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Nordic Energy Research

Nordic Energy Technology Scoreboard

Nordic Energy Technology Scoreboard

Full Version

Antje Klitkou, Lisa Scordato and Eric Iversen

Preface

This is the extended 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-Arantegui (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 Gjærde
Director, Nordic Energy Research

Oslo, June 2010

This report is available in both a concise and full version. The concise version is available in hard copy. Both versions are can be downloaded from www.nordicenergy.net

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1 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).

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 hydropower, 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.

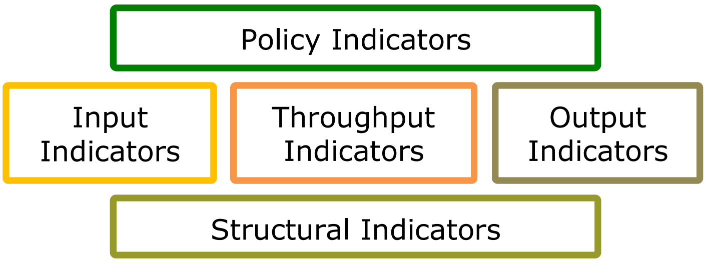
10. **Public acceptance** – improving the availability and comparability of data.

With these challenges in mind, three strategies were employed in selecting and compiling the indicators that make up this scoreboard.

- A **near-view** strategy based on compiling available data 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.
- A **mid-view** strategy based on harvesting indicators using standard-definitions, such as classifications in databases of patents or articles. 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 instead.
- A **long-view** strategy involving long-term development work to provide relevant measures that may be useful in the future. These indicators require improvement of the collection and classification of the areas identified above.

Using the three strategies above, a selection of indicators have been gathered and 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 5 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. Despite Finland and Sweden being the only two Nordics to use nuclear power in their energy mix they spend a relatively smaller share of energy R&D on nuclear technologies than Norway for example.

   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 generation. Norway generates more electricity than it consumes thanks to the common Nordic grid 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 hydropower 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.

While this project was able to yield interesting results, further development hinges on the improvement of data. Comprehensive, consistent and well categorised data collection in areas where data is insufficient 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.

2 Concepts and issues

Different dimensions of human activities and conditions have long been subjected to measurement. Measurements, for example, allow comparisons over time and between populations; compiling measurements can be a useful means to and can be helpful in taking stock and in determining the extent of change that may be due to given factors. In terms of innovation, cross-country comparisons can be used to posit an empirical relation between knowledge accumulation and growth of output or productivity.

There are some initial caveats which should be noted at the outset of this report. A general one is that sometimes the zeal to measure can obscure or blind one to the purpose of the exercise in the first place. Indicators on the conditions and performance of low-carbon energy technology are in many cases still taking shape. In this situation, international data collection agencies such as the International Energy Agency (IEA), the Organisation of Economic Cooperation and Development (OECD), Eurostat, and others provide an indicator that the data used has been collected according to established standards and guidelines which are documented along with limitations (cf. the near-view strategy below). This presentation emphasises data collected from such recognised authorities. In applying the data, however, one should remain critical of their use.

A second more specific caveat is that some activities and conditions lend themselves better to measurement than others (Verbeek et al., 2002). Even straightforward measures, such as emissions, can pose difficulties. The measurement of scientific and technological activities is a far more challenging area that poses a set of general challenges both in terms of the collection and the interpretation of data (OECD, 1992).

2.1 Innovation indicators: a system overview

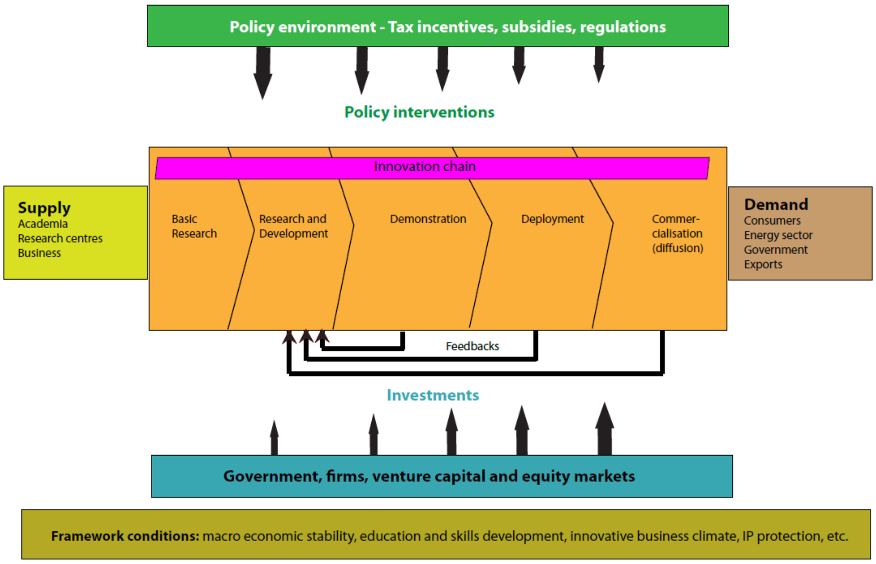
The conceptual framework established by the OECD in the early 1990s provides a useful point of reference for this exercise. The Oslo Manual defines innovation in terms of new products and processes and significant technological changes in product and processes (OECD, 1992). More generally, "innovation" can be seen as an original contribution to the stock of knowledge in the economy (Verspagen, 1994, p. 159). Innovation process encompasses a series of scientific, technological, organisational, financial and commercial activities, whose boundaries are not necessary sharp. The underlying activities and the overall process are furthermore not homogeneous, but they may be particular to a given situation; they are not set in stone but may change, etc.

The OECD's Frascati Manual 1993 notes that innovation activities can only really be measured indirectly, using input and output of impact indicators. The following figure lays out the schematic dimensions of a generic innovation process in the context of a set of external factors that will affect innovative activities (IEA, 2008, p. 170). These external or structural elements include policy factors as well as underlying conditions such as access to a skilled labour force.

Following Grupp and Schwitalla's taxonomy (Grupp & Schwitalla, 1989), *Input indicators* or *resource indicators* include a diverse set of measures for the allocation of human and other resources to the innovation process. Common input measures include R&D outlays and R&D personnel. They are the most standardised measures of innovative activity. These measures however generally do not pick up input to other innovation activities that are not directly associated to R&D. Collaborative R&D efforts or R&D activities of international industry players across national borders are difficult to capture by national data. The Frascati manual lists the following six activities:

- Tooling-up and industrial engineering
- Manufacturing start-up and pre-production development
- Marketing for new products
- Acquisition of disembodied technology
- Acquisition of embodied technology
- Design

Figure 2: Innovation Systems and measurements: application to the field of renewable energy.

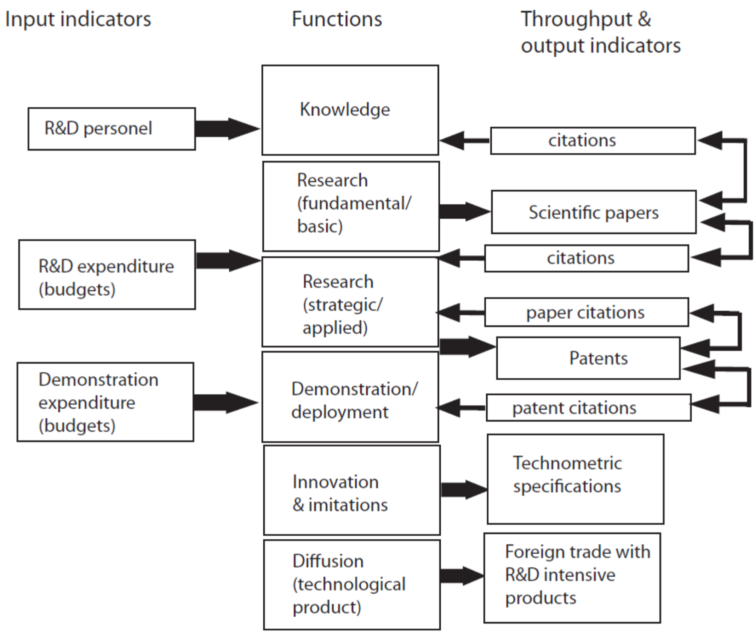


Source: adapted and modified from Grubb, 2004 and Foxon, 2003 and ETP 2008

The second one is particularly notable in the renewable energy context due to the importance of scaled production facility (see below).

Output indicators attempt to capture the economic effects of the innovative activity in question. Measuring output is more challenging. One challenge is that economic effects are not the only interesting products of innovation processes; there are others such as a learning effect 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.

Figure 3: R&D functions and their linkage to in- and output indicators.



Source: Amended figure (Grupp & Schwitalla, 1989)

In addition to these standard measures, a third class of measure is so-called *by-put* or *throughput* indicators (Grupp & Schwitalla, 1989). Throughput indicators are measures that attempt to capture the intermediate products of the innovation process, especially those emanating from the formal R&D processes. The main throughput indicators are: patents, bibliometric, and citation statistics. Figure 3 provides a presentation of these categories of measurement in terms of their function during the innovation process (Grupp & Schwitalla, 1989).

2.2 Aspects of low-carbon technologies

The nature of low-carbon energy technologies pose a number of particular measurement challenges in addition to the general issues mentioned above.[1] One challenge is how to measure emerging technologies (IEA, 2006). A number of low-carbon energy technologies are interesting to track. In terms of the figure above, they are still in the middle of the *innovation chain*. An additional challenge is that the set of technologies in question vary as to their maturity as well as the maturity of their intermediate and end markets. This raises the question of how to account for the differences between and within the types of renewable energy technologies.

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 here (IEA, 2006):

(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_2 capture and storage and integrated bio-energy systems.

A further set of challenges is associated with the scale of the technologies. A major aspect here is that the innovation chain for ”low-carbon” technologies may be distinct from other types of innovation in at least one important way: it 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. Standardised statistics are being developed to capture this peculiarity.

Another aspect to consider is associated with scale. These technologies are not necessarily stand-alone technologies but may involve significant changes in different parts of existing value chains. For example biofuels require change or complementary developments in engine manufacturing as well as fuel distribution. A first implication that is caused by the systemic of the technologies is that cooperation is likely to be important during the development and deployment of the technologies. Public-private cooperation is one way to overcome resistance and path dependency in the energy sector. Strategic oriented energy companies are investing heavily in R&D and do often so in close collaboration with research institutes. Measures of cooperation are therefore important, but difficult to get.

A second implication is that the deployment of the technologies may face different degrees of resistance from established and competing systems based on other (e.g. carbon-based) energy sources. A degree of coordination is necessary in order to overcome such resistance. This implies coordination-costs to facilitate deployment of the emerging technological systems. Figure 4 from Grubb (2004) illustrates that these technologies face a fundamental challenge in competition with the established and pervasive fossil fuel paradigm. It suggests first that an overall measure for the dissemination of renewable technologies will ultimately be their ability to compete with the costs of energy generation based on fossil fuels. Switching costs are very high and build barriers for further development and deployment of emerging low-carbon energy technologies.

Achieving price parity with fossil fuels is a remote aim. This suggests the importance of public involvement to adjust the playing field through taxes on the one hand and subsidies on the other: i.e. Fossil fuel and carbon taxes/renewable technologies and subsidies tend towards 1. Another feature is that technologies related to fossil fuels do not stand still. Innovation also continues to improve the efficiency of fossil fuels. Following Grubb, this suggests the use of data on R&D budget for fossil fuels as a measure of *carbon-lock-in*, i.e. comparison of expenditures on the different groups of technologies in IEA's RD&D budget indicator – energy efficiency, fossil fuels, renewables and nuclear technologies, hydrogen and fuel cells, other power and storage technologies, total other technologies or research (Grubb, 2004). See also Kaloudis & Pedersen (Kaloudis & Pedersen, 2008) on the use of R&D for a composite of all energy production technologies.

[1] See Smith (2008) for a discussion.

Figure 4: Main stages of technology development. Source: Grubb (2004)

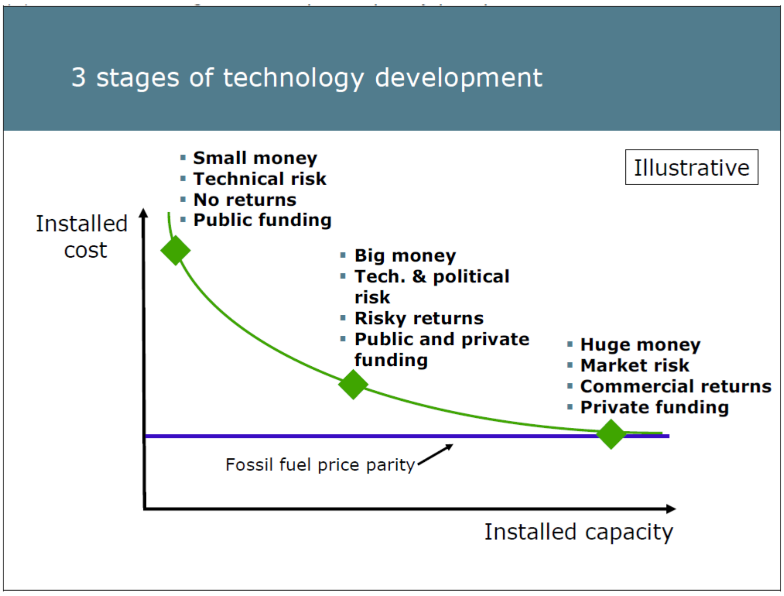


Table 1: Modes of energy innovation (adapted from Smith, 2008)

	Incremental change	*Radical change*	*Disruptive change*
Climate control technologies without emission reduction	Reduced deforestation	Sulphate emissions in atmosphere Carbon sinks	
Emission reducing innovation	Enhanced engine efficiency District heating and cooling Gas baseload power	Carbon sequestration/ clean coal (including capture and geological storage) Advanced motor fuels Bioenergy Fluidised bed combustion (improved combustion efficiency) Advanced materials for transportation Efficient combustion technologies	
Low or zero emissions technologies	Heat pumping technologies for buildings (including storage) Development of existing nuclear capabilities Hydropower	Geothermal energy Solar panels Wind energy systems	Fusion power Hydrogen Ocean energy Photovoltaic power systems Concentrated solar power (orbital sun-tracking mirrors) Advanced fuel cells Advanced energy storage technologies (batteries, capacitors, compressed gas storage)

In this context it is useful to appreciate that different renewable energy technologies may represent incremental, disruptive, or radical forms of innovation (Smith, 2008). Table 1 maps some renewable technologies in terms of the Smith matrix. Combining technology maturity and this systemic dimension, the table suggests that different technologies might be expected to 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.

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 (for example a new set of patent-based measures is currently being made available for the first time: see below). One challenge is thus to present a clear and accurate picture of relevant aspects of the changing landscape from the different empirical information derived from different sources (a list of selected literature is enclosed to the inception report of this project).

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 emerging technology aspect is underscored by the prominence of trends and scenarios and other forms of extrapolation in some of the sources. The literature can be divided into three types in terms of the sort of data they build upon:

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

The literature indicates that at least four generic aspects of low-carbon energy technologies may affect the choice of metrics. They:

- involve emerging technologies;
- are heterogeneous and coexist at different stages of maturity;
- are complex technologies, which are systemic in nature; and,
- include some *sui generis* aspects: e.g. large outlays for deployment/demonstration sites.

This literature suggests that the selection of indicators that are relevant and available will tend to be found in the early stages of the development of an innovation system (Figure 2 and Figure 4). This is especially the case for second and, more so, for third-generation technologies. This implies that available indicators are found mostly on input (e.g. public R&D budgets) and throughput indicators (particularly patent and bibliometric based measures). The literature recommends metrics that focus on differences within specific technological types. This may either be in terms of horizontal comparisons of year-to-year developments in the particular technology or in terms of vertical comparisons of the particular metric between countries.

Technologies at a very early point of development also face greater risks that may prevent them from reaching their assumed potentials. These risks are compounded by the systemic nature of the technologies. Thus an aim that has been widely advocated is to encourage a diversity of renewable technologies. So although one size does not necessarily fit all, an argument can be made to include a general metric for the level of diversification between the technologies. Several aspects in the literature point to the importance of public support in one shape or another. This includes the early stage technology argument, inasmuch as public support is seen as important in overcome cooperation-costs and other more systemic challenges. In this setting measures reflecting activity of the ‘policy environment’ of Figure 2 are important.

Finally the literature implies the importance of cooperation between different actors (i.e. complexity of technology, its scale, its systemic nature). This indicates the desirability of measures that pick up cooperation and collaboration (not least international cooperation) at different stages of the development and deployment of these technologies.

3 Strategy and data coverage

3.1 Strategy and distinctions in the selection of indicators

Our approach for the scoreboard 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.

A preliminary distinction suggested by the previous chapter is that there are basically three strategies to collect and present data for such a scoreboard.

- There is a **near-view strategy** that is based on compiling available data collected according to standardised guidelines and established routines — such as the concerted multinational efforts of IEA or Eurostat. This dimension is emphasised in the interest of reliability and comparability. It is the dominant strategy for analysis in the literature reviewed. These data are collected on a regular basis and are therefore relatively current. They are therefore useful in laying the basis to analyse trends. Near-view indicators tend to be centred on conventional input and output indicators. A set of measures of this type will form the core of the scoreboard.

- There is next a **mid-view strategy**. This strategy is based on harvesting indicators based on standard-definitions. This strategy can be applied to the two main through-put indicators. Applying data from patents and bibliometric-based data in turn relies on establishing common definitions of the patent-classes (IPC or ECLA) and search-terms respectively. To map industrial activity at a sufficiently fine-grained level also depends on defining existing classification systems (NACE). Some of these have been defined (see below), but are not necessarily used in the available data. The scoreboard recommends categories especially for through-put indicators.

- Finally there is the **long-view strategy**. This strategy involves long term development work to provide relevant measures that may be useful in future. In the case of the Nordic countries, these are indicators of private-investment (through venture capital), licensing, and applying, developing and/or improving relevant industrial classification systems for industrial activity and export. Technological standards may for example be developed as long-view indicators (see http://energy.ihs.com/). The follow-up of measurable governmental goals on low-carbon energy is another strategy.

3.2 Data coverage

First we define the geographical coverage of the scoreboard while identifying a set of benchmark countries where comparable data is available; and we explore the potential time-series for different data:

- **Country Coverage**: the exercise emphasises indicators which are available across country and across time. Country-coverage is tied to the core-countries. These are the five Nordic countries: Denmark, Finland, Iceland, Norway and Sweden. We will also operate with a set of European reference countries, which include: United Kingdom, Germany, Spain, Portugal, France, Italy, the Netherlands and Austria. In addition the USA, Japan and the EU 27 are used as baselines.
- **Timeframe**: primarily following a near-view strategy, we propose to rely on periodic data (annual) with at least a 10 year run of data. The default time-frame is 1998-2007. 2008 figures are used when available. A longer time frame is used for public RD&D budgets which are displayed from mid 1970's.
- **Technologies**: the exercise will concentrate on four renewable energy technologies: wind, photovoltaic solar, bio-fuels, geothermal; and carbon capture and storage (CCS).

3.3 Categorisation of the metrics

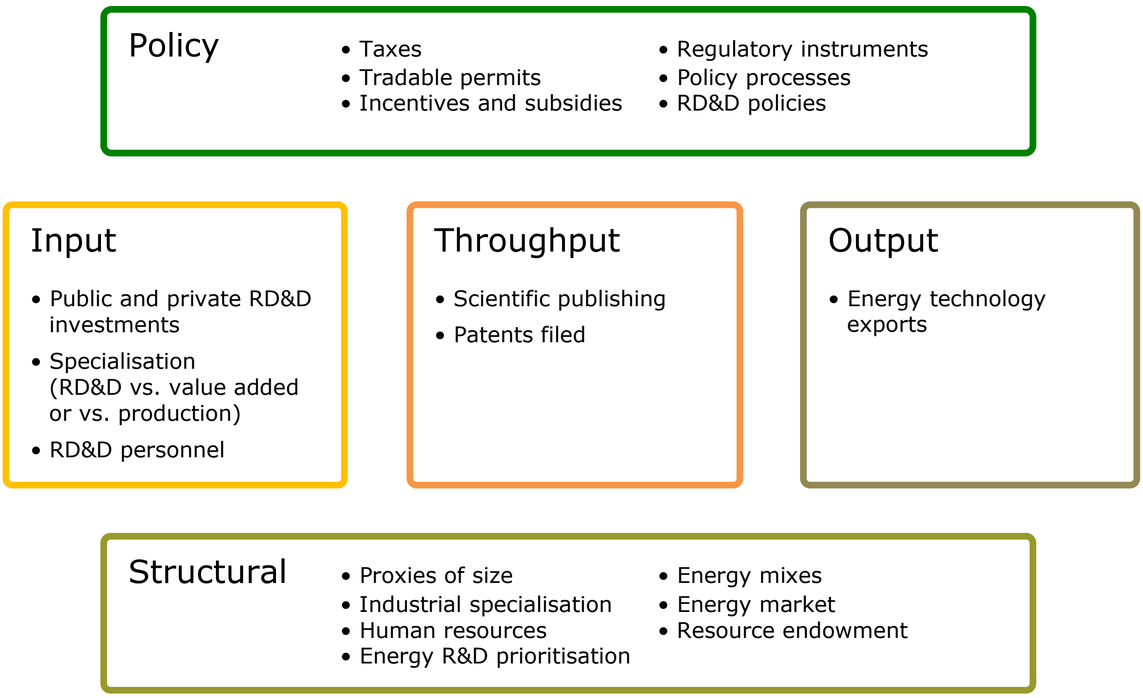
The core of the scoreboard will be three sets of measures of capacity and performance. A first set of measures will be a base-line of *structural indicators*. These key country variables will include conventional measures to put national capacity into perspective (e.g. population, GDP, etc.), human resources, industry specialisation, energy prices, energy balances by energy source as well as measures to capture resource endowment (e.g. solar radiation, wind energy potential, etc.) which might affect national performance.

The second set of the core builds on more traditional *input and output indicators* found in existant sources, following the near-view strategy. In light of the scan of the growing literature, this core-data will size up on the one hand RD&D expenditure and other available input factor data that may shape the development of the strategic energy technologies in question, and, on the other hand dimensions of national output and performance in these segments.

In addition to this core-data, an *extended set of measures* will be explored. Two extensions are envisioned in order to take into account other factors that may play an instrumental part in shaping the innovation processes in the respective countries. The first extension is to include 'throughput' indicators primarily in the form of patent- and bibliometric-based metrics. These *throughput indicators* can also provide measures especially of research collaboration. A second extension is to compile comparable indications of different forms of policy-contributions across countries. Here a set of *policy measures* are assessed, such as taxes, tradable permits, financial incentives and subsidies, regulatory instruments, RD&D related policy measures, and policy processes.

The result is that the overall exercise will combine a set of conventional and extended indicators.

Figure 5: Schematic overview of the indicators used in the report



3.4 Ongoing debate on indicators relevant to energy

As has been mentioned there is a growing literature that attempts to size up the development, production and use of low-carbon energy technologies. Some of these activities are of clear relevance with regard to the Nordic Energy Technology Scoreboard and are shortly described hereafter.

3.4.1 EU level activities

At the EU level regular mapping of energy research capacities is being undertaken within SETIS (SET-Plan Information System). Part of this work, led by the Institute for Prospective Technological Studies (IPTS) of the European Commission’s Joint Research Centre (JRC), was finalised in 2009. The results, presented in a report on R&D Investment in the Priority Technologies of the European Strategic Energy Technology Plan, estimates the current research and development (R&D) investments in selected low-carbon energy technologies in the EU-27 funded by the Member States. The report is a central reference input to the Communication on Financing Low-carbon Technologies, part of the implementation of the Strategic Energy Technology Plan (SET-Plan) for Europe. The assessment is focused on a single indicator representing research and development inputs: the R&D investments.

The report is highly relevant in the context to the Nordic scoreboard project as it presents and discusses common methodological issues. There is also a certain overlap concerning the technologies considered in this project: wind energy, photovoltaics (PV), carbon dioxide capture and storage (CCS) and bio-fuels (the remaining ‘SET Plan priority technologies’ not included in this project are: concentrating solar power, hydrogen and fuel cells, smart grids, nuclear fission and nuclear fusion).

On the output side new activities to map the growth in environmentally sound technologies or eco-innovation are being planned by the European Patent Office (EPO). The results are to be published in April 2010, however preliminary raw data from the EPO shows that patent applications for environmental technologies indicate rapid growth. In the ten years from 1998, patent applications for new energy innovations grew by an average of 6% per year. Wind power, fuel cells, solar thermal and photovoltaic energy technologies have shown the strongest growth since the late 1990s. The US, Germany, Japan and the Netherlands are leading the way with the highest number of innovations in the new energy sector, with companies such as General Electric, Siemens and Nissan having made the most patent applications (Euractive, 2009). The initiative is carried out in co-operating with the UN Environment Programme (UNEP) and the International Centre on Trade and Sustainable Development (ICTSD) in a joint study to examine the role of patents in the development and transfer of Environmentally Sound Technologies (EST). The first part of the study is directed to energy generation and involves a ‘mapping’ of environmental aspects of energy generation with places in the IPC and a ‘tagging’ of EST-related patent applications in the relevant IPC subgroups. The ‘mapping’ scheme is attached in Annex 5 at the end of this report.

Other activities developing indicators is the ‘Measuring eco innovations' (MEI) project for the European Commission funded by DG Research. Specifically, MEI offers a conceptual clarification of eco-innovation, developing a typology based on an understanding of innovation dynamics. It identifies and discusses the main methodological challenges in developing indicators and statistics on eco-innovation and how these may be overcome. Challenges for eco-innovation measurement to investigated are:

- The ongoing nature (changing characteristics) of an eco-innovation
- The novelty and importance of an innovation
- Possibilities for combining different innovation measures (input indicators and output indicators, direct and indirect measures)

Within this framework studies have been undertaken which examines patents as a measure for eco-innovation (Oltra, Kemp, & de Vries, 2008)

3.4.2 OECD and IEA activities

Furthermore this pilot project shares methodological issues on indicator development discussed with the OECD. The development of a set of indicators of environmentally sound technology innovation (‘EST innovation') is one of the key elements of the OECD 2009-2010 Programme of Work of the Working Party on National Environmental Policies. Interesting work has been done to develop robust search algorithms to develop indicators of the EST innovation (for a discussion on patents see on patents in this report).

The latest insights from the International Energy Agency (IEA) energy indicator work also includes important aspects related to the project. The goal is to show policymakers how in-depth indicators can be used to track the progress in efficiency and identify new opportunities for improvements. Strong statistical foundation is essential to support energy indicator activities. The IEA has therefore taken steps to ensure that all member countries can participate fully in strengthening the data collection, which currently has limitations on quality, detail and timeliness. Sector level data are still in need to be improved. In this regards the IEA urges countries to collect detailed energy consumption data at the sub-sector level; and complement value-added data with physical production of key commodities (IEA, 2009b). In occasion of the IEAs 35th anniversary in 2009 the IEA Energy Scoreboard was published, which assesses IEA member countries on 35 key energy trends (IEA, 2009a).

A common conclusion of the above mentioned activities is that, with respect to private R&D expenditures, data are unavailable or incomplete (compare also section 4.2.3 Private R&D investments).

4 Indicators and methodological considerations

We distinguish between five types of measures: 1) structural indicators that size up national capacities; 2) input indicators that capture investments into RD&D activities: 3) output measures that reflect the output from different technology and innovation activities, 4) throughput indicators based on patent and bibliometric measures and 5) a set of measurable policies. The scoreboard will consist of a core of three types of near-view indicators and an extension of two types of mid-view indicators.

4.1 Structural indicators

The scoreboard is built first on a set of structural indicators to take account of inherent differences at the national level. To capture national effects, six sets of variables are proposed. These are designed to promote comparability across country and time by putting the presentation of the indicators into perspective of the national context.

- Proxies of size
- Industrial specialisation
- Human resource measures (R&D personnel)
- Framework conditions
- Energy mixes by energy source
- Energy market
- Resource endowment measures

4.1.1 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_2 emissions per capita, energy production, net import of energy and R&D intensity as percentage of GDP and shares of 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 2).

