Production and consumption of energy in the Nordic region – a competitive international perspective

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- A COMPETITIVE INTERNATIONAL PERSPECTIVE

CONTENT

1 ENERGY – A CHANGING SCENE

1.1 Background and purpose

From the end of the second World War to the oil crisis in 1973 the supply of energy in the world was characterized by cheap access to oil. In October 1973 (at the Jewish High Holiday of Yom-Kippur) forces from Egypt and Syria attacked Israel. The consequences were dramatic: the oil price increased from 3 to 12 dollars a barrel. The world economy was shaken. US, the largest economy of the world, was forced to act and former US Secretary of State, Henry Kissinger, became the main actor in the negotiations with representatives of the oil-producing countries (OPEC)[1]. From American point of view an increase of the oil-price could become an advantage as Japan and Germany were the main competitors. These countries have few natural resources and their competitiveness would be weakened in relation to that of US with its oil, gas and coal reserves.

The problem was that OPEC wanted to raise the oil-prices to levels that would lead to difficulties in balancing the world economy. The negotiations were interrupted. As a consequence the IEA (International Energy Agency) was founded (in November 1974) to help countries co-ordinate a collective response to major disruptions in oil supply.[2] Most OECD-countries are members of IEA. After a period of stabilization oil prices rose dramatically with the fall of the shah of Iran and the war between Iran and Iraq (Odell 1986).

More attention was now paid to the supply of energy as a share of the world economy. This change led to search for energy sources in "stable"

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[1] OPEC (Organization of the Petroleum Exporting Countries) was created by Iran, Iraq, Kuwait, Saudi Arabia and Venezuela in September 1960. *OPECs objective is to co-ordinate and unify petroleum policies among Member Countries, in order to secure fair and stable prices for petroleum producers, an efficient, economic and regular supply of petroleum to consuming nations; and a fair return on capital to those investing in industry* (OPEC 2014-09-23, p 1).

[2] The objectives of the IEA include *to maintain and improve systems for coping with oil supply disruptions, to promote rational energy policies in a global context through cooperative relations with non-member countries, industry and international organisations* and *to operate a permanent information system on the international oil market* (IEA 2014-09-23, p 1).

political territories. Big investments were made in technology enabling extraction of oil and gas offshore e.g. in the North Sea. In the Nordic region, Norway and Denmark became important producers of oil and gas[3]. Relatively high oil and gas prices during many years have brought increasing investments in offshore activities. Furthermore, the Norwegian State has created the Government Pension Fund – Global to facilitate government savings to finance rising public pension expenditures, and support long-term considerations in the spending of government petroleum revenues (Government.no 2015-01-21).

The drastic lower oil and gas prices by the end of 2014 show the vulnerability of the energy market and its dependence on international changes. One important factor influencing the present market is the use of fracturing (fracking) at extraction of oil and gas, which has led to less imports of energy to US. Advances in the techniques of horizontal drilling and hydraulic fracking have been introduced and become competitive (FT 2014b). The technique is controversial due to its environmental impact. Fracking, though, enables drilling firms to access difficult-to-reach resources of oil and gas (BBC News 2014-09-23).

Another factor behind the low energy prices is the large production of oil in Saudi Arabia. Saudi Arabia and some other countries generally regulate their production to hinder too much production. But at present Saudi Arabia tries to decrease the oil price to a level that will cut off production from areas with high extraction costs (SvD 2014a). At the same time Russia tries to find alternatives to the European market (FT 2014a). These efforts are in accordance with EU´s policy to reduce the dependence on energy supply from Russia.

The comparatively high costs at extracting energy sources offshore put extra pressure on operators at falling prices. These costs are in the Nordic region stressed by the extraction of energy in sources of the North Sea. The difficulties to extract oil and gas offshore at low costs are illustrated by the movement of oil rigs to Holland or Scotland that can offer cheap "parking" (SvD 2014b).

These observations reflect a world of changing conditions for production and consumption of energy. At present the production of

[3] Here the Nordic region includes Denmark, Finland, Iceland, Norway and Sweden.

renewable energy tends to increase. But the consumption of energy increases chiefly in emerging economies based on mainly fossil fuels (BP Statistical Review 2014). Demand and supply of energy is thus challenged on global, regional and local/regional levels.

The purpose of the study is an attempt to throw some light on the connection between conditions for producing energy and competitiveness. This is accomplished by studying the development of production and consumption of energy on different geographical levels: the global level, EU and the Nordic region. Focus is the competitive ability of the Nordic region regarding international challenges.

1.2 Design and disposition

The paper describes changing conditions such as varying oil prices at extraction of the largest commercial sources of energy in the world. Regional aspects concerning economic political issues are observed. The impact of changes of the energy markets exemplified by introduction of new technology at production of energy, is analysed in a Nordic perspective. The design of the paper reflects the assumption of mutual relationships of changes of the energy markets. See figure 1.

