations of resources without providing immediately profitable output.

Another aspect to consider is that these are not necessarily stand-alone technologies but are systemic, and may involve significant changes in existing value chains. For example, bio-fuels require change or complementary developments in engine manufacturing as well as fuel distribution. Measurements of certain technologies may not capture progress in related fields that may help or hinder development of the measured technology.

The deployment of these technologies may therefore face different degrees of resistance from established and competing systems based on other (e.g. carbon-based) energy sources.

<sup>1</sup> See Smith (2008) for a discussion.

In this context it is useful to appreciate that different renewable energy technologies may represent incremental, disruptive, or radical forms of innovation (Smith, 2008). Different technologies might have different development rates, which in turn implies different degrees of public funding to overcome coordination costs, technological and market uncertainty, and rigidities in existing structures. Indicators of low-carbon energy technologies therefore entail significant limitations and uncertainties, and must be interpreted with this in mind.

For a more extensive discussion on the measurement of low-carbon energy innovation and the challenges posed by low-carbon technologies, please refer to the full version of this report, available for download at [www.nordicenergy.net](http://www.nordicenergy.net).

# Overview of Scope and Indicators

## DATA COVERAGE AND SCOPE

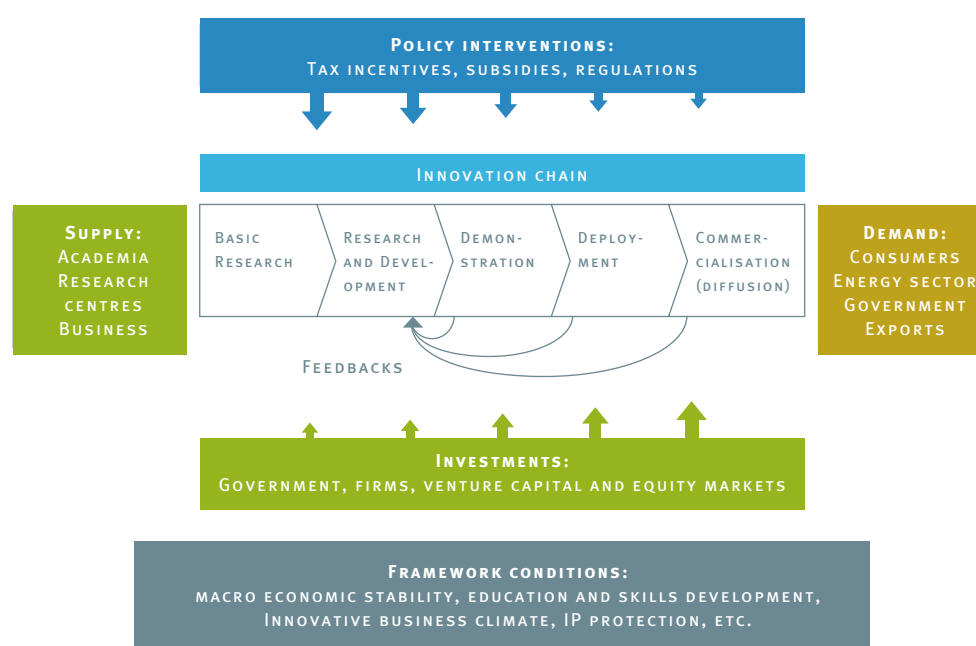
The geographical, chronological and technological scope of the scoreboard is defined as follows:

- **Country Coverage:** The five Nordic countries of Denmark, Finland, Iceland, Norway and Sweden form the core of the scoreboard. In addition, a set of reference countries and regions have been included: The United Kingdom, Germany, Spain, Portugal, France, Italy, the Netherlands, Austria, USA, Japan and the EU 27.
- **Timeframe:** The scoreboard is based on periodic data (annual) with at least a 10 year run. The default time-frame is 1998-2007. 2008 figures are used when available and a longer time frame is used when relevant.
- **Technologies:** The scoreboard will concentrate on following low-carbon energy technologies: Wind, photovoltaic solar, bio-fuels, geothermal, as well as carbon capture and storage (CCS). This is due to data availability and the interests and competencies of the core countries.

## CATEGORISATION OF INDICATORS

The indicators used in this scoreboard have been categorised based on an interpretation of the schematic dimensions of a generic innovation process as pictured in Figure 2 (IEA, 2008, p. 170). This shows the core innovation process in the centre with inputs to the system on the left and outputs from the system to the right. External factors that affect innovative activities such as access to a skilled labour force or policy factors are pictured above and below the core innovation process.

**FIGURE 2: THE LOW-CARBON ENERGY INNOVATION SYSTEM**



Source: adapted and modified from Grubb, 2004 and Foxon, 2003 and ETP 2008

The five categories of indicators used in this scoreboard are based on this model, and are explained below. Figure 3 illustrates how these categories relate to the model presented in Figure 2.

1. **Structural** indicators that size up national capacities
2. **Input** indicators that capture investments into RD&D activities
3. **Throughput** indicators based on patent and bibliometric measures
4. **Output** indicators that reflect the results of innovation activities
5. **Policy** indicators

**Structural** indicators are key country variables that include conventional measures to put national capacity into perspective, such as population, GDP, human resources, industry specialisation, energy prices, and energy balances by energy source.

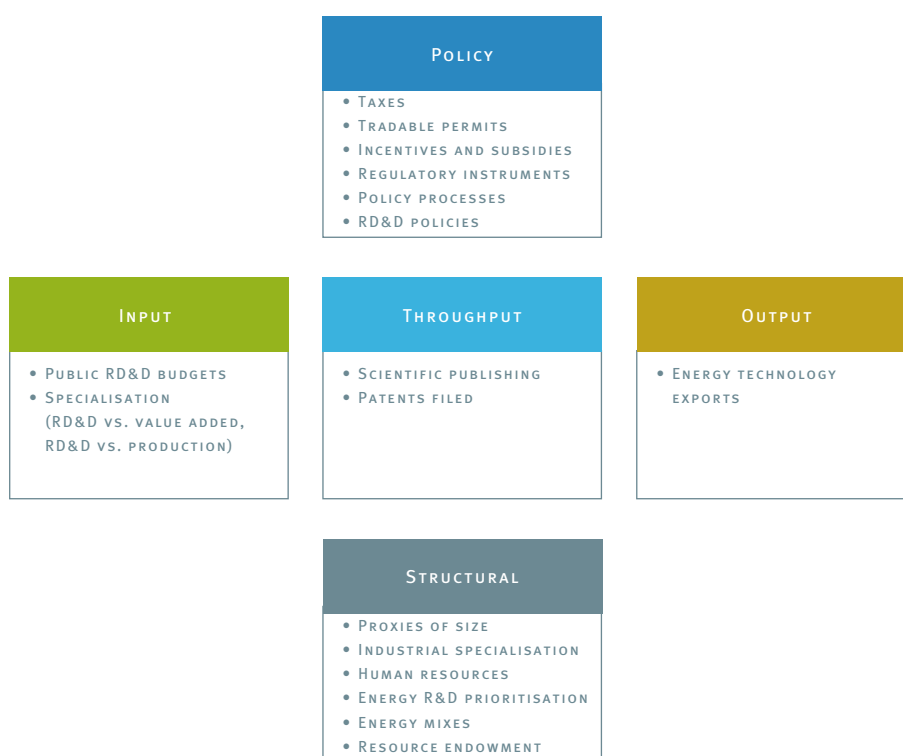
Following Grupp and Schwitalla's taxonomy (1989), **Input** indicators include a diverse set of measures for the allocation of human and other resources to the innovation process. These are the most standardised measures of innovative activity and often include R&D outlays and R&D personnel.

**Throughput** indicators (Grupp & Schwitalla, 1989) are measures that attempt to capture the intermediate products of the innovation process, especially those emanating from the formal R&D processes. Common throughput indicators are patent, bibliometric and citation statistics.

**Output** indicators attempt to capture the economic effects of the innovative activity in question. Measuring output is more challenging than input. One challenge is that economic effects are not the only interesting products of innovation processes; there are others such as learning effects which will only indirectly contribute to the bottom-line. The second is that it is not always easy to distinguish the economic effects of the innovative activity from that of other activities taking place in tandem or in parallel.

**Policy** indicators measure different forms of policy-contributions across countries. These include taxes, tradable permits, financial incentives and subsidies, regulatory instruments, RD&D related policy measures, and policy processes.

For a complete overview of the indicator categorisations in this scoreboard, please refer to the full version of this report, available for download at [www.nordicenergy.net](http://www.nordicenergy.net).

**FIGURE 3: SCHEMATIC OVERVIEW OF INDICATORS**

# Strategic Approach

The approach taken for the selection of indicators proceeds from the view that the scoreboard should first and foremost be relevant for policymakers. Relevant indicators are those that provide current and important information about aspects of capacity and of performance that are linked to the technologies in the countries in question. Above and beyond this the scoreboard should be based on detailed, dependable, and up-to-date information that is publically available to facilitate replication; it should be reliable and comparable over time and across country; and it should be robust, sufficiently fine-grained, as well as clear and accessible. It should also correspond and contribute to wider international initiatives especially in Europe.

There is a growing literature that attempts to size up the development, production and use of renewable energy technologies. This is an area where much overlapping activity is taking place and where new sources continue to appear. In general the available literature highlights the formative nature of the technologies: it underlines the importance of metrics to monitor developments on the one hand while noting the difficulty in presenting and interpreting metrics for emerging technologies on the other. The literature can be divided into three types in terms of the sort of data the contributions build upon:

- Based on core data from existing and recognised sources;
- Based on non-core data sources (e.g. those with limited coverage for one country or one technology);
- Based on data that requires adaptation to be applied to the technologies selected in this scoreboard (e.g. bibliometric and patent data); as well as data sources which hold promise for future work.

With these factors in mind, the following three strategies have been used to collect and present data for this scoreboard.

- There is a **near-view strategy** that is based on compiling available data which is collected according to standardised guidelines and established routines – such as the concerted multinational efforts of IEA or Eurostat. This data is current, reliable and comparable. The indicators for the *Structural*, *Input* and *Output* indicators compiled in this scoreboard have used this near-view strategy.
- There is next a **mid-view strategy**. This strategy is based on harvesting indicators based on standard-definitions, such as classifications in databases of patents or articles. This strategy has been used for the *Throughput* indicators in this scoreboard. Due to the speed of development in low-carbon energy technologies, some classification systems do not capture industrial activity at a sufficiently fine-grained level. Where this has limited data gathering, this scoreboard has recommended categories, keywords and patent classes instead.
- Finally there is the **long-view strategy**. This strategy involves long term development work to provide relevant measures that may be useful in the future. In the case of the Nordic countries, these are indicators of private-investment (through venture capital), licensing, and the application and development of relevant industrial classification systems for industrial activity and export. Technological standards may for example be developed as long-view indicators. The follow-up of measurable governmental goals on low carbon energy is another potential strategy.

For a complete account of the strategic approach taken in the development of this scoreboard and an overview of relevant literature please refer to the full version of this report, available for download at [www.nordicenergy.net](http://www.nordicenergy.net).

# Structural Indicators

The scoreboard is built first on a set of structural indicators to take account of inherent differences at the national level. This group of indicators is represented as the lowest box in Figure 3. To capture national effects, six sets of variables are proposed to promote comparability across country and time.