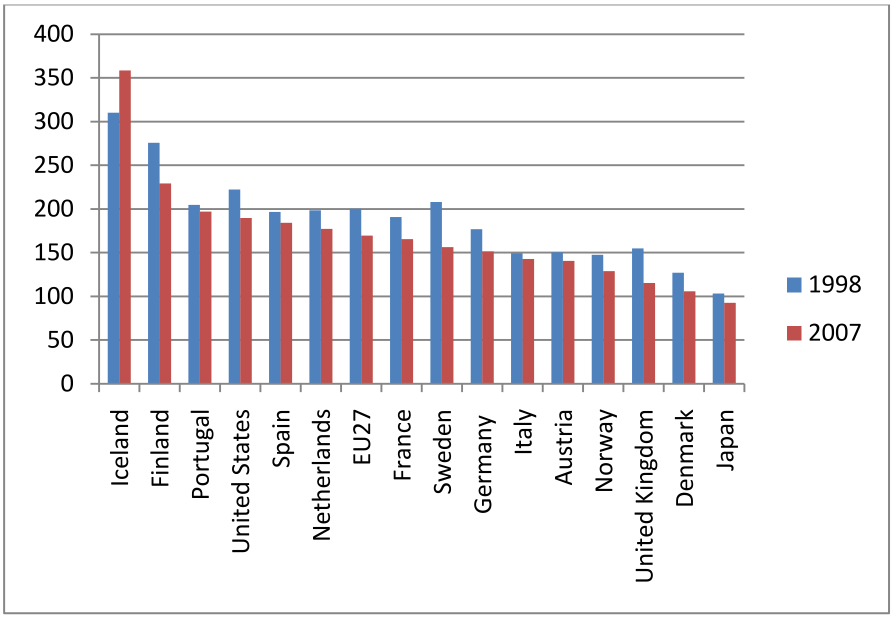
Table 2: Overview table of selected country variables for 2007. Source: Eurostat and IEA.

	Pop. (mill)	GDP (billion €) [a]	CO_2/pop (t CO_2/ capita)	Energy prod. (Mtoe)	Net imports (Mtoe)	R&D intensity % of GDP	% of Energy in GBOARD	% of total IEA budgets [d]	Energy RD&D - government budgets [e]
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[c]	2,2	195,829
Italy	59,3	1 289	7,38	26,38	157,99	1,18	4[c]	4,14	368,443
Portugal	10,6	132	5,20	4,62	21,82	1,21	0,9[c]	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[c]	29,73	2645,788
EU27	496,5	10 685	10,4[b]	849,55	988, 35	1,85	3		

Notes to Table 2: a) billions €, at 2000 exchange rates, source: Eurostat; b) 2006 value, source: (EC, 2009); c) 2006; d) percentage of total IEA (€8898 mill=100%) public energy RD&D budgets; e) millions € (2008 prices and exchange rates), source: IEA

Energy intensity (Figure 6) reflects the energy consumption of an economy and its overall energy efficiency. It is calculated as the ratio of gross inland energy consumption divided by the gross domestic product (in constant prices, base year 1995).

Figure 6: Energy intensity of the economy - Gross domestic consumption of energy divided by GDP (at constant prices, 1995=100) - kgoe per 1000 €. Source: Eurostat

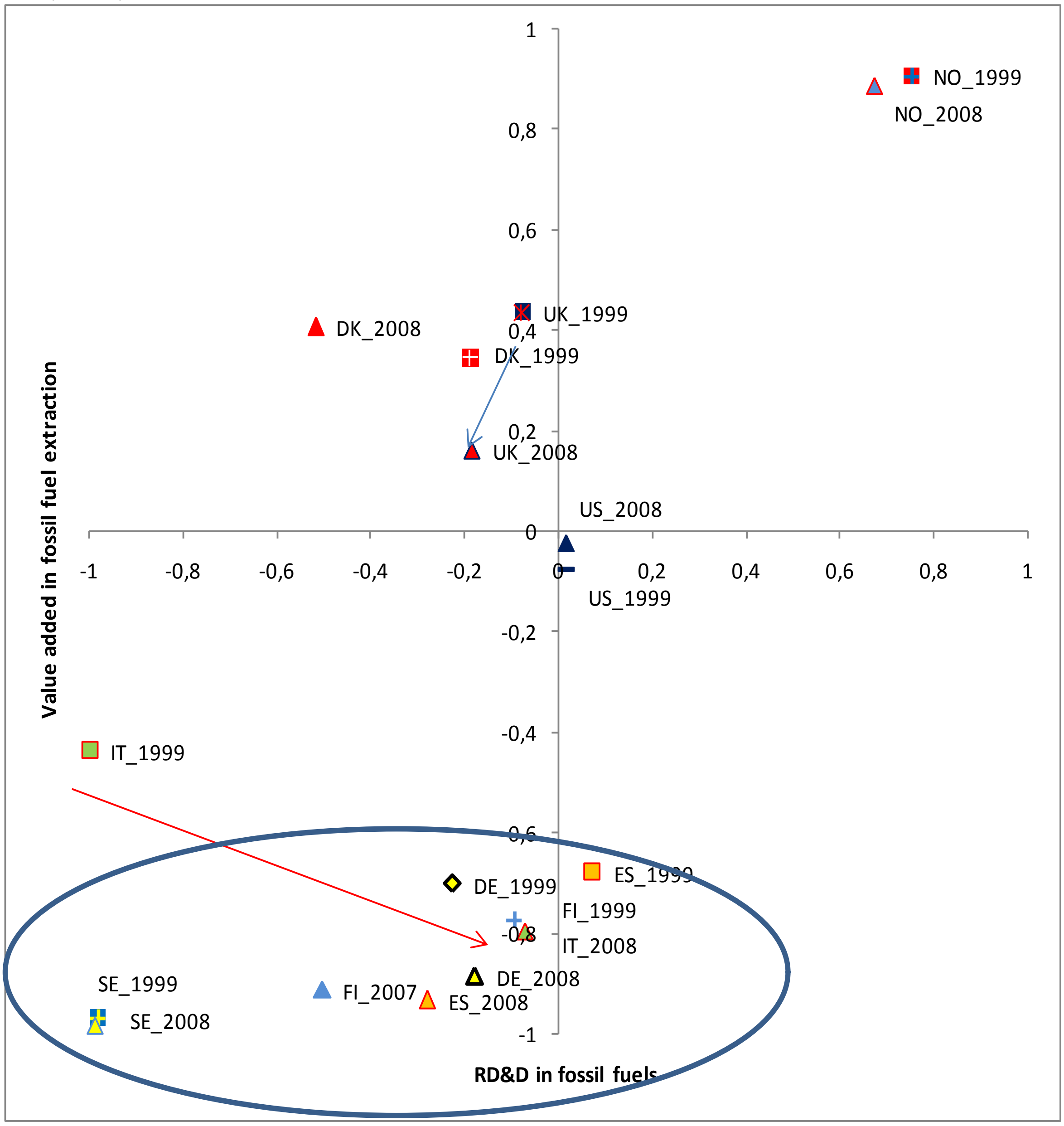


Note: Latest available year for Iceland is 2006

4.1.2 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. For the analysis of the industrial specialisation of the Nordic countries we suggest to use two sets of indicators: the specialisation of value added by industry sector and the specialisation of R&D personnel by industry sector. 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 by fossil fuel extraction to the economy 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. The specialisation for energy production based on wind is calculated similarly (see section 4.2.2). The value added data is accessible from the OECD STAN database, 2009-2010 for all OECD countries, but by today the latest data on Iceland are from 2006. The data on public RD&D budgets can be retrieved from IEA (see section 4.2.1).

Figure 7: Revealed symmetric comparative advantage for fossil fuels. 1999 and 2008. 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.

Figure 7 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.

The *Revealed symmetric comparative advantage* (RSCA) is calculated as following:

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

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

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

Results are plotted in a diagram where the RD&D budget is one axis and energy production the other axis. Both axes go from -1 to +1.

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.

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).

As a conclusion can be said that 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_2 emissions by carbon capturing and storage.

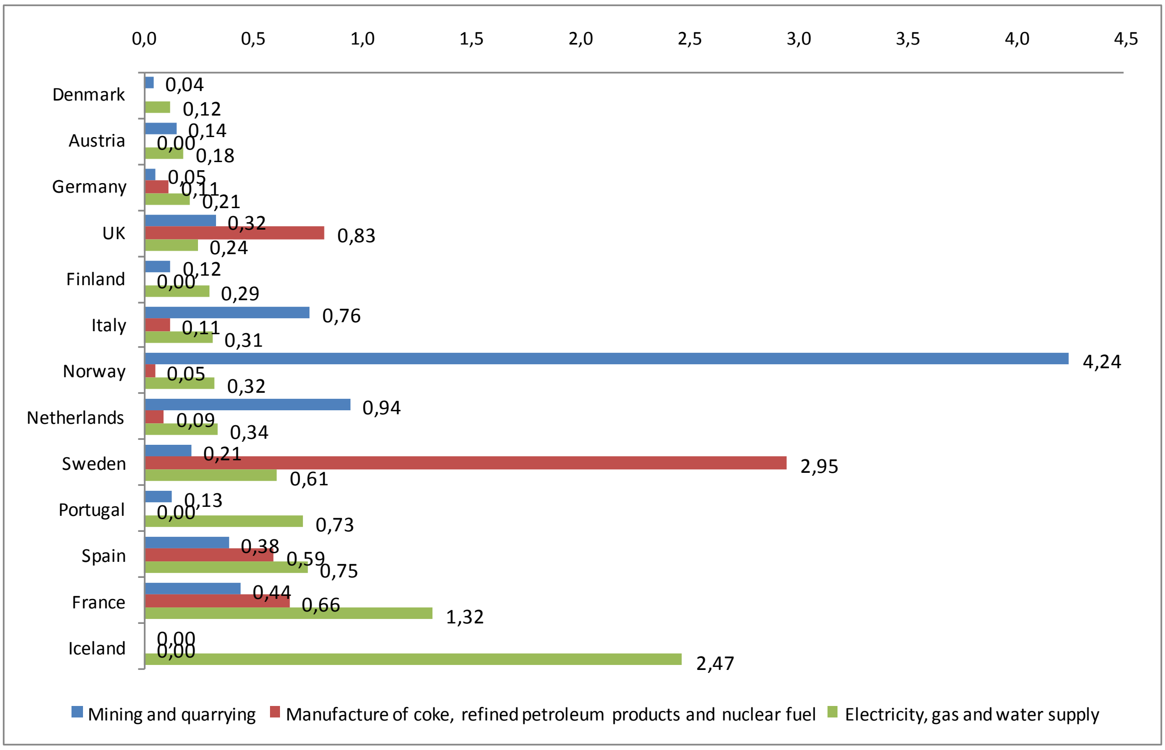
4.1.3 Human Resources

As a proxy for human resources in the industrial sectors we use shares of total R&D personnel in the selected industrial sectors. We calculated the shares of total R&D personnel for 2007 (2006 for Iceland) in following industrial sectors 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 8 illustrates that the share of R&D personnel in the energy related business enterprise sector varies across the countries analysed but is generally modest across. Notably Norway has a relatively high share of R&D personnel in Mining, Sweden in Manufacture of coke, refined petroleum products and Nuclear fuel and Iceland in Electricity, gas and water supply.

Figure 8: R&D skills, share of all NACE branches of total R&D personnel in business enterprise sector, NACE 10-14, NACE 23 and NACE 40-41. 2007 full time equivalent. Source: Eurostat.



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

4.1.4 Framework conditions for R&D on low-carbon energy technologies

A useful indicator for analysing general framework conditions for the development of new energy technologies is data on governments appropriations allocated to R&D in different socio economic sectors, provided by Eurostat data: *Government budget appropriations or outlays for R&D* (GBAORD). The data is collected from government R&D funders and maintained by Eurostat and the OECD and follows the Nomenclature for the Analysis and Comparison of Scientific Programmes and Budgets. The socio-economic objective 05 *Production, distribution and rational utilisation of energy* is the most relevant category. Sub-categories distinguish between different renewable energy technologies, but values are still very patchy and not yet available for the Nordic countries. There is therefore room for improving the collection of data for the energy related subgroups of GBAORD. However, as explained in the coming section of this report, the R&D database from the IEA follows a scientific/technical nomenclature and contains data with a high level of detail. The IEA data is therefore more useful when comparing countries' energy RD&D budgets by energy technology.

Table 3: Classification of energy relevant sectors in GBAORD

Code	GBOARD term
05	**Production, distribution and rational utilisation of energy**
0500	General research on production, distribution and rational utilisation of energy
0505	Renewable energy sources
05051	Solar thermal and photovoltaic
05052	Geothermal energy
05053	Water, wind and wave energy
0500	General research on production, distribution and rational utilisation of energy

The following figures illustrate the trends in GBAORD from 1998 to 2007 in the Nordic countries, Japan, USA and EU27.

Figure 9: GBAORD towards Production, distribution and rational utilisation of energy, Euro per inhabitant (2-year moving average). Source: Eurostat

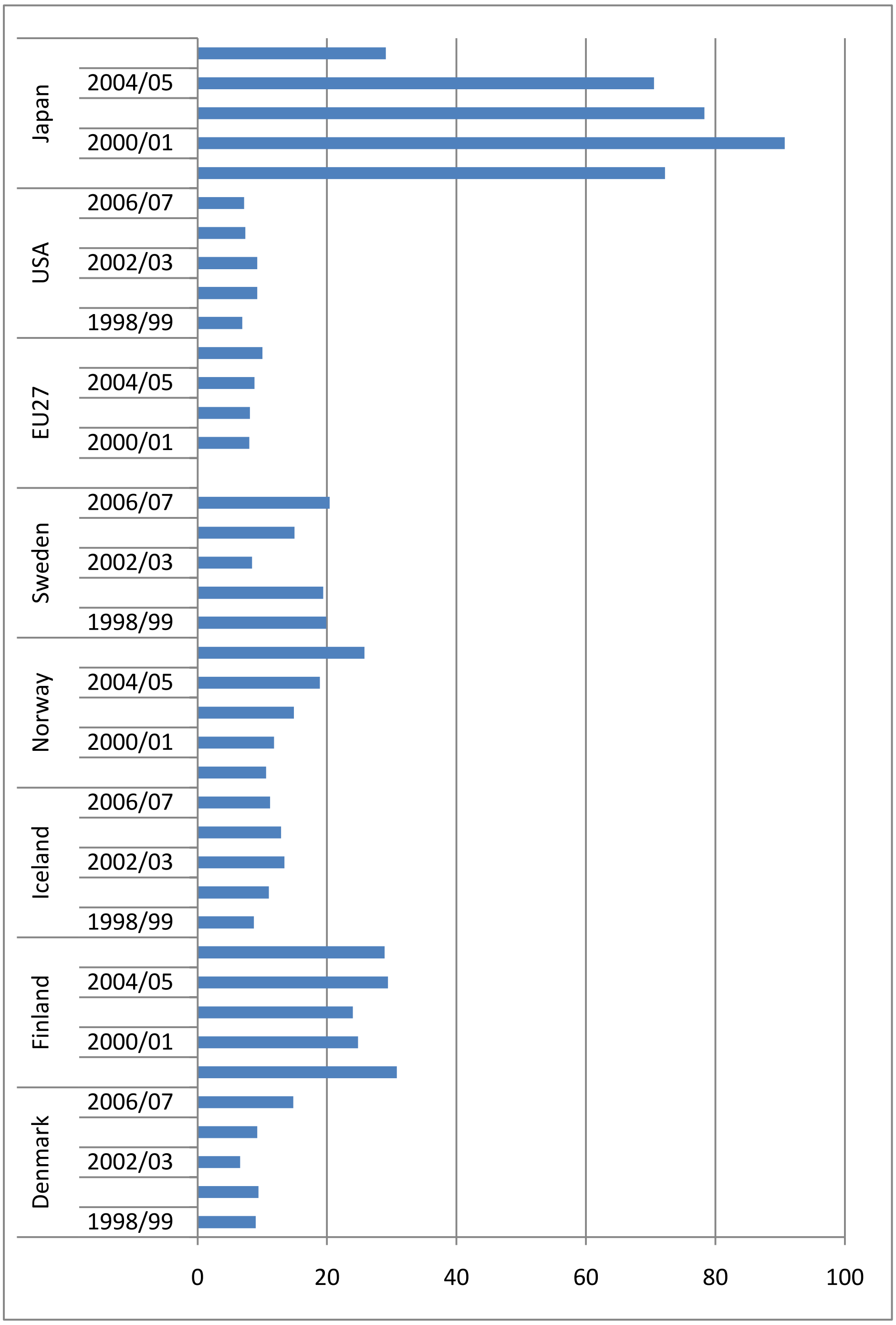
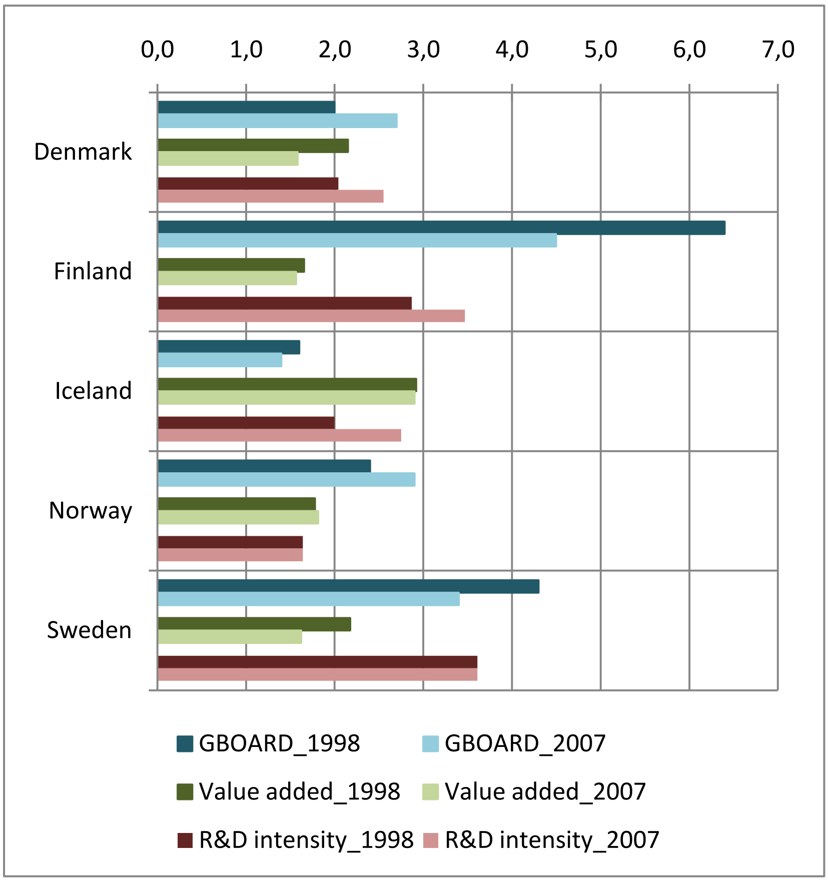


Figure 10 provides an overview of the framework conditions for the development of renewable energy technologies in the main five Nordic countries. It highlights a high but declining share in the GBOARD on energy in Finland and Sweden, and a lower but clear increasing GBOARD share for Denmark and Norway. The share of value added generated in the electricity generating sector is highest and also 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.

Figure 10: Framework conditions for the development of renewable energy technologies in the Nordic countries. Percentage Shares of totals. 1998 and 2007. Sources: Eurostat, OECD Stan database.



Note to figure 10: Share of GBAORD on Production, distribution and rational utilisation of energy, share of value added in the industry sectors Electricity, gas, steam and hot water supply and general R&D intensity of the countries as a share of GDP.

4.1.5 Energy mixes

For the purposes of compiling and collecting data on energy mixes the Eurostat database has proved to be the most useful source. Eurostat has developed a coherent and harmonised system of energy statistics. Annual data collection covers the 27 Member States of the EU, the candidate countries of Croatia and Turkey, and the European Economic Area countries of Iceland and Norway; time-series run back to 1985 for some countries, but are more generally available from 1990 (Eurostat).

For each country data has been collected for gross electricity production and primary energy production. This has been done in order to allow for comparisons between the countries' most important sources for electricity generation with the countries' energy production profiles. Energy production is also an indicator of energy investments.

A further important indicator is the net installed capacity of renewable energies. The IEA data from According to IEA the net maximum capacity of renewable energies is "the maximum active power that can be supplied, continuously, with all plant running, at the point of outlet... This assumes no restriction of interconnection to the network" (IEA, 2009c). The data on installed capacity fuelled by renewable energy sources gives a good insight into the position of the different energy technologies. Capacity data serves as an indicator for the potential of electricity production, but there can be large differences between the capacity and production data, especially for decentralised solar photovoltaic installations (IEA, 2009c). Worldwide growth of capacity is highest in wind and solar power, for the Nordic countries the installation of solar power is less important. The capacity data is collected from IEA statistics (but is also available in Eurostat) and is presented in the Appendix.

Gross electricity generation

Figure 11: Denmark, gross electricity generation, GWh. Source: Eurostat

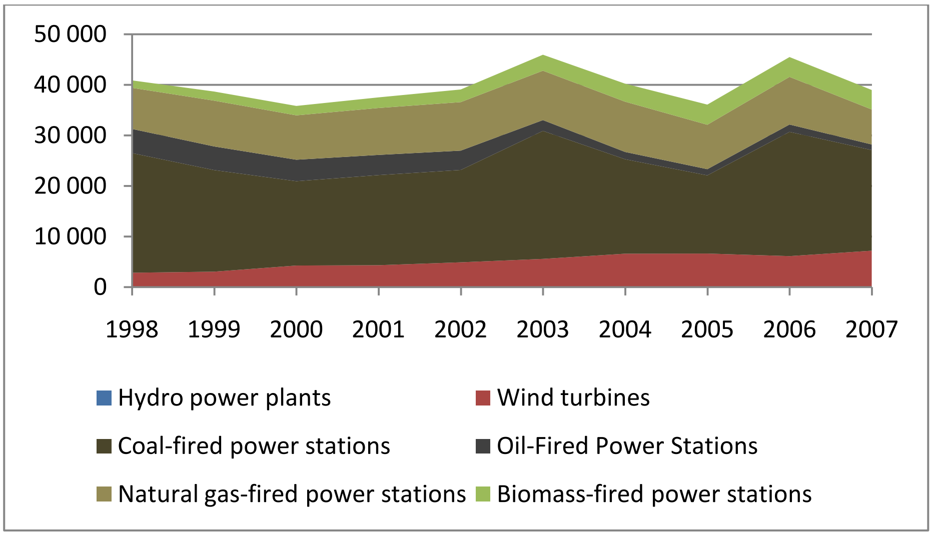


Figure 12: Finland, gross electricity generation, GWh. Source: Eurostat

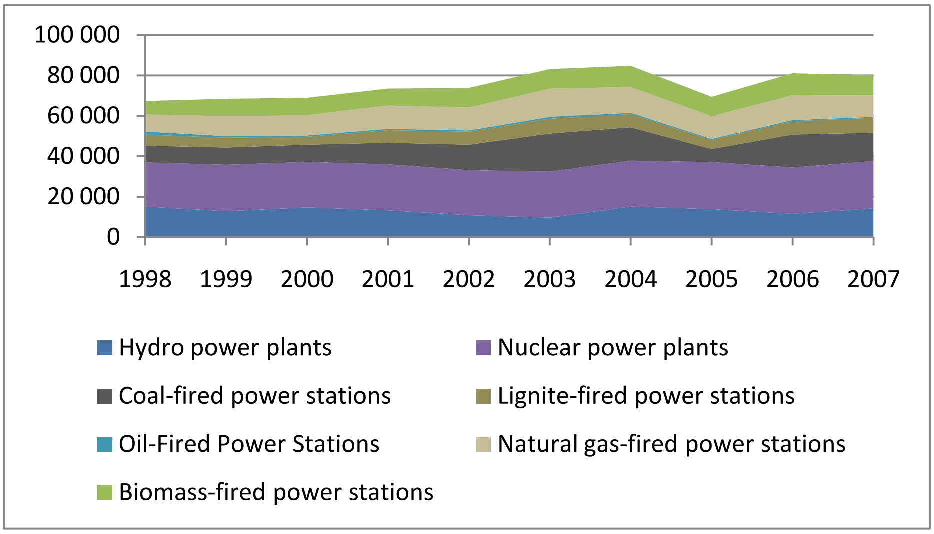


Figure 13: Iceland, gross electricity generation, GWh. Source: Eurostat

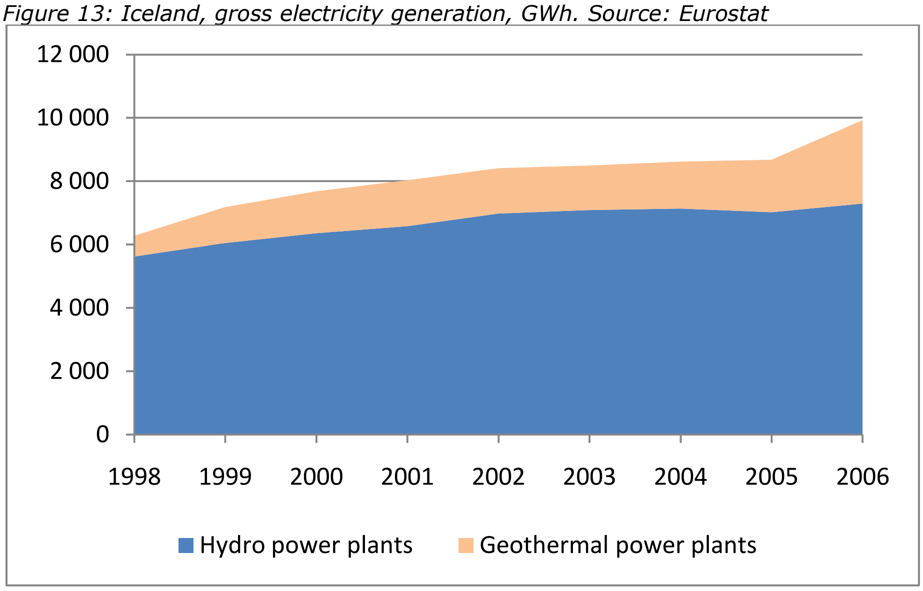


Figure 14: Norway, gross electricity generation, GWh. Source: Eurostat

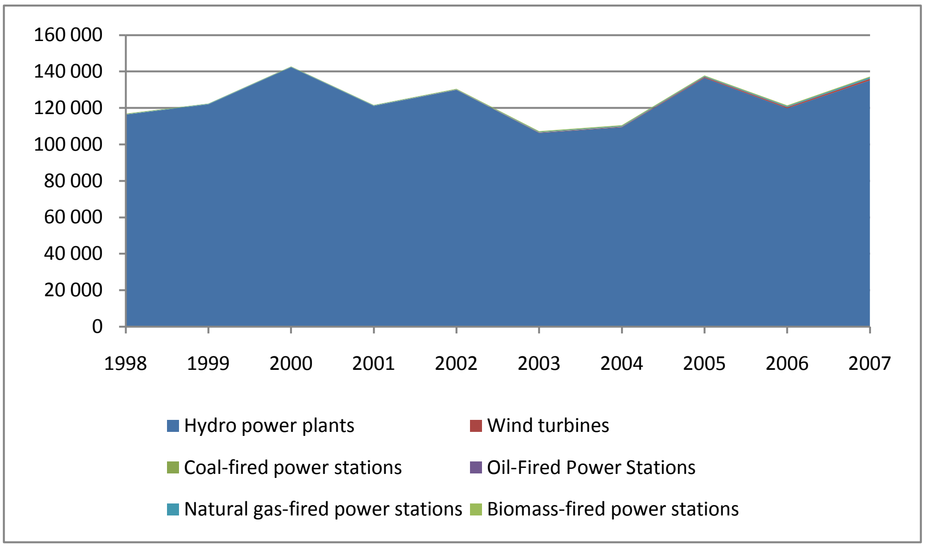


Figure 15: Sweden, gross electricity generation, GWh. Source: Eurostat

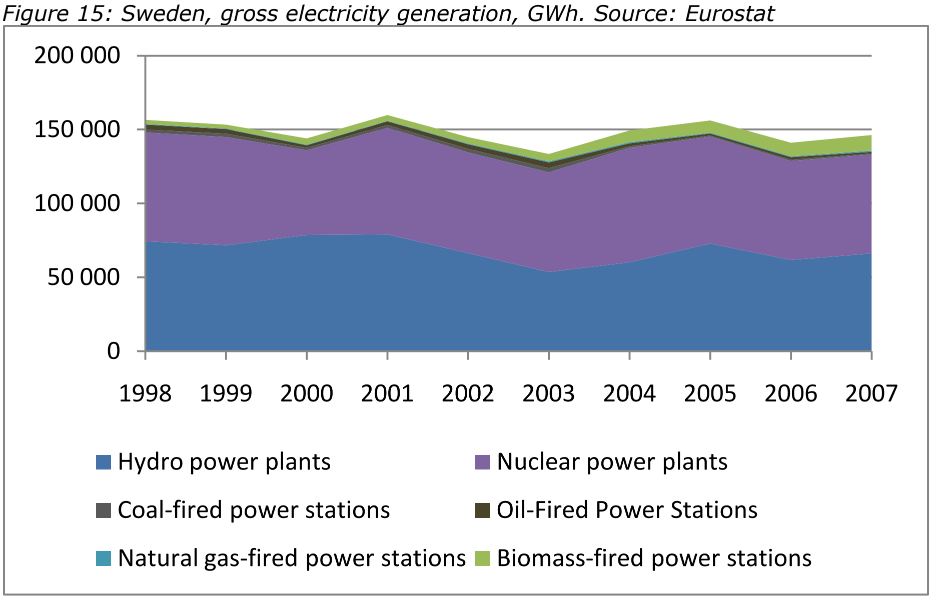
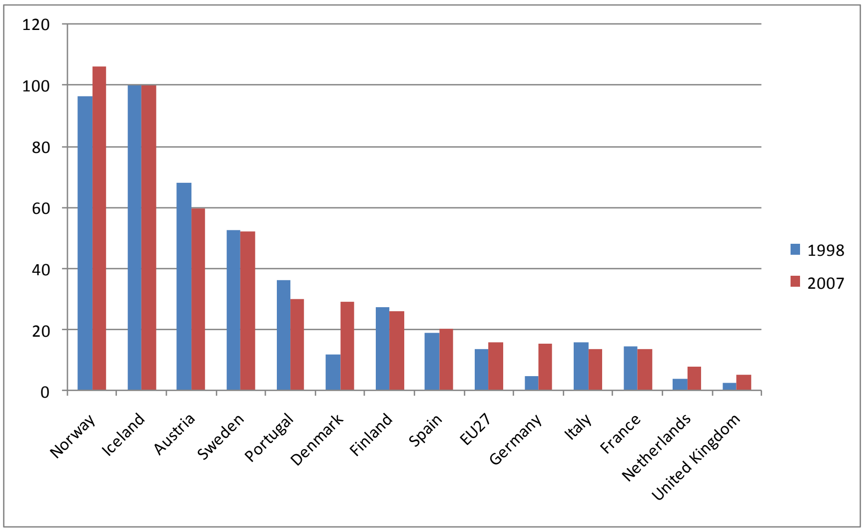


Figure 16 gives a ranked order of the included countries according to the share of electricity consumption provided by renewable energy sources for two points in time, 1998 and 2007. The fact that Norway has a higher share than 100% is due to the fact that Norway is exporting electricity on a large scale, 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 hare of 52%, and Finland has a share of 26% in 2007. Among the reference countries should be highlighted Austria 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 16: Percentage share of renewable energy - Contribution of electricity from renewables to total electricity consumption, 1998 and 2007. Source: Eurostat



Note to figure 16: Shares for the USA and Japan are not available in Eurostat.