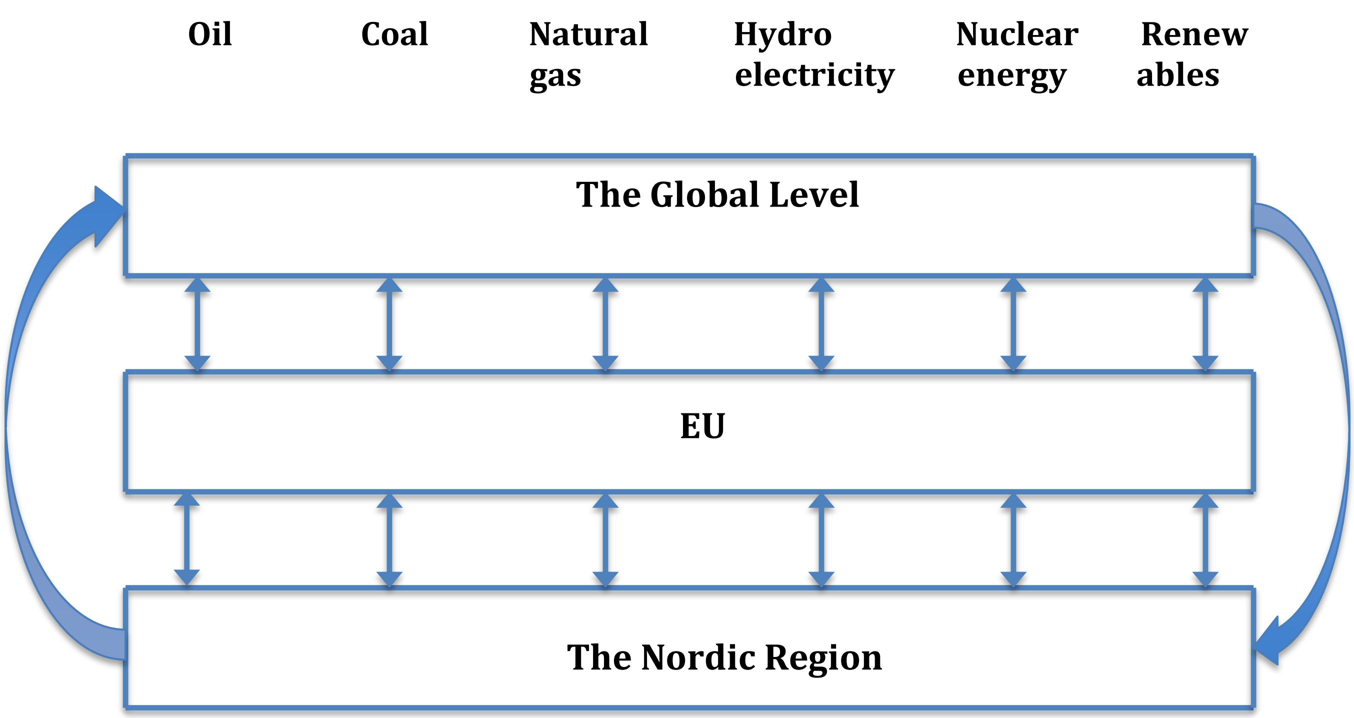

Figure 1 The design of the paper.

The following issues are raised:

* Changes in extracting energy chiefly during 2003 – 2013. Impact on competitiveness regarding Nordic energy sources.

* Conditions in EU concerning production and consumption of energy. Impact on competitiveness regarding Nordic energy sources.

* The Nordic competitiveness regarding production and consumption of energy in relation to the world and EU?

* Are there strategic advantages in the current political and economic situation enabling Nordic competitiveness as producer and consumer of energy?

The global level is the starting point of the paper and creates a frame of reference when raising the issue about when we will run out of fossil fuels which is discussed in chapter 2. Chapter 3 focuses on production and consumption of the main sources of energy: oil, coal, natural gas, hydroelectricity, nuclear energy, wind and biofuels in a global perspective chiefly during the period 2003 – 2013.

In chapter 4 the present situation regarding production and consumption of energy in EU-countries is observed. Suppliers of energy such as oil and gas via pipelines from Russia and Norway are also investigated. This context includes identification of political aims in EU and Russia to become less energy dependent on each other.

The mapping of the energy markets in the world and in EU enable identification of competitive Nordic sources of energy as regards production as well as presence on the energy market. Chapter 5 also pays attention to the unique Norwegian position as producer of energy. Furthermore, the generation of electricity and the transmission nets in and between the Nordic countries and links to surrounding countries are mapped. The ability to store electricity by using reservoirs is another factor analysed in this chapter. In addition, this chapter deals with renewable energy, nuclear energy and other sources of energy used for generating electricity.

Chapter 6 focuses the use of energy. The interplay between type of sector and level of consumption is observed. Besides, the greenhouse gas emissions are identified. Some concluding remarks related to the issues bring the paper to an end (chapter 7).

1.3 Distinctions

Here, the following distinctions are made at discussing energy-issues:
- stored and renewable energy
- commercial and non-commercial energy
- quantity and quality

Stored sources of energy such as coal, oil and natural gas are fossil fuels created from renewable energy. But this process is slow. Therefore they are defined as non-renewable sources. *Renewable energy* such as wind, geothermal, solar, biomass and waste are included in energy flows of the nature.

The number of forms of energy that are sold and registered *commercially* are limited. In many countries the demand of energy to a large extent is satisfied by *non-commercial energy* such *as* wood and droppings collected by households and not registered in energy balances.