- Proxies of size
- Industrial specialisation
- Human resources
- Energy mix by energy source
- Energy R&D prioritisation
- Energy markets

## PROXIES OF SIZE

Several factors affect trends in energy demand in a given country. Population and gross domestic product (GDP) are two major drivers. Thus we present country size along three dimensions: total population and GDP. Other key indicators include: CO<sub>2</sub> emissions per capita, energy production, net import of energy and R&D intensity as percentage of GDP and shares of Government Budget Appropriations or Outlays for R&D (GBOARD) on production, distribution and rational utilisation of energy, share of the total IEA RD&D budget, and volume of a country's government budget on energy RD&D (see Table 1).

**TABLE 1: OVERVIEW TABLE OF SELECTED COUNTRY VARIABLES FOR 2007.**

|             | Population<br>(mill.) | GDP<br>(bill. €) <sup>a</sup> | CO <sub>2</sub> /pop<br>(t CO <sub>2</sub> /capita) | Energy<br>production<br>(Mtoe) | Net energy<br>imports<br>(Mtoe) | R&D<br>intensity<br>(% of GDP) | % of<br>Energy in<br>total public<br>RD&D <sup>b</sup> | % of<br>total IEA<br>budgets <sup>d</sup> | Govt.<br>energy<br>RD&D<br>budget <sup>e</sup> |
|-------------|-----------------------|-------------------------------|-----------------------------------------------------|--------------------------------|---------------------------------|--------------------------------|--------------------------------------------------------|-------------------------------------------|------------------------------------------------|
| Denmark     | 5,4                   | 194                           | 9,24                                                | 27,04                          | -5,51                           | 2,55                           | 2,7                                                    | 1,16                                      | 103,122                                        |
| Finland     | 5,3                   | 165                           | 12,19                                               | 15,95                          | 19,98                           | 3,47                           | 4,5                                                    | 1,66                                      | 147,406                                        |
| Iceland     | 0,3                   | 13                            | 7,53                                                | 3,95                           | 1,17                            | 2,75                           | 1,4                                                    | :                                         | :                                              |
| Norway      | 4,7                   | 214                           | 7,85                                                | 213,91                         | -186,78                         | 1,64                           | 2,9                                                    | 1,17                                      | 104,550                                        |
| Sweden      | 9,2                   | 323                           | 5,05                                                | 33,58                          | 19,00                           | 3,61                           | 3,4                                                    | 1,02                                      | 90,459                                         |
| Germany     | 82,3                  | 2 246                         | 9,71                                                | 137,03                         | 201,58                          | 2,53                           | 2,9                                                    | 4,73                                      | 420,931                                        |
| Austria     | 8,3                   | 241                           | 8,38                                                | 10,90                          | 23,31                           | 2,54                           | 1,7                                                    | 0,37                                      | 32,709                                         |
| France      | 63,6                  | 1 637                         | 5,81                                                | 135,45                         | 135,86                          | 2,04                           | 5,3                                                    | 9,82                                      | 873,446                                        |
| Netherlands | 16,4                  | 478                           | 11,13                                               | 61,45                          | 38,57                           | 1,71                           | 3                                                      | 1,55                                      | 137,997                                        |
| Spain       | 44,9                  | 797                           | 7,68                                                | 30,33                          | 123,77                          | 1,27                           | 3,1                                                    | 0,86                                      | 76,753                                         |
| UK          | 60,8                  | 1 912                         | 8,60                                                | 176,23                         | 44,88                           | 1,82                           | 0,5 <sup>c</sup>                                       | 2,2                                       | 195,829                                        |
| Italy       | 59,3                  | 1 289                         | 7,38                                                | 26,38                          | 157,99                          | 1,18                           | 4 <sup>c</sup>                                         | 4,14                                      | 368,443                                        |
| Portugal    | 10,6                  | 132                           | 5,20                                                | 4,62                           | 21,82                           | 1,21                           | 0,9 <sup>c</sup>                                       | 0,02                                      | 2,028                                          |
| USA         | 302,1                 | 12 721                        | 19,10                                               | 1665,18                        | 713,97                          | 2,62                           | 1,1                                                    | 28,18                                     | 2507,052                                       |
| Japan       | 127,8                 | 5 636                         | 9,68                                                | 90,42                          | 434,68                          | 3,44                           | 15,2 <sup>c</sup>                                      | 29,73                                     | 2645,788                                       |
| EU27        | 496,5                 | 10 685                        | 10,4 <sup>f</sup>                                   | 849,55                         | 988,35                          | 1,85                           | 3                                                      |                                           |                                                |

Source: Eurostat and IEA.

a) 2000 exchange rates, source: Eurostat; b) GBAORD; c) 2006; d) percentage of total IEA (€8898 mill=100%) public energy RD&D budgets; e) millions € (2008 prices and exchange rates), source: IEA; f) 2006, source: EC, 2009.

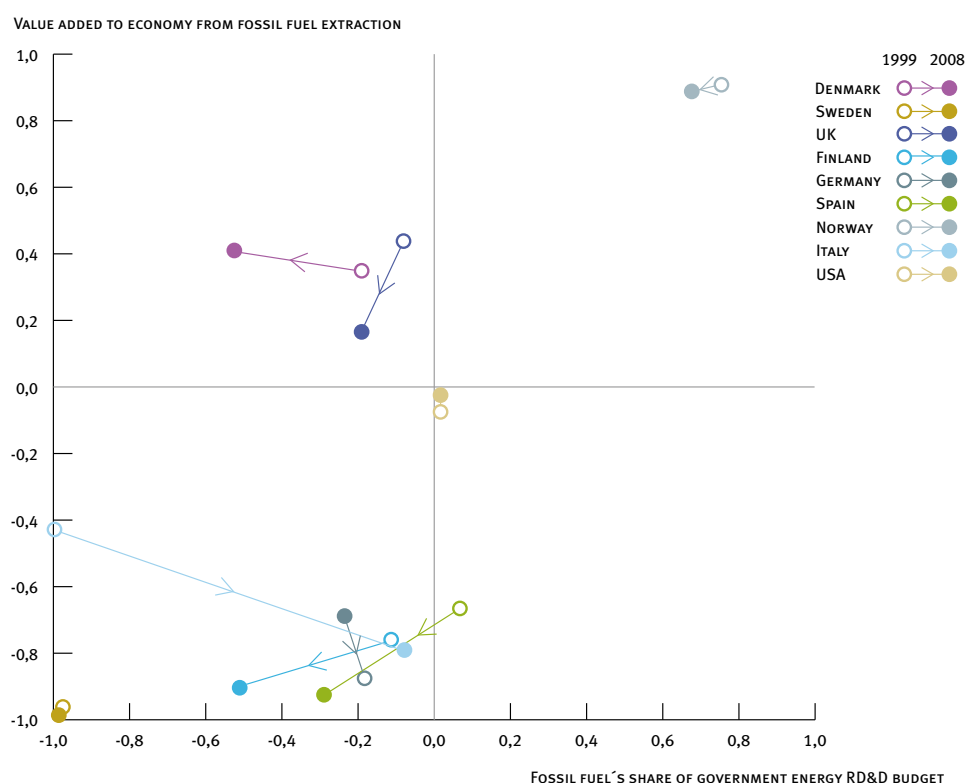
WITH ITS COLD WINTERS AND ABUNDANT  
NATURAL RESOURCES, ENERGY IS AN  
ESPECIALLY IMPORTANT SECTOR IN THE  
NORDIC REGION



#### INDUSTRIAL SPECIALISATION

Industrial specialisation has an impact on the specialisation of the available human resources for RD&D and should therefore be considered as a structural indicator for energy technology development and deployment. This scoreboard has used indicators of industrial specialisation to shed light on the importance of fossil-fuels in the economies and research communities of various countries. This is achieved by comparing the value added based on fossil fuel extraction with the degree to which government RD&D budgets prioritise fossil-fuel research. In comparing these variables a similar method used by Laursen (1998) for the calculation of the Revealed Symmetric Comparative Advantage of different economies has been applied. See the full version of this report for the relevant equations used.

Figure 4 analyses the Nordic countries and following reference countries: Germany, Italy, Spain, United Kingdom and USA. It combines specialisation of value-added in mining and quarrying of energy producing materials (ISIC 10-12) and specialisation in RD&D budgets on fossil fuels. The figure demonstrates the high importance of the oil and gas sector for Norway regarding both value added and RD&D, but both have slightly decreased since 1999. For the other Nordic countries the comparative advantage of value-added in mining and quarrying of energy producing materials is only minor, with the exception of Denmark. RD&D budgets for fossil fuels show a clear priority in Norway due to RD&D on petroleum and gas exploration, but also on CCS (16% of the RD&D on fossil fuels in 2008). However, Norway has almost no electricity production based on fossil fuels, while Denmark and Finland still depend heavily on fossil fuels for electricity generation. Sweden is not dependent on fossil fuels and has no RD&D budgets related to that either. Note that the largest Swedish energy company, Vattenfall, is owner of several lignite-fired power stations in Germany, and is therefore also active in RD&D projects on CCS there. But this is not covered by governmental budgets on energy RD&D.

**FIGURE 4: REVEALED SYMMETRIC COMPARATIVE ADVANTAGE FOR FOSSIL FUELS. 1999 AND 2008.**

For an explanation of how this figure has been calculated please refer to page 47 in the Annex.

Sources: IEA and OECD, STAN, 2009-2010.

Based on specialisation of RD&D government budgets in fossil fuels and specialisation of value-added in Mining and quarrying of energy producing materials. Values for RD&D for Finland are from 1999 and 2007. Values for Value added for Sweden and USA are from 1999 and 2007, and for Italy from 2000 and 2008.

Among the reference countries there are two main groups: First, the UK and USA, which are at the average of the total sample in both indicators. Second, the group around Germany, Italy and Spain, which has a declining specialisation on fossil fuel-based value added and RD&D budgets. The only country with an increasing specialisation on RD&D is Italy on fossil fuels and CCS (24% of the RD&D on fossil fuels in 2008).

In conclusion, there are several countries with a high but diminishing share of value-added based on mining and quarrying of fossil energy products, while Norway is in a special position with a high specialisation in RD&D on fossil fuels, including CCS. There are different strategies to become a low-carbon economy: in addition to replacing fossil fuels with renewable energy sources it is also an option to handle CO<sub>2</sub> emissions by carbon capturing and storage.