Primary energy production

The following figures illustrate the different primary energy production trends in the Nordic countries from 1998 to 2007 for renewable energies, fossil fuels and nuclear. In line with the trends in the EU primary energy production is declining since a few years. A notable exception is Iceland which has seen a sharp increase in energy production the last two years. The figures demonstrate also 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.

Figure 17: Denmark, Primary energy production 1000 toe. Source: Eurostat

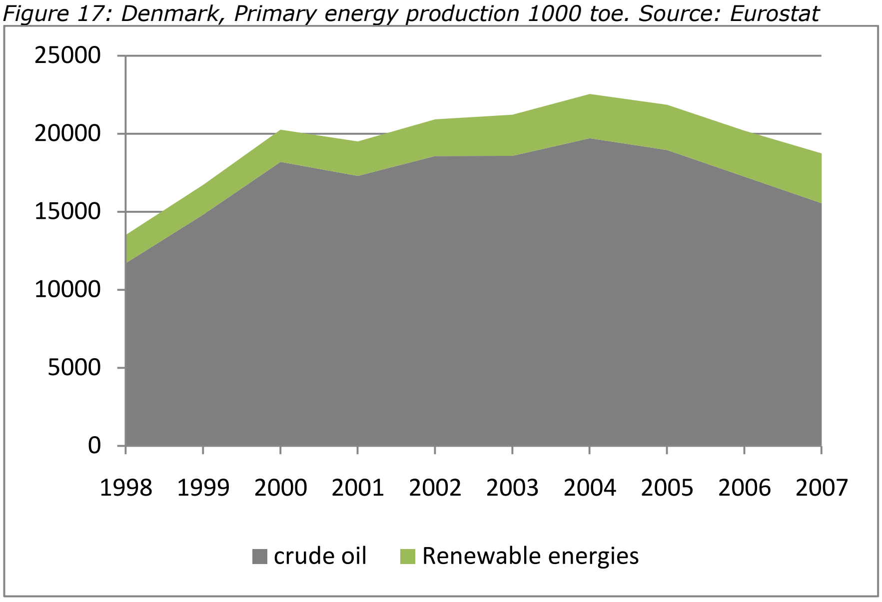


Figure 18: Sweden, Primary energy production, 1000 toe. Source: Eurostat

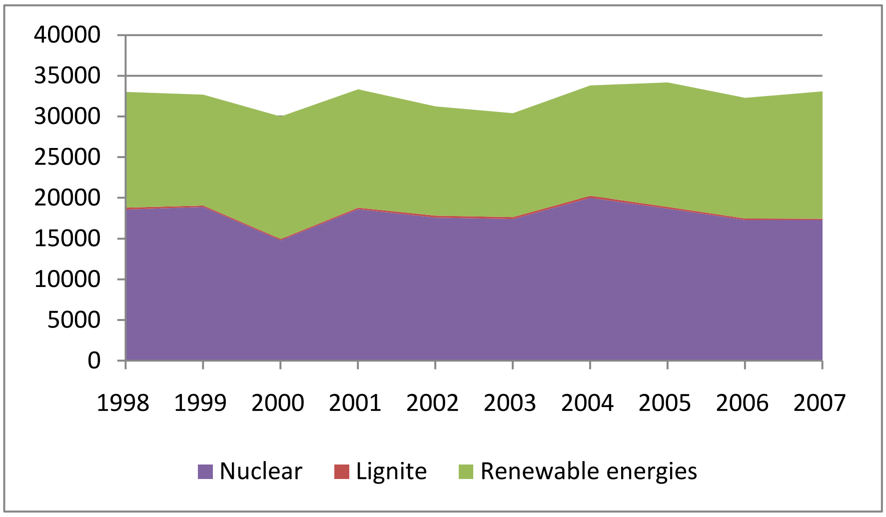


Figure 19: Norway, Primary energy production, 1000 toe. Source: Eurostat

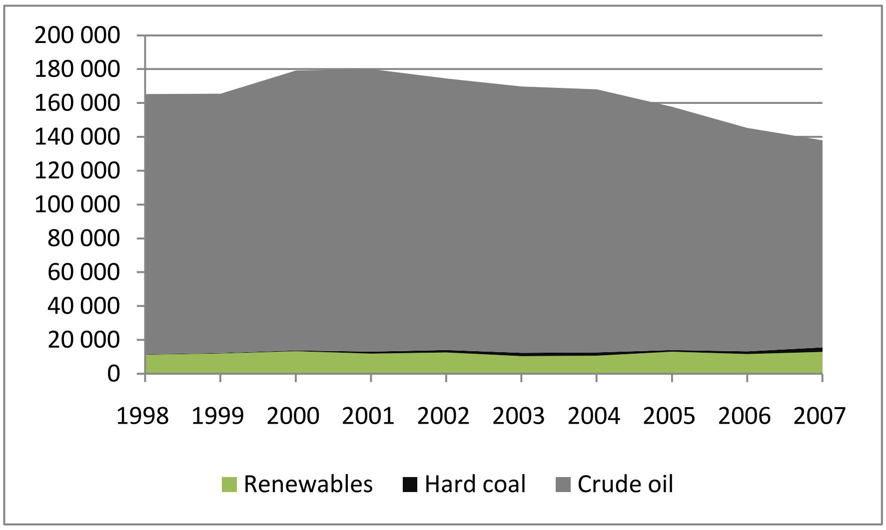


Figure 20: Finland, Primary energy production, 1000 toe. Source: Eurostat

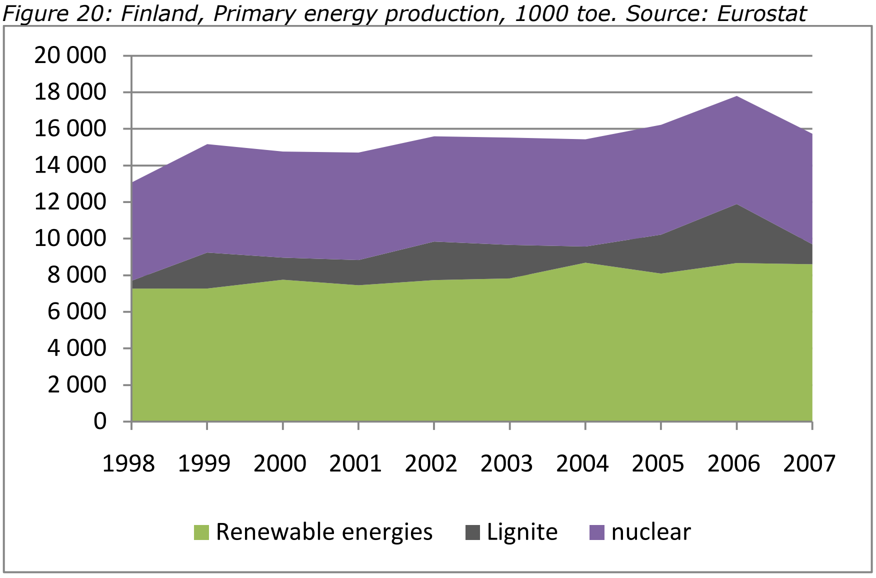
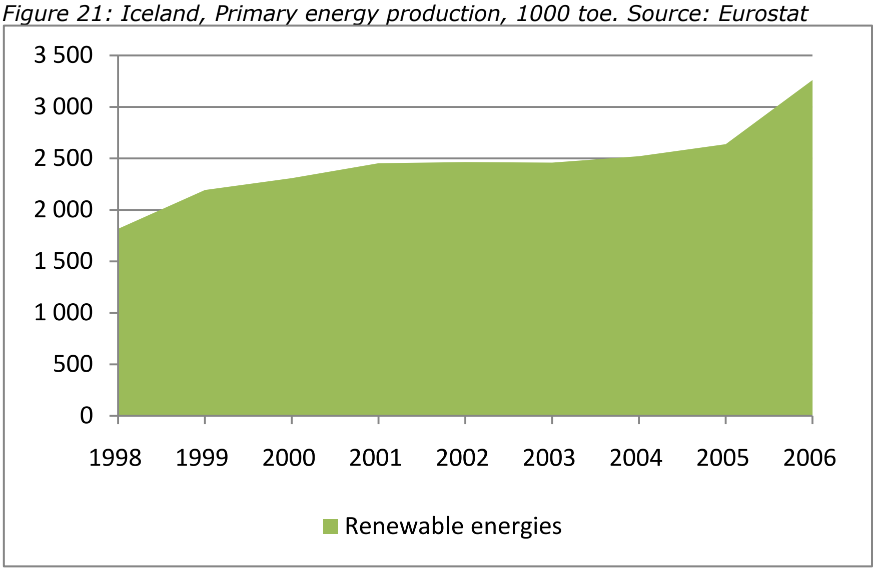


Figure 21: Iceland, Primary energy production, 1000 toe. Source: Eurostat



4.1.6 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 (see Figure 22). The data is openly accessible and provided by Nordel on an annual basis. As can be seen there is a quite remarkable electricity exchange taking place between the Nordic countries themselves and between Nordic countries and continental Europe, mainly Germany, the Netherlands, Estonia and from Russia.

Nordic cooperation in the field of production, distribution and consumption of electric energy began in 1963, when Nordel was established. Iceland is not connected to the Nordic transmission grid but participates in the Nordel collaboration. From the mid-1990s the electricity sector in the Nordic countries changed into a common market and the establishment of the Nord Pool power exchange of Transmission system operators (TSOs), which has also been the model market in a European context and USA. The common organisation for the regulating regulation of the power market was established in 2002.

The rationale behind the integration of electricity markets is the need for security of supply, the ability to maintain environmental commitments, the avoidance 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_2 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).

Table 4 and Figure 23 illustrate the exchange of electricity inside the Nordel cooperation and between Nordel and other European regions in 2008.

Figure 22: Exchange of electricity between Nordel countries for three 3-years average periods compared, 2000-2008, GWh. Source: Nordel.

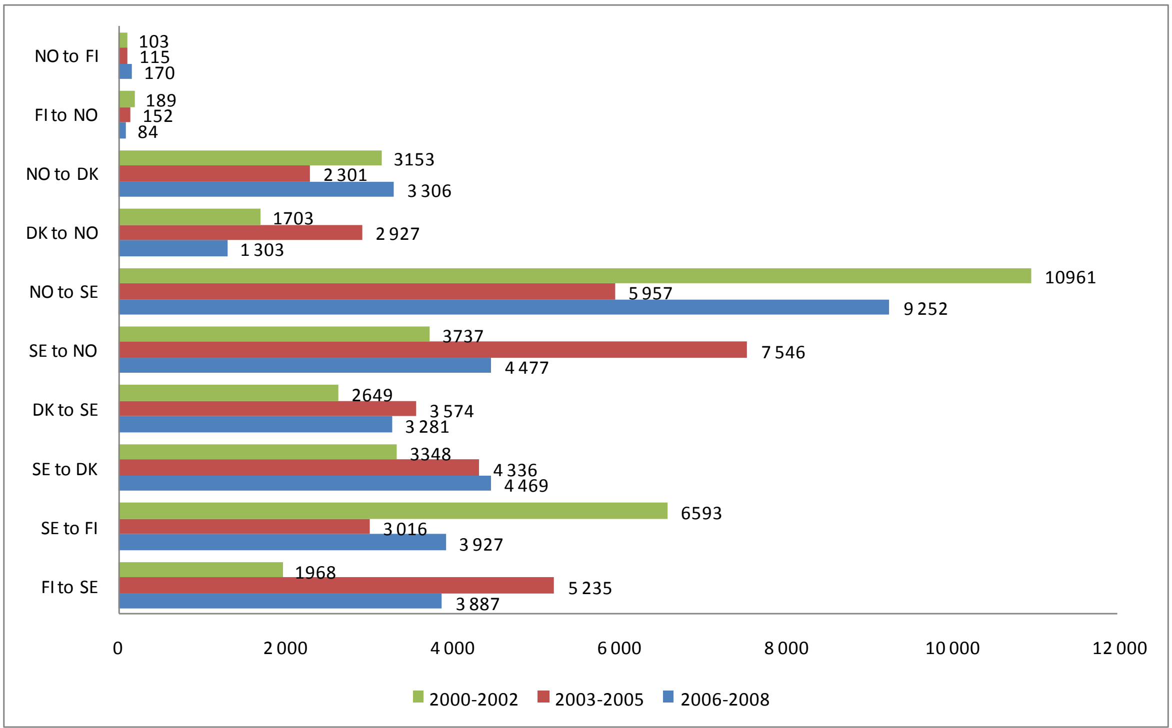
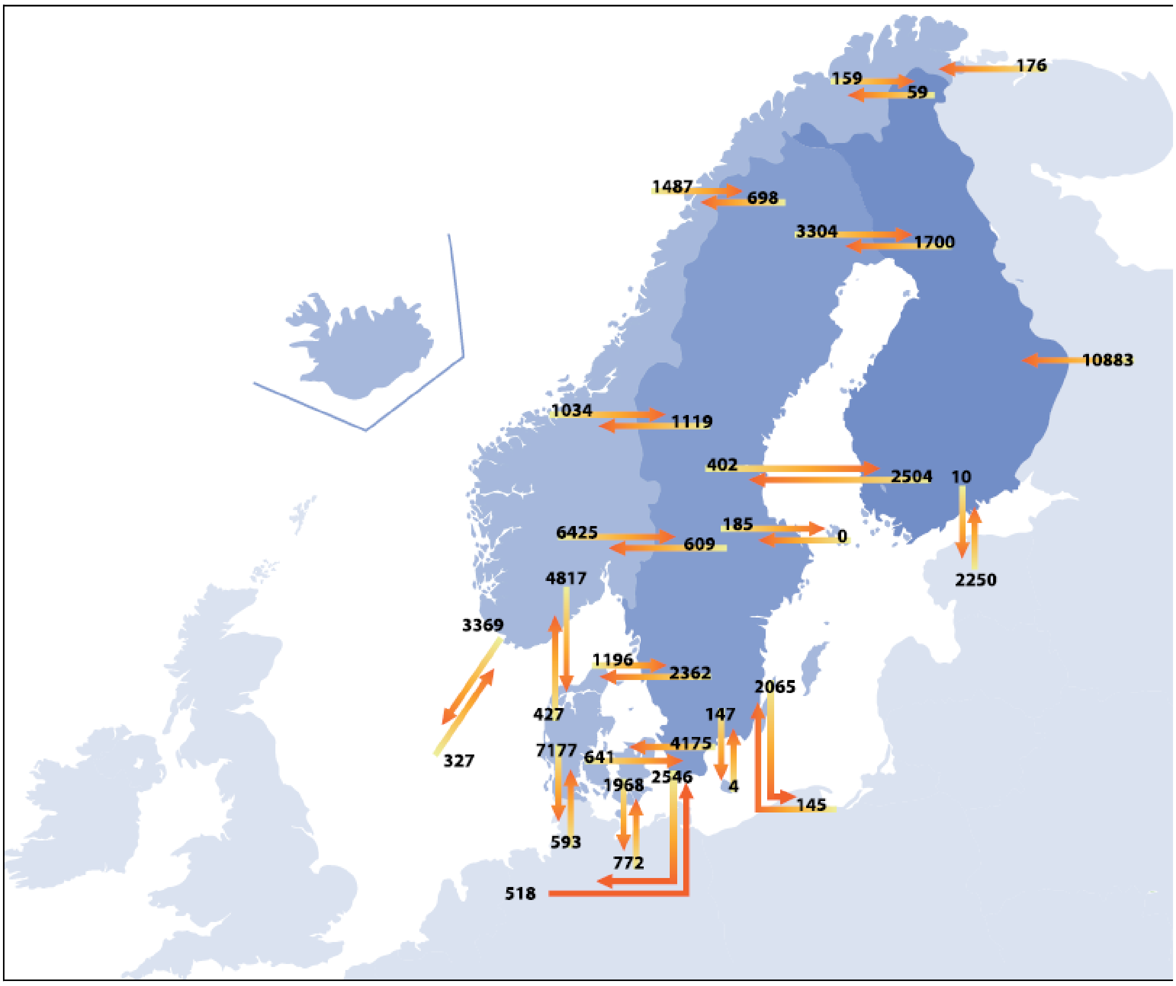


Table 4: Exchange of electricity 2008, GWh. Source: Nordel (2009)

	To					
	Denmark	Finland	Norway	Sweden	Other Countries*	
From						*Total from*
Denmark	-	-	427	1 841	9 145	*11 413*
Finland	-	-	59	4 204	10	*4 273*
Norway	4 817	159	-	8 946	3 369	*17 291*
Sweden	6 684	3 891	2 426	-	4 611	*17 612*
Other countries [1)]	1 365	13 133	503	663	-	*15 664*
Total to	*12 866*	*17 183*	*3 415*	*15 654*	*17 135*	*66 253*
					Nordel	
Total to	12 866	17 183	3 415	15 654	49 118	
Total from	11 413	4 273	17 291	17 612	50 589	
Total from Russia					11 059	
Total from EU					38 059	
Net imports	1 453	12 910	-13 876	-1 958	-1 471	
Net imports /total consumption	4,0 %	14,8 %	-10,8 %	-1,4 %	-0,4 %	

*Russia, Estonia, Germany, Poland, Netherlands

Figure 23: Exchange of electricity, 2008, GWh. Source: Nordel (2009)



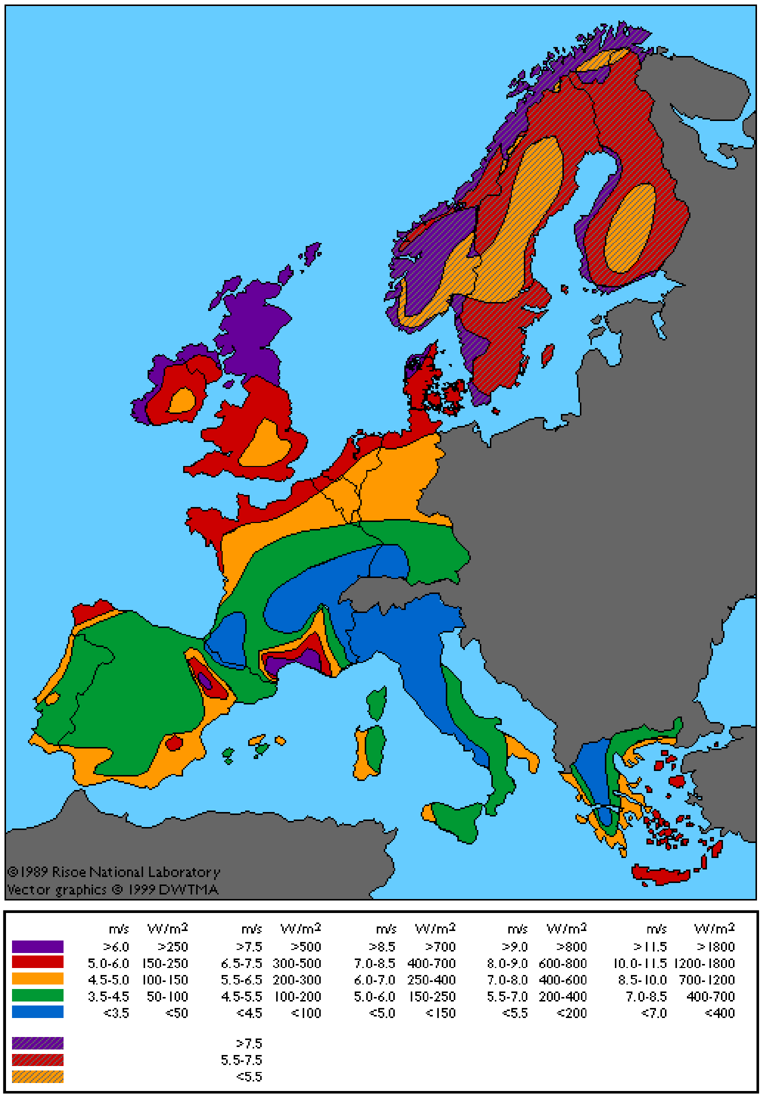
4.1.7 Resource endowments

The natural resources or natural conditions present in a given country are relevant for the deployment of its domestic energy technologies, but not necessarily for energy technology development. In this project we propose to use resource endowments as a baseline. Thus we do not propose to use resource endowments as an indicator but rather to show the differences in the countries' natural conditions which are relevant for the deployment of energy technologies in the individual countries. We include here a short overview of the specific conditions regarding solar radiation, wind-resources, hydropower and the accessibility of geothermal resources. Good and comparable data for resource endowments could potentially be used for relating it to industrial specialisation. With regard to CCS it is interesting to look at CO_2 storage sites present in individual countries' territories as compared with the countries efforts in supporting CCS technology development and deployment.

Wind energy

Some of the strongest wind resources are observed in Northern Europe. Winds are particularly strong along the entire coastline and large parts of inland Norway. The Swedish south-western coastline has particularly good wind conditions. Also Finland has excellent wind sources. Denmark has good wind conditions in the north-west. Mapping of wind sources indicates that all four Nordic countries have large potential for the further deployment of wind power (Klitkou, Pedersen, Scordato, & Mariussen, 2008).

Figure 24: European wind potential.

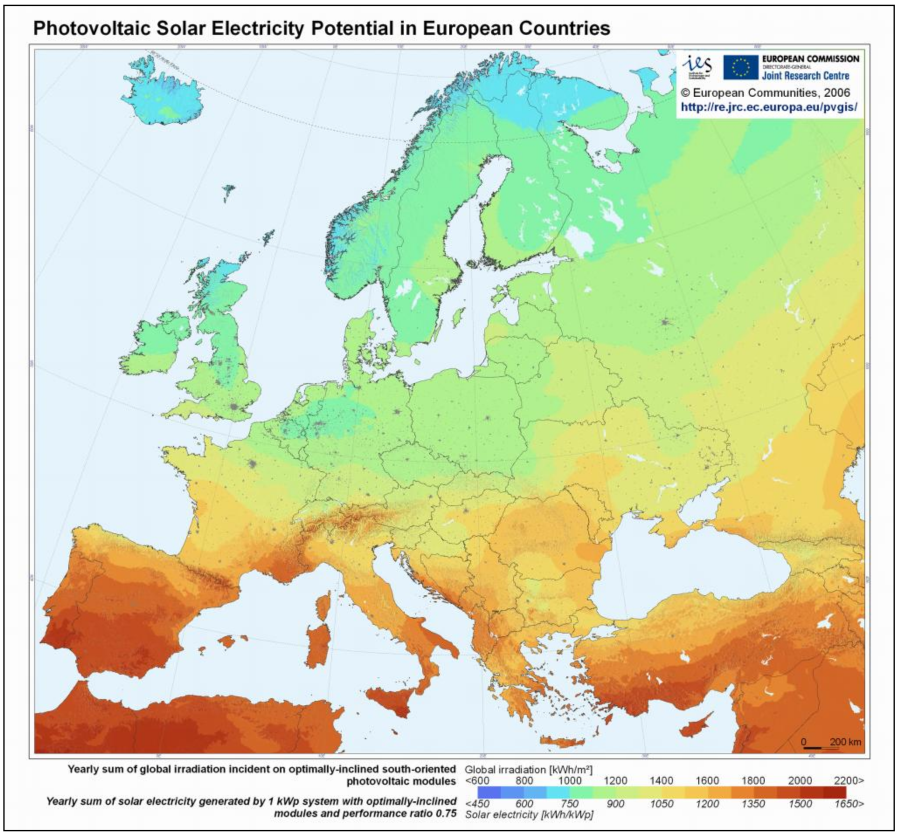


Wind resources at 50 meters above ground level for five different topographic conditions:
1) Sheltered terrain, 2) Open plain, 3) At a coast, 4) Open sea, and 5) Hills and ridges.
Source: European Wind Atlas (Troen & Petersen, 1989)

Solar Photovoltaic energy

Solar energy is the most abundant permanent energy resource on earth and it is available for use in its direct (solar radiation) and indirect (wind, biomass, hydro, ocean etc.) forms. Here we concentrate on the direct use of solar radiation. The seasonal variation of solar radiation in the Nordic countries is large; the main part of solar radiation is obtained between March and September. Compared with the rest of the European continent (in Southern Europe up to more than 2200 kWh/m^2) the Nordic countries have low annual average irradiation at about 1000-1200 kWh/m^2 (see Figure 25).

Figure 25: Photovoltaic Electricity Potential in European Countries.



Note: Based on the yearly sum of global irradiation on a horizontal (inclined) surface; source: (Šúri, Huld, Dunlop, & Ossenbrink, 2007), http://re.jrc.ec.europa.eu/pvgis/.