The volumes of energy are described in different *quantitative* measures such as watt-hours and million tons. The *quality* (or utility), however, is difficult to define. In physics the definition exergi is often used to describe the quality of different types of energy.

The following presentation focuses sources of fossil fuels (coal, oil and natural gas) and other commercial sources; hydroelectricity, nuclear energy and some forms of renewable energy.

2 WHEN WILL WE RUN OUT OF FOSSIL FUELS?

The issue when we will run out of fossil fuels has been hot during many years. A decisive factor at discussing this issue is the price of different sources of energy. This has led to studies of mainly the development of the supply and demand of oil as it is the most important source of commercial energy in the world. But this dependence on oil comprises turbulence as the oil has become a strategic tool at political conflicts. Since the oil crisis in 1973 changes of the oil price have been dramatic exemplified by the present fall of the price. Changes of this kind influence what countries will stay competitive at different prices of oil.

Another decisive factor at analysing the competitiveness of countries is the size of the energy reserves. This leads to the need to identify countries able to supply energy to competitive prices for many years. Here, the relation R/P (Reserves/Production) is seen as an indicator of present and future competitiveness of countries on the oil and natural gas markets. Knowledge of this relation forms a frame of reference at discussing the issue of production and consumption of energy in the Nordic countries in perspective of global changes.

The properties of *oil* such as high energy value per weight and volume, its easyness to transport, usefulness for many purposes and its existence in limited territories of the world make oil to an important commodity of the international market. The use of oil within the transport sector combined with its relatively short time before it runs out stress how important it is to observe the role of oil when discussing issues of the world economy. Figure 2 illustrates the uneven distribution of oil reserves of the world.

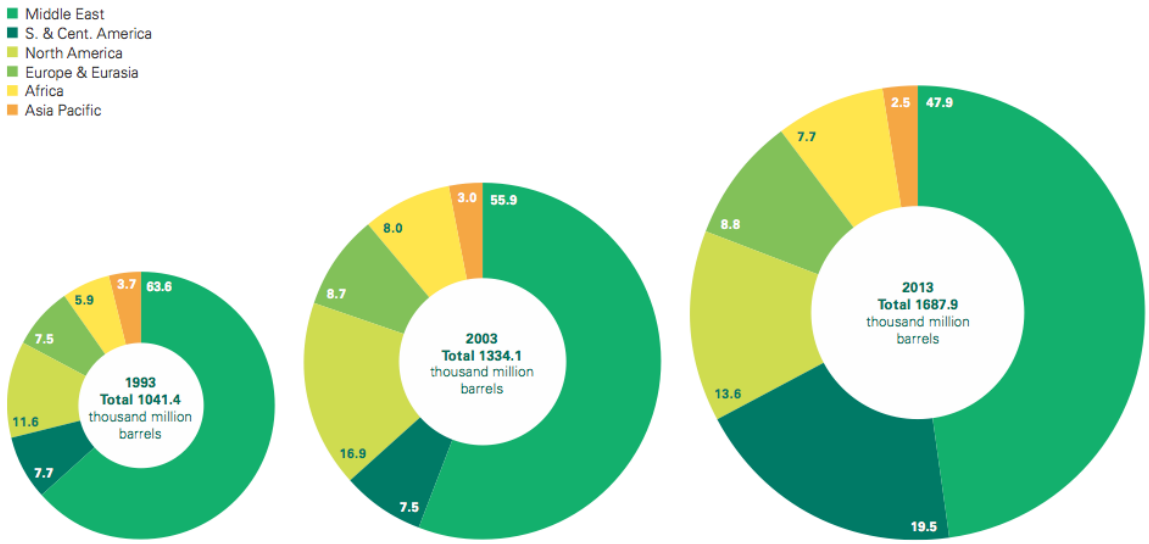

Figure 2 Distribution of proved reserves of oil in 1993, 2003 and 2013 (percentage).
Source: BP Statistical Review 2014.

Furthermore, the figure shows the increase of the reserves. During the past decade global proved reserves increased by 27%. The length of time of remaining reserves varies from a few years (e.g. Colombia, Turkmenistan and Thailand) to more than 100 years (e.g. Canada[4], Iran and Iraq (BP Statistical Review 2014).

The competitiveness of *natural gas* is related to its environmentally friendly characteristics. The transportation of gas has not led to environmental problems in terms of adverse effects on landscapes or marine conditions even if explosions constitute a danger to life. But this type of accidents have not occurred frequently and does not seem to constrain pipelined supplies. Furthermore, the lower CO_2 emissions from gas in comparison to coal and oil make gas competitive. More attention, however, should be paid to environmental impact of growing international movements of gas in its liquefied state by ocean going

[4] Big deposits of oil sands explain the length of time of remaining reserves of Canada. Canada´s proved oil reserves are the second largest in the world (Government of Canada 2014-09-23). The sands are found in the Athabasca, Peace River and Cold Lake areas in Alberta and part of Saskatchewan (Canadian Association of Petroleum Producers 2014-09-23).

tankers (Odell 2004). Figure 3 reflects big reserves of gas in Iran and Russian Federation.