GEOHERMAL ENERGY IS AN IMPORTANT FACTOR IN ICELAND'S ENERGY MIX, PROVIDING BOTH ELECTRICITY AND HEATING. THIS IS REFLECTED IN THE HIGH SHARE OF R&D PERSONNEL IN THE ELECTRICITY, GAS AND WATER SUPPLY SECTOR IN FIGURE 5



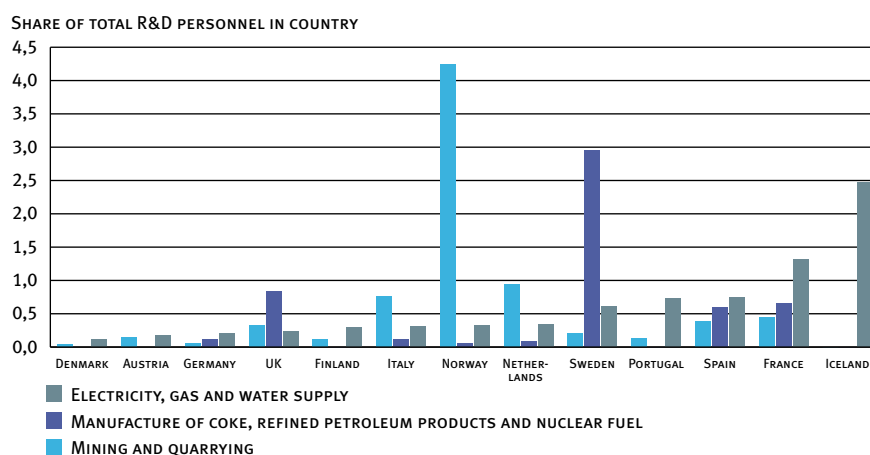
## HUMAN RESOURCES

As a proxy for human resources in different industrial sectors this scoreboard uses shares of total R&D personnel in selected industrial sectors. The shares of total R&D personnel for 2007 (2006 for Iceland) in following industrial sectors have been calculated based on 2000 prices of national currency:

- Mining and quarrying (ISIC 10-14)
- Coke, refined petroleum products and nuclear fuel (ISIC 23)
- Electricity, gas and water supply (ISIC 40-41)

Figure 5 illustrates that the share of R&D personnel in the energy-related business enterprise sector varies across the countries analysed, but is generally modest. Notably Norway has a relatively high share of R&D personnel in Mining and quarrying, Sweden in Manufacture of coke, refined petroleum products and Nuclear fuel and Iceland in Electricity, gas and water supply. This reflects the relative importance of these sectors to the economies and energy mixes of these countries.

**FIGURE 5: R&D SKILLS, SHARE OF ALL NACE BRANCHES OF TOTAL R&D PERSONNEL IN 3 INDUSTRIAL SECTORS. 2007 FULL TIME EQUIVALENTS.**



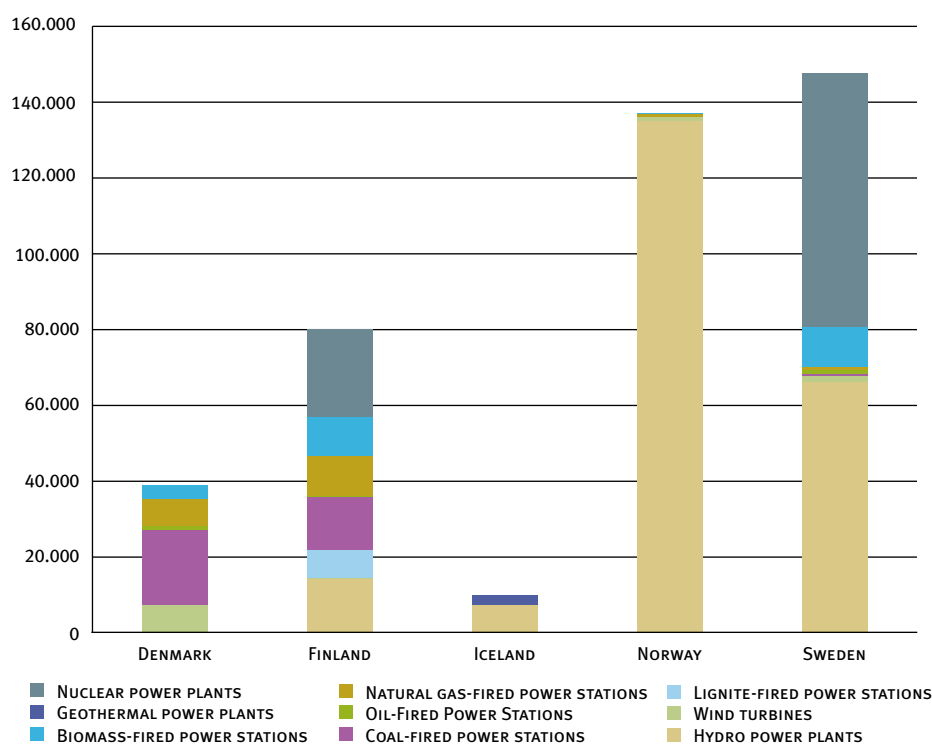
Source: Eurostat.

Notes: Latest year for Italy 2006; Netherland 2005 (ISIC codes 10-14, 23, 40); Denmark: confidential for manufacture of coke, etc)

## ENERGY MIX BY ENERGY SOURCE

The different energy sources making up the mix of both electricity production and primary energy production are relevant structural indicators. Figure 6 depicts the main sources of gross electricity production in the Nordic countries. Danish electricity generation is somehow stable and still dominated by fossil energy sources (coal and natural gas power stations), but wind turbines and biomass-fired power plants gain importance. Finland's electricity generation has increased over the period and has a quite diverse set of electricity sources, with still high shares of coal, lignite and natural gas-fired power plants, and nuclear power plants. The importance of hydropower is declining, but the share of biomass-fired power plants is increasing. Iceland's electricity generation has increased significantly and is dominated by hydropower. The importance of geothermal energy for electricity generation has increased over the last years. Norway's electricity generation has increased in the period and is totally dominated by hydropower. The Swedish electricity generation has slightly declined over the period. It is mainly divided between nuclear power generation and hydropower plants; biomass-fired power stations contribute increasingly.

**FIGURE 6: GROSS ELECTRICITY GENERATION IN THE NORDIC COUNTRIES. 2007. GWH.**



Source: Eurostat.

Value for Iceland is from 2006.

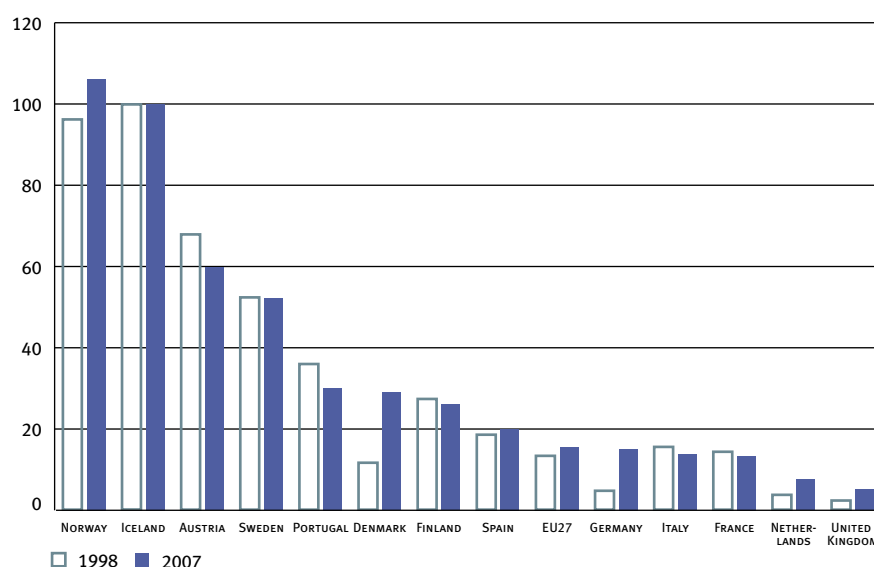
Figure 7 gives a ranked order of the included countries according to the share of electricity consumption provided by renewable energy sources for two points in time, 1998 and 2007. The fact that Norway has a higher share than 100% is due to the fact that Norway is exporting electricity on a large



Hydropower is behind a significant share of electricity generation in Norway, Iceland and Sweden, and is the key to the region's impressive 66% renewable electricity mix

scale, while Iceland cannot export electricity. Denmark has more than doubled its share of renewable energy of electricity consumption from 12% to 29%, while Sweden has a high, but stable share of 52%, and Finland has a share of 26% in 2007. Among the reference countries, Austria should be highlighted with a share of 60% in 2007 (a decrease of 8 percent points since 1998). The European Union has reached 15.6% in 2007, while the United Kingdom and the Netherlands are far behind with 5% and 8% in 2007.

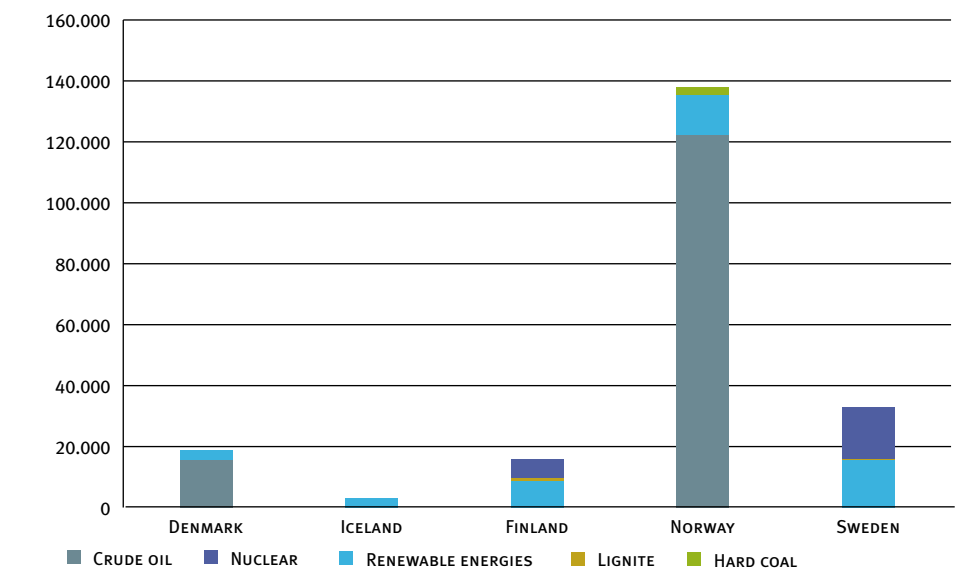
**FIGURE 7: SHARE OF RENEWABLE ENERGY – CONTRIBUTION OF ELECTRICITY FROM RENEWABLES TO TOTAL ELECTRICITY CONSUMPTION, 1998 AND 2007.**



Source: Eurostat.

Note: Shares for the USA and Japan are not available in Eurostat.

**FIGURE 8: PRIMARY PRODUCTION OF ENERGY IN 1000 TOE. 2007.**



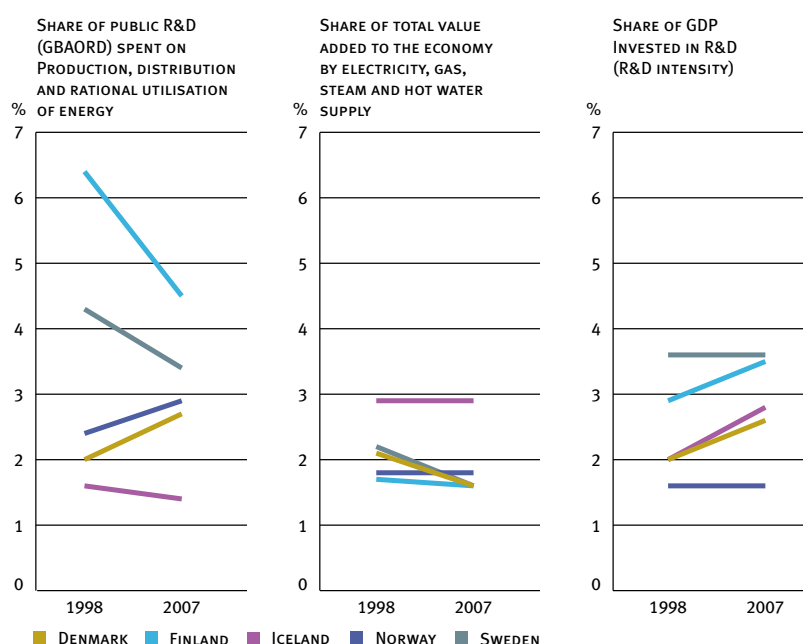
Source: Eurostat.  
Value for Iceland is from 2006.