Hydropower

Hydropower resources are abundant in four Nordic countries. Norway possesses Western Europe's largest hydro resources, both in terms of its current installed capacity and of its economically feasible potential. *Hydropower & Dams World Atlas 2009* reported a gross theoretical capability of 600 TWh/yr, of which 206 TWh is economically exploitable.

Sweden has one of the highest hydro potentials in Western Europe: the Swedish WEC Member Committee reports a gross theoretical capability of 200 TWh/ yr, of which 90 TWh, is economically exploitable. The average annual capability of the 16 200 MW hydro capacity installed at the end of 2008 produced 68 TWh, about 76% of the economic potential.

A significant proportion of the natural flows suitable for power production in Finland are located in preservation areas. A large part, 7,400 TWh/yr of the technically exploitable capability (22,600 TWh/yr) is located in conserved water flows (WEC, 2007). The economical potential was 16 TWh at the end of 2008, the installed capacity 3 049 MW, and the actual production was 14 TWh in 2008.

Apart from Iceland's geothermal resources, the country's hydropower potential represents virtually its only indigenous source of commercial primary energy. The economical potential was 40TWh at the end of 2008, the installed capacity 1 879 MW, and the actual production was 12.4 TWh in 2008.

Geothermal energy

There are different sources of geothermal energy. Hot water (or hot rock) is one source; it is found several kilometres beneath the Earth' surface. The geothermal energy is used via power plants driven by hot steam. Another source is the shallow ground for use in geothermal heat pumps.

Countries with running capacity from geothermal energy are the USA (1935 MW, 2007)*, the Philippines (1856 MW, 2007)*, Mexico (953 MW, 2007)*, Indonesia (992 MW, 2007)*, Italy (711 MW, 2007)*, Japan (530 MW, 2007)*, Iceland (485 MW, 2008)**, and New Zealand (373 MW, 2007)*.[2]

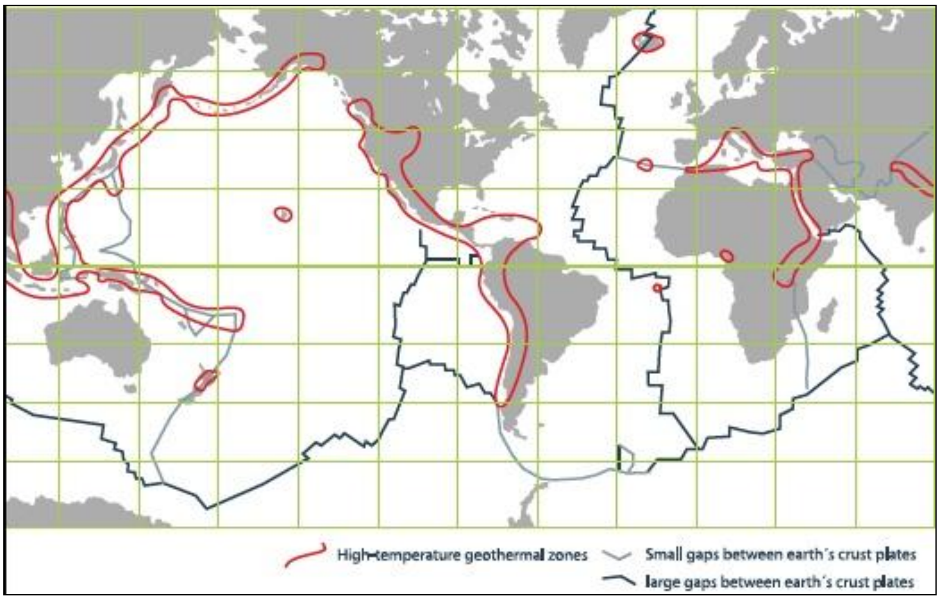
Heat pumps based on shallow ground temperature can be used all over the world, and this is the geothermal energy utilisation that has grown the most on a global scale (www.fornybar.no).

Amongst the Nordic countries Iceland has the highest geothermal energy potential resulting from the country's volcanic nature and its location on the Mid-Atlantic Ridge. The high-temperature resources are sited within the volcanic zone (southwest to northeast), whilst the low temperature resources lie mostly in the peripheral area. An assessment of Iceland's potential for electricity production has been put at 20 TWh annually.

Norway's total reliance on indigenous hydropower resources for its electricity supply has meant that few other energy resources have been utilised. Heat pump installations have become more common in Norway, albeit the majority are air-source based.

Also Denmark's and Sweden's utilisation of geothermal heat is on a very limited scale. There are however many small ground-source heat pumps installed for residential buildings and district heating schemes (WEC, 2007). The figure below illustrates the most important geothermal zones and borders between the shelves that earth's crust is made of.

Figure 26: Important geothermal zones and borders.



Source: http://www.fornybar.no/sitepageview.aspx?articleID=98

[2] Sources: *Bertani, **Ketilsson at the GIA-IGA meeting in Madrid, 5-6 May 2009.

4.2 Input measures

The scoreboard will feature a set of technology specific input and output indicators to size up performance of activities linked to the specific technologies in question. Technology specific input measures are: expenditure on research, development and demonstration activities (RD&D expenditure) decomposed to identify the demonstration dimension.

4.2.1 Public RD&D investments

The IEA RD&D statistics are used as input measures. The IEA energy R&D statistics are collected from government R&D funders and use a scientific/technical nomenclature and are publicly accessible. The budgets are reported on a level of detail that makes it possible to distinguish between the energy technologies used in this report. The IEA database also covers 17 EU Member States. All Nordic countries, with the exception of Iceland are included in the database. The database allows for an analysis of public energy RD&D investments over a long time period. In this report values from mid 1970 to the latest available data, 2008 has been covered. The tables give data for every second year.

On top of research and development budgets the IEA database covers *demonstration budgets*. Demonstration projects are large “test” projects which are not yet operating on a commercial scale. Demonstration budgets are however scarcely reported in the database. As has been explained elsewhere most IEA member countries do not provide data on funds towards demonstration, or do not report them separately (Wiesenthal, Leduc, H-G., & Haegeman, 2009). Demonstration budgets are typically available since 2004 and for the Nordic countries some data is available, but the systematic reporting and colleting of demonstration budgets need to be improved further. The demonstration budgets are nevertheless presented in a table in the annex as share of overall RD&D budgets.

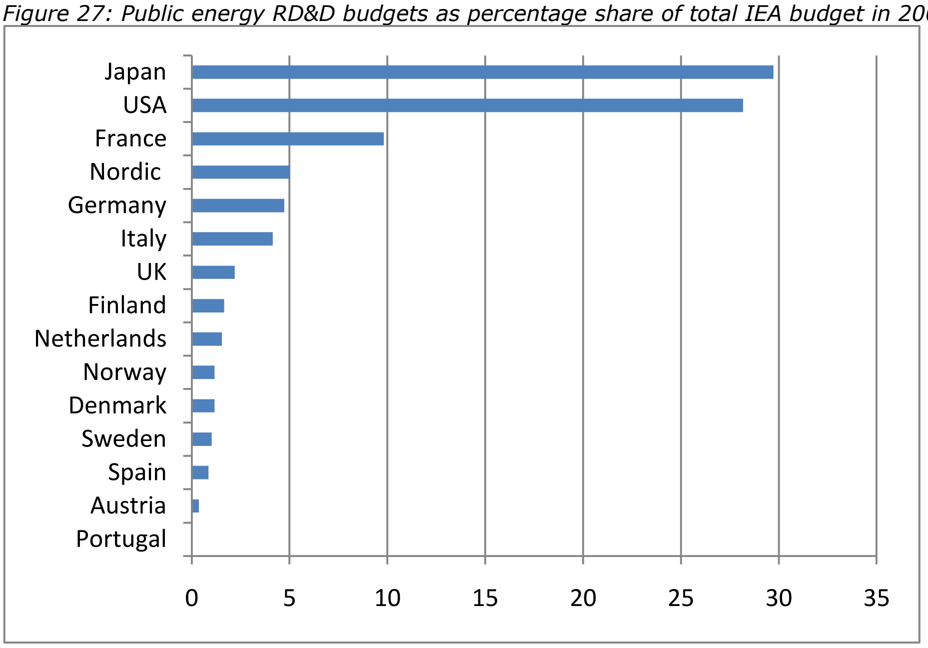
The Annex includes detailed tables also for the reference countries and EU27. A further important indicator would be the overall (public and private) R&D spending (GERD) in the energy sector. This is however not possible, as the socio-economic objective 5 (production, distribution and rational utilisation of energy) in the Eurostat GERD dataset contains many gaps. For Sweden, Finland and Denmark there is no data and the information for Iceland and Norway exists, but is very inconsistent.

Table 5: Classification of (selected) energy relevant sectors in IEA RD&D statistics.

GROUP I: ENERGY EFFICIENCY
GROUP II: FOSSIL FUELS
II.3 Total CO_2 Capture and Storage
GROUP III: RENEWABLE ENERGY SOURCES
III.1.2 Photovoltaics
III.2 Wind Energy
III.4 Total Bio-Energy
III.4.2 Production of other biomass-derived fuels including from wastes
III.5 Geothermal Energy
III.6 Total Hydropower
GROUP IV: NUCLEAR FISSION and FUSION

An indicator for the need of international RD&D energy cooperation has been constructed by calculating the countries’ share of public energy RD&D budgets of the overall IEA spending The Nordic countries budgets for energy RD&D combined constitute only 5% of the total IEA budget in 2007, while Japan and USA give more than 50% of the total IEA funding (see Figure 27). A conclusion from this is that international research cooperation is essential, especially for small countries in order to increase their access to a larger pool of resources and strategic knowledge, generate synergies and avoid duplication.

Figure 27: Public energy RD&D budgets as percentage share of total IEA budget in 2007. Source: IEA



In the next figures the trends in RD&D budget distribution over the main groups are illustrated, as classified by the IEA:

- Energy Efficiency
- Fossil fuels
- Renewable energy sources
- Nuclear fission and fusion
- Hydrogen and fuel cells
- Other power and storage technologies
- Total other technologies or research

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 28: Denmark, Mill. €. RD&D budgets for main groups, 1975-2008. Source: IEA

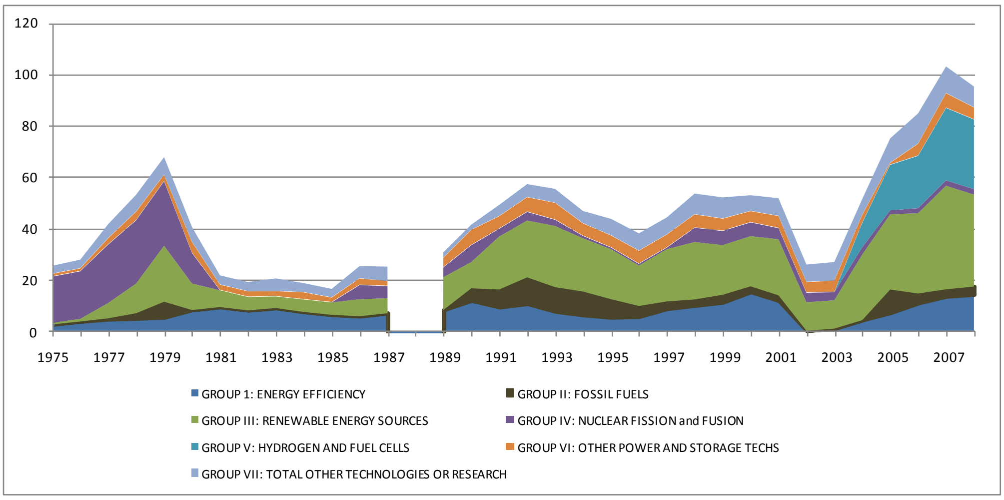


Figure 29: Norway, Mill. €. RD&D budgets for main groups, 1975-2008. Source: IEA

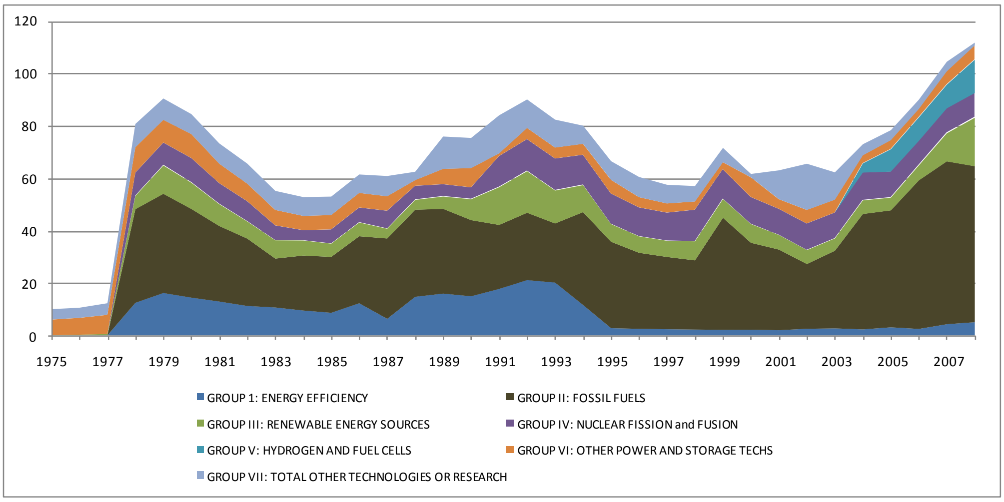


Figure 30: Sweden, Mill. €. RD&D budgets for main groups, 1975-2008. Source: IEA

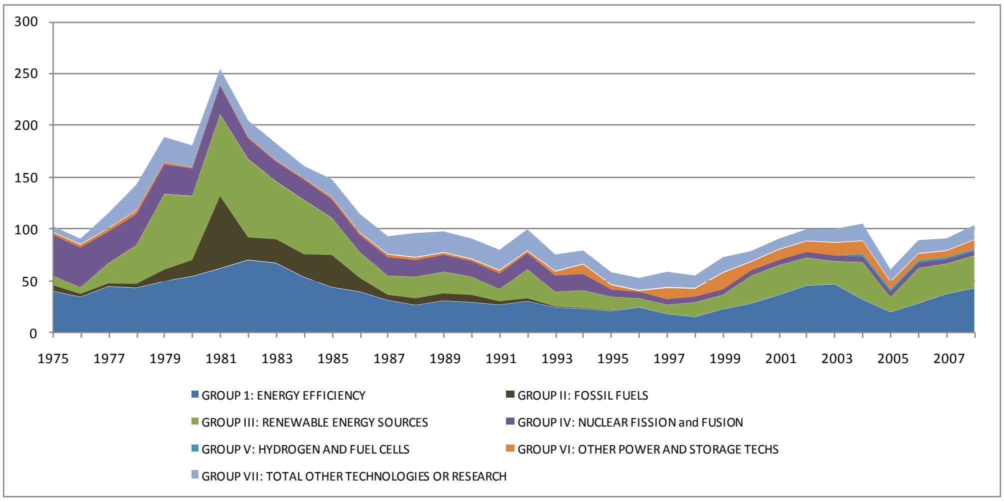


Figure 31: Finland, Mill. €. RD&D budgets for main groups, 1990-2007. Source: IEA

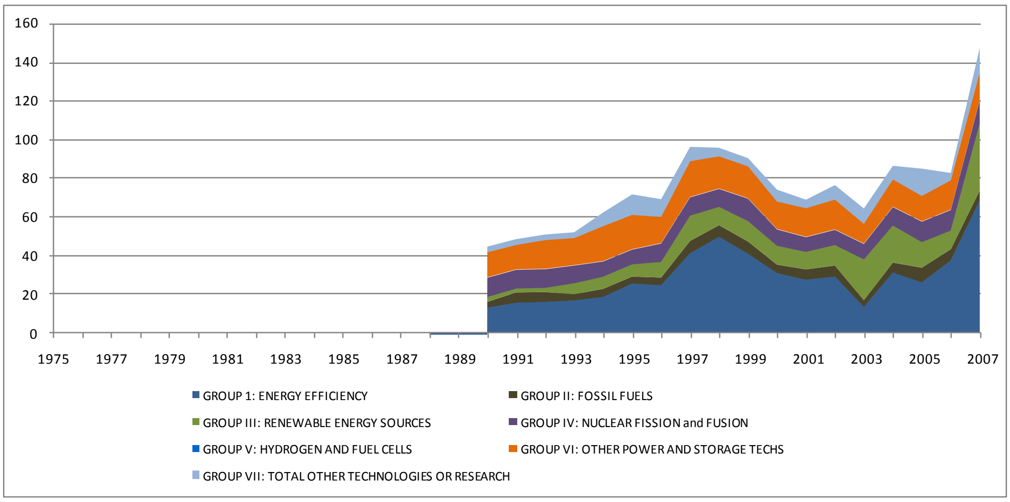
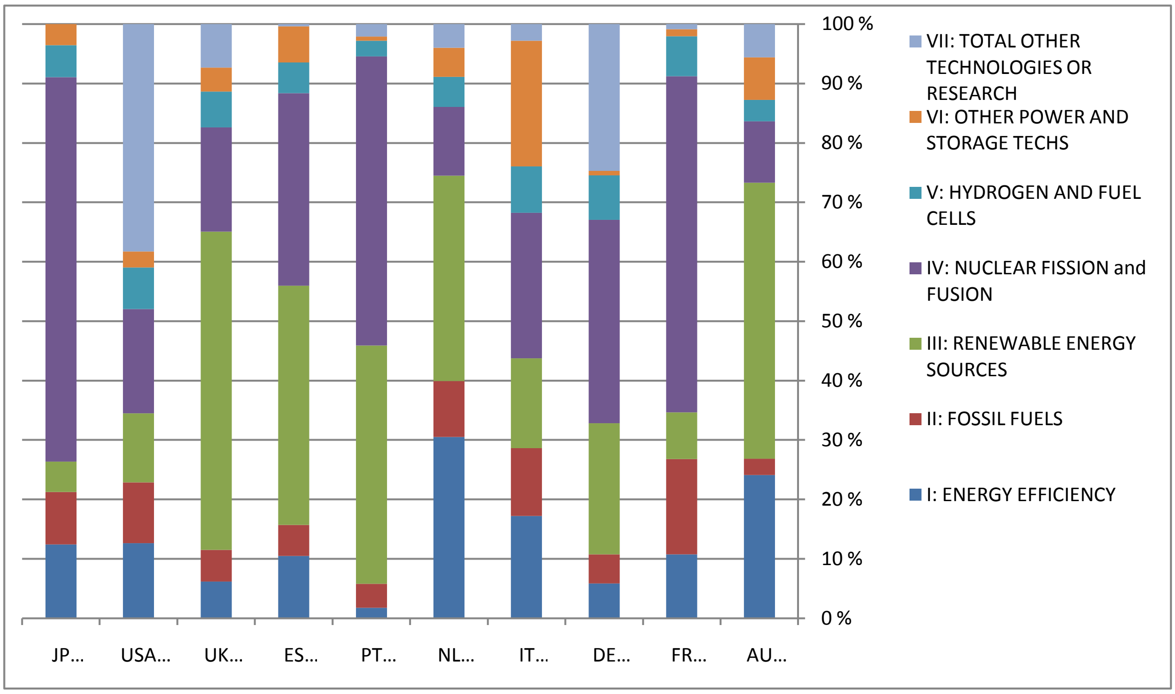


Figure 32: Reference countries, Mill. €. RD&D budgets for main groups, 2007. Source: IEA.



The advantage of the IEA database is that it provides public RD&D budgets by energy technologies over a relatively long time period. This means that it is possible to compare trends in budget distributions by renewable energy sources and other low-carbon technologies such as CCS. The figures presented below illustrate budget developments, where data is available since mid 1970's, where availsble upto 2007 for the five energy technologies relevant for this project. The technologies are classified by the IEA in the following way:

- Total CO_2 Capture and Storage
- Wind energy
- Geothermal energy
- Solar Photovoltaics
- Total hydropower
- Production of transportation bio-fuels, including from wastes

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 solar photovoltaic 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 solar photovoltaic are clear to see. In Sweden, an early focus on wind has subsided, while solar photovoltaic 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 33: Denmark, Distribution of low-carbon energy RD&D budgets, Mill €. 1975-2007, Source: IEA

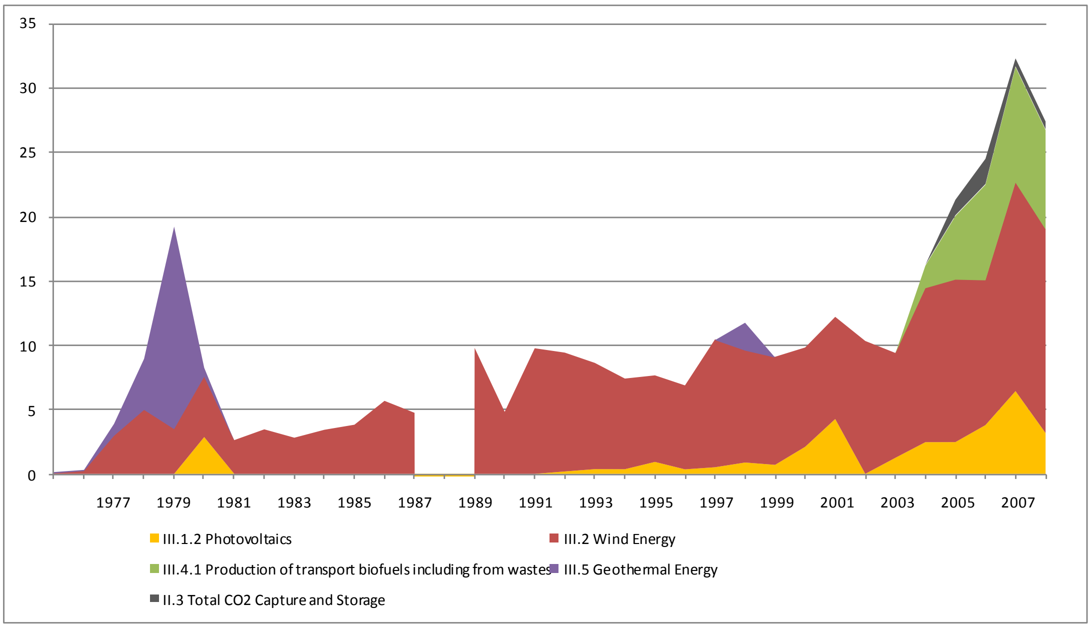


Figure 34: Finland, Distribution of low-carbon energy RD&D budgets, Mill €, 1975-2007. Source: IEA

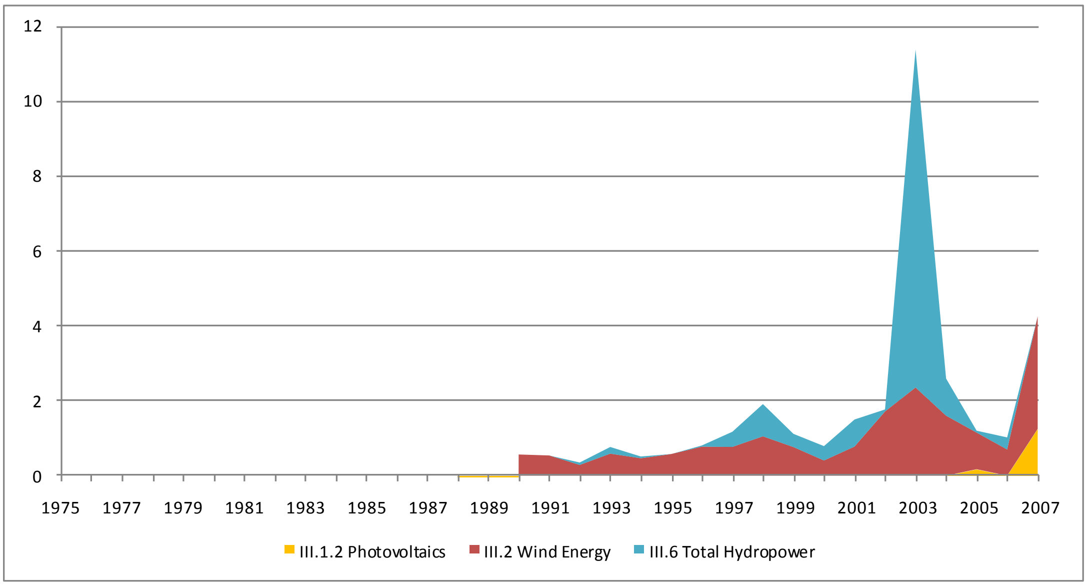


Figure 35: Norway, Distribution of low-carbon energy RD&D budgets, Mill , 1978-2008. Source: IEA

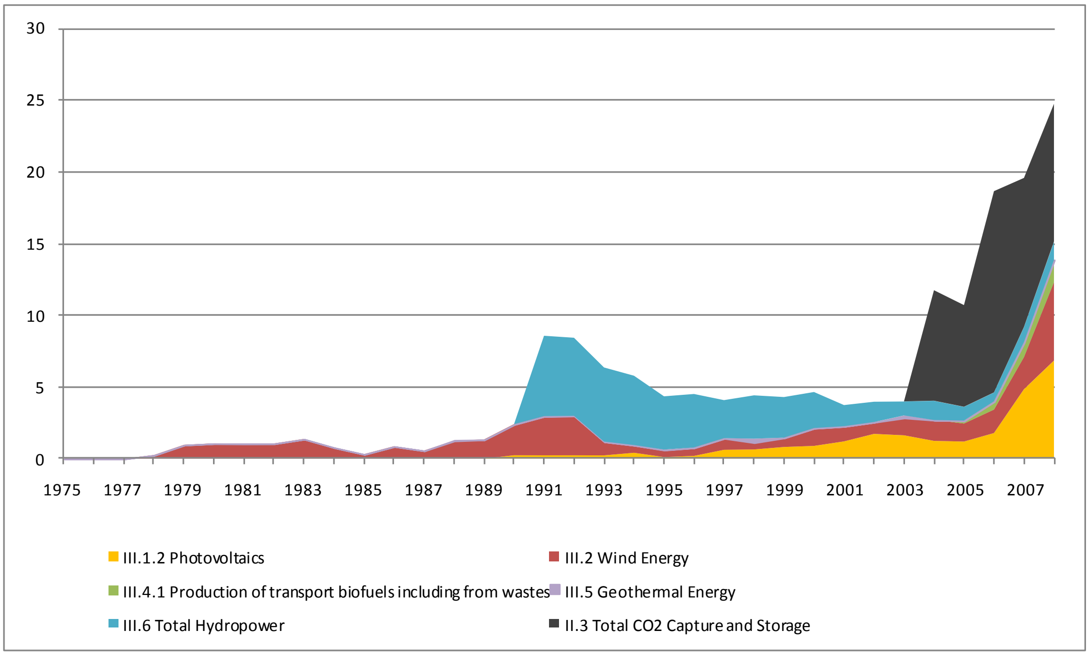
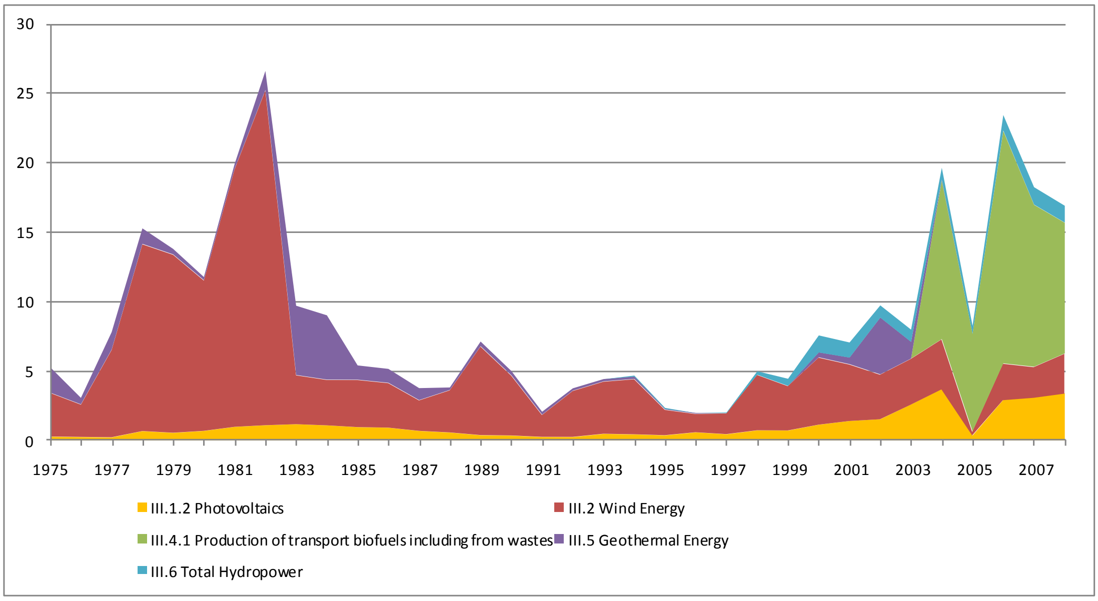