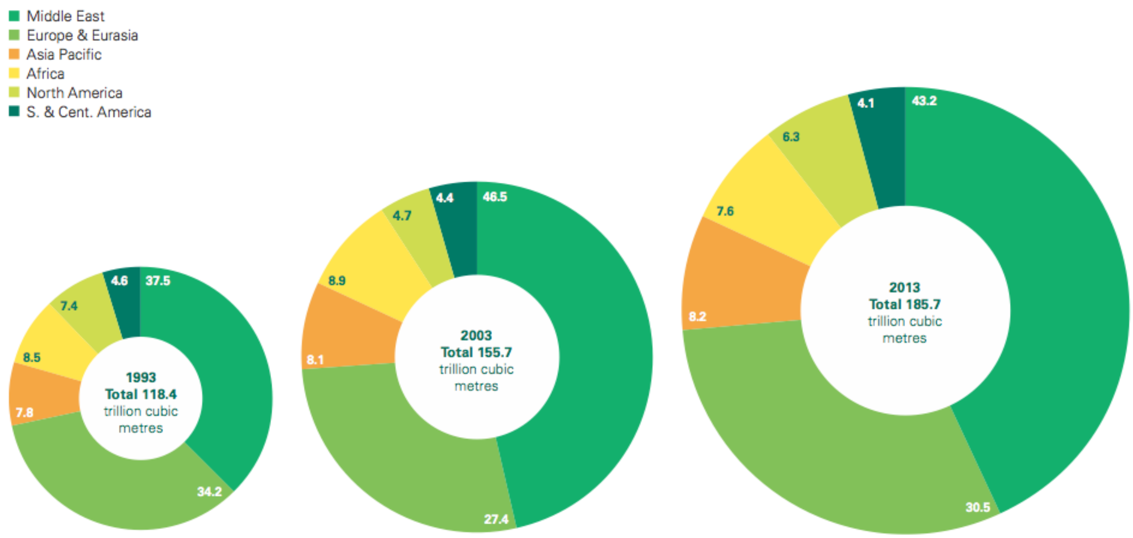

Figure 3 Distribution of proved reserves of natural gas in 1993, 2003 and 2013 (percentage).
Source: BP Statistical Review 2014.

The reserves tend to increase. During the past decade global proved reserves increased by 19 %. The length of time of remaining reserves varies from some years (e.g. Germany, Italy and United Kingdom) to more than 100 years (e.g. Iran, Iraq and Kuwait)(BP Statistical Review 2014).

The geographical pattern of production and consumption of natural gas is defined by the properties of gas. Gas is hard to store and often demand big investments in pipelines, which is the main means of transportation. The pipelines are constructed both within and between countries. A consequence is a tendency to invest in pipelines between large areas of production and consumption. An alternative is to freeze the gas to minus 162 degrees when it becomes liquefied. Liquefied Natural Gas (LNG) is used when pipelines are hard to construct such as long distant connections to islands. About a fourth of the gas deliveries are performed by LNG-ships. By the freezing procedure 600m^3 natural gas are reduced to 1m^3 liquefied gas. When the gas arrives to the port of destination it is by heating transformed to gas enabling transportation by pipelines to the customers (Ruhr 2011-01-03).

The transmission costs play a decisive role at explaining the construction of gas networks. The need for big investments in pipelines restrict the extension of links. This importance of minimising the transmission costs is underlined by the tendency to exploit deposits located far away from the markets. In this respect construction of big pipelines seem to go hand in hand with investments in transport-systems based on ocean going LNG-ships linking deposits of gas with markets all over the world.

Even if the share is stable the consumption of gas in the world has increased during the past decade. In 2003 the consumption was 2 332 Mtoe and 3 020 in 2013; an increase of 688 Mtoe (30%)(BP Statistical Review 2004, 2014). This development is related to the introduction of new technology at exploiting energy sources. The most remarkable impact concerns the way fracking has created opportunities for exploitation of natural gas in different territories[5].

The R/P ratio (Reserves/Production) varies over time and between countries. At present this calculation, based on the development during 2013, shows that *coal* will run out in 113 years, natural gas in 55 years and oil in 53 years. But the time between regions and countries varies a lot. For example, the coal in Russia will run out in 452 years, in US in 266 years and in China in 31 years (BP Statistical Review 2014)[6].

But here observed predictions presented by P.R. Odell show continuing strong combination of oil, natural gas and coal. The use of gas will increase and will become the most important source of energy during the 21st century (Odell 2004)[7].

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[5] Fracking is shorthand for hydraulic fracturing; how the rock is fractured apart by the high pressure mixture (BBC News 2014-09-23).

[6]. In 2003 the R/P ratio (Reserves/Production) of the world for oil was 41 years, for natural gas 67 years and for coal 192 years (BP Statistical Review 2004).

[7] Peter R. Odell is professor emeritus at International Energy Studies, Erasmus University, Rotterdam. See also Odell 2010.

3 GLOBAL PERSPECTIVE

3.1 Introduction[8]

The consumption of energy in the world is mainly based on the use of oil, coal, natural gas, hydroelectricity and nuclear energy even if the importance of renewable energy tends to increase. Figure 1 shows the development of the consumption of energy in the world related to sources.