It is also interesting to compare the countries' most important sources for electricity generation with the countries' energy production profiles. Figure 8 illustrates the different primary energy production profiles of the Nordic countries for renewable energies, fossil fuels and nuclear. The figure demonstrates clearly the strong presence of an oil extraction industry in Norway in particular, but also in Denmark. On the other hand renewable energies and nuclear power are dominating the energy production mix in both Sweden and Finland. In line with the trends in the EU primary energy production is declining recently. A notable exception is Iceland which has seen a sharp increase in energy production the last two years. For a more comprehensive discussion of energy mixes and figures showing development over time, please refer to the full version of this report.

## ENERGY R&D PRIORITISATION

A useful indicator for analysing general framework conditions for the development of new energy technologies is data on government appropriations allocated to R&D in different socio economic sectors – showing how energy R&D is prioritised relative to other sectors. Data is provided by Eurostat: *Government budget appropriations or outlays for R&D (GBAORD)*. This indicator can be compared against other measures such as the value-added of Electricity, gas, steam and hot water supply, and the general R&D intensity of an country (R&D as a share of GDP), to show a broader picture of relevant framework conditions.

**FIGURE 9: ENERGY R&D PRIORITISATION AND FRAMEWORK CONDITIONS. SHARES OF TOTALS. 1998 AND 2007.**



Sources: Eurostat, OECD STAN database.

Figure 9 summarises key framework conditions for the development of renewable energy technologies in the five Nordic countries. It highlights a high but declining share in GBOARD on energy in Finland and Sweden, and a lower but increasing GBOARD share for Denmark and Norway. The share of value-added generated in the electricity generating sector is highest and stable in Iceland, while Denmark and Sweden have a declining value-added in this sector. For Finland and Norway the share is rather stable. General R&D intensity is highest and also stable in Sweden, but here Finland, Denmark and Iceland are catching up. Norway's R&D intensity is lowest, but this has to be seen in relation to a very high GDP caused by high income based on oil and gas production.

## ENERGY MARKET

A useful structural indicator of the linkages within the Nordic countries' energy market is the rate of exchange of electricity. This is made by looking at the percentage change of electricity imports/exports in 1998 and in 2007. What this indicator explains is the strong interdependence of the Nordic countries' electricity market. Over the last ten years the interdependence pattern has changed remarkably, as in the case for the electricity exchange between Norway and Sweden and between Sweden and Denmark.

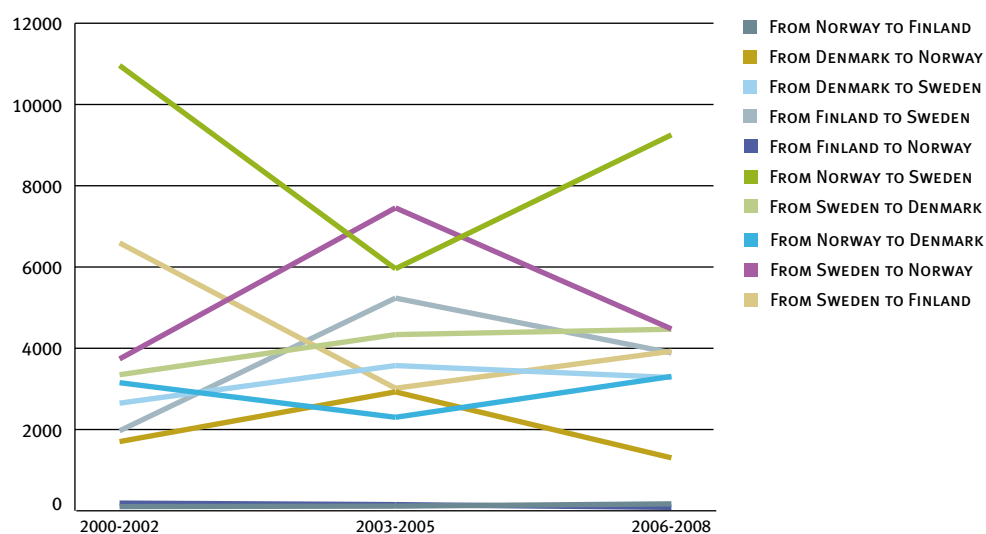
Nordic cooperation in the field of production, distribution and consumption of electric energy began in 1963, and is a leading example globally. The rationale behind the integration of electricity markets is the need for security of supply, the ability to maintain environmental commitments, the avoidance



The Nordic region has one of the most interconnected electricity grids in the world, with stable sources of hydropower in the North balancing fluctuating sources of wind in the south.

of over-investment for peak load, and the further integration of a European market. A common challenge is the commitments agreed upon at the EU level for the integration of renewables and reduction of CO<sub>2</sub> emissions by the year 2020. The substantial foreseen expansion of wind-power in the system will require greater transmission capacity. Closer cooperation between regions is necessary for achieving efficient operation and investments. The TSOs are important players for infrastructure development, efficient use of resources and technologies (Nordel, 2009).

**FIGURE 10: EXCHANGE OF ELECTRICITY BETWEEN NORDEL COUNTRIES FOR THREE 3-YEAR AVERAGE PERIODS, 2000-2008, GWH.**



Source: Nordel.

Note: Iceland is not connected to the Nordic grid.

**FIGURE 11: EXCHANGE OF ELECTRICITY, 2008, GWH.**



Resource endowments are important as they are natural framework conditions for energy technology deployment, but not necessarily for energy technology development. A set of standard measures has been given in the full version of this report to take into account the natural resources that are relevant to the deployment of technologies in the individual countries, including measures for solar radiation, wind resources, hydropower and the accessibility of geothermal resources.

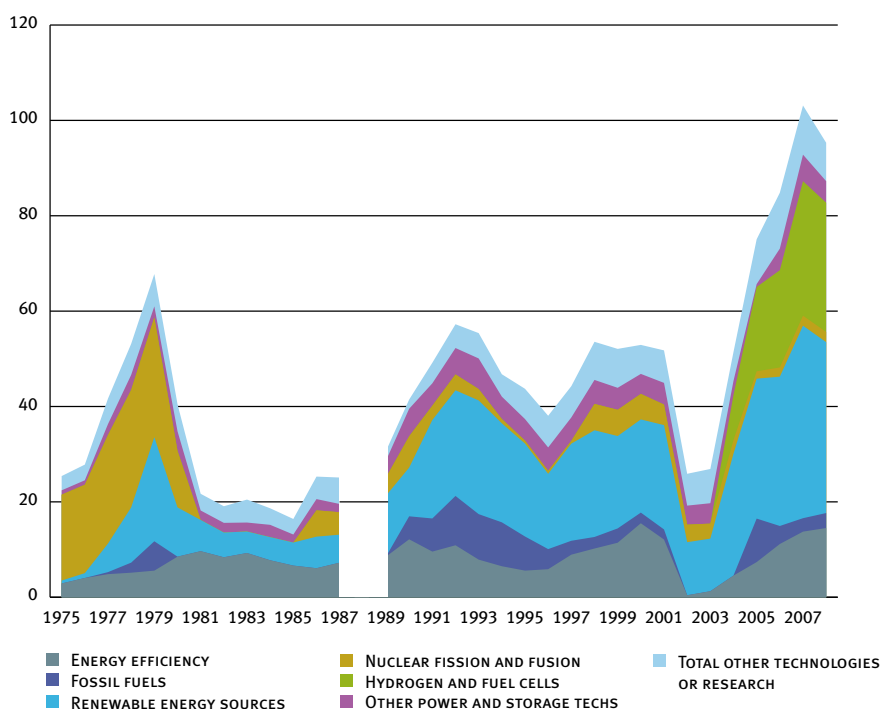
# Input Indicators

Input measures are represented by the box on the left of Figure 3. Due to the lack of comparable data available for private RD&D, public RD&D budgets collected by the IEA are used as the primary input indicator in this scoreboard. A detailed discussion of different input indicators, including private RD&D, can be found in the full version of this report. The indicators in this group assess public RD&D for all energy technologies and for selected low-carbon technologies. In addition, an indicator of international specialisation is demonstrated, comparing RD&D budgets in a certain technology with electricity production from that technology.

## PUBLIC RD&D IN ALL ENERGY TECHNOLOGIES

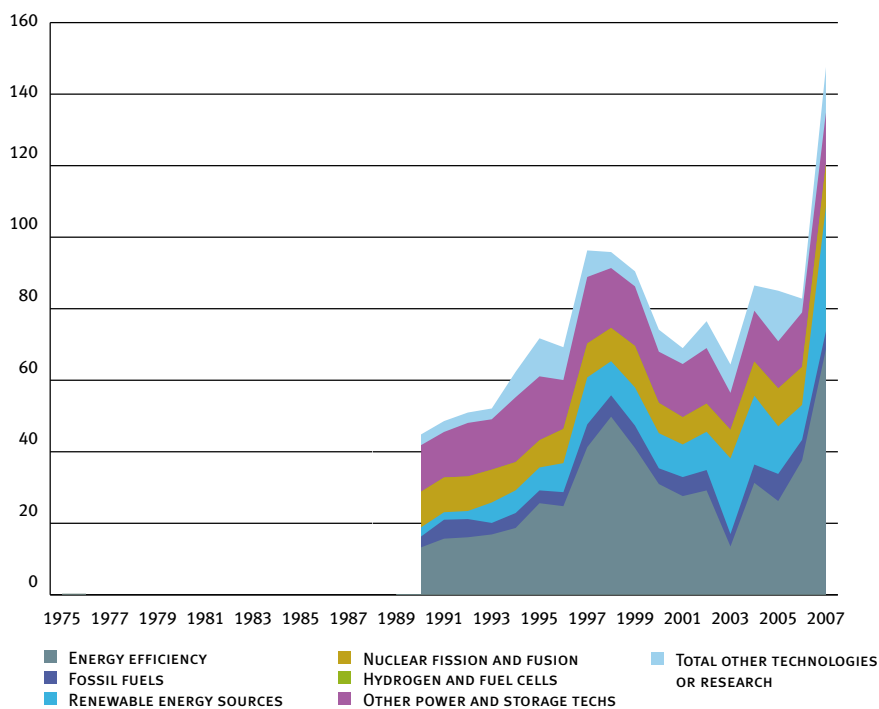
IEA statistics on public RD&D budgets cover a wide range of technologies and countries over a significant time period. All Nordic countries, with the exception of Iceland are included in the database. In Denmark we see a steady prioritisation of renewable technologies, and more recently of hydrogen and fuel cells. In Finland we see a prolonged focus on energy efficiency, and recent jump in total funding - especially in energy efficiency and renewables. In Norway the importance of fossil-fuel-related technologies is evident, while in Sweden the surge in funding in the early 1980's for renewable and fossil-fuel technologies is most stark.