Figure 36: Sweden, Distribution of low-carbon energy RD&D budgets, Mill €. 1975-2008. Source: IEA

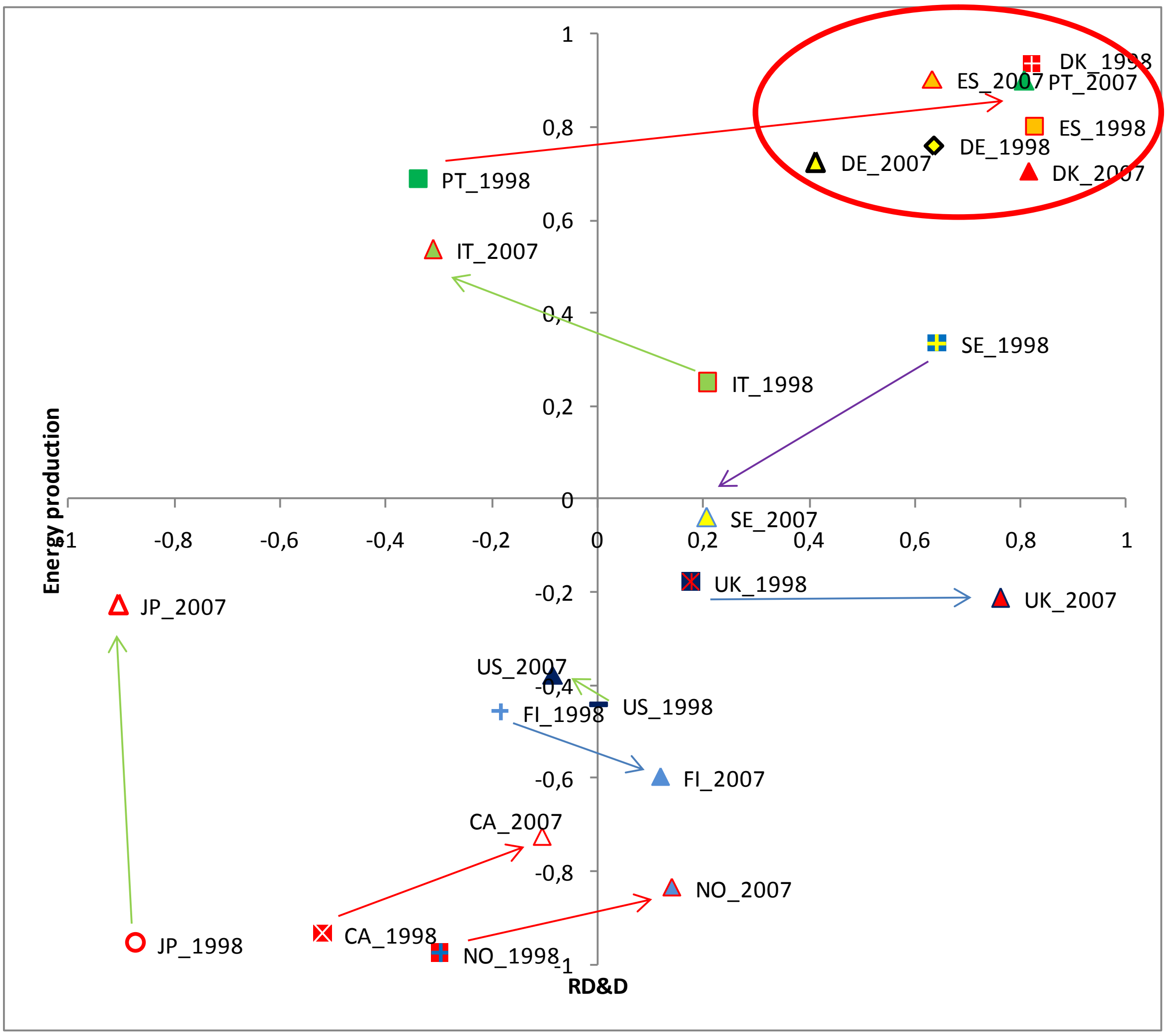


4.2.2 International specialisation

There are different patterns of RD&D specialisation and energy production. We suggest following analysis of the international specialisation of energy RD&D combined with the specialisation in energy production. We propose to apply the Revealed symmetric comparative advantage (see the text box section 4.1.2 for an explanation on the RSCA). In this report we give the example for wind energy. The RSCA for wind energy in the next figure combines indicators on RD&D budgets for wind RD&D with indicators on energy production based on 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, and in 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 its RD&D efforts, but slightly increased the energy production specialisation. And the United Kingdom has increased RD&D specialisation, but slightly decreased energy production specialisation.

Figure 37: Revealed symmetric comparative advantage for wind energy for Nordic countries and selected reference countries. 1998 and 2007. Sources: IEA.



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

4.2.3 Private R&D investments

Eurostat BERD

Unlike public R&D funding, data on private RD&D expenditure on energy are unavailable or incomplete. The BERD (*Business and enterprise sector expenditure on energy R&D)* database contains figures on the business and enterprise sector's expenditure on R&D broken down by different sectors. Energy related R&D expenditures include the following sectors:

- Electricity, gas and water supply
- Manufacturing sectors related to the energy field:
  - Manufacture of coke, refined petroleum products and nuclear fuel
  - Manufacture of electrical machinery and apparatus

A drawback is however that these NACE classifications do not provide a breakdown by technological fields. Unfortunately the BERD database contains too many gaps and data for several EU Member States are missing. No data for instance exists for Denmark, although there is good data for Norway. As has been recently observed by other experts (see for e.g Wiesenthal et al., 2009) data on corporate R&D expenditures, especially by technology are difficult to obtain. The lack of private R&D data can be explained by a missing regulatory framework that obliges private companies to report on their R&D investments. Reasons of confidentiality can also explain the reluctance of companies to 'expose' their investment levels to the general public. Nevertheless previous attempts have been made to gather information on companies R&D investments dedicated to individual technologies.

An interesting approach has been used by the experts in the IPTS/JRC report, mentioned earlier in this report. Their method puts together data on R&D investments of individual companies, selected primarily from the EU Industrial Investment Scoreboard, with additional information about the company through web-published annual reports and direct contacts. This approach has been complemented by data extracted from official databases (BERD) and EU-financed projects[3]. This method has allowed making estimations of companies' R&D investments by the SET-Plan priority technologies. The purpose of this report is not to replicate such a methodological approach in a Nordic context but rather to shed light over existing attempts to gather input indicators in the field relevant for this project. In this context we would nevertheless like to emphasise one of the conclusions of the IPTS/JRS report:

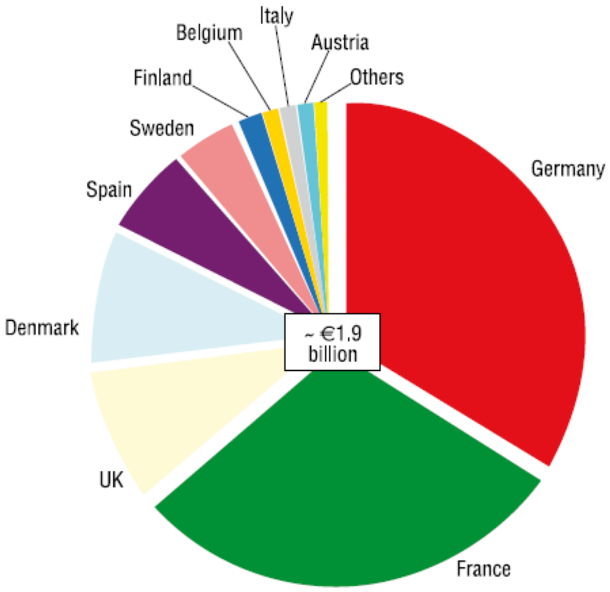
> The data collection on ERTD expenditures in Europe would be facilitated with the appointment of a European institution that ensures a systematic collection of validated and disaggregated data on public and private ERTD expenditures. For a comprehensive database, it is vital that such an institution has enough power and prestige, in particular to urge companies to provide data on private expenditures (Wiesenthal et al., 2009, p. 27).

A recommendation of the present pilot project would be to transpose this conclusion into a Nordic context. A Nordic institution could have the appropriate responsibility to ensure a systematic collection and for setting up a database in particular on private Energy Research, Technology and Development (ERTD) expenditures. For efficiency reasons this should be done in cooperation with National statistic offices. Reliable data on corporate RD&D expenditures are necessary for policymakers and stakeholder organisations. Especially important are they to get a clear understanding for future RD&D funding needs.

Furthermore, results from the IPTS/JRC report indicate that corporate R&D investments are spread throughout the EU Member States, but that "companies with a substantial R&D investment in low-carbon technologies are largely concentrated in a few Member States, namely Germany, France, UK, Denmark, Spain and Sweden" (Wiesenthal et al., 2009, p. 34). These companies would in fact together account for almost 95 per cent of the total.

[3] The report mentions: SRS NET and EEE: Scientific Reference System on new energy technologies, energy end-use efficiency and energy RTD; and ERMINE: Electricity Research Road Map in Europe. For more information on SRS NET see: http://ec.europa.eu/research/fp6/ssp/srs_net_en.htm and for ERMINE: http://www.ermine.cesiricerca.it/

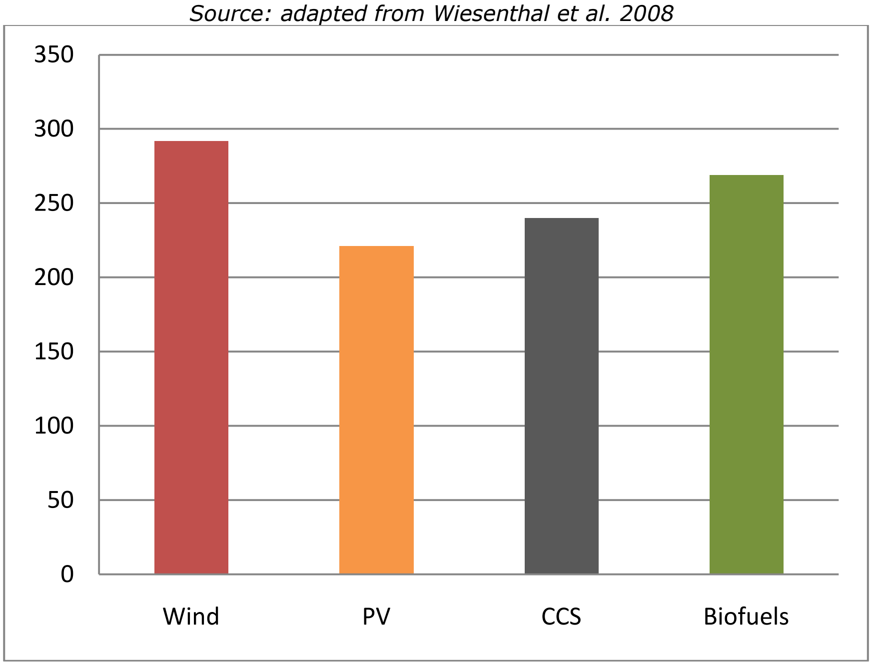
Figure 38: Indicative regional distribution of corporate R&D investment (2007) in SET-Plan priority technologies by countries that host the headquarters of the R&D investing companies. Source (Wiesenthal et al., 2009)



As is noted by Wiesenthal et al. the figures presented in the diagram are subject to important uncertainties associated with the methodology applied.

The corporate investments in the EU Member States presented in the IPTS/JRC report are differentiated by energy technology in the following figure. From a Nordic perspective this data is valuable, but it lacks information from the non-EU Member States, and here especially Norway, where it is well known that Norwegian companies invest heavily in CCS (e.g. Statoil, Aker Clean Carbon) and offshore wind.

Figure 39: Corporate R&D investments in EU Member States by energy technology, 2007 (€ million). Source: adapted from Wiesenthal et al. 2008



4.3 Throughput measures

4.3.1 Bibliometric – based measures for scientific publishing

Bibliometric-data is based on scientific publications and includes information on the type of publication, title, authors and their location, etc. 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. It is an established throughput indicator as bibliometric-based measures capture the intermediate production of the innovation process, especially those resulting at early stages of the innovation process.

Compiling and comparing data of relevant literature published by national scientists provides the basis for other indicators in addition to intermediate production of the innovation process. For example, the concentration of publication in given fields can be used as a further measure of the intensity of scientific activity; the degree of citations to given articles can be used as a measure of scientific impact; and the co-authorship patterns can be used to investigate collaboration and cooperation. For the purpose of the Nordic scoreboard a future project could concentrate on the volume of publishing by technology field and on international co-authorship patterns.

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 extended report). We propose 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 et al., 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 to the use of this type of data. The delineation is also important here, because in several fields it is necessary to avoid many 'false friends', such as both in wind energy and solar photovoltaics many articles would stem from astrophysics. For two fields we have distinguished between subfields, such as for bio-fuels between the three generations of bio-fuels and for CCS between carbon capture and carbon storage. The keywords for the subfields may also be merged. An updated list of keywords has been developed and is given in the appendix of this report. However, new data retrieval has not been done so far.

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 2nd 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 2nd generation bio-fuels and photovoltaics (Klitkou et al., eNERGIA report Part 2, p. 103).

Table 6: Scientific publishing 1998–2006. Sources: ISI Web of Science, ENERGIA (Klitkou et al., 2008).

	2nd generation bio-fuels	CCS	Hydrogen	Photovoltaics	Wind
Denmark	134	22	328	148	243
Finland	78	13	256	251	59
Norway	25	71	195	105	99
Sweden	171	62	690	582	202

Table 7: Summary on scientific publishing for Denmark, Finland, Norway and Sweden. Rating based on comparison between countries. Sources: ISI Web of Science, ENERGIA (Klitkou et al., 2008).*

	2nd generation bio-fuels	CCS	Hydrogen	Photovoltaics	Wind
Denmark	++	+	++	+	+++
Finland	+	+	++	++	+
Norway	+	++	++	+	++
Sweden	+++	++	+++	+++	+++

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

4.3.2 Patents and low-carbon energy technologies

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, technology transfer, etc.

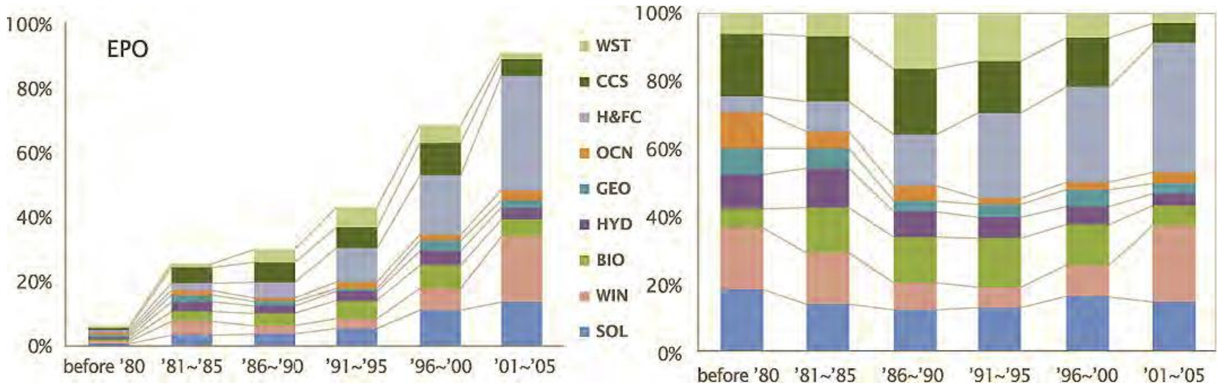
However, using patent-data to monitor emerging technologies faces several recognised challenges. A major one involves categorisation. It is difficult to accurately identify renewable energy technologies in the patent record. Since there is no one-to-one correspondence between patent classes and these 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, 2009a) to name a few. The approaches generally combine targeted IPC-based searches with some form of expert verification[4]. In addition, the UK and Nordic efforts also use assignee information of known actors in the field to complement their searches.

The WIPO effort uses a comprehensive set of data (EPO, WIPO, USPTO, JPO, KIPO, SIPO). The approach is pragmatic: it combines keywords with an IPC search. There is the question of accuracy since the IPC (sub)-classes are not subjected to a verification process.
Efforts at the Nordic level have also used a combination of IPC class search with keywords. In addition the help of experts in the technological areas have been enlisted and the patent portfolios of relevant actors have been reviewed.

[4] WIPO combine only keywords with an IPC search.

Figure 40: WIPO Applications at EPO by technology - Number of patent applications, claimed priorities, worldwide.



Source: WIPO (2009) Patent-based Technology Analysis Report – Alternative Energy. p 29.

The eNERGIA project gave the following results on patenting. "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).

Table 8: Summary on EPO patent applications for Denmark, Finland, Norway and Sweden. Absolute numbers of patent applications. Sources: EPO, ENERGIA (Klitkou et al., 2008).

	Photovoltaics	Wind	2^{nd} generation Bio-fuels	CCS	Hydrogen
Denmark	0	107	52	3	14
Finland	3	5	12	1	0
Norway	18	8	7	9	16
Sweden	4	13	14	0	2

Table 9: Summary on EPO patent applications for Denmark, Finland, Norway and Sweden. Rating based on comparison between countries. Sources: EPO, ENERGIA (Klitkou et al., 2008).*

	Photovoltaics	Wind	2^{nd} generation Bio-fuels	CCS	Hydrogen
Denmark	-	+++	+++	+	++
Finland	+	+	++	-	-
Norway	++	+	+	++	++
Sweden	+	+	++	-	-

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

In future the most promising and comprehensive approach thus far comes from the EPO. One advantage is that the identification process is primarily done by the patent office. In terms of treating incoming applications, it is potentially more efficient and more accurate to identify concurrently at the patent office rather than to depend on an ex-post methodology. The EPO approach which will be available in March 2010 uses the more detailed ECLA patent class system[5] to define technology which is systematically vetted by researchers, field experts and EPO examiners. The latest (October 2009) version of PATSTAT includes the results of a comprehensive effort to identify a set of low-carbon technologies in EPO and more widely.

5 See http://www.intellogist.com/wiki/ECLA_Classification_System

4.4 Output measures

Relevant output indicators can include energy production, installed capacity, energy technology exports, technology transfer, the definition of standards, $C0_2$ 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.

4.4.1 Energy technology exports

Energy technology export is one of the main outputs of energy technology development. The UN database Comtrade has been used for measuring energy technology exports. However, the list of commodities included in this database does not allow coverage of all energy technologies covered by this scoreboard. There are commodities which address *wind power* (HS 850231) and *hydropower* (HS 841011-13, 841090). For this scoreboard we use just wind power technologies. As has been pointed out by Johnstone and Hascic (2009b), *solar photovoltaic* 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.

Table 10: Wind energy relevant Harmonised Commodity Codes

Chapter 85:	Electrical machinery and equipment and parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles
Heading 8502:	Electric generating sets and rotary converters
HS 850231	Wind-powered generating sets

Most of the Nordic export of wind technology comes from Denmark, which is shown in Figure 41. When observing the figure it should be kept in mind that two different axes with different scales have been used; the left one for Denmark and the right one for the other Nordic countries. Export of Danish wind technology has been compared with the rest of the world. Figure 42 illustrates the leading position of Danish wind technology export in a global context.

Figure 41: Wind technology export from the Nordic countries. 1999-2008. Mill. USD. Source: UN Comtrade Database.

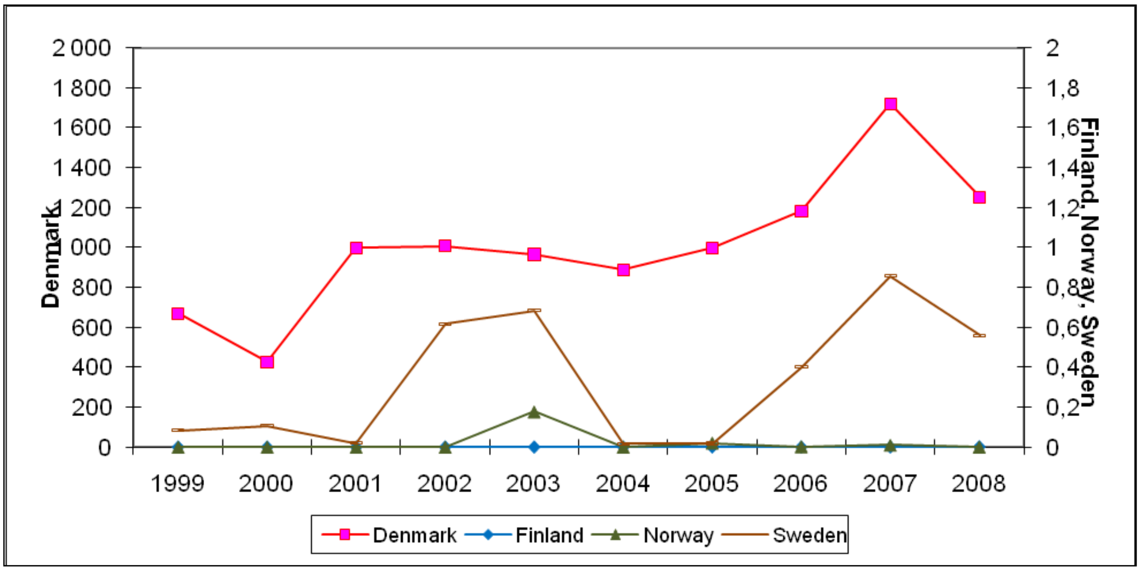
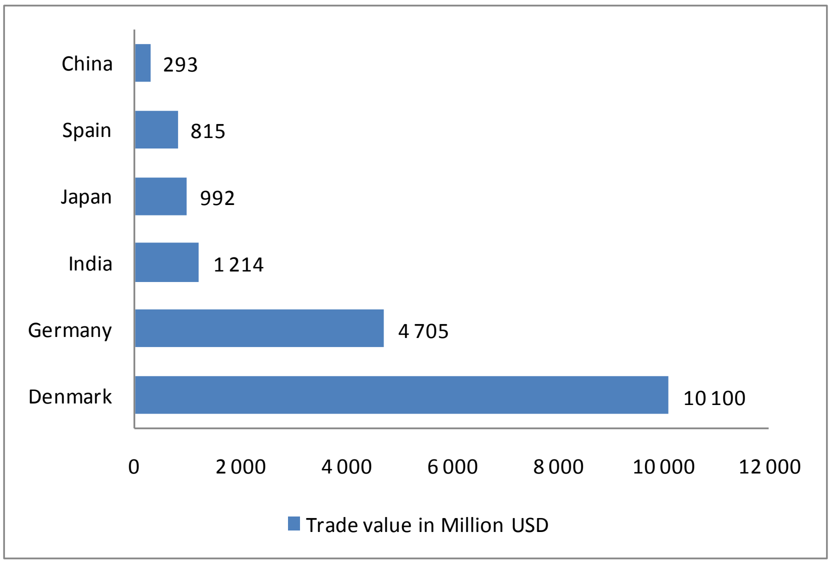


Figure 42: Trade value of exported wind technology. 1999-2008. Mill. USD. Source: UN Comtrade Database.



4.5 Assessment of policy measures

The policy framework conditions give important background information for the understanding of the deployment of low-carbon energy technologies. We can distinguish between more directly targeted policy measures and instruments and more indirect measures.

Thus, we suggest creating such policy measure overviews based on publicly available information provided by the International Energy Agency. For the purpose of this scoreboard we use an existing database, the IEA Global Renewable Energy Policies and Measures database (short IEA Renewable Energy Policy database). The advantage of this database is that it is publicly available, comparable, covers over ten years of policy implementation and many countries worldwide. The purpose of this activity is to make an assessment of which measurable policies are in place and how long these have been in place.

The database has however some drawbacks:

- The information is not complete and may – partially – not be updated;
- Some of the policy measures are not categorised at all;
- Many policy measures are categorised with several types (for example Education and outreach, Policy processes) and they are not weighted;
- Many policy measures are categorised with several technology targets (Hydropower, Solar Photovoltaic, Multiple Renewable Energy Resources etc.) and they are not weighted;
- 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.

The following six groups of policy instrument types are included:

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

We suggest including all financial policy measures which were introduced since 1998 (all measures, both in force, superseded and ended measures) and also those which had been introduced before 1998, but which are still in force. Previous attempts have been made to give an overview of different policy types for renewable energy (Johnstone & Hascic, 2008; Johnstone, Hascic, & Popp, 2008). They have applied a similar approach based on patents counts and the IEA Renewable Energy Policy database. Johnston has shown that different policy types have been introduced with a certain temporal regularity (Johnstone & Hascic, 2008).

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. This approach does also allow assessing the endurance of policy measures.

Colour codes represent different status of the respective policy measure. The year where the policy is included in the figure indicates the year it was put in force, regardless of its status. The number indicates how many policies of that category were put into force that year that have the same status.

Ended	In force	Superseded

Figure 43: 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									1									1
					1		1											
										1								
Tradable Permits																		
											1							
									1	1	1							
Incentives/Subsidies								1						2				1
											1							
										1								
Regulatory Instruments																		
								2	1									
Policy Processes			1									1						1
															1		1	
											1							
RD & D													1					1

Figure 44: 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
												1						
Taxes																	1	
							1		2		1							
Tradable Permits																		
												1	1					
Incentives/Subsidies								1					1				2	
									2									
				1														
Regulatory Instruments															1	1		
			1					1										
Policy Processes															1			1
							1		1		1							
									1		1	1	1					
RD & D														1			1	
									1									

Figure 45: 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												1						
Policy Processes												1					1	

Figure 46: 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	1								2	1			1	1			1	
													1					
Tradable Permits	1														1			
Incentives/Subsidies									1		1	1						1
										1		1						
Regulatory Instruments																		
								1										
Policy Processes									1	1	1	1	1	2			1	1
										1		1						
RD & D													1	1			1	

Figure 47: 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
												1	1	1	2			
Taxes	1			2									1	1		2		
								1										
Tradable Permits													1					
							2						1		1			
Incentives/Subsidies											1		1			1	2	
								1		2								
Regulatory Instruments									1							2		1
							1											
Policy Processes							1				1				1	1		
							1	1										
RD & D													1					
													1					

5 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:

- *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.
- *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.
- *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.
- *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.
- *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.
- *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.

- *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.

- *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.

- *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.

- *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.