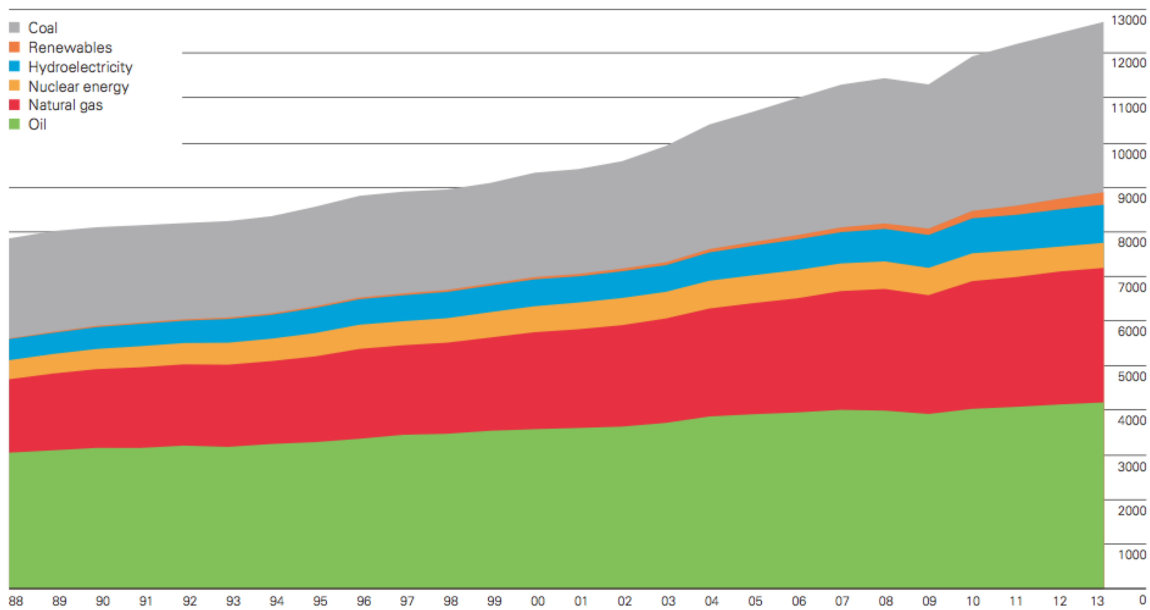

Figure 1 Consumption (Mtoe) of energy related to sources 1988 – 2013. Source: BP Statistical Review 2014.

The increasing consumption of energy is underlined by the growth of coal during the past decade. Still, oil is the dominant fuel but has lost market share for 14 years in a row. On contrary hydroelectric and other renewables in power generation reached record shares in 2013. China dominates the scene among the emerging economies demanding more energy. The consumption of energy related to the largest sources of commercial energy in the world is shown in table 1[9].

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[8] This section is based on BP Statistical Review 2014.

[9] The figures of water, nuclear energy and renewables are given for consumption. Therefore, the figures of oil, natural gas and coal also are given for consumption enabling comparison.

Table 1 The consumption of energy related to oil, natural gas, coal, hydroelectricity, nuclear energy and renewables in 2013.

Type of energy	Mtoe	%
Oil	4 185,1	33
Natural gas	3 020,4	24
Coal	3 826,7	30
Hydroelectricty	855,8	7
Nuclear energy	563,2	4
Renewables	279,3	2
Total	12 730,5	100

Source: BP Statistical Review 2014.

The consumption of commercial energy in the world increased with 28% during the period 2003 – 2013; from 9 944 to 12 730 Mtoe. This increase is mainly explained by the growth of coal. Otherwise, the development during many years was characterized by increasing use of natural gas. Thereby, gas would become the second largest energy source. But the strong demand for energy in China has meant more extraction of coal and the share of coal of the world´s energy consumption increased from 26 to 30% during the period 2003 – 2013. The share of oil, on the other hand, decreased from 38 to 33%. Consumption of natural gas had the same share (24%) in 2003 and 2013. Hydroelectricity increased (from 6 to 7%) and the use of renewable energy grew fast (from 0,1 to 2%). The use of nuclear energy had a declining tendency (from 6 to 4%).

But the properties of gas and new technology at exploiting gas deposits emphasize the importance of gas as a competitive global source of energy. Therefore, the next section pays attention to gas issues.

3.2 Natural gas

The observation of natural gas as source of energy is during the past decade related to the use of fracking, which is the process of drilling down into the earth before a high-pressure water mixture is directed at the rock to release the gas inside. By injection of water, sand and chemicals the rock at high pressure allows the gas to flow out to the head of the well. New pathways can be created to release gas and used to extend existing channels (BBC News 2014-09-23).

But the technique is controversial by its environmental impact. One reason is the huge amount of water that must be transported to the fracking site at high environmental cost. Another issue concerns worry that potentially carcinogenic chemicals used may escape and contaminate groundwater around the fracking site. The industry, however, argues that pollution incidents are the results of bad practice rather than risky technique. On the other hand environmental campaigners say that fracking is simply distracting energy firms and governments from investing in renewable sources of energy.