**FIGURE 12: DENMARK, RD&D BUDGETS FOR MAIN GROUPS, MILL €, 1975-2008.**



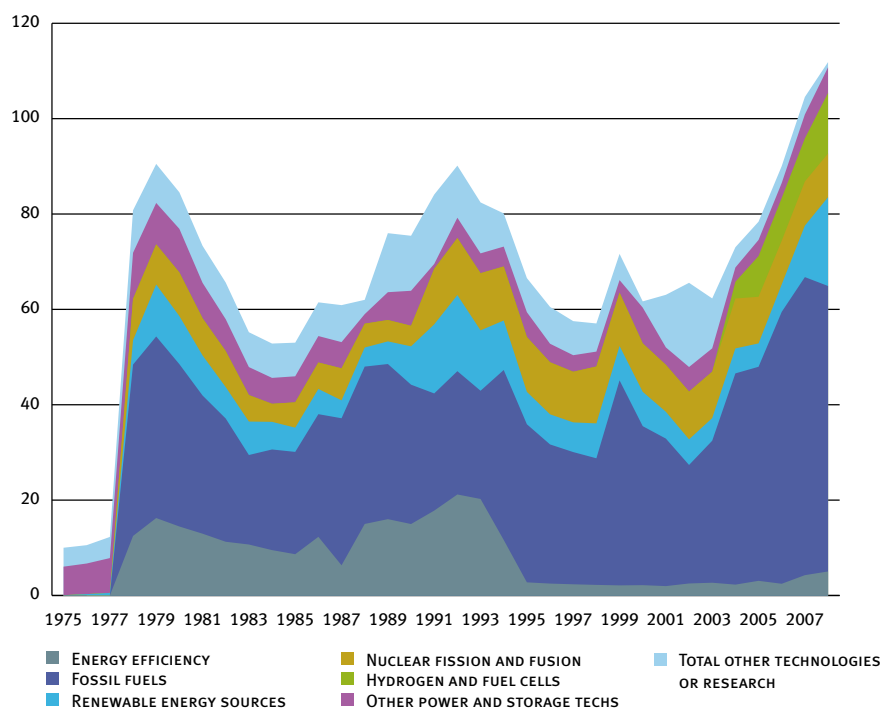
Source: IEA.

**FIGURE 13: FINLAND, RD&D BUDGETS FOR MAIN GROUPS, MILL €, 1975-2008.**



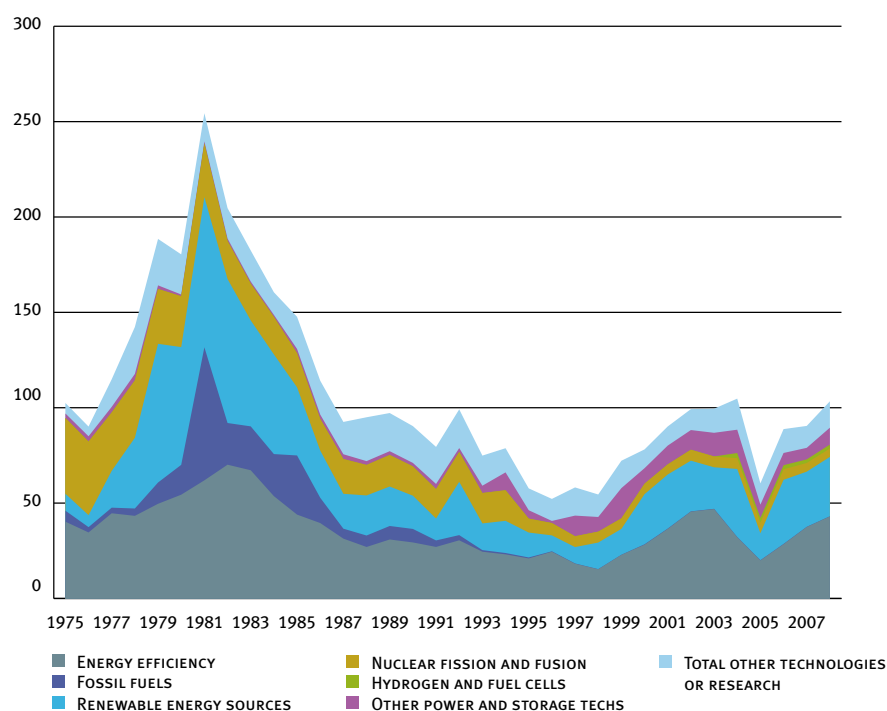
Source: IEA.

**FIGURE 14: NORWAY, RD&D BUDGETS FOR MAIN GROUPS, MILL €, 1975-2008.**



Source: IEA.

**FIGURE 15: SWEDEN, RD&D BUDGETS FOR MAIN GROUPS, MILL €, 1975-2008.**

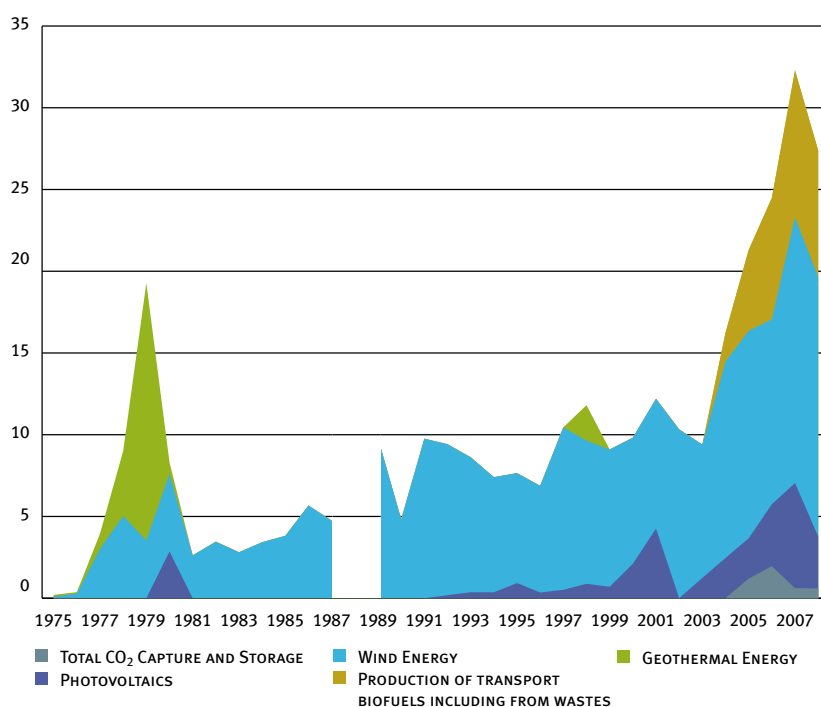


Source: IEA.

## PUBLIC RD&D IN SELECTED LOW-CARBON ENERGY TECHNOLOGIES

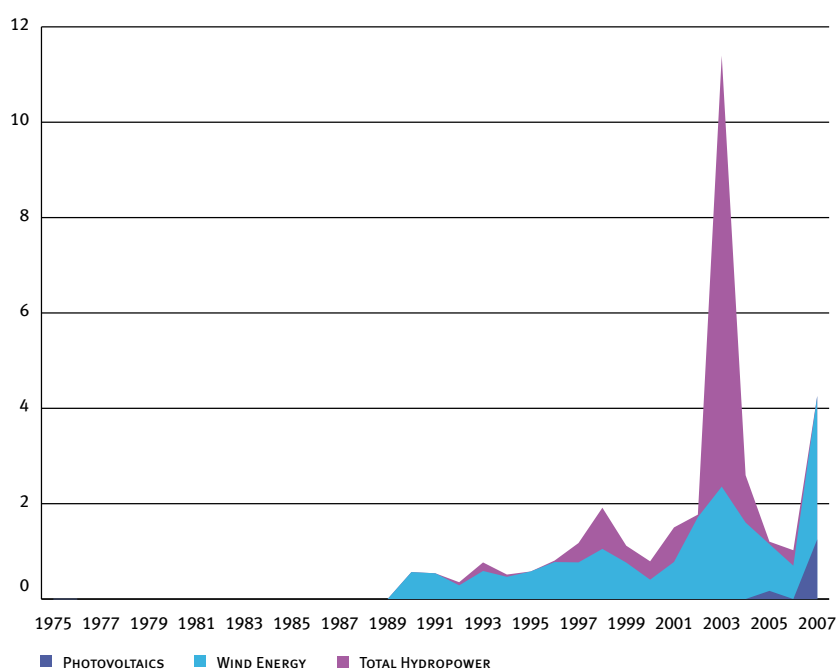
The following figures illustrate public RD&D budget developments for the low-carbon energy technologies covered in this scoreboard: Wind, geothermal, PV solar, bio-fuels, and CCS. Hydropower has been included here to offer context in renewable energy RD&D. In Denmark, the prolonged focus on wind energy has clearly evident, with a recent increase in funding for bioenergy and PV solar technologies. In Finland wind energy has also been the most consistent, reflected by Finnish competencies in the manufacture of parts for the wind industry. Finnish hydropower RD&D has also received substantial but inconsistent support in recent years. In Norway, sizable increases in funding for CCS and PV solar are clear to see. In Sweden, an early focus on wind has subsided, while PV solar has gradually received more attention. Bioenergy's attention has increased rapidly to become the most dominant recipient of Swedish public RD&D funding amongst these technologies.

**FIGURE 16: DENMARK, DISTRIBUTION OF LOW CARBON ENERGY RD&D BUDGETS, MILL €, 1975-2008.**



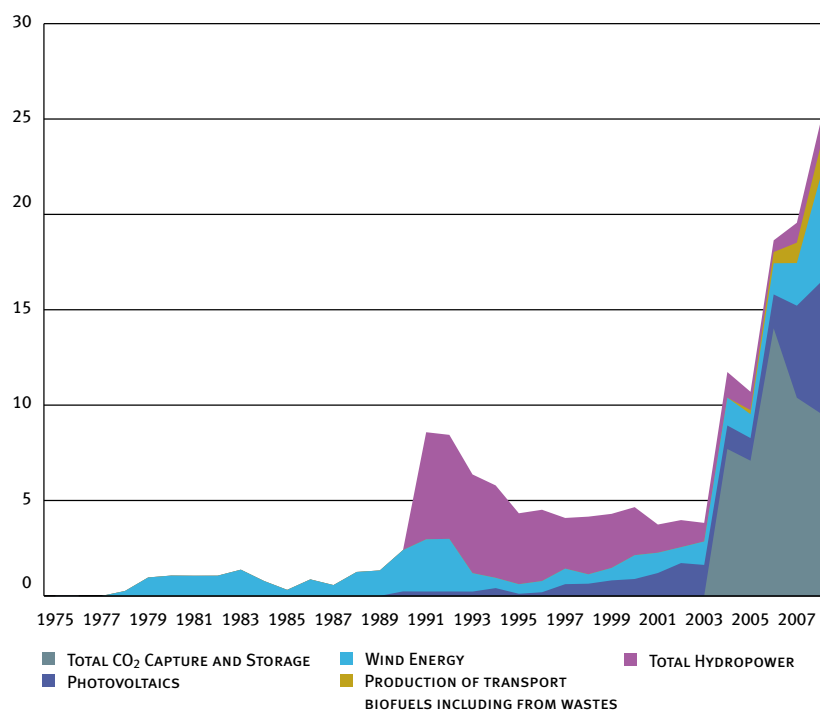
Source: IEA.