Annexes

Annex 1: Public RD&D budgets

Public RD&D budgets from GBAORD

Table 11: GBAORD towards Production, distribution and rational utilisation of energy, Euro per inhabitant. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	4,4	4,6	4,4	5	3,1	3,5	4,5	4,7	6,1	8,7
Finland	15,4	15,4	13,6	11,2	11,2	12,8	14,5	14,9	14,1	14,8
Iceland	4,3	4,4	6,2	4,8	6,6	6,8	5,7	7,2	5,7	5,5
Norway	5,6	5	6	5,8	7,2	7,7	8	10,9	13,4	12,4
Sweden	8,4	11,5	12,2	7,2		8,4	8,4	6,6	10,5	9,9
Germany	7,1	7,2	6,8	6,2	6,1	6,2	5,7	5,9	6,2	6,6
Spain	2,6	3,1	2,9	1,2	1,7	2,3	3,2	4	6	7,9
United Kingdom	0,7	0,8	0,9	1	1,1	0,7	0,9	0,5	1	
France	10,8	10,5	11	9,4	9,4	10,9	12	11,5	10,5	12
Italy	5,4	4,9	5,3	5,4				6,5	6,1	
Austria	0,9	1,1	0,9	1,2	1,3	1,3	1,4	1,7	1,4	3,8
Netherlands	4,6	5,5	7,3	8,4	5,9	6,9	6,8	4,9	4,9	7,2
Portugal	0,7	0,5	0,6	1	1,1	1	0,8	1	1	
EU27			4,1	3,9	3,9	4,2	4,4	4,4	4,7	5,3
United States	3,1	3,8	4	5,2	4,9	4,3	3,8	3,6	3,3	3,9
Japan	32,6	39,6	47	43,7	41,3	37	36	34,5	29,1	

Table 12: GBOARD towards production, distribution and rational utilisation of energy, percentage of GDP. Source: Euostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	0,01	0,02	0,01	0,01	0,01	0,01	0,01	0,01	0,02	0,02
Finland	0,07	0,06	0,05	0,04	0,04	0,05	0,05	0,05	0,04	0,04
Iceland	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,01
Norway	0,02	0,02	0,01	0,01	0,02	0,02	0,02	0,02	0,02	0,02
Sweden	0,03	0,04	0,04	0,03		0,03	0,03	0,02	0,03	0,03
Germany	0,03	0,03	0,03	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Spain	0,02	0,02	0,02	0,01	0,01	0,01	0,02	0,02	0,03	0,03
France	0,05	0,05	0,05	0,04	0,04	0,04	0,05	0,04	0,04	0,04
Italy	0,03	0,02	0,03	0,02				0,03	0,02	
Netherlands	0,02	0,02	0,03	0,03	0,02	0,02	0,02	0,02	0,01	0,02
Austria	0	0	0	0	0	0	0	0,01	0	0,01
Portugal	0,01	0	0,01	0,01	0,01	0,01	0,01	0,01	0,01	
United Kingdom	0	0	0	0	0	0	0	0	0	
EU27			0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
United States	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01	0,01
Japan	0,12	0,12	0,12	0,12	0,13	0,13	0,12	0,12	0,11	

Table 13: Percentage of GBOARD at production, distribution and rational utilisation of energy (percentage of total). Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	2	1,9	1,8	2	1,2	1,4	1,7	1,7	2,1	2,7
Finland	6,4	6,2	5,4	4,3	4,2	4,6	4,9	4,8	4,4	4,5
Iceland	1,6	1,5	2	1,6	2	1,9	1,7	1,7	1,5	1,4
Norway	2,4	2,1	2,3	2	2,1	2,3	2,3	2,9	3,3	2,9
Sweden	4,3	5,9	5,8	3,1		2,9	3	2,3	3,6	3,4
Germany	3,7	3,6	3,4	3,1	3	3	2,8	2,8	2,9	2,9
Spain	3,5	3,8	3,1	1,1	1,3	1,7	2	2,2	2,7	3,1
France	5,1	4,9	4,8	3,9	3,7	4,3	4,7	4,3	4,5	5,3
Italy	5	4,6	4	3,6				4	4	
Netherlands	2,5	2,9	3,6	4	2,7	3,2	3,1	2,2	2,1	3
Austria	0,6	0,7	0,5	0,7	0,7	0,7	0,7	0,9	0,7	1,7
Portugal	1,4	0,9	0,9	1,4	1,3	1,2	0,9	1	0,9	
United Kingdom	0,5	0,5	0,5	0,5	0,5	0,3	0,4	0,2	0,5	
EU27			3	2,7	2,6	2,7	2,8	2,7	2,8	3
United States	1,3	1,5	1,2	1,4	1,3	1,2	1,1	1	0,9	1,1
Japan	19,9	19,3	18,1	17,4	17,5	17,2	17,1	16,8	15,2	

Table 14: GBAORD towards Production, distribution and rational utilisation of energy, in Mill. €. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	23,08	24,50	23,67	26,49	16,78	18,71	24,19	25,44	33,33	47,53
Finland	79,51	79,25	70,12	57,94	58,41	66,41	75,61	77,91	74,32	78,08
Iceland	1,16	1,23	1,73	1,35	1,88	1,95	1,66	2,12	1,71	1,69
Norway	24,58	22,42	26,99	26,13	32,52	35,19	36,49	49,98	61,98	57,97
Sweden	74,70	101,96	107,99	63,75		74,86	75,07	59,47	95,32	90,49
Germany	584,68	593,84	556,34	513,24	503,08	514,28	473,93	490,61	514,66	542,74
Spain	102,17	122,59	117,88	49,80	71,62	96,12	133,68	171,00	264,37	349,99
France	649,54	629,98	666,05	571,54	576,63	671,74	746,40	718,64	663,40	760,08
Italy	304,55	278,04	303,00	307,30				381,87	359,47	
Netherlands	72,04	86,53	115,87	134,56	94,27	111,46	109,93	79,46	79,63	118,53
Austria	6,97	8,97	7,00	9,97	10,15	10,24	11,18	13,82	11,76	31,72
Portugal	7,33	5,49	6,22	10,50	11,80	10,40	8,40	10,50	10,50	
United Kingdom	41,40	43,96	52,35	59,25	64,04	41,04	51,57	29,98	62,49	
United States	845,52	1 061,63	1 116,50	1 474,16	1 408,31	1 239,92	1 100,97	1 064,22	990,76	1 179,86
Japan	4 121,67	5 014,19	5 964,91	5 550,89	5 265,39	4 725,59	4 594,89	4 401,70	3 719,78	
EU27			1 979,17	1 890,39	1 901,63	2 047,49	2 168,62	2 173,11	2 308,45	2 636,45

Public RD&D budgets from IEA

Table 15: Distribution of renewable energy and CCS related RD&D budgets, in Mill. €. Source: IEA

		1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2008
Denmark	II.3 Total CO2 Capture and Storage	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,96	0,605
	III.1.2 Photovoltaics	0	0	2,859	0	0	0	..	0	0,185	0,361	0,35	0,881	2,103	0	2,462	3,788	3,17
	III.2 Wind Energy	0,278	5,029	4,742	3,457	3,425	5,672	..	4,821	9,234	7,042	6,523	8,758	7,717	10,324	12,022	11,311	15,88
	III.4 Total Bio-Energy	0	0,975	1,547	1,742	1,433	0,953	..	1,928	7,757	9,389	6,821	6,064	5,08	0,802	10,581	13,817	14,757
	III.4.1 Production of transport biofuels including from wastes	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1,754	7,426	7,727
	III.5 Geothermal Energy	0,093	3,976	0,707	0	0	0	..	0	0	0	0	2,168	0	0	0	0	0
	III.6 Total Hydropower	0	0	0	0	0	0	..	0	0	0	0	0	0	0	0	0	0
Finland	II.3 Total CO2 Capture and Storage	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	III.1.2 Photovoltaics	..	..	..	..	..	..	..	0	0	0	0	0	0	0	0	0	..
	III.2 Wind Energy	..	..	..	..	..	..	..	0,566	0,287	0,466	0,776	1,052	0,406	1,717	1,604	0,7	..
	III.4 Total Bio-Energy	..	..	..	..	..	..	..	1,124	1,716	5,069	6,671	6,875	8,82	8,438	15,985	7,015	..
	III.4.1 Production of transport biofuels including from wastes	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	..
	III.5 Geothermal Energy	..	..	..	..	..	..	..	0	0	0	0	0	0	0	0	0	..
	III.6 Total Hydropower	..	..	..	..	..	..	..	0	0,066	0,048	0,032	0,863	0,385	0,054	0,993	0,324	..
Norway	II.3 Total CO2 Capture and Storage	..	..	..	..	..	..	..	..	..	..	..	..	..	..	7,7	14,025	9,589
	III.1.2 Photovoltaics	0	0	0	0	0	0	0	0,233	0,23	0,406	0,189	0,637	0,884	1,719	1,232	1,778	6,817
	III.2 Wind Energy	0	0,255	1,064	1,058	0,78	0,863	1,253	2,168	2,76	0,54	0,588	0,493	1,25	0,834	1,463	1,634	5,462
	III.4 Total Bio-Energy	0	0,255	1,064	1,605	2,041	2,185	1,841	2,774	3,151	2,928	1,092	1,254	1,217	0,767	0,908	1,307	3,83
	III.4.1 Production of transport biofuels including from wastes	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0,588	1,59
	III.5 Geothermal Energy	0	0	0	0	0	0	0,051	0	0	0	0	0,267	0	0	0	0	0
	III.6 Total Hydropower	0	0	0	0	0	0	0	0	5,451	4,843	3,737	3,023	2,517	1,419	1,34	0,614	1,267
Sweden	II.3 Total CO2 Capture and Storage	..	..	..	..	..	..	..	..	..	..	..	..	0	0	0	0	0
	III.1.2 Photovoltaics	0,233	0,654	0,669	1,076	1,067	0,902	0,556	0,337	0,236	0,421	0,568	0,709	1,114	1,505	3,657	2,879	3,349
	III.2 Wind Energy	2,323	13,464	10,836	24,132	3,27	3,205	3,034	4,312	3,304	3,965	1,314	3,988	4,83	3,211	3,599	2,624	2,872
	III.4 Total Bio-Energy	1,858	6,732	24,222	28,92	26,497	11,358	10,194	5,81	19,924	10,393	4,511	7,006	18,066	15,437	26,243	25,542	21,463
	III.4.1 Production of transport biofuels including from wastes	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11,442	16,785	9,435
	III.5 Geothermal Energy	0,464	1,116	0,223	1,372	4,632	1,001	0,179	0,306	0,167	0,171	0,051	0	0,356	4,094	0,059	0	0
	III.6 Total Hydropower	0	0	0	0	0	0	0	0	0	0,079	0	0,248	1,229	0,882	0,847	1,118	1,213

Table 16: Distribution of energy related RD&D budgets for main technology groups, in Mill. €. Source: IEA

		1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2007	2008
Denmark	1: ENERGY EFFICIENCY	4,033	5,146	8,509	8,379	7,749	6,081	..	12,148	10,896	6,5	5,876	10,215	15,514	0,417	4,548	11,162	13,758	14,519
	II: FOSSIL FUELS	0	2,105	0	0	0	0	..	4,821	10,342	9,208	4,215	2,422	2,233	0	0	3,78	2,815	3,135
	III: RENEWABLE ENERGY SOURCES	1,02	11,578	10,326	5,199	4,858	6,625	..	10,22	22,161	20,764	15,793	22,378	19,543	11,127	25,575	31,313	40,378	35,838
	IV: NUCLEAR FISSION and FUSION	18,542	24,637	11,873	0	0	5,514	..	6,556	3,324	0,903	0,63	5,523	5,355	3,681	2,847	1,936	2,094	2,133
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	9,447	20,393	28,205	27,112
	VI: OTHER POWER AND STORAGE TECHS	0,927	3,157	4,103	2,018	2,575	2,36	..	5,785	5,54	4,694	4,897	5,032	4,19	3,986	2,951	4,525	5,563	4,517
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	3,291	6,51	5,684	3,484	3,473	4,72	..	1,928	4,986	4,694	6,646	7,996	6,083	6,677	6,071	11,722	10,31	8,054
Finland	1: ENERGY EFFICIENCY	..	..	..	..	..	..	..	13,012	15,931	18,53	24,626	49,647	30,821	29,032	31,144	37,425	68,531	..
	II: FOSSIL FUELS	..	..	..	..	..	..	..	2,944	5,095	4,176	3,916	5,969	4,396	5,697	5,119	5,745	5,032	..
	III: RENEWABLE ENERGY SOURCES	..	..	..	..	..	..	..	2,584	2,253	6,349	8,117	9,553	9,824	10,701	19,256	9,765	34,796	..
	IV: NUCLEAR FISSION and FUSION	..	..	..	..	..	..	..	9,975	9,67	7,891	9,561	9,296	8,466	7,864	9,538	10,617	11,976	..
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	VI: OTHER POWER AND STORAGE TECHS	..	..	..	..	..	..	..	13,027	14,96	18,144	13,677	16,743	14,318	15,542	14,223	15,247	14,392	..
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	..	..	..	..	..	..	..	3,002	2,902	7,109	9,177	4,474	6,164	7,512	7,057	3,859	12,68	..
Norway	1: ENERGY EFFICIENCY	0	12,487	14,467	11,267	9,516	12,301	14,783	14,985	21,185	11,646	2,498	2,221	2,167	2,52	2,28	2,458	4,265	5,04
	II: FOSSIL FUELS	0	35,933	34,04	25,846	21,104	25,723	33,428	29,224	25,855	35,637	29,178	26,549	33,34	24,85	44,294	57,017	62,501	59,866
	III: RENEWABLE ENERGY SOURCES	0,291	5,096	10,084	6,59	5,793	5,288	3,785	8,04	15,963	10,384	6,318	7,321	7,201	5,374	5,237	5,765	10,794	18,627
	IV: NUCLEAR FISSION and FUSION	0	8,665	9,149	7,546	3,783	5,547	5,141	4,311	11,961	11,331	10,915	11,928	10,168	10,014	10,473	9,15	9,266	9,161
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3,512	8,98	9,042	12,714
	VI: OTHER POWER AND STORAGE TECHS	6,414	9,684	9,149	6,692	5,434	5,547	2,148	7,341	4,255	4,168	3,884	3,126	7,501	5,157	2,988	3,137	5,012	5,367
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	3,848	8,919	7,659	7,682	7,205	7,071	3,222	11,536	10,926	6,961	7,725	5,902	1,3	17,657	4,246	3,542	3,67	1,086
Sweden	1: ENERGY EFFICIENCY	34,611	43,316	54,404	70,135	53,652	39,543	26,725	29,372	30,489	23,118	24,5	15,32	28,207	45,549	32,111	28,454	37,477	43,028
	II: FOSSIL FUELS	2,787	3,847	15,649	21,845	22,047	13,261	6,497	7,079	2,721	0,711	0,228	0,051	0,185	0,106	0,09	0,122	0,073	0,062
	III: RENEWABLE ENERGY SOURCES	6,272	37,084	61,734	75,488	52,267	24,759	20,515	17,43	27,921	16,874	8,339	13,933	26,285	26,586	35,696	33,625	28,926	31,136
	IV: NUCLEAR FISSION and FUSION	38,561	30,082	26,644	19,961	19,64	16,606	16,369	15,367	15,675	16,044	6,469	5,72	5,484	5,748	5,666	5,536	4,561	4,396
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2,698	2,126	1,884	2,074
	VI: OTHER POWER AND STORAGE TECHS	2,787	3,385	0,924	1,291	1,067	2,263	2,405	1,819	2,041	9,352	1,112	7,692	8,143	10,304	12,217	6,41	6,049	8,844
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	5,11	24,62	21,035	15,926	11,852	17,748	23,153	19,296	20,298	12,672	11,549	11,796	9,845	10,975	16,295	12,522	11,489	13,831

Table 17: Distribution of energy related RD&D budgets for main technology groups, reference countries, in Mill. €. Source: IEA

		1976	1978	1980	1982	1984	1986	1988	1990	1992	1994	1996	1998	2000	2002	2004	2006	2007	2008
Austria	1: ENERGY EFFICIENCY	..	13,77	16,62	16,185	18,323	14,423	13,629	6,126	6,171	11,36	10,461	8,008	8,247	8,865	10,687	10,47	7,878	..
	II: FOSSIL FUELS	..	1,568	0,392	5,688	3,001	0,583	1,077	0,209	1,381	0,999	1,954	0,691	0,513	0,46	0,491	0,97	0,901	..
	III: RENEWABLE ENERGY SOURCES	..	9,101	12,7	9,274	5,349	3,924	6,158	2,258	4,437	7,819	7,178	11,5	7,535	10,837	10,381	14,507	15,202	..
	IV: NUCLEAR FISSION and FUSION	..	11,8	8,157	8,495	11,162	3,576	2,76	1,16	2,133	1,885	1,63	2,784	3,119	3,88	3,512	3,853	3,372	..
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6,746	1,191	..
	VI: OTHER POWER AND STORAGE TECHS	..	7,003	8,245	7,495	7,291	6,263	7,224	3,141	3,7	4,982	4,873	4,879	3,713	4,241	8,177	3,759	2,331	..
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	..	12	4,423	4,44	8,595	2,771	2,97	0,768	1,597	1,315	2,314	4,196	3,762	4,381	3,228	4,137	1,834	..
France	1: ENERGY EFFICIENCY	..	..	..	..	..	25,864	16,945	27,918	20,422	9,081	7,978	7,273	14,102	61,493	62,914	81,856	94,064	..
	II: FOSSIL FUELS	..	..	..	..	..	63,321	54,942	51,852	45,758	43,479	41,1	34,738	36,143	201,26	162,39	146,67	139,76	..
	III: RENEWABLE ENERGY SOURCES	..	..	..	..	..	24,212	10,769	9,602	8,577	5,925	5,529	4,58	15,559	32,215	33,552	55,692	68,954	..
	IV: NUCLEAR FISSION and FUSION	..	..	..	..	..	753,11	637,777	536,77	502,54	476,93	537,47	586,84	619,76	577,692	529,7	517,37	494,15	..
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	23,955	25,137	53,467	58,574	..
	VI: OTHER POWER AND STORAGE TECHS	..	..	..	..	..	0	0	0	0	0	0	0	0,83	0,89	4,607	2,412	10,589	..
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	..	..	..	..	..	0	0	0	0	0	0	0	8,888	13,539	9,501	6,846	7,356	..
Germany	1: ENERGY EFFICIENCY	70,3	70,62	83,43	62,661	28,724	26,332	19,698	18,081	12,701	13,78	23,077	13,714	9,881	16,588	21,539	21,424	24,713	28,8
	II: FOSSIL FUELS	102,9	230,7	256,4	269,01	222,87	177,74	134,228	95,756	50,065	21,561	3,667	1,343	10,049	14,447	10,315	13,352	20,537	35,71
	III: RENEWABLE ENERGY SOURCES	19,56	50,01	114,7	182,89	109,05	61,539	90,611	107,4	122,59	88,421	97,497	86,42	80,28	80,798	59,405	91,471	92,955	109,8
	IV: NUCLEAR FISSION and FUSION	1022	1026	1109	1697,5	966,01	655,41	382,638	346,86	239,84	191,99	165,99	172,95	159,66	125,639	146,75	145,36	143,96	165,9
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	27,471	26,444	31,485	37
	VI: OTHER POWER AND STORAGE TECHS	0	83,64	71,26	0	14,247	21,007	7,035	9,481	4,908	3,193	12,639	23,452	23,073	37,135	5,183	3,447	3,361	6,3
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	0,203	14,15	7,822	3,26	5,467	6,879	0,14	2,099	5,584	19,961	11,623	8,731	11,958	8,454	116,59	107,98	103,92	111,2
Italy	1: ENERGY EFFICIENCY	..	34,42	39,17	37,144	64,854	72,484	62,784	56,593	..	60,698	65,3	60,218	28,69	29,21	24,288	65,659	63,399	91
	II: FOSSIL FUELS	..	0,821	0	0	13,169	10,299	7,39	0	..	0	0	0	0	15,773	14,904	45,685	42,093	34
	III: RENEWABLE ENERGY SOURCES	..	20,49	37,38	34,537	121,29	51,534	65,556	57,431	..	36,813	47,17	40,456	27,697	60,756	56,083	38,248	55,604	79
	IV: NUCLEAR FISSION and FUSION	..	469,3	636,8	859,42	1208	1089,3	520,359	249,73	..	144,26	135,66	125,09	132,89	112,633	94,392	93,495	90,422	75
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	21,249	28,582	25
	VI: OTHER POWER AND STORAGE TECHS	..	6,093	6,543	3,515	14,764	12,926	113,661	37,006	..	23,628	19,397	18,631	97,124	91,368	86,333	110,49	77,95	65
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	..	2,712	3,838	4,329	35,856	42,237	313,77	342,66	..	70,69	54,971	41,72	39,868	40,894	38,64	10,624	10,393	10
Netherlands	1: ENERGY EFFICIENCY	20,01	31,65	39,31	32,361	39,457	53,935	49,972	67,888	51,665	57,25	69,642	71,948	46,785	47,073	..	42,116	..	..

	II: FOSSIL FUELS	6,188	9,909	27,85	57,194	42,509	34,743	19,635	16,404	16,7	30,102	14,598	12,031	10,377	20,253	..	12,992	..	..
	III: RENEWABLE ENERGY SOURCES	18,15	25,05	32,11	26,339	27,977	32,033	24,028	42,318	24,332	30,415	32,784	47,424	36,83	48,695	..	47,675	..	..
	IV: NUCLEAR FISSION and FUSION	172,4	152,8	137,6	73,751	53,772	45,588	43,096	42,111	67,191	60,456	19,585	17,185	27,244	19,968	..	16,003	..	..
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	6,979	..	..
	VI: OTHER POWER AND STORAGE TECHS	14,85	13,39	12,3	3,01	4,505	7,135	5,6	2,137	23,941	42,544	20,558	14,239	11,22	10,669	..	6,705	..	..
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	6,806	12,11	16,06	24,835	22,672	25,612	31,754	38,734	11,611	8,924	13,138	16,562	20,354	8,715	..	5,526	..	..
Portugal	1: ENERGY EFFICIENCY	..	..	0,482	0	5,788	1,657	2,338	3,132	0,68	0,484	0,831	0,13	0,258	0,117	1,235	0,005	0,036	0,2
	II: FOSSIL FUELS	..	..	0,075	0	0,361	0,848	1,006	1,336	2,009	0,317	0,109	0,243	0,407	0,75	0,687	0,023	0,082	0,277
	III: RENEWABLE ENERGY SOURCES	..	..	2,1	0	5,305	4,354	2,922	2,243	2,902	0,694	1,415	1,533	0,964	1,468	1,373	0,379	0,813	1,17
	IV: NUCLEAR FISSION and FUSION	..	..	9,673	0	3,704	3,213	2,441	6,251	2,563	2,702	0,151	0	0	0	0	0,94	0,988	0,944
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	0,053	0,115
	VI: OTHER POWER AND STORAGE TECHS	..	..	0	0	0,595	0	0,166	0,072	0,027	0	0,012	0,044	0,019	0,009	0	0,011	0,015	0,003
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	..	..	0,171	0	3,855	2,508	2,34	2,428	0,154	0,008	0,014	0,212	0,219	0	0	0	0,042	0,045
Spain	1: ENERGY EFFICIENCY	9,798	6,995	6,384	24,035	94,009	8,036	6,293	4,819	16,343	10,222	4,843	8,997	5,517	2,461	2,761	5,714	8,039	9,606
	II: FOSSIL FUELS	20,48	11	35,49	47,768	71,532	3,642	6,799	3,77	3,145	5,615	5,473	3,467	4,24	3,145	6,068	2,895	4,001	5,066
	III: RENEWABLE ENERGY SOURCES	8,662	9,634	56,73	41,809	89,99	25,476	18,241	25,948	29,597	19,515	18,883	23,51	21,845	20,042	25,17	29,774	30,919	36,68
	IV: NUCLEAR FISSION and FUSION	82,39	103,7	85,11	43,651	50,605	15,761	36,089	31,895	42,069	45,843	43,294	29,493	32,73	30,385	15,08	19,063	24,858	24,19
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2,375	3,967	6,412
	VI: OTHER POWER AND STORAGE TECHS	0	0	0	2,761	53,8	23,292	0	0	0	0	0,419	0,479	2,094	0	0	0	4,687	4,857
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	21,79	12,19	6,985	4,792	28,569	0	27,855	0	27,104	24,368	17,095	2,609	0,762	1,308	1,809	3,115	0,282	0,3
UK	1: ENERGY EFFICIENCY	52,17	50,06	43,92	87,468	70,714	64,355	52,486	34,565	32,673	4,142	2,21	0,834	2,231	..	..	4,614	12,051	17,37
	II: FOSSIL FUELS	68,77	100,4	89,71	68,355	76,29	71,594	55,24	35,164	14,263	10,629	12,986	7,962	6,905	5,705	7,027	12,467	10,506	14,4
	III: RENEWABLE ENERGY SOURCES	4,571	25,56	39,59	42,828	37,528	26,01	31,654	30,545	30,214	16,327	10,406	5,233	6,834	15,5	27,454	65,981	104,91	82,39
	IV: NUCLEAR FISSION and FUSION	721,8	651,4	617,3	561,74	562,19	418,04	356,848	235,32	163,53	44,858	26,985	24,079	26,474	23,028	25,065	37,947	34,337	47,5
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	3,753	9,547	11,791	12,98
	VI: OTHER POWER AND STORAGE TECHS	0,941	0,318	2,593	2,592	5,282	4,559	3,497	1,679	3,003	6,718	1,855	1,927	2,64	6,348	4,554	8,714	7,851	10,7
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	38,45	64,12	78,95	89,735	85,385	44,781	46,188	8,247	6,756	8,659	6,864	30,339	29,383	1,476	0	14,707	14,384	16,62
USA	1: ENERGY EFFICIENCY	36,06	220,1	454,6	194,04	203,1	211,41	159,167	186	276,29	397,02	368,64	365,81	451,49	464,84	291,03	299,83	316,5	342,9
	II: FOSSIL FUELS	501,9	978,6	1316	511,96	350,76	359,49	474,957	884,97	382,68	450,49	306,86	154,12	173,82	341,289	329,86	265,36	256,77	316,5
	III: RENEWABLE ENERGY SOURCES	191,3	703,1	1046	451,42	278,6	190,03	136,366	111,62	124,23	205,1	183,16	212,47	176,56	198,907	185,89	170,19	291,26	305
	IV: NUCLEAR FISSION and FUSION	1904	2731	2345	2258,5	1566,3	1303,5	1133,32	870,89	534,06	393,32	248,12	206,05	228,78	233,471	293,4	379,45	439,7	686,2

	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	114,51	153,11	175,67	182,3
	VI: OTHER POWER AND STORAGE TECHS	57,74	277,9	131,9	96,218	68,938	60,756	56,671	55,357	38,792	107,61	107,93	109,67	103,73	116,531	86,527	95,198	67,498	74,9
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	477,3	689,3	782	98,624	366,72	425,41	430,018	455,14	752,75	712,07	703,75	709,83	764,93	934,518	909,11	834,48	959,66	1045
Japan	1: ENERGY EFFICIENCY	90,84	106,2	52,6	17,453	18,662	19,851	51,732	2,551	12,653	164,52	199,86	312,54	412,82	454,943	313,18	339,27	328,54	311,5
	II: FOSSIL FUELS	10,57	20,48	292,3	350,97	335,17	335,28	315,736	252,61	234,49	265,95	244,49	188,75	76,679	246,649	235,45	272,05	233,37	251,6
	III: RENEWABLE ENERGY SOURCES	40,45	49,93	151,9	152,7	123,34	107,35	104,863	84,791	78,588	76,143	77,824	85,111	108,63	124,958	221,67	180,34	135,44	133,2
	IV: NUCLEAR FISSION and FUSION	621,4	1175	1701	1756,7	1744	1949,1	1211,98	1810,4	1809	1884	2038,3	1823,9	1855,3	2065,24	1747,1	1703	1712,4	1735
	V: HYDROGEN AND FUEL CELLS	..	..	..	..	..	..	..	..	..	..	..	..	..	..	153,04	162,32	142,28	147,3
	VI: OTHER POWER AND STORAGE TECHS	2,915	6,69	50,56	67,833	56,72	67,648	59,177	67,724	69,592	49,441	51,458	90,751	116,98	54,421	52,688	79,54	93,746	82,22
	VII: TOTAL OTHER TECHNOLOGIES OR RESEARCH	310,5	11,75	33,46	44,374	53,309	22,357	17,562	15,367	75,802	81,023	84,008	75,873	53,282	250,25	0	0	0	0