Still, there are some advantages of fracking. The technique allows drilling firms to access difficult-to-reach resources of oil and gas. In US the drilling has boosted the oil production and driven down gas prices. Estimations indicate that it has offered gas security to the US and Canada for about 100 years. Furthermore, it generates electricity at half the CO_2 emissions of coal (BBC News 2014-09-23).

The most remarkable change during the period 2003 – 2013 is the increase of the production in US. US has passed Russian Federation as the largest producer of gas in the world. Norway is the only European country among the largest gas producers in the world. See table 2.

Table 2 Production (Mtoe) of natural gas in 2003 and 2013 in the 10 largest gas producing countries of the world.

Country	Year 2003	Year 2013	Change
US	494,8	627,2	+132,4
Russian Federation	505,4	544,3	+ 38,9
Iran	74,4	149,9	+ 75,5
Qatar	28,3	142,7	+114,4
Canada	166,2	139,3	- 26,9
China	31,5	105,3	+ 73,8
Norway	65,8	97,9	+ 32,1
Saudi Arabia	54,1	92,7	+ 38,6
Algeria	74,5	70,7	- 3,8
Indonesia	65,9	63,4	- 2,5
Total	1 560,9	2 033,4	+ 472,5

Note: The countries are ranked according to the volume produced in 2013. The total world production of natural gas in 2013 was 3 041 Mtoe of which former Soviet Union 699.

Russian Federation is used synonymous with Russia.

Source: Processing of BP Statistical Review 2014.

Table 3 illustrates the ability to export gas from each of the 10 countries by comparing the volume produced and the volume consumed.

Table 3 Production and consumption of natural gas (Mtoe) and the differences between volumes produced and consumed in the largest countries of the world in 2013.

Country	Prod.	Cons.	Prod.-Cons.
US	627,2	671,0	- 43,8
Russian Federation	544,3	372,1	+ 172,2
Iran	149,9	146,0	+ 3,9
Qatar	142,7	23,3	+ 119,4
Canada	139,3	93,1	+ 46,2
China	105,3	145,5	- 40,2
Norway	97,9	4,0	+ 93,9
Saudi Arabia	92,7	92,7	+ - 0
Algeria	70,7	29,1	+ 41,6
Indonesia	63,4	34,6	+ 28,8
Total	2033,4	1 611,4	+ 422,0

Note: The total world consumption of natural gas in 2013 was 3 020 Mtoe.
Source: Processing of BP Statistical Review 2014.

The largest differences between production and consumption of gas are registered for Russian Federation and Qatar enabling export of gas. Norway is the third largest gas exporting country. Both Qatar and Norway are characterized by big production but small home markets. US and China import, while demand and supply of Saudi Arabia is balanced.

The big producers - US and Russia - deviate concerning both production and consumption during the past decade. The production of natural gas in US is found in the interval 468 Mtoe (in 2005) to 627 Mtoe (in 2013), while the Russian production is found in the interval 475 Mtoe (in 2009) to 546 Mtoe (in 2011). These figures indicate increasing growth of gas production in US. The Russian production is stabilized around 540 Mtoe. Continuation of the US growth means surplus of gas in the near future. The present deficit of 44 Mtoe of the US market should be seen in relation to the tremendous increase of the consumption of gas; from 560 Mtoe to 671 Mtoe during the period 2006 to 2013. The Russian consumption of gas indicates stabilization around 370 Mtoe (BP Statistical Review 2014).

3.3 Oil

Table 4 illustrates the changes of oil production in the 10 largest countries between 2003 and 2013.

Table 4 Production (Mtoe) of oil in 2003 and 2013 in the 10 largest oil producing countries of the world.

Country	Year 2003	Year 2013	Change
Saudi Arabia	486,2	542,3	+ 56,1
Russian Federation	425,7	531,4	+105,7
US	332,3	446,2	+113,9
China	169,6	208,1	+ 38,5
Canada	140,2	193,0	+ 52,8
Iran	198,5	166,1	- 32,4
United Arab Emirates	126,2	165,7	+ 39,5
Iraq	66,0	153,2	+ 87,2
Kuwait	115,6	151,3	+ 35,7
Mexico	188,2	141,8	- 46,4
Total	2 248,5	2 699,1	+450,6

Note: The countries are ranked according to the volume produced in 2013. The total world production of oil in 2013 was 4 133 Mtoe of which OPEC 1 740.

Source: Processing of BP Statistical Review 2014.

Five out of the 10 largest oil producing countries of the world are located in Middle East. But Russian Federation and US registered the largest growth during the past decade even if the increase of Iraq in relative terms was larger.

Here is also observed that as regards production of oil the Norwegian position is declining. Norway was ranked the 7th largest producer in the world in in 2003, while its position in 2013 was number 16. Table 5 illustrates the ability to export oil from each of the 10 countries by comparing the volume produced and the volume consumed.

Table 5 Production and consumption of oil (Mtoe) and the differences between volumes produced and consumed in the largest producing countries of the world in 2013.