**FIGURE 17: FINLAND, DISTRIBUTION OF LOW CARBON ENERGY RD&D BUDGETS, MILL €, 1975-2007.**



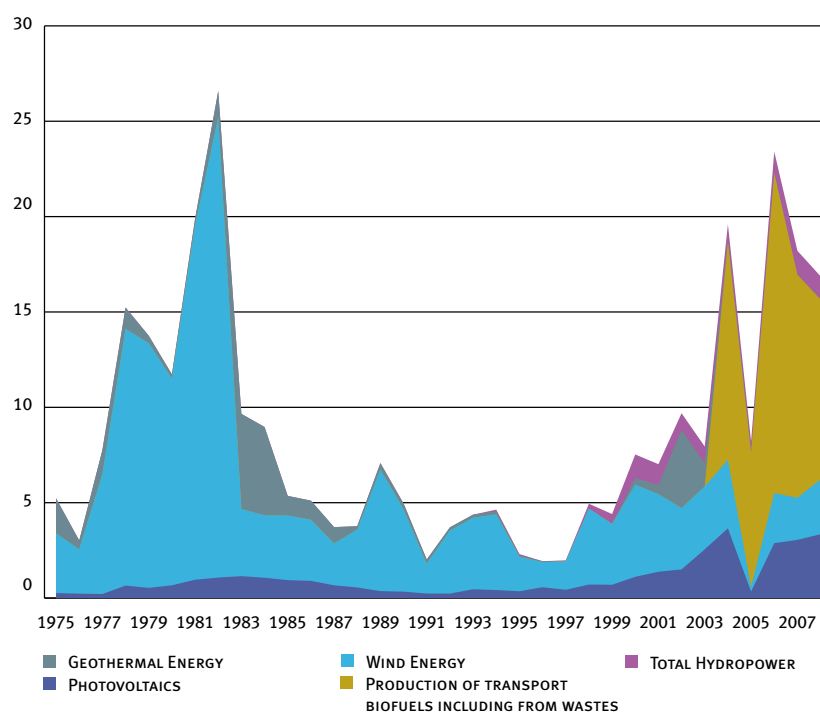
Source: IEA.

**FIGURE 18: NORWAY, DISTRIBUTION OF LOW CARBON ENERGY RD&D BUDGETS, MILL €, 1978-2008.**



Source: IEA.

**FIGURE 19: SWEDEN, DISTRIBUTION OF LOW CARBON ENERGY RD&D BUDGETS, MILL €, 1975-2008.**



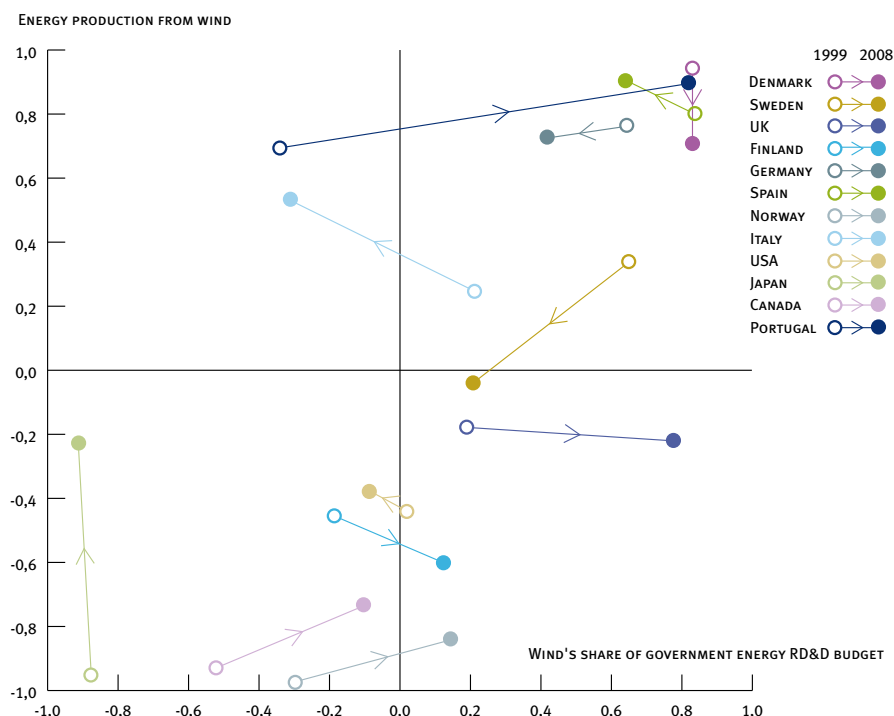
Source: IEA.

## INTERNATIONAL SPECIALISATION

This indicator looks to combine public prioritisation of RD&D in certain technologies with production of electricity from those technologies. Revealed symmetric comparative advantage (RSCA) is used here to compare these two variables (see the full version of this report for an explanation of how RSCA is calculated). Due to the fact this scoreboard has been developed as a pilot project, only wind energy has been developed here as an example. The figure below therefore combines indicators on RD&D budgets for wind with indicators on energy production from wind turbines. A baseline for the calculation of the RSCA is the sum of selected countries for both sets of indicators (Denmark, Finland, Norway, Sweden, Germany, Italy, Japan, Spain, United Kingdom, USA, Canada and Portugal). For both sets of indicators the RSCA has been calculated for two points of development - 1998 and 2007 - to depict the change in the period.

The upper right corner reveals the countries with the highest comparative advantage both in terms of RD&D and energy production. Here we have Denmark, Germany and Spain, for both years. Portugal came into this group in 2007. Sweden's comparative advantage has declined from 1998 to 2007. Finland, Norway and Canada have increased their specialisation in RD&D, but the actual energy production from wind is still very low. The development of Japan is interesting: Japan increased the energy production specialisation, but not at all RD&D specialisation. Italy and USA have decreased their RD&D efforts, but slightly increased energy production specialisation. The United Kingdom has increased RD&D specialisation, but slightly decreased energy production specialisation.

**FIGURE 20: REVEALED SYMMETRIC COMPARATIVE ADVANTAGE FOR WIND ENERGY. 1998 AND 2007.**



For an explanation of how this figure has been calculated please refer to page 47 in the Annex.

Source: IEA.

Based on RD&D budget shares for wind RD&D and energy production shares for wind energy production.

# Throughput Indicators

Throughput indicators are represented in the centre of Figure 3, and are commonly based on bibliometric (scientific publishing) and patent data. Because neither the publishing of scientific articles nor the filing of patents can be considered the desired end result of an innovation process, throughput indicators are said to capture intermediate outcomes. Due to the fact this scoreboard has been developed as a pilot project, a list of recommended keywords and an assessment of previously developed indicators have been included instead of new indicators.

## BIBLIOMETRIC INDICATORS

Bibliometric data is based on scientific publications and includes information on the type of publication, title, authors and their location, for example. Bibliometric data provides insight into the production of scientific literature in a given field and can be used to gauge the contributions in a given discipline by scientists working in a given country. Bibliometric-based measures capture the development of the intermediate production of the innovation process, especially those resulting at early stages of the innovation process.

Following basic bibliometric indicators can be developed:

- Volume of national publishing by technology field;
- International co-authorship patterns by technology field;
- Scientific impact of the national publishing by technology field based on citation measures.

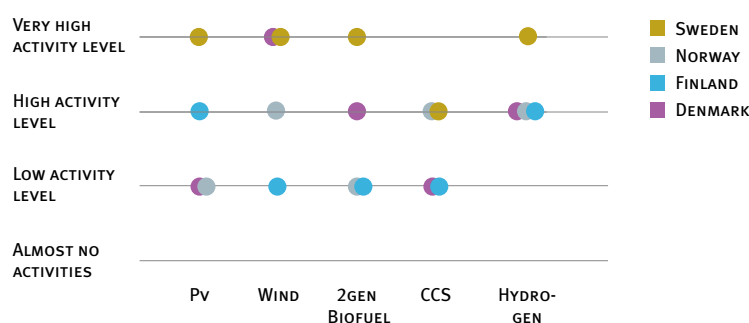
Bibliometric data can be extracted from the ISI Web of Science of Thomson Reuters using keywords tailored to each technology field (a list is found in the full version of the report). This report proposes to use the Science Citation Index and Social Science Citation Index (excluding Arts & Humanities Citation Index) and to include the following document types: article, letter, meeting abstract, note, proceeding paper and review, but not book review or editorial material. It is also possible to use the Scopus database or more specialised databases matched with either ISI WoS or Scopus.

The application of bibliometric data hinges on the definition of keywords. We propose to apply revised search strings based on key words for each technology field as they have been developed in 2007 for the eNERGIA project (Klitkou, Pedersen, Scordato, & Mariussen, 2008). The keywords are used to check titles, author keywords, abstracts and keywords added by the database provider. However, these search strings should be updated regularly because of new technology developments, and they should be verified by technology experts. There are also potential limitations in using this type of data. The delineation of the technology fields is important here, because in several fields it is necessary to avoid too broad a coverage.

The eNERGIA project gave the following results on scientific publishing. The comparative analysis reveals that Sweden has a very high activity level in almost all selected technology fields. Only in CCS the publishing is 'just' high. Denmark has a very high output on wind energy, and a high output on 2<sup>nd</sup> generation biofuels and hydrogen, while CCS and photovoltaics are on a low level. Finland has a high level of activity in hydrogen and photovoltaics, while the other technologies are covered only on a low

level. Norway had high publication output in CCS, hydrogen and wind energy, but lower levels on 2<sup>nd</sup> generation bio-fuels and photovoltaics (Klitkou et al., eNERGIA report Part 2, p. 103).

**FIGURE 21: SUMMARY OF SCIENTIFIC PUBLISHING FOR DENMARK, FINLAND, NORWAY AND SWEDEN. RATING BASED ON COMPARISON BETWEEN COUNTRIES\*.**



Sources: ISI Web of Science, eNERGIA (Klitkou et al., 2008).

## PATENT-BASED INDICATORS

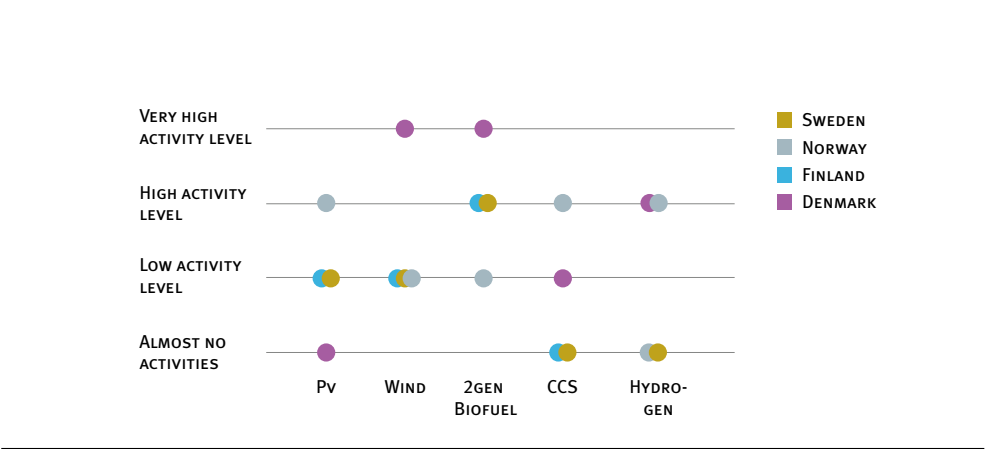
Patents provide a promising proxy to capture ongoing research activity in the field of low-carbon technologies. A patent is an indication of inventive activity has yielded a technology that is new to the field and that has an assumed commercial potential. Indicators based on patenting activity can for example be used to better understand the innovative activities taking place in the private sector. It can also provide an idea of actors (by country or type) who are actively innovating in these technological areas, the degree to which they collaborate, the degree of technology transfer, and so on.