Table 18: Budgets for demonstration, shares of total RD&D budgets. Source: IEA

		2004	2005	2006	2007	2008
Denmark	II.3 Total CO2 Capture and Storage					
	III.1.2 Photovoltaics		33,2%	34,6%	5,2%	1,7%
	III.2 Wind Energy		11,3%	0,4%	0,8%	3,0%
	III.3 Ocean Energy	100,0%	65,3%	14,5%	61,1%	2,4%
	III.4 Total Bio-Energy	18,7%	8,4%	10,7%	56,8%	63,0%
	III.4.1 Production of transport biofuels including from wastes			11,4%	77,2%	88,7%
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen		2,4%	26,9%	0,9%	0,2%
	V.2 Total Fuel Cells	9,6%	0,4%	22,2%	30,0%	1,3%
	TOTAL ENERGY RD&D	5,8%	8,7%	14,5%	20,4%	13,2%
Norway	II.3 Total CO2 Capture and Storage			44,5%	28,5%	18,9%
	III.1.2 Photovoltaics					
	III.2 Wind Energy					71,4%
	III.3 Ocean Energy					40,3%
	III.4 Total Bio-Energy					0,9%
	III.4.1 Production of transport biofuels including from wastes					2,3%
	III.5 Geothermal Energy					
	III.6 Total Hydropower					7,2%
	V.1 Total Hydrogen	2,0%	18,4%	43,6%		26,2%
	V.2 Total Fuel Cells					
	TOTAL ENERGY RD&D	6,4%	10,8%	19,0%	11,4%	17,0%
Sweden	II.3 Total CO2 Capture and Storage					
	III.1.2 Photovoltaics					
	III.2 Wind Energy					
	III.3 Ocean Energy				71,4%	100,0%
	III.4 Total Bio-Energy	27,3%	43,2%	53,8%	37,7%	27,5%
	III.4.1 Production of transport biofuels including from wastes	62,7%	74,1%	81,9%	67,1%	58,2%
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen					
	V.2 Total Fuel Cells					
	TOTAL ENERGY RD&D	13,8%	15,4%	21,5%	19,7%	22,0%
France	II.3 Total CO2 Capture and Storage					
	III.1.2 Photovoltaics		0,3%	1,1%		
	III.2 Wind Energy					
	III.3 Ocean Energy					
	III.4 Total Bio-Energy					
	III.4.1 Production of transport biofuels including from wastes					
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen					
	V.2 Total Fuel Cells			1,9%		
	TOTAL ENERGY RD&D		0,1%	0,1%		
Italy	II.3 Total CO2 Capture and Storage					

	III.1.2 Photovoltaics				47,1%	25,0%
	III.2 Wind Energy				100,0%	100,0%
	III.3 Ocean Energy					
	III.4 Total Bio-Energy				78,3%	75,0%
	III.4.1 Production of transport biofuels including from wastes				100,0%	100,0%
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen					
	V.2 Total Fuel Cells				60,0%	60,0%
	TOTAL ENERGY RD&D				20,9%	26,9%
Netherlands	II.3 Total CO2 Capture and Storage		56,5%	13,4%		
	III.1.2 Photovoltaics		6,0%	5,5%		
	III.2 Wind Energy		7,5%	17,0%		
	III.3 Ocean Energy					
	III.4 Total Bio-Energy		55,9%	51,8%		
	III.4.1 Production of transport biofuels including from wastes					
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen					
	V.2 Total Fuel Cells		9,3%	20,0%		
	TOTAL ENERGY RD&D		30,6%	23,7%		
Portugal	II.3 Total CO2 Capture and Storage					
	III.1.2 Photovoltaics					
	III.2 Wind Energy					
	III.3 Ocean Energy					
	III.4 Total Bio-Energy		25,1%			
	III.4.1 Production of transport biofuels including from wastes					
	III.5 Geothermal Energy					
	III.6 Total Hydropower					
	V.1 Total Hydrogen					
	V.2 Total Fuel Cells					
	TOTAL ENERGY RD&D	21,9%	41,4%	0,1%	2,0%	
United Kingdom	II.3 Total CO2 Capture and Storage			3,1%		27,3%
	III.1.2 Photovoltaics	54,7%	78,6%		37,8%	48,3%
	III.2 Wind Energy		89,7%	93,8%	76,0%	84,9%
	III.3 Ocean Energy			16,3%	13,6%	9,3%
	III.4 Total Bio-Energy	0,4%	45,9%	7,6%	85,0%	26,5%
	III.4.1 Production of transport biofuels including from wastes					
	III.5 Geothermal Energy				5,4%	62,0%
	III.6 Total Hydropower				100,0%	100,0%
	V.1 Total Hydrogen			4,5%		
	V.2 Total Fuel Cells				2,4%	
	TOTAL ENERGY RD&D	10,3%	37,6%	30,8%	38,0%	21,3%

Annex 2: Energy production by energy sources

Table 19: Hydropower, primary production, in Gwh. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	27	30	30	28	32	21	26	22	23	28
Finland	15 051	12 780	14 660	13 204	10 776	9 591	15 070	13 784	11 494	14 177
Iceland	5 621	6 047	6 356	6 578	6 977	7 088	7 134	7 019	7 293	
Norway	115 676	121 454	138 916	120 417	129 415	105 612	108 863	135 665	119 351	133 934
Sweden	74 328	71 691	78 584	79 060	66 360	53 540	60 123	72 808	61 722	66 160
Germany	17 216	19 647	21 732	22 733	23 124	19 264	21 077	19 581	19 931	20 904
Spain	34 005	22 863	29 470	41 021	23 038	41 054	31 554	19 553	25 890	27 763
France	62 667	72 929	67 710	75 177	61 134	59 698	60 397	52 286	56 659	58 706
Italy	41 220	45 365	44 336	46 811	39 519	36 932	42 698	36 067	36 994	32 816
Netherlands	106	90	142	117	108	72	95	88	106	107
Austria	37 164	40 493	41 840	40 187	39 931	32 878	36 423	35 874	34 878	35 993
Portugal	12 983	7 274	11 323	14 034	7 800	15 723	9 869	4 731	11 002	10 092
United Kingdom	5 237	5 361	5 086	4 056	4 788	3 227	4 843	4 922	4 593	5 089
EU27	343 464	340 908	353 247	372 695	315 402	306 242	323 633	306 970	308 996	309 972

Table 20: Wind energy, primary production, in Gwh. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	2 820	3 029	4 241	4 306	4 877	5 561	6 583	6 614	6 108	7 173
Finland	24	49	78	70	64	93	120	170	156	188
Iceland	0	0	0	0	0	0	0	0	0	
Norway	7	25	31	27	75	218	252	506	637	900
Sweden	316	358	457	482	608	679	850	936	987	1 430
Germany	4 593	5 528	9 352	10 456	15 856	18 859	25 509	27 229	30 710	39 713
Spain	1 352	2 744	4 724	6 966	8 704	12 075	15 601	21 219	23 297	27 509
France	20	37	77	131	269	391	596	963	2 189	4 052
Italy	232	403	563	1 179	1 404	1 458	1 847	2 344	2 971	4 034
Netherlands	640	645	829	825	910	1 330	1 867	2 067	2 733	3 438
Austria	45	51	67	172	203	366	924	1 328	1 752	2 015
Portugal	88	123	168	256	362	496	816	1 773	2 925	4 037
United Kingdom	877	850	947	965	1 256	1 285	1 935	2 904	4 225	5 274
EU27	11 278	14 204	22 250	26 977	35 710	44 370	58 815	70 486	82 306	104 259

Table 21: Photovoltaic power, primary production, in Gwh. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	-	-	-	-	-	-	-	-	-	-
Finland	1	1	2	2	2	2	2	3	3	4
Iceland	-	-	-	-	-	-	-	-	-	-
Norway	3	0	0	0	0	0	0	0	0	0
Sweden	0	0	0	1	0	0	0	0	0	0
Germany	35	30	60	116	188	333	557	1 282	2 220	3 075
Spain	4	17	18	24	30	41	56	41	119	501
France	0	0	5	6	7	7	8	10	12	17
Italy	16	17	18	19	21	24	29	31	35	39
Netherlands	3	6	8	14	17	31	33	34	35	36
Austria	2	2	3	4	7	12	14	14	15	17
Portugal	1	1	1	1	2	3	3	3	5	24
United Kingdom	0	1	1	3	4	3	4	8	11	11
EU27	62	75	116	191	279	458	718	1 447	2 480	3 754

Table 22: Geothermal energy, primary production, in 1000 toe. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	3	3	3	3	4	4	4	3	13	14
Finland										
Iceland	1 330	1 670	1 758	1 884	1 861	1 846	1 904	2 030	2 630	:
Norway										
Sweden										
Germany	10	10	10	124	128	132	134	138	167	212
Spain	4	5	8	8	8	8	8	8	8	8
France	117	112	124	109	128	129	130	130	130	130
Italy	3 836	3 999	3 103	3 188	3 464	4 810	4 888	4 791	4 966	5 002
Netherlands										
Austria	8	21	23	23	29	34	35	35	34	32
Portugal	51	70	49	64	84	78	78	66	88	193
United Kingdom	1	1	1	1	1	1	1	1	1	1
EU27	4 119	4 317	3 419	3 629	3 976	5 320	5 398	5 334	5 577	5 771

Table 23: Bio-fuels, Primary production, in 1000 toe. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	0	0	0	22	36	40	58	64	88	88
Finland	-	-	-	-	-	-	-	-	-	-
Norway	-	-	-	-	-	-	-	-	-	-
Sweden	0	0	0	17	37	76	160	235	291	407
Germany	89	116	222	315	494	730	994	2 229	3 856	5 218
Spain	0	0	51	51	120	172	175	259	172	382
France	258	269	323	318	339	367	407	463	684	1 160
Italy	0	0	0	0	0	0	255	179	199	180
Netherlands	0	0	0	0	0	0	2	53	97	85
Austria	14	16	17	19	20	20	37	53	89	212
Portugal	0	0	0	0	0	0	0	0	70	163
United Kingdom	0	0	0	0	0	0	0	8	225	384
EU27	375	400	614	788	1 049	1 444	2 195	3 835	6 187	8 809

Table 24: Renewable energies, primary production, in 1000 toe. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	1 814	1 906	2 065	2 207	2 351	2 637	2 834	2 902	2 946	3 193
Finland	7 257	7 261	7 742	7 440	7 721	7 813	8 671	8 078	8 654	8 589
Iceland	1 814	2 191	2 306	2 451	2 462	2 457	2 519	2 636	3 259	
Norway	11 236	11 940	13 296	11 851	12 539	10 368	10 632	12 987	11 605	12 876
Sweden	14 206	13 611	15 040	14 531	13 415	12 759	13 544	15 285	14 813	15 639
Germany	8 337	8 646	9 628	10 428	11 593	13 580	15 762	17 555	20 827	28 121
Spain	6 875	6 130	7 016	8 307	7 076	9 324	8 972	8 709	9 384	10 288
France	17 894	18 465	18 160	18 540	16 935	17 612	18 035	17 492	17 968	18 645
Italy	8 813	9 569	8 548	8 981	8 636	10 090	11 875	11 528	12 198	11 901
Netherlands	1 646	1 717	1 831	1 879	1 967	2 024	2 116	2 257	2 389	2 496
Austria	6 030	6 744	6 695	6 871	6 952	6 653	7 147	7 273	7 456	7 839
Portugal	3 734	3 369	3 826	4 070	3 643	4 336	3 894	3 578	4 320	4 610
United Kingdom	2 296	2 438	2 600	2 516	2 784	2 871	3 146	3 602	3 949	4 368
EU27	95 419	96 056	99 197	101 861	100 345	108 639	116 650	120 454	128 146	138 831

Table 25: Hard coal, primary production, in 1000 toe. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU27	144102	132557	119038	114292	110827	109380	103758	99180	93511	88604
Denmark	-	-	-	-	-	-	-	-	-	-
Germany	30633	28506	24164	19697	18875	18693	18701	18036	15332	15714
Spain	7659	7005	6544	6148	5756	5368	5135	5086	4703	4454
France	2915	2717	1898	1182	889	1037	99	0	0	0
Italy	0	0	0	69	104	159	62	60	13	100
Netherlands	-	-	-	-	-	-	-	-	-	-
Austria	0	0	0	0	0	0	0	0	0	0
Portugal	0	0	0	0	0	0	0	0	0	0
Finland	-	-	-	-	-	-	-	-	-	-
Sweden	0	0	0	0	0	0	0	0	0	0
UK	25155	21533	18221	18708	17547	16490	15300	11882	10421	9757
Iceland	-	-	-	-	-	-	-	-	-	-
Norway	218	272	425	1200	1431	1976	1949	987	1607	2681

Table 26: Crude oil, primary production, in 1000 toe. Source: Eurostat

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
EU27	171448	177619	169827	158748	161616	151556	140870	128320	116712	115297
Denmar	11690	14799	18176	17280	18551	18563	19692	18935	17231	15526
Germany	2994	2804	3234	3347	3587	3773	3538	3545	3453	3430
Spain	532	301	229	341	319	325	257	168	140	143
France	1997	1824	1692	1662	1341	1431	1388	1248	1119	1031
Italy	5705	5087	4636	4147	5613	5653	5521	6191	5850	5948
Netherlands	2731	2609	2422	2336	3173	3179	2988	2346	2084	2653
Austria	1068	1084	1095	1032	1059	1029	1080	983	1004	1004
Portugal	-	-	-	-	-	-	-	-	-	-
Finland	-	-	-	-	-	-	-	-	-	-
Sweden	0	0	0	0	0	0	0	0	0	0
UK	135015	139866	128761	119004	118505	108300	97314	86393	77986	78269
Iceland	-	-	-	-	-	-	-	-	-	-
Norway	153799	153265	165451	166994	160494	157403	155467	143771	132022	122368

Table 27: Gross electricity generation, Nordic countries, in Gwh. Source: Eurostat

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	Hydro power plants	27	30	30	28	32	21	26	22	23	28
	Wind turbines	2 820	3 029	4 241	4 306	4 877	5 561	6 583	6 614	6 108	7 173
	Coal-fired power stations	23 653	20 081	16 673	17 819	18 257	25 307	18 673	15 463	24 567	19 898
	Oil-Fired Power Stations	4 778	4 675	4 246	3 991	3 822	2 135	1 439	1 221	1 450	1 106
	Natural gas-fired power stations	8 128	9 056	8 774	9 273	9 590	9 764	9 941	8 780	9 418	6 912
	Biomass-fired power stations	1 470	1 801	1 859	2 102	2 502	3 162	3 562	3 989	3 923	3 860
Finland	Hydro power plants	15 051	12 780	14 660	13 204	10 776	9 591	15 070	13 784	11 494	14 177
	Nuclear power plants	21 853	22 974	22 479	22 773	22 295	22 731	22 716	23 271	22 906	23 423
	Coal-fired power stations	8 272	8 522	8 535	10 659	12 611	18 880	16 503	6 492	16 320	13 969
	Lignite-fired power stations	5 442	4 871	3 962	6 210	6 448	7 320	6 525	4 482	6 643	7 403
	Oil-Fired Power Stations	1 567	773	610	652	601	934	615	497	483	468
	Natural gas-fired power stations	8 412	10 113	10 080	11 552	11 304	13 941	12 779	11 251	12 317	10 544
	Biomass-fired power stations	6 696	8 363	8 557	8 411	9 740	9 700	10 509	9 607	10 860	10 060
	Wind turbines	24	49	78	70	64	93	120	170	156	188
Iceland	Hydro power plants	5 621	6 047	6 356	6 578	6 977	7 088	7 134	7 019	7 293	
	Geothermal power plants	655	1 136	1 323	1 451	1 433	1 406	1 483	1 658	2 631	
	Oil-Fired Power Stations	5	5	5	4	6	0	4	5	4	
	Biomass-fired power stations	0	0	0	0	0	0	2	4	2	
Norway	Hydro power plants	116 259	121 887	142 266	121 026	129 837	106 216	109 373	136 441	119 726	135 052
	Wind turbines	7	25	31	27	75	218	252	506	637	900
	Coal-fired power stations	42	41	40	41	41	42	43	42	43	50
	Oil-Fired Power Stations	7	10	9	9	22	31	28	23	29	27
	Natural gas-fired power stations	222	281	211	270	198	299	374	375	471	730
	Biomass-fired power stations	296	112	173	190	282	398	421	379	446	432

Sweden	Hydro power plants	74 378	71 713	78 619	79 082	66 395	53 598	60 178	72 874	61 738	66 188
	Nuclear power plants	73 583	73 188	57 316	72 109	68 111	67 415	77 486	72 377	66 977	66 969
	Coal-fired power stations	2 102	2 242	1 636	1 879	2 357	2 846	1 010	648	879	653
	Oil-Fired Power Stations	3 264	3 094	1 729	2 475	3 089	3 871	1 955	1 379	1 669	1 079
	Natural gas-fired power stations	431	398	462	361	563	700	749	559	582	781
	Biomass-fired power stations	2 760	2 646	4 206	3 881	4 327	5 007	7 943	8 301	9 211	10 578
	Wind turbines	316	358	457	482	608	679	850	936	987	1 430

Table 28: Net installed capacity of renewable energies in Nordic countries in MW, 1998-2007. Source: IEA

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Denmark	Total Capacity (MWe)	1 771	2 120	2 760	2 931	3 443	3 784	3 987	4 098	3 962	3 761
	Hydro	11	11	10	11	11	11	11	11	9	9
	Pumped Storage	0	0	0	0	0	0	0	0	0	0
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	1	1	1	1	2	2	2	3	3	3
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	1 443	1 759	2 392	2 498	2 892	3 117	3 125	3 129	3 135	3 124
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	182	198	230	241	270	285	312	306	299	233
	Solid Biomass	95	110	86	133	215	311	474	584	455	333
	Gas from Biomass	39	41	41	47	53	58	63	65	61	59
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	230	246	246	271	282	298	306	321	337	357
	Cap. of Solar Collectors (MWth)	161	172	172	190	197	209	214	225	236	250
Finland	Total Capacity (MWe)	4000	4121	4423	4568	4610	4721	4785	4841	4883	4974
	Hydro	2881	2881	2882	2926	2964	2966	2999	3035	3062	3102
	Pumped Storage	0	0	0	0	0	0	0	0	0	0
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	2	2	3	3	3	3	4	4	5	5
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	17	38	38	39	43	52	82	82	86	110
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	0	0	0	0	0	0	0	0	0	0
	Solid Biomass	1100	1200	1500	1600	1600	1700	1700	1720	1730	1757
	Gas from Biomass	0	0	0	0	0	0	0	0	0	0
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	8	9	10	11	11	12	14	16	18	19

	Cap. of Solar Collectors (MWth)	6	6	7	8	8	8	10	11	13	13
Iceland	Total Capacity (MWe)	1096	1188	1236	1311	1357	1357	1366	1396	1586	2244
	Hydro	956	1016	1064	1109	1155	1155	1163	1163	1163	1758
	Pumped Storage	0	0	0	0	0	0	0	0	0	0
	Geothermal	140	172	172	202	202	202	202	232	422	485
	Solar Photovoltaics	0	0	0	0	0	0	0	0	0	0
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	0	0	0	0	0	0	0	0	0	0
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	0	0	0	0	0	0	0	0	0	0
	Solid Biomass	0	0	0	0	0	0	0	0	0	0
	Gas from Biomass	0	0	0	0	0	0	1	1	1	1
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	0	0	0	0	0	0	0	0	0	0
	Cap. of Solar Collectors (MWth)	0	0	0	0	0	0	0	0	0	0
Norway	Total Capacity (MWe)	27 780	28 279	28 206	27 764	28 138	28 318	27 797	28 237	29 341	29 737
	Hydro	27 645	28 203	28 126	27 679	27 914	28 076	27 512	27 850	28 941	29 297
	Pumped Storage	663	663	1 360	1 360	1 652	1 318	1 424	1 440	1 396	1 465
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	5	6	6	6	6	7	7	7	8	8
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	4	14	13	13	97	97	152	270	282	322
	Industrial Waste (Non-Renewable)	0	0	0	5	5	5	5	5	5	5
	Municipal Waste	26	26	26	26	15	26	26	26	26	26
	Solid Biomass	100	30	35	35	101	107	95	79	79	79
	Gas from Biomass	0	0	0	0	0	0	0	0	0	0
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	0	0	0	0	0	11	14	13	13	13
	Cap. of Solar Collectors (MWth)	0	0	0	0	0	8	10	9	9	9

Sweden	Total Capacity (MWe)	17 840	18 232	18 319	18 833	18 452	18 405	18 754	19 821	20 767	20 556
	Hydro	16 260	16 451	16 525	16 568	16 232	16 143	16 345	16 345	16 270	16 637
	Pumped Storage	91	19	19	45	45	45	43	43	36	45
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	2	3	3	3	3	3	3	4	5	1
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	174	196	209	295	357	399	452	493	516	710
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	120	93	200
	Municipal Waste	73	74	74	170	170	170	264	291	657	414
	Solid Biomass	1 331	1 490	1 490	1 778	1 670	1 670	1 670	2 526	3 202	2 570
	Gas from Biomass	0	18	18	19	20	20	20	42	24	24
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	181	185	207	229	165	307	336	371	409	440
	Cap. of Solar Collectors (MWth)	127	130	145	160	116	215	235	260	286	308

Table 29: Net installed capacity of renewable energies in MW for reference countries, 1998-2007. Source: IEA.

		1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Austria	Total Capacity (MWe)	12 230	12 486	12 515	12 522	12 610	13 189	13 459	13 790	13 987	15 261
	Hydro	11 444	11 648	11 664	11 668	11 690	11 701	11 750	11 811	11 853	12 009
	Pumped Storage	3 572	3 572	3 572	3 572	3 572	3 573	3 580	3 580	3 580	3 580
	Geothermal	0	0	0	0	0	0	0	0	0	2
	Solar Photovoltaics	3	4	5	7	9	15	19	22	35	35
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	27	35	54	69	133	343	560	827	969	977
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	9	12	12	12	12	364	364	364	364	432
	Solid Biomass	747	787	780	766	766	766	766	766	766	1 699
	Gas from Biomass	0	0	0	0	0	0	0	0	0	92
	Liquid Biomass	0	0	0	0	0	0	0	0	0	15
	Solar Surface (1000 m^2)	1 876	2 000	2 100	2 200	2 400	2 570	2 750	3 009	3 312	3 667
	Cap. of Solar Collectors (MWth)	1 313	1 400	1 470	1 540	1 680	1 799	1 925	2 106	2 318	2 567
France	Total Capacity (MWe)	25 355	25 379	25 427	25 479	25 687	26 488	26 613	27 055	27 845	28 744
	Hydro	25 095	25 115	25 123	25 149	25 306	25 214	25 100	25 109	25 125	25 132
	Pumped Storage	4 303	4 302	4 302	4 302	4 302	4 303	4 303	4 303	4 303	4 303
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	5	6	7	7	8	9	11	13	15	25
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	240	240	240	240	240	240	240	240	240	240
	Wind	15	18	57	83	133	222	363	723	1 412	2 220
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	0	0	0	0	0	586	670	668	732	735
	Solid Biomass	0	0	0	0	0	217	229	228	232	297
	Gas from Biomass	0	0	0	0	0	0	0	74	89	95
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	547	529	513	503	499	515	534	593	768	979

	Cap. of Solar Collectors (MWth)	383	370	359	352	349	361	374	415	538	685
Germany	Total Capacity (MWe)	13 144	15 023	17 135	20 877	24 410	26 337	29 275	31 782	36 572	39 410
	Hydro	8 854	8 853	8 982	9 393	9 499	8 256	8 271	8 341	8 995	8 587
	Pumped Storage	5 857	5 469	4 654	4 562	4 562	4 198	4 198	4 198	4 854	5 223
	Geothermal	0	0	0	0	0	0	1	1	1	2
	Solar Photovoltaics	54	70	114	195	260	388	708	1 508	2 831	3 811
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	2 672	4 138	6 095	8 754	12 001	14 609	16 629	18 428	20 622	22 247
	Industrial Waste (Non-Renewable)	692	993	885	1 200	1 200	1 100	1 100	4	14	137
	Municipal Waste	540	555	585	585	585	847	1 016	1 256	1 369	1 301
	Solid Biomass	103	127	129	190	285	526	884	1 008	1 094	1 400
	Gas from Biomass	229	287	345	560	580	599	654	1 074	1 409	1 665
	Liquid Biomass	0	0	0	..	..	12	12	162	237	397
	Solar Surface (1000 m^2)	2 535	2 418	2 890	4 207	4 754	5 477	6 235	7 197	8 610	9 510
	Cap. of Solar Collectors (MWth)	1 775	1 693	2 023	2 945	3 328	3 834	4 365	5 038	6 027	6 657
Italy	Total Capacity (MWe)	21 235	21 786	22 003	22 430	22 874	23 352	23 891	25 323	27 001	27 960
	Hydro	20 058	20 444	20 346	20 434	20 514	20 660	20 744	20 993	21 072	21 117
	Pumped Storage	7 000	7 027	6 957	6 978	6 957	6 957	6 955	7 103	7 544	7 544
	Geothermal	547	585	590	573	666	707	642	671	671	671
	Solar Photovoltaics	18	18	19	20	22	26	31	34	45	87
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	164	232	363	664	780	874	1 127	1 635	1 902	2 702
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	65	34	31	27
	Municipal Waste	167	165	287	320	378	446	511	1 162	1 063	1 091
	Solid Biomass	154	198	218	221	290	383	503	510	1 923	1 936
	Gas from Biomass	127	144	180	198	224	256	268	284	294	329
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	240	244	271	301	348	400	460	680	866	1 152
	Cap. of Solar Collectors (MWth)	168	171	190	211	244	280	322	476	606	806

Netherlands	Total Capacity (MWe)	826	905	963	1 066	1 359	1 551	1 935	2 583	2 868	2 700
	Hydro	37	37	37	37	37	37	37	37	37	37
	Pumped Storage	0	0	0	0	0	0	0	0	0	0
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	6	9	13	21	26	46	49	51	52	53
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	363	410	447	485	670	906	1 073	1 224	1 558	1 748
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	394	394	394	394	394	400	400	429	429	506
	Solid Biomass	26	55	72	129	189	160	238	343	299	324
	Gas from Biomass	0	0	0	0	0	0	0	0	0	0
	Liquid Biomass	0	0	0	0	43	2	138	499	493	32
	Solar Surface (1000 m^2)	264	310	360	416	475	524	582	620	646	673
	Cap. of Solar Collectors (MWth)	185	217	252	291	333	367	407	434	452	471
Portugal	Total Capacity (MWe)	4 772	4 897	4 908	4 979	5 097	5 171	5 725	6 476	7 141	7 685
	Hydro	4 501	4 527	4 526	4 560	4 587	4 588	4 852	5 034	5 065	5 052
	Pumped Storage	561	597	597	597	597	597	537	537	1 048	1 029
	Geothermal	10	14	14	14	14	14	14	14	25	25
	Solar Photovoltaics	1	1	1	1	1	2	2	2	3	24
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	48	57	83	125	190	268	553	1 064	1 681	2 201
	Industrial Waste (Non-Renewable)	0	0	0	0	0	3	3	4	3	3
	Municipal Waste	0	64	64	64	71	71	71	77	77	77
	Solid Biomass	211	233	219	214	233	224	224	273	279	290
	Gas from Biomass	1	1	1	1	1	1	6	8	8	13
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	223	230	238	246	254	261	269	289	304	330
	Cap. of Solar Collectors (MWth)	156	161	167	172	178	183	188	202	213	231
Spain	Total Capacity (MWe)	17 711	18 751	20 472	21 757	23 431	24 563	27 195	28 893	30 957	34 868

	Hydro	16 632	16 897	17 960	18 032	18 068	18 043	18 167	18 220	18 318	18 372
	Pumped Storage	5 095	5 095	5 288	5 288	2 518	2 518	5 347	5 347	5 347	5 347
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	9	9	12	16	20	27	37	60	169	638
	Solar Thermal	0	0	0	0	0	0	0	0	11	11
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	848	1 613	2 206	3 397	4 891	5 945	8 317	9 918	11 722	15 097
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	94	94	94	94	94	94	189	189	189	189
	Solid Biomass	128	138	150	167	285	329	344	354	388	396
	Gas from Biomass	0	0	50	51	73	125	141	152	160	165
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	341	362	403	462	519	581	689	797	948	1 198
	Cap. of Solar Collectors (MWth)	239	253	282	323	363	407	482	558	664	839
United Kingdom	Total Capacity (MWe)	5 152	5 268	5 473	5 673	5 799	6 171	6 545	7 475	7 900	8 517
	Hydro	4 263	4 265	4 273	4 417	4 378	4 274	4 287	4 289	4 240	4 269
	Pumped Storage	2 788	2 788	2 788	2 788	2 788	2 788	2 788	2 788	2 726	2 744
	Geothermal	0	0	0	0	0	0	0	0	0	0
	Solar Photovoltaics	1	1	2	3	4	6	8	11	14	14
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	1	1	1	1	1	1	1	1
	Wind	331	357	412	427	534	742	933	1 565	1 955	2 477
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	162	161	184	189	203	217	223	234	237	237
	Solid Biomass	84	84	133	133	144	255	303	475	512	530
	Gas from Biomass	311	400	468	503	535	676	790	900	941	989
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	283	298	396	365	446	583	583	863	1 066	1 320
	Cap. of Solar Collectors (MWth)	198	209	277	256	312	408	408	604	746	924
Japan	Total Capacity (MWe)	46 895	47 486	48 593	49 018	49 351	50 116	50 674	51 976	52 905	52 792
	Hydro	45 382	45 860	46 324	46 356	46 403	46 712	46 737	47 292	47 358	47 313

	Pumped Storage	23 905	24 305	24 305	24 735	24 706	24 706	24 689	25 159	25 159	25 489
	Geothermal	533	533	533	533	533	535	535	535	532	532
	Solar Photovoltaics	133	209	330	453	637	860	1 132	1 421	1 709	1 919
	Solar Thermal	0	0	0	0	0	0	0	0	0	0
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	6	34	84	175	277	508	769	1 227	1 805	1 527
	Industrial Waste (Non-Renewable)	0	0	0	0	0	0	0	0	0	0
	Municipal Waste	841	850	1 322	1 501	1 501	1 501	1 501	1 501	1 501	1 501
	Solid Biomass	0	0	0	0	0	0	0	0	0	0
	Gas from Biomass	0	0	0	0	0	0	0	0	0	0
	Liquid Biomass	0	0	0	0	0	0	0	0	0	0
	Solar Surface (1000 m^2)	0	0	0	12 066	12 402	12 683	7 726	6 999	7 510	7 218
	Cap. of Solar Collectors (MWth)	0	0	0	8 446	8 681	8 878	5 408	4 899	5 257	5 053
United States	Total Capacity (MWe)	113 904	115 684	114 883	113 051	112 282	118 337	118 019	121 022	124 541	131 244
	Hydro	98 560	99 062	98 881	95 844	93 994	99 215	98 404	98 887	99 282	99 770
	Pumped Storage	18 898	18 945	19 522	18 334	19 299	20 522	20 764	21 347	21 461	21 886
	Geothermal	2 917	3 001	2 793	3 003	3 012	2 133	2 152	2 285	2 274	2 214
	Solar Photovoltaics	100	117	139	168	212	293	363	493	698	974
	Solar Thermal	360	449	419	246	202	388	388	388	401	465
	Tide/Wave/Ocean	0	0	0	0	0	0	0	0	0	0
	Wind	1 698	2 251	2 377	3 918	4 531	5 995	6 456	8 706	11 329	16 515
	Industrial Waste (Non-Renewable)	808	941	638	378	730	691	545	461	456	366
	Municipal Waste	2 390	2 461	2 627	2 497	2 492	2 442	2 196	2 167	2 188	2 218
	Solid Biomass	6 525	6 785	6 129	6 112	6 151	6 115	6 446	6 471	6 670	7 056
	Gas from Biomass	546	617	880	885	958	1 030	1 004	1 097	1 176	1 491
	Liquid Biomass	0	0	0	0	0	35	65	67	67	75
	Solar Surface (1000 m^2)	20 861	20 364	19 395	18 558	17 893	17 359	17 030	16 613	17 222	17 843
	Cap. of Solar Collectors (MWth)	14 603	14 255	13 577	12 991	12 525	12 151	11 921	11 629	12 055	12 490

Annex 3: Export of energy technology

Table 30: Export of Wind-powered electric generating sets. Nordic and reference countries. In USD. Source: UN Comtrade.