Country	Prod.	Cons.	Prod.-Cons.
Saudi Arabia	542,3	135,0	+ 407,3
Russian Federation	531,4	153,1	+ 378,3
US	446,2	831,0	- 384,8
China	208,1	507,4	- 299,3
Canada	193,0	103,5	+ 89,5
Iran	166,1	92,9	+ 73,2
United Arab Emirates	165,7	35,6	+ 130,1
Iraq	153,2	31,5	+ 121,7
Kuwait	151,3	21,8	+ 129,5
Mexico	141,8	89,7	+ 52,1
Total	2 699,1	2001,5	+697,6

Note: The consumption in Iraq is given the same value (31,5 Mtoe) as in the IEA report "Iraq Energy Outlook. World Energy Outlook Special Report" as there is no consumption value given in the BP Statistical Review. The IEA report has constructed a domestic energy balance for Iraq in 2010 based on available data (which have limitations)(IEA 2014-09-25).
The total world consumption of oil in 2013 was 4 185 Mtoe.
Source: Processing of BP Statistical Review 2014.

The largest differences between production and consumption of oil are registered for Saudi Arabia and Russian Federation but surplus of more than 100 Mtoe also enables big export of oil from United Arab Emirates, Iraq and Kuwait. US and China are, on the other hand, in need of large import volumes.

Among the big producers US deviates as both big producer and consumer during the past decade. US also shows an astonishing increase of production during the last year. Combined with efforts to restrict consumption the tendency of the market in US is less dependence on oil from abroad. The Chinese signs are the opposite. In spite of increasing production the fast growing demand means more import-dependence.

In spite of declining production Norway still has a large export of oil as their consumption is small. In 2013 the difference between production (83 Mtoe) and consumption (10,6 Mtoe) enabled export of 73 Mtoe.

3.4 Coal

Coal is characterized by the correlation between territories of production and consumption. China is the leading and US is the next largest producer and consumer of coal. These two countries account for about 60 % of the coal market. Table 6 shows the production of coal in the 10 largest coal producing countries of the world.

Table 6 Production (Mtoe) of coal in 2003 and 2013 in the 10 largest coal producing countries of the world.

Country	Year 2003	Year 2013	Change
China	917,4	1 840,0	+ 922,6
US	553,6	500,5	- 53,1
Australia	189,4	269,1	+ 79,7
Indonesia	70,3	258,9	+188,6
India	144,4	228,8	+ 84,4
Russian Federation	127,1	165,1	+ 38,0
South Africa	134,1	144,7	+ 10,6
Kazakhstan	43,3	58,4	+ 15,1
Poland	71,4	57,6	- 13,8
Colombia	32,5	55,6	+ 23,1
Total	2 283,5	3 578,7	+1 295,2

Note: The countries are ranked according to the volume produced in 2013. The total world production of coal in 2013 was 3 881 Mtoe.
Source: Processing of BP Statistical Review 2014.

The countries in table 6 account for 92% of the world production of coal. The most remarkable change concerns the Chinese increase of production; its share of the world production grew from 36% in 2003 to 47% in 2013.

In the Nordic region there is coal at Svalbard in Norway and at northwestern part of Skåne in Sweden enabling production during some periods. In Sweden this mining took place at Billesholm to the beginning of 1990´s (SNA 1995), while the Norwegian production of coal was nearly 1,9 million ton in 2013 (Statistical Yearbook of Norway 2013a).

3.5 Hydroelectricity

Table 7 shows the 10 top hydroelectric generating countries of the world.

Table 7 The 10 largest countries producing hydroelectricity in 2003 and 2013. Consumption in Mtoe[10].

Country	Year 2003	Year 2013	Change
China	64,2	206,3	+142,1
Canada	76,1	88,6	+ 12,5
Brazil	69,2	87,2	+ 18,0
US	63,0	61,5	- 1,5
Russian Federation	35,7	41,0	+ 5,3
India	15,7	29,8	+ 14,1
Norway	24,0	29,2	+ 5,2
Venezuela	13,7	19,0	+ 5,3
Japan	21,1	18,6	- 2,5
France	13,5	15,5	+ 2,0
Total	396,2	596,7	+ 200,5

Note: The countries are ranked according to the consumption in 2013.
The total world production of hydroelectricity in 2013 was 856 Mtoe.
Source: BP Statistical Review 2014.

The countries in table 7 consume 70% of the hydroelectric energy in the world. The Chinese consumption is much larger than in other countries and its share is 24% of the world consumption, up 8% during the past decade. This position reflects investments in large projects. China operates two of the 10 biggest hydroelectric power plants in the world including the world´s largest Three Gorges project. This project started in 1993 and was completed in 2012. Furthermore, the Longtan hydropower project located on the Hongshui River is the seventh largest hydroelectric facility in the world. The construction of this project started in 2007 and became fully operational in 2009 (Power Technology 2014-10-01).

But large investments in hydroelectric power plants are also found in other countries ranked among the 10 largest in the world. Thus, the

[10] Based on gross primary generation and not accounting for cross-border electricity supply. Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power station (BP Statistical Review 2014).

power plant Itaipu located on the Parana River at the border between Brazil and Paraguay is ranked as the world´s second largest hydropower plant. The third biggest hydroelectric power station is located on the Caroni River in the Bolivar State of southeastern Venezuela and the Tucurui Hydropower Complex situated on the Tocantins River in Brazil is ranked as the fourth largest hydroelectric power plant in the world. In US the world´s fifth biggest hydroelctric plant is located on the Columbia River within Grand Coulee hydropower project (Power Technology 2014-10-01).