However, using patent-data to monitor emerging technologies faces several recognised challenges. A major one involves categorisation. It is difficult to accurately identify renewable energy technologies in the patent record. Since there is no one-to-one correspondence between patent classes and these technologies, different approaches have been employed to tackle the question of how to exclude irrelevant patents while including relevant patents. A complementary question is how to map patents classes as unambiguously as possible to individual technologies where there is potential overlap. There have been several recent attempts to address these questions at the national level (e.g. the UK: Chatham House report of Lee, Iliev, & Preston, 2009), the regional level (the Nordic level: Klitkou et al., 2008), and the international level (OECD: e.g. Johnstone & Hascic, 2009) to name a few. An overview of these efforts is provided in the full version of the report. Results from the eNERGIA project are presented below.

*“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 [they] 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” (Klitkou et al., eNERGIA report Part 2, p. 103).

**FIGURE 22: SUMMARY OF EPO PATENT APPLICATIONS FOR DENMARK, FINLAND, NORWAY AND SWEDEN. RATING BASED ON COMPARISON BETWEEN COUNTRIES.\***



Sources: EPO, ENERGIA Technology reports, 2008.

A more comprehensive discussion and presentation of data regarding bibliometric and patent indicators is available in the full version of this report, available for download at [www.nordicenergy.net](http://www.nordicenergy.net).

# Output Indicators

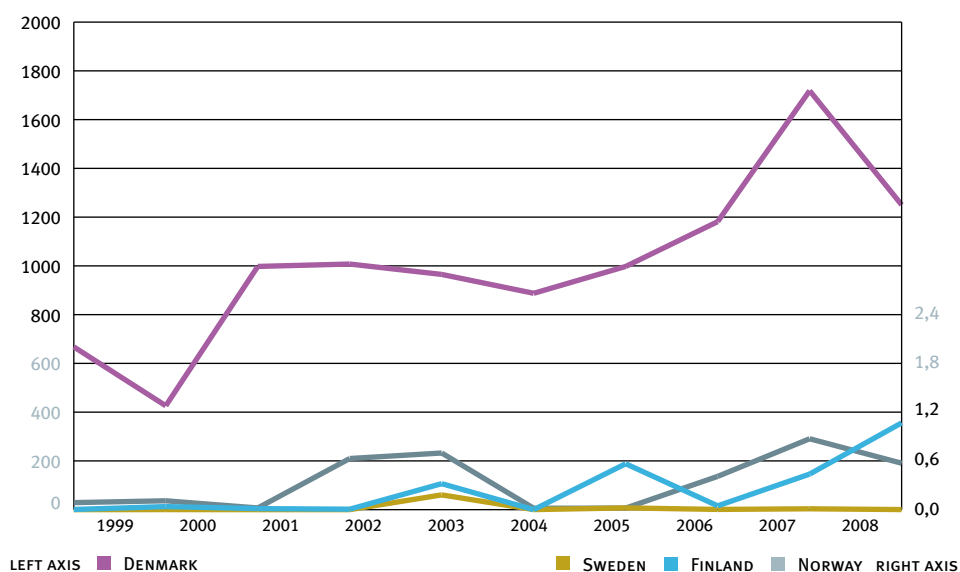
Output indicators reside on the right-hand side of Figure 3, and capture the desired end results of inputs into the innovation system. Relevant output indicators can include energy production, installed capacity, energy technology exports, technology transfer, the definition of standards, Co2 emissions or societal acceptance for example. Depending on which of these indicators is used, challenges crop up in areas such as data availability, and causality between inputs and outputs of the innovation system. This scoreboard looks at energy technology exports, which are relevant indicators for the Nordic countries which do not have large domestic markets.

## ENERGY TECHNOLOGY EXPORTS

Energy technology export is one of the main outputs of energy technology development. The UN Comtrade database is widely used but of the technologies covered by this scoreboard only wind power is categorised clearly in this database. As an example of the shortcomings of this source, as pointed out by Johnstone and Hascic (2009), PV solar technology may be covered by HS 8541.40, but the commodity group includes not only photovoltaic devices but also light-emitting diodes and semiconductor devices and is therefore far too broad.

Most of the Nordic export of wind technology comes from Denmark, which is shown in Figure 21. The figure uses two different axes with different scales, the left for Denmark and the right for the other Nordic countries. The export of Danish wind technology has been compared with the rest of the world in Figure 22.

**FIGURE 23: WIND TECHNOLOGY EXPORT FROM THE NORDIC COUNTRIES. 1999-2008. MILL. USD.**

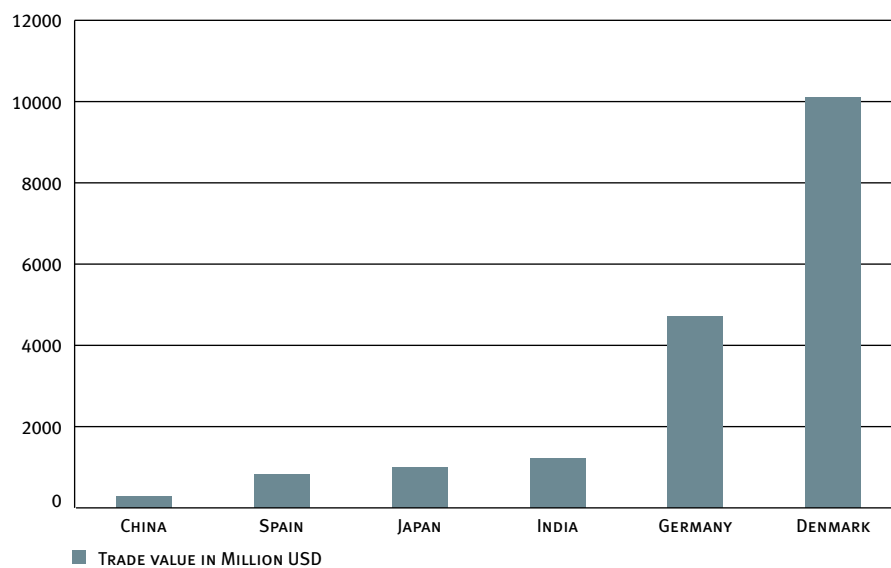


Source: UN Comtrade Database.

Denmark has become the worlds leading exporter of wind energy technology over the last decade, exporting more than double the next largest exporter, Germany.



**FIGURE 24: TRADE VALUE OF EXPORTED WIND TECHNOLOGY. 1999-2008. MILL. USD.**



Source: UN Comtrade Database.

For further discussion of output indicators please refer to the full version of this report, available for download at [www.nordicenergy.net](http://www.nordicenergy.net).

# Policy Indicators

As policies are the efforts of governments to influence the speed and direction of the innovation process, indicators of policy framework conditions give important background information on the development of low-carbon technologies. Measuring policies quantitatively is no easy task, but databases such as the IEA Global Renewable Energy Policies and Measures database (referred to as the IEA Renewable Energy Policy database) facilitate some first steps. This database has some drawbacks however:

1. The information is not complete and may – partially – not be updated;
2. Some of the policy measures are not categorised at all;
3. Many policy measures are simultaneously categorised under several categories, and they are not weighted;
4. Many policy measures are simultaneously categorised under several technology targets, and they are not weighted;
5. The ending year of finalised, superseded or changed policy measures is not given in the database and this makes it difficult to assess the continuity or discontinuity of policy.

However, these drawbacks can be handled by improving and updating the information in this database in the future. The IEA Renewable Energy Policy database allows searching according to different criteria, among others country, year of introduction, current state of the policy measure, policy type, technology target of the policy measure and addressed sector. Policy measures from all five Nordic countries are included, categorised into the following groups:

1. Taxes: renewable energy tax credits and carbon taxes;
2. Tradable permits: green certificates, and quota policies or renewable energy obligations;
3. Incentives and subsidies: feed-in tariff and feed-in premium;
4. Regulatory instruments: acts, concessions and other regulations;
5. Policy processes: White papers, action plans, strategies, agreements, public funds and programmes; and,
6. RD&D: RD&D and technology programmes, RD&D strategies.

The figures below present the policy data gathered from these databases. It seems that a large number of countries first introduced R&D support measures in the 1970s and that other measures, such as investment incentives have been introduced gradually after that. In more recent years a number of countries (including Finland, Sweden, Denmark and Norway) have introduced quantity obligations and tradable permits.

The year where the policy is included in the figure indicates the year it was introduced, regardless of its status.

- Policy introduced and still in force
- ▼ Policy introduced and since superseded
- Policy introduced and since phased out

**FIGURE 25: DENMARK – POLICY MEASURES IN THE IEA DATABASE – ENDURANCE OF MEASURES.**

|                        | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Taxes                  |      |      |      |      | ▼    |      | ▼    |      | ►    |      |      |      |      |      |      |      |      | ►    |
| Tradable Permits       |      |      |      |      |      |      |      |      |      | ●    | ▼    |      |      |      |      |      |      |      |
| Incentives/Subsidies   |      |      |      |      |      |      |      | ►    | ●    | ●    | ▼    | ●    |      | ►►   |      |      |      | ►    |
| Regulatory Instruments |      |      |      |      |      |      |      |      |      | ●    |      |      |      |      |      |      |      |      |
| Policy Processes       |      |      | ►    |      |      |      |      | ●●   | ●    |      |      | ►    |      |      | ▼    |      | ▼    | ►    |
| RD&D                   |      |      |      |      |      |      |      |      |      |      | ●    |      | ►    |      |      |      |      | ►    |

**FIGURE 26: FINLAND – POLICY MEASURES IN THE IEA DATABASE – ENDURANCE OF MEASURES.**

|                        | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Taxes                  |      |      |      |      |      |      | ▼    |      | ▼▼   |      | ▼    | ●    |      |      |      |      | ►    |      |
| Tradable Permits       |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Incentives/Subsidies   |      |      |      |      |      |      |      | ►    | ▼▼   |      |      | ●    | ►●   |      |      |      | ►►   |      |
| Regulatory Instruments |      |      |      | ●    |      |      |      |      |      |      |      |      |      |      | ►    | ►    |      |      |
| Policy Processes       |      |      | ●    |      |      |      | ▼    | ●    | ▼    |      | ▼    |      |      |      | ►    |      |      | ►    |
| RD&D                   |      |      |      |      |      |      |      |      | ▼●   |      | ●    | ●    | ●    | ►    |      |      | ►    |      |