	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	Total
Denmark	667 676 091	426 429 454	997 747 203	1 007 531 677	964 967 579	887 602 130	997 705 929	1 181 530 007	1 718 601 575	1 250 421 369	10 100 213 014
Finland	2 272	36 961	40 434	5 483	313 614		553 918	45 997	433 707	1 051 176	2 483 562
Norway		640			178 145	609	93 107	18 216	1 032	903	292 652
Sweden	84 792	106 943	20 353	617 119	683 528	80 432	86 011	401 295	85 537	561 709	2 727 719
Austria	8 199	198 192	282 536	86 273	1 490 208	4 279 489	467 932	767 809	1 357 270	4 010 798	12 948 706
France	346 662	79 498	481 733	936 532	1 213 356	2 069 455	2 716 181	3 951 812	4 410 248	2 494 422	18 699 899
Germany	30 838 288	43 660 000	37 979 000	20 739 000	78 941 000	97 434 000	590 279 000	831 517 000	969 479 000	2 004 190 000	4 705 056 288
Italy	8 734 663	2 394 503	6 171 455	1 451 284	1 436 903	611 755	12 646 018	158 759 798	44 454 144	23 817 687	260 478 210
Netherlands	914 456	1 644 958	1 750 298	797 405	2 150 087	15 518 895	498 711	3 240 105	15 758 659	15 104 195	57 377 769
Portugal		294			2 102	6 263				121 654 132	121 662 791
Spain	13 493 533	6 698 376	4 083 177	3 117 152	44 841 448	36 627 903	181 657 618	326 999 918	197 977 299		815 496 424
United Kingdom	2 057 608	589 529	4 115 687	4 226 007	17 898 119	4 108 219	2 723 646	3 737 218	15 171 297	9 791 468	64 418 798
Japan	47 664	15 395 540	5 221	1 108 885	1 253 928	359 969	8 476 414	142 839 376	354 009 471	468 847 186	992 343 654
USA	6 955 815	1 678 733		1 758 400	1 545 682	25 866 007	3 626 370	83 309 704	14 157 874	22 072 970	160 971 555

Table 31: Industrial specialisation based on shares of total value added by industrial sector relative to the total economy. 35 sectors. 1998 and 2007 (2006 for Iceland). Sources: OECD, STAN, 2009-2010, STAN 2007.

		Denmark		Finland		Norway		Sweden		Iceland	
	ISIC Rev.3	1998	2007	1998	2007	1998	2007	1998	2007	1998	2006
AGRICULTURE, HUNTING, FORESTRY AND FISHING	01-05	2,68 %	1,83 %	3,62 %	3,35 %	2,27 %	2,18 %	2,08 %	2,13 %	10,45 %	7,54 %
MINING AND QUARRYING OF ENERGY PRODUCING MATERIALS	10-12	2,15 %	2,41 %	0,11 %	0,10 %	24,9 %	20,0 %	0,31 %	0,18 %	..	..
MINING OF COAL AND LIGNITE EXTRACTION OF PEAT	10	..	..	0,11 %	0,10 %	0,0 %	0,0 %	0,01 %	0,00 %	..	..
EXTRACTION OF CRUDE PETROLEUM AND NATURAL GAS AND RELATED SERVICES	11	..	..	..	..	24,9 %	20,0 %	..	..	..	..
MINING AND QUARRYING EXCEPT ENERGY PRODUCING MATERIALS	13-14	0,11 %	0,07 %	0,19 %	0,17 %	0,2 %	0,2 %	..	..	..	..
FOOD PRODUCTS, BEVERAGES AND TOBACCO	15-16	2,81 %	2,02 %	1,71 %	1,91 %	1,62 %	1,43 %	0,30 %	0,18 %	6,02 %	4,16 %
TEXTILES, TEXTILE PRODUCTS, LEATHER AND FOOTWEAR	17-19	0,50 %	0,27 %	0,55 %	0,37 %	0,22 %	0,17 %	0,27 %	0,18 %	0,48 %	0,32 %
WOOD AND PRODUCTS OF WOOD AND CORK	20	0,50 %	0,53 %	1,17 %	1,00 %	0,45 %	0,46 %	0,79 %	0,85 %	0,21 %	0,20 %
PULP, PAPER, PAPER PRODUCTS, PRINTING AND PUBLISHING	21-22	1,79 %	1,40 %	6,36 %	5,65 %	1,74 %	1,43 %	3,60 %	2,83 %	1,44 %	1,16 %
COKE, REFINED PETROLEUM PRODUCTS AND NUCLEAR FUEL	23			0,40 %	0,35 %			0,26 %	1,10 %	0,00 %	0,00 %
CHEMICALS EXCLUDING PHARMACEUTICALS	24ex2423	0,71 %	0,55 %							0,55 %	0,55 %
PHARMACEUTICALS	2423	0,85 %	1,43 %			0,27 %	0,39 %			..	..
RUBBER AND PLASTICS PRODUCTS	25	0,82 %	0,89 %	0,81 %	0,74 %	0,25 %	0,20 %	0,65 %	0,63 %	0,43 %	0,28 %
OTHER NON-METALLIC MINERAL PRODUCTS	26	0,79 %	0,66 %	0,80 %	0,93 %	0,39 %	0,46 %	0,42 %	0,46 %	0,70 %	0,99 %
BASIC METALS	27	0,39 %	0,18 %	1,16 %	1,43 %	0,97 %	0,70 %	0,98 %	1,11 %	1,58 %	1,85 %
FABRICATED METAL PRODUCTS, except machinery and equipment	28	1,44 %	1,31 %	1,54 %	1,80 %	0,74 %	0,87 %	1,95 %	1,86 %	1,19 %	0,85 %
MACHINERY AND EQUIPMENT, N.E.C.	29	2,60 %	2,25 %	2,93 %	3,67 %	1,04 %	1,14 %	2,73 %	2,94 %	0,55 %	0,43 %
OFFICE, ACCOUNTING AND COMPUTING MACHINERY	30	0,06 %	0,15 %	0,02 %	0,02 %	0,02 %	0,02 %	0,16 %	0,08 %	..	..
ELECTRICAL MACHINERY AND APPARATUS, NEC	31	0,63 %	0,94 %	0,79 %	1,26 %	0,47 %	0,40 %	0,55 %	0,62 %	0,19 %	0,12 %
RADIO, TELEVISION AND COMMUNICATION EQUIPMENT	32	0,42 %	0,83 %	2,54 %	11,67 %	0,20 %	0,34 %	0,65 %	1,17 %	0,02 %	0,01 %
MEDICAL, PRECISION AND OPTICAL INSTRUMENTS	33	0,67 %	0,99 %	0,65 %	0,47 %	0,26 %	0,31 %	0,84 %	0,75 %	0,18 %	0,27 %
MOTOR VEHICLES, TRAILERS AND SEMI-TRAILERS	34	0,27 %	0,23 %	0,30 %	0,34 %	0,16 %	0,17 %	1,88 %	2,93 %	0,05 %	0,03 %
OTHER TRANSPORT EQUIPMENT	35	0,37 %	0,15 %	0,51 %	0,29 %	1,48 %	1,34 %	0,59 %	0,49 %	0,68 %	0,34 %

MANUFACTURING NEC	36			0,56 %	0,46 %	0,39 %	0,31 %	0,57 %	0,51 %	0,41 %	0,28 %
RECYCLING	37			0,02 %	0,04 %	0,06 %	0,46 %	0,04 %	0,09 %	0,05 %	0,05 %
ELECTRICITY, GAS, STEAM AND HOT WATER SUPPLY	40	2,15 %	1,58 %	1,65 %	1,57 %	1,78 %	1,82 %	2,17 %	1,62 %	2,92 %	2,90 %
COLLECTION, PURIFICATION AND DISTRIBUTION OF WATER	41	0,13 %	0,04 %	0,23 %	0,19 %	0,16 %	0,12 %	0,31 %	0,24 %	0,20 %	0,16 %
CONSTRUCTION	45	5,48 %	5,32 %	6,33 %	5,18 %	4,74 %	3,68 %	4,21 %	4,00 %	8,25 %	10,51 %
WHOLESALE AND RETAIL TRADE; REPAIRS	50-52	11,70 %	13,16 %	9,85 %	11,14 %	8,61 %	12,97 %	10,37 %	11,76 %	11,22 %	11,14 %
HOTELS AND RESTAURANTS	55	1,70 %	1,40 %	1,43 %	1,20 %	1,45 %	1,52 %	1,51 %	1,32 %	1,67 %	1,88 %
TRANSPORT AND STORAGE	60-63	5,01 %	5,86 %	7,60 %	6,85 %	7,30 %	5,91 %	5,92 %	5,03 %	5,87 %	5,84 %
POST AND TELECOMMUNICATIONS	64	2,09 %	2,88 %	2,65 %	3,81 %	1,52 %	2,53 %	1,93 %	2,58 %	1,84 %	2,77 %
FINANCIAL INTERMEDIATION	65-67	4,89 %	7,30 %	4,85 %	3,18 %	2,75 %	4,21 %	4,16 %	4,65 %	4,45 %	8,15 %
REAL ESTATE ACTIVITIES	70	9,88 %	9,18 %	10,28 %	9,10 %	6,68 %	6,92 %	10,92 %	9,13 %	8,29 %	8,48 %
COMPUTER AND RELATED ACTIVITIES	72	1,16 %	2,41 %	1,31 %	1,83 %	1,19 %	1,72 %	2,51 %	3,22 %	0,97 %	1,23 %
RESEARCH AND DEVELOPMENT	73	0,30 %	0,25 %	0,50 %	0,39 %	0,43 %	0,35 %			0,47 %	0,40 %
OTHER BUSINESS ACTIVITIES	74	5,39 %	6,04 %	3,93 %	4,02 %	3,99 %	5,65 %	7,02 %	8,20 %	3,80 %	6,03 %
COMMUNITY SOCIAL AND PERSONAL SERVICES	75-99	27,80 %	24,96 %	22,13 %	17,39 %	20,71 %	19,78 %	25,87 %	21,59 %	24,75 %	20,44 %

a) Share for 2006
b) Share for 2003
c) Share for 2000

Annex 4: Bibliometric keywords

This preliminary set of keywords is based on Klitkou et al (2008). It has been improved during the project.

Wind energy

(TS=(Wind energ* OR Wind power OR wind turbin* OR wind mill* OR offshore wind* OR onshore wind* OR airborne turbine* OR near-shore turbine* OR wind resource assessment OR wind farm* OR Upwind rotor* OR horizontal-axis rotor* OR pitch regulation OR stall regulation OR variable-speed drive OR doubly-fed induction generator OR permanent magnet generator - full converter OR joined blades OR blade winglet* OR slew-ring-type bearings))

NOT (SO =(ASTROPHYSICAL JOURNAL OR JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS OR ASTRONOMY & ASTROPHYSICS OR ANNALES GEOPHYSICAE OR MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY OR SPACE SCIENCE REVIEWS OR ASTRONOMY AND ASTROPHYSICS OR PLANETARY AND SPACE SCIENCE OR SOLAR PHYSICS OR ASTROPHYSICS AND SPACE SCIENCE OR ICARUS OR ANNALES GEOPHYSICAE-ATMOSPHERES HYDROSPHERES AND SPACE SCIENCES OR ASTRONOMY LETTERS-A JOURNAL OF ASTRONOMY AND SPACE ASTROPHYSICS OR ASTRONOMICAL JOURNAL OR NUOVO CIMENTO DELLA SOCIETA ITALIANA DI FISICA C-GEOPHYSICS AND SPACE PHYSICS OR ASTRONOMY REPORTS OR ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES OR COORDINATED MEASUREMENTS OF MAGNETOSPHERIC PROCESSES OR HELIOSPHERIC COSMIC RAY TRANSPORT, MODULATION AND TURBULENCE OR COSMIC RESEARCH OR SOLAR SYSTEM RESEARCH OR SPACE WEATHER-THE INTERNATIONAL JOURNAL OF RESEARCH AND APPLICATIONS OR TO THE EDGE OF THE SOLAR SYSTEM AND BEYOND OR HELIOSPHERE AT SOLAR MAXIMUM OR YOUNG NEUTRON STARS AND THEIR ENVIRONMENTS OR ASTROPARTICLE PHYSICS OR PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF JAPAN OR COMPARATIVE MAGNETOSPHERES OR PUBLICATIONS OF THE ASTRONOMICAL SOCIETY OF THE PACIFIC OR SOLAR WIND-MAGNETOSPHERE-IONOSPHERE DYNAMICS AND RADIATION MODELS OR CHINESE JOURNAL OF ASTRONOMY AND ASTROPHYSICS OR ENERGY RELEASE AND PARTICLE ACCELERATION IN THE SOLAR ATMOSPHERE - FLARES AND RELATED PHENOMENA OR NEW ASTRONOMY REVIEWS OR PLASMA PHYSICS AND CONTROLLED FUSION OR GEOPHYSICAL RESEARCH LETTERS OR JOURNAL OF GEOPHYSICAL RESEARCH-OCEANS OR ASTROPHYSICAL JOURNAL LETTERS OR ADVANCES IN SPACE RESEARCH OR JOURNAL OF PHYSICAL OCEANOGRAPHY OR JOURNAL OF ATMOSPHERIC AND SOLAR-TERRESTRIAL PHYSICS OR JOURNAL OF GEOPHYSICAL RESEARCH-ATMOSPHERES OR JOURNAL OF SOLAR ENERGY ENGINEERING-TRANSACTIONS OF THE ASME)

Solar photovoltaics

(TS =(solar photovoltaic* OR (solar AND silicon*) OR solar cell* OR (silicon* AND wafer) OR Photoelectrochemical Cell*) OR (thin film*) OR (anti reflection coating) OR (screen printing) OR passivation)

NOT ((TS=(astronom* OR astrophysic* OR Space science* OR solar corona* OR CELL CARCINOMA OR medic*) OR (SO=(Astronomy* OR ASTROPHYSICAL JOURNAL OR JOURNAL OF GEOPHYSICAL RESEARCH-SPACE PHYSICS OR ANNALES GEOPHYSICAE OR ASTRONOMISCHE NACHRICHTEN OR MONTHLY NOTICES OF THE ROYAL ASTRONOMICAL SOCIETY OR SOLAR PHYSICS OR ASTROBIOLOGY OR ASTRONOMICAL JOURNAL OR ICARUS OR (JOURNAL OF COSMOLOGY AND ASTROPARTICLE PHYSICS) OR (MERCURY, MARS AND SATURN) OR (NEW EYES TO SEE INSIDE THE SUN AND STARS) OR (POLAR CAP THERMOSPHERE/IONOSPHERE AND ITS ROLE IN SOLAR-TERRESTRIAL PHYSICS) OR (RECONNECTION AT SUN AND IN MAGNETOSPHERES) OR SPACE SCIENCE*))

Biofuels

- 1st generation:

(TS=biofuel*) OR (TS=bio-fuel*) OR (TS=bioethanol) OR (TS=biomethanol) OR (TS=biogasoline) OR (TS=biodiesel)

- 2nd generation:

(TS=cellulosic bioethanol) OR (TS=Biomass-to-liquid*) OR (TS=Fischer-Tropsch diesel) OR (TS=Synthetic biodiesel) OR (TS=Synthetic diesel) OR (TS=Biomethanol) OR (TS=Heavier alcohols) OR (TS=Bio-DME) OR (TS=Hydro-treated biodiesel) OR (TS=Synthetic natural gas) OR (TS=Lignocellulosic biomass*) OR (TS=Lignocellulosic material*) OR (TS=advanced hydrolysis) OR (TS=advanced fermentation) OR (TS=gasification synthesis) OR (TS=anaerobic digestion) OR (TS=Hydrolysis fermentation) OR (TS=advanced biofuel*) OR (TS=advanced bioenergy) OR (TS=2nd generation biofuel*) OR (TS=advanced bioethanol) OR (TS=biochar pyrolysis)

- 3rd generation:

((TS=biofuel*) OR (TS=bio-fuel*)) AND (TS=algae*)

Geothermal energy

TS=(geothermal energy OR geothermal electricity OR geothermal plant* OR geothermal "hot dry rock" OR enhanced geothermal system* OR engineered geothermal system*)

Carbon Capturing and Storage (CCS)

- Carbon capture:

(TS=Carbon dioxide captur*) OR (TS=CO2 captur*) OR (TS=carbon captur*) OR (TS="post-combustion separation") OR (TS="pre-combustion separation") OR (TS="oxy-fuel combustion") OR (TS="Oxy-fuel Firing")

- Carbon storage:

(TS="Carbon dioxide storag*") OR (TS="CO2 storag*") OR (TS=carbon storag*) OR (TS="Depleted Oil and Gas Field*") OR (TS="Enhanced Oil Recovery") OR (TS="Enhanced Gas Recovery") OR (TS="Saline aquifer*") OR (TS="Un-mineable coal seam*") OR (TS="carbon dioxide sequestration") OR (TS="CO2 sequestration") OR (TS="CO2 injection*") OR (TS="carbon dioxide injection*")

Annex 5: Patent classes for renewable energy technologies

The following table is borrowed from the EST inventory on energy generation used by the joint EPO/UNEP/ICTSD study.

			number of documents (1)	IPC source
ENE RGY GENERATION:				
geothermal			5342	F24J3, F03G4 and parts of F03G7/04
	Earth coil heat exchangers		597	part of F24J3/08
	Hot Dry Rock systems (drilling)		357	part of F24J3/08
	geothermal heat pump (for buildings)		140	part of F24J3/06
	Hardware (pipes)		1202	part of F24J3/08
hydro			44124	mainly F03B
	conventional		13970	F03B1, F03B3, F03B7
	OTEC (ocean thermal energy conversion)		591	F03G7/05
	OWC (oscillating water column)		530	part of F03B13
	salinity gradient		1020	part of F03G7/04
	stream (river and tidal)		4479	parts of F03B13/26 and F03B17/06
	wave (pelamis etc.)		6960	F03B13/14
Solar energy (3):				
	solar thermal		62487	mainly F24J2
		dish	1330	F24J2/12
		Fresnel lenses	942	part of F24J2/08
		trough concentrators	2043	F24J2/14
		tower concentrators	1729	F24J2/07
		heat exchange systems	26299	other parts of F24J2
		mountings and tracking	7555	F24J2/38, 2/52, 2/54
		mechanical power	3418	parts of F03G6
	PV (photovoltaic)		83330	Mainly parts of H01L31 (most H01L31/04)
		amorphous Si	2312	parts of H01L31/075, 31/0376 and 31/0368
		CuInSe2 materials	1568	parts of H01L31/032, 31/0336
		pv with concentrators	6220	H01L31/052, 31/042, 31/058
		DSSC (dye sensitized solar cells)	4170	parts of H01G9/20
		group II-VI materials	1529	parts of H01L31/072, 31/18
		group III-V materials	2556	parts of H01L31/068, 31/072, 31/18E, 31/0304
		microcrystalline Si	193	parts of H01L31/18
		polycrystalline Si	504	parts of H01L31/18
		pv roof systems	4800	parts of h01l31/048 and E04D13/18

	thermal-pv hybrids		1590	H01L31/058
wind energy (4):			37995	Mainly F03D
	blades and rotors		9859	F03D1/06, 3/06
	components and gearbox		11251	F03D11/00, 11/02
	control of turbines etc.		9508	F03D7
	generator and configuration		5243	F03D9/00, parts of H02K7/18
	nacelles		605	parts of F03D
	offshore towers		830	parts of : F03D1, 11/04, E04H12/14 and B63B35
	onshore towers		6030	parts of : F03D1, 11/04, E04H12/14
Biofuels (5)				
	CHP turbines for bio-feed		1307	parts of F02C6/18
	Gas turbines for bio-feed		626	parts of F02C3/28
	bio-diesel		2324	parts of C10L, C10G, C11B, C11B, C07C67
	bio-pyrolysis		4550	C10C5/00, parts of C10B53/02
	torrefaction of biomass		120	parts of C10L9, C10L5/40, C10B53/02
	bio-ethanol: cellulosic		1672	C12P7/10
	bio-ethanol: grain		5894	C12P7/06
	bio-alcohols produced by other means than fermentation		208	parts of C07C29, C07C31
AUXILIARY TECHNOLOGIES:				
Carbon Capture and Storage (1):				
	capture (1.1):			
		CO2 absorption	2699	parts of B01D53/14
		CO2 adsorption	2387	parts of B01D53
		CO2 biological separation	94	parts of B01D53
		CO2 chemical separation	2008	parts of B01D53/62
		CO2 removal via membrane/ diffusion	998	parts of B01D53/22
		CO2 removal via rectification and condensation	1328	parts of F25J3/02, 23/06
	CO2 storage (subterranean or sub-marine)		730	parts of F17C1/00, E21B41/00
Energy Storage (2)				
	Fuel cells (2.1)	bio fuel cells	887	parts of H01M
		DMCF+DAFC	10251	"
		MCFC	3545	"

		PEMFC	21508	"
		recycling of fuel cells	2571	"
		SOFC	16346	"
	Advanced batteries (2.2)			
		charge management	104202	parts of H01M
		Flow	2158	"
		lithium-ion	57392	"
		NiMH	4131	"
		recycling of batteries	2528	"
		ultra-capacitors	6583	"
IGCC (3)	IGCC		2528	parts of C10L3, F02C2/28, 6/18, F01K23/06
	IGCC with CCS		22	parts of C10L3, F02C2/28, 6/18, F01K23/06

(1) The number of families is roughly one third of the number of documents indicated.

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Glossary

Energy Intensity:
Energy intensity gives an indication of the effectiveness with which energy is being used to produce added value. It is defined as the ratio of Gross Domestic Consumption of energy to Gross Domestic Product.

Gross Inland Consumption:
Gross inland consumption is the quantity of energy consumed within the borders of a country. It is calculated using the following formula: primary production + recovered products + imports + stock changes – exports –bunkers (i.e. quantities supplied to sea-going ships).

Gross generation:
The total amount of electric energy produced by generating units and measured at the generating terminal in kilowatt hours (kWh) or megawatt hours (MWh).

Final Energy Consumption:
Final energy consumption is the energy finally consumed in the transport, industrial, commercial, agricultural, public and household sectors. It excludes deliveries to the energy transformation sector and to the energy industries themselves.

Net generation:
The amount of gross generation less the electrical energy consumed at the generating station(s) for station service or auxiliaries. Note: Electricity required for pumping at pumped-storage plants is regarded as electricity for station service and is deducted from gross generation.

Primary Energy Production:
Primary energy production is the extraction of energy from a natural source. The precise definition depends on the fuel involved:

Hydropower, Wind energy, Solar photovoltaic energy:
Quantities of electricity generated. Production is calculated on the basis of the gross electricity generated and a conversion factor of 3 600 kJ/kWh.

Geothermal energy:
Quantities of heat extracted from geothermal fluids. Production is calculated on the basis of the difference 189 between the enthalpy of the fluid produced in the production borehole and that of the fluid disposed of via the re-injection borehole.

List of abbreviations

List of acronyms

€	Euro
BERD	Business Expenditures on R&D
CCS	Carbon dioxide Capture and Storage
ECLA	European Classification
EPO	European Patent Office
ERMINE	Electricity Research Road Map in Europe
ERTD	Energy Research, Technology and Development
EST	Environment Sound Technologies
EU or EU-27	European Union
EW	ERAWATCH
GBAORD	Government Budget Appropriations or Outlays on R&D
GDP	Gross Domestic Product
HRST	Human resources in Science and Technology
HS	Harmonised Commodity Description and Coding System
ICTSD	International Centre on Trade and Sustainable Development
IEA	International Energy Agency
IEADCC	IEA Climate Change Database
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)
MEI	Measuring eco innovations
MS	Member State of the European Union
NACE	Statistical Classification of Economic Activities
OECD	Organisation for Economic Co-operation and Development
PPP	Purchasing Power Parities
PV	Photovoltaic
R&D	Research and Development
RD&D	Research, Development and Demonstration
RCTA	Revealed Comparative Technology Advantage
RON (95)	Research Octane Number ("EuroSuper" or "EuroPremium")
RTD	Research Technology Development
SET-Plan	(European) Strategic Energy Technology Plan
S&T	Science and Technology
SRS NET and EE	Scientific Reference System on new energy technologies, energy end-use efficiency and energy RTD
UN	United Nations
UNEP	United Nations Environment Programme
USD	US Dollar
WEC	World Energy Council

Unit abbreviations

GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt hour
kcal	kilocalorie
KJ	kilo joule
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
PPP	Purchasing power parity
Toe	Tone of oil equivalent= 107 kcal
TWh	Terawatt hour