**FIGURE 27: ICELAND – POLICY MEASURES IN THE IEA DATABASE – ENDURANCE OF MEASURES.**

|                      | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|----------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Incentives/Subsidies |      |      |      |      |      |      |      |      |      |      |      | ►    |      |      |      |      |      |      |
| Policy Processes     |      |      |      |      |      |      |      |      |      |      |      | ►    |      |      |      |      | ►    |      |

**FIGURE 28: NORWAY – POLICY MEASURES IN THE IEA DATABASE – ENDURANCE OF MEASURES.**

|                        | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Taxes                  | ▶    |      |      |      |      |      |      |      | ▶▶   | ▶    |      |      | ▶    | ▶    |      |      | ▶    |      |
| Tradable Permits       | ▶    |      |      |      |      |      |      |      |      |      |      |      | ●    |      | ▶    |      |      |      |
| Incentives/Subsidies   |      |      |      |      |      |      |      |      | ▶    | ▼    | ▶    | ▶▼   |      |      |      |      |      | ▶    |
| Regulatory Instruments |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| Policy Processes       |      |      |      |      |      |      |      | ●    | ▶    | ▶▼   | ▶    | ▶▼   | ▶    | ▶▶   |      |      | ▶    | ▶    |
| RD&D                   |      |      |      |      |      |      |      |      |      |      |      |      | ▶    | ▶    |      |      | ▶    |      |

**FIGURE 29: SWEDEN – POLICY MEASURES IN THE IEA DATABASE – ENDURANCE OF MEASURES.**

|                        | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
| Taxes                  | ▶    |      |      | ▶▶   |      |      |      | ▼    |      |      |      | ●    | ▶●   | ▶●   | ●●   | ▶▶   |      |      |
| Tradable Permits       |      |      |      |      |      |      |      |      |      |      |      |      | ▶    |      |      |      |      |      |
| Incentives/Subsidies   |      |      |      |      |      |      | ●●   | ▼    |      | ▼▼   | ▶    |      | ▶●   |      | ●    | ▶    | ▶▶   |      |
| Regulatory Instruments |      |      |      |      |      |      | ▼    |      | ▶    |      |      |      |      |      |      | ▶▶   |      | ▶    |
| Policy Processes       |      |      |      |      |      |      | ▶    |      |      |      | ▶    |      |      |      | ▶    | ▶    |      |      |
| RD&D                   |      |      |      |      |      |      | ●    | ●    |      |      |      |      | ▶▼   |      |      |      |      |      |

Source: IEA Renewable Energy Policy Database

# Conclusions and recommendations

This report has compiled and structured a wide-range of indicators for the conditions and performance of low-carbon energy technology in the Nordic countries. The report has been developed to meet three aims:

1. to provide a tool, equipping decision-makers with an understanding of the nature and state of clean energy technology development, and therefore insight into how to influence this development;
2. to act as a pilot study, utilising a limited geographic and technological scope to develop sound methodologies that can be adapted to more comprehensive scoreboards in the future; and,
3. to be a vehicle to promote better data collection, by demonstrating indicators where data is available and proposing indicators where data gaps exist.

This pilot project has drawn on data collected by international data collection agencies such as the IEA, the OECD, and Eurostat according to established standards and guidelines. The focus has been on these core-data for the core-set of Nordic countries.

As a result, the pilot project demonstrates a set of indicators based on existing longitudinal and comparative core-data for the Nordic countries. The indicators are related to different stages and levels of technological innovation systems. The applied model differentiates between structural indicators, input indicators, throughput indicators, output indicators and policy indicators.

To conclude, following ten recommendations for the further work on indicators of low-carbon energy are proposed:

## **1. RELIABLE INPUT INDICATORS**

There is a need for addressing the lack of consistent and reliable data on private-sector RD&D budgets and the need for an improved collection of data on public demonstration budgets by the IEA. The existing IEA data is still patchy and needs to be improved.

## **2. OUTPUT INDICATORS BASED ON MEASUREMENT OF INDUSTRIAL ACTIVITIES**

The measurement of industrial activities has turned out to be the major weakness of the available data on low-carbon energy. It is proposed an improved categorisation and collection of data on low-carbon energy related industrial activities, such as value added from the manufacture of certain energy technology equipment, and an improved categorisation and collection of export goods data. The latest amendment of the industrial classification systems (NACE) introduced subcategories that capture this industrial activity (such as 28.110 for wind turbine manufacturing). It is important that individual countries begin to collect data for these categories according to the common guidelines.

## **3. PRIVATE INVESTMENTS AND LICENSING**

There are also areas where indicators would be helpful but where the data is difficult to assemble. These include a wider set of reliable data involving *private investments* (through venture capital) and licensing of low-carbon energy technology.

#### 4. TECHNOLOGY TRANSFER

The development of low-carbon energy technologies can be facilitated by *international technology transfer*. New indicators that capture the scope, type and direction of technology transfer would therefore be important.

#### 5. INTERNATIONAL STANDARDS

There are also areas where important data sources exist but concerted effort to collect it has not yet been systematically pursued. Particularly relevant in this case are indicators that capture the elaboration of international standards in the area of low-carbon energy technologies. Technological standards are essential for low-carbon energy technologies, which are based on technology platforms involving a wide range of different actors. Further work could concentrate on developing useful indicators based on existing information about this activity, such as on relevant committee activities, resulting standards, and the application of those standards.

#### 6. RELATIONSHIP BETWEEN INDICATORS

With reference to different aspects that shape the innovation system, the report presents a set of core-data according to what it calls the ‘near-view strategy’. It furthermore proposes some composite indicators to show how individual data-types can be combined to explore interesting relationships (examples of this are the Revealed symmetric comparative advantage indexes constructed by combining RD&D data with either energy production and/or value added data). These data-sources can be compiled in different ways based on the type of problem a policymaker is interested in, provided that certain basic precautions are taken (e.g. that units of analysis are consistent and the data is otherwise compatible). In the future, such indexes should also use throughput measures, such as patents or publications, and relations between different types of indicators should be explored.

#### 7. BIBLIOMETRIC AND PATENT INDICATORS

Extensions to the core-data are also suggested in this report. The report particularly recommends ways to adapt and incorporate *bibliometric and patent-data* so as to improve innovation indicators for low-carbon energy technology. These ‘throughput’ indicators may be particularly useful as they help to address a major empirical shadow in the existing data material, namely the lack of consistent and reliable data on private-sector RD&D, which can be compared across countries and over time. They need regular updating since technological development creates new possibilities and solutions which have to be captured by new keywords and categories.

#### 8. MONITORING CARBON STORAGE

Data on carbon storage infrastructure, such as available carbon storage sites and carbon transport infrastructure will be necessary in the future for the implementation of carbon capture and storage in large scale. The existing and future carbon storage sites need to be regularly monitored to avoid environmental disasters, and these data should be made public.

## **9. POLITICAL FRAMEWORK CONDITIONS**

Political framework conditions are important for the outcome of technology development and deployment. There is a need for improved categorisation of measurable policy variables to assess policy framework conditions.

## **10. PUBLIC ACCEPTANCE**

Improved comparable information on public acceptance of new energy technologies would also be helpful. Social acceptance (or resistance to) a technology is considered to be an important element in any innovation process. It is assumed that society has a stake in, and some influence over, the development and introduction of a new technology or product. In this way societal actors, be they consumer organisations, environmental groups or others, can be seen as stakeholders, who influence public opinion, governments and firms (Deuten, Rip, & Jelsma, 1997). Some interesting work on this is being developed in Eurobarometer activities, but this does not include Norway or Iceland and is also neither continuous nor systematic.

It is the hope of the authors and those commissioning this report that it may serve to improve the quality of future scoreboards. By presenting a methodology for measuring and comparing low-carbon energy technology development, offering a 'proof of concept' and by highlighting the shortcomings in data, this report has taken a step in the right direction. We hope that future efforts can take it a step further.

# Annex

COMPLETE DATA TABLES FOR ALL FIGURES CAN BE FOUND IN THE ANNEX OF THE FULL VERSION OF THIS REPORT, AVAILABLE FOR DOWNLOAD AT [WWW.NORDICENERGY.NET](http://WWW.NORDICENERGY.NET).

## LIST OF ACRONYMS

|             |                                                              |
|-------------|--------------------------------------------------------------|
| €           | Euro                                                         |
| BERD        | Business Expenditures on R&D                                 |
| CCS         | Carbon dioxide Capture and Storage                           |
| ECLA        | European Classification                                      |
| EPO         | European Patent Office                                       |
| EST         | Environment Sound Technologies                               |
| EU or EU-27 | European Union                                               |
| GBAORD      | Government Budget Appropriations or Outlays on R&D           |
| GDP         | Gross Domestic Product                                       |
| HS          | Harmonised Commodity Description and Coding System           |
| IEA         | International Energy Agency                                  |
| IPC         | International Patent Classification                          |
| IPTS        | Institute for Prospective Technological Studies (of the JRC) |
| ISI WoS     | ISI Web of Science                                           |
| ISIC        | International Standard Industrial Classification             |
| JRC         | Joint Research Centre (of the European Commission)           |
| NACE        | Statistical Classification of Economic Activities            |
| OECD        | Organisation for Economic Co-operation and Development       |
| PV          | Photovoltaic                                                 |
| R&D         | Research and Development                                     |
| RD&D        | Research, Development and Demonstration                      |
| RCA         | Revealed Comparative Advantage                               |
| RSCA        | Revealed Symmetric Comparative Advantage                     |
| SET-Plan    | (European) Strategic Energy Technology Plan                  |
| S&T         | Science and Technology                                       |
| UN          | United Nations                                               |
| USD         | US Dollar                                                    |

## UNIT ABBREVIATIONS

|      |                                   |
|------|-----------------------------------|
| GJ   | Gigajoule                         |
| GW   | Gigawatt                          |
| GWh  | Gigawatt hour                     |
| kcal | Kilocalorie                       |
| KJ   | Kilojoule                         |
| kgoe | Kilogram of oil equivalent        |
| kW   | Kilowatt                          |
| kWh  | Kilowatt hour                     |
| Mt   | Million tonnes                    |
| Mtoe | Million tonnes of oil equivalent  |
| MW   | Megawatt                          |
| MWh  | Megawatt hour                     |
| MWe  | Megawatt electric                 |
| MWth | Megawatt thermal                  |
| Toe  | Tone of oil equivalent = 107 kcal |
| TWh  | Terawatt hour                     |

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Taking a technology's share of government energy RD&D as an example, the Revealed Symmetric Comparative Advantage (RSCA) for both 1999 and 2008 are calculated separately using the following formula.

$$RCA_{RDD} = \frac{\frac{RDD_{if}}{\sum_i RDD_{if}}}{\frac{\sum_f RDD_{if}}{\sum_{if} RDD_{if}}}$$

First the Revealed comparative advantage (RCA) is calculated and then RSCA:

$$RSCA = \frac{RCA - 1}{RCA + 1}$$

The results range from -1 to +1, comparing the score of that country with the average of all countries in the sample for that year. A positive score therefore indicates that the technology in question had a larger share of total government energy RD&D budgets than the average share for all countries included in the figure for that year.

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