The sixth and the eighth largest hydroelectric power stations in the world are located on the Yenisei River in Russia; Sayano-Shushenskaya and Krasnoyarsk Hydroelectric Power plants. The Robert-Bourassa is located on the La Grande River in Quebec, Canada , and ranked as the world´s ninth largest hydroelectric power plant. Also the tenth largest hydroelectric power plant in the world is Canadian and located on the Churchill River in Newfoundland and Labrador (Power Technology 2014-10-01).

Hydropower is related to advantages such as the source is clean and does not produce greenhouse gasses or other air pollution and leaves behind no waste. Hydropower is also an efficient way to generate electricity. By modern hydro turbines as much as 90% of the available energy can be converted into electricity, while the best fossil fuel plants are only about 50% efficient. This means low costs in comparison to the cost of nuclear and the cost of fossil fuel (Facts about hydropower 2014-10-01).

3.6 Nuclear energy

Generating of electricity by nuclear energy is in many countries seen as a risky and pollutant form of energy. The difficulties to store radioactive waste during many years and the risk for accidents of reactors have brought hot political discussions intensified after the accidents in Harrisburg 1979, in Chernobyl 1986 and in Fukushima 2011. A consequence is increasing security costs influencing the interest in investments in nuclear power plants. For example, the impact on output of the accident in Fukushima has been essential such as the permanent shutdown of eight reactors in Germany as well as the eventual halt to all 50 of Japanese operable reactors while awaiting permission to restart in a new reinforced regular framework (IEA 2014-10-02). Table 8 shows the 10 largest countries producing nuclear energy and the changes of production between 2003 and 2013.

Table 8 The 10 largest countries producing nuclear energy in 2003 and 2013. Consumption in Mtoe[11].

Country	Year 2003	Year 2013	Change
US	181,9	187,9	+ 6,0
France	99,8	95,9	- 3,9
Russian Feferation	33,6	39,1	+ 5,5
South Korea	29,3	31,4	+ 2,1
China	9,8	25,0	+ 15,2
Canada	16,8	23,1	+ 6,3
Germany	37,4	22,0	- 15,4
Ukraine	18,4	18,8	+ 0,4
United Kingdom	20,1	16,0	- 4,1
Sweden	15,3	15,1	- 0,2
Total	462,4	474,3	+ 11,9

Note: The countries are ranked according to the consumption in 2013. The total world consumption of nuclear energy in 2013 was 563 Mtoe.
Source: BP Statistical Review 2014.

The countries in table 8 consume 84% of the consumption of nuclear energy in the world. The production in the world between 2003 and 2013 decreased from 598 Mtoe to 563 Mtoe. This change should be seen in relation to especially the Japanese development. In 2010, the year before the Fukushima accident, the consumption was 66 Mtoe. In 2013 the consumption was 3 Mtoe. The share of nuclear energy of the world consumption decreased during the past decade from 6,0% to 4,4%. The tendency is increasing consumption of nuclear energy in emerging economies, while stagnation and decrease characterize developed economies (BP Statistical Review 2014).

[11] Based on gross primary generation and not accounting for cross-border electricity supply. Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power station (BP Statistical Review 2014).

3.7 Renewable energy

3.7.1 Introduction

The growth of renewable energy is robust albeit from a low base. But this expansion is also challenged by sustaining expensive subsidy regimes that has become visible where penetration rates are highest exemplified by the below-average growth of Europe´s leading renewable producers (BP Statistical Review 2014).

Here is observed that hydroelectricity and biofuels are shown separately. Table 9 shows the development of the use of renewable energy between 2003 and 2013.

Table 9 The 10 largest countries consuming renewable energy, excluding hydroelectricity and biofuels, in 2003 and 2013. Consumption in Mtoe.[12]

Country	Year 2003	Year 2013	Change
US	18,8	58,6	+ 39,8
China	0,8	42,9	+ 42,1
Germany	6,3	29,7	+ 23,4
Spain	3,6	16,8	+ 13,2
Brazil	3,5	13,2	+ 9,7
Italy	2,6	13,0	+ 10,4
India	1,2	11,7	+ 10,5
United Kingdom	1,7	10,9	+ 9,2
Japan	5,2	9,4	+ 4,2
France	0,9	5,9	+ 5,0
Total	44,6	212,1	+167,2

Note: The countries are ranked according to the consumption in 2013.
The total world consumption of renewables in 2013 was 279 Mtoe.
Source: BP Statistical Review 2014.

The countries in table 9 account for 76% of the renewable energy of the world excluding hydroelectricity and biofuels. The consumption of

[12] Based on gross generation from renewable sources including wind, geothermal, solar, biomass and waste and not accounting for cross-border electricity supply. Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power station.

these countries increased nearly 4 times between 2003 and 2013. The largest consumption is found in US, while the Chinese growth is ahead of US. The consumption of renewable energy of the world grew from 67 to 279 Mtoe during the past decade. In 2013 the share of US of the world production was 21%, while the Chinese share was 15%.

3.7.2 Wind

Among the renewable sources the generation from wind has grown strongly. Figure 4 shows installed wind capacity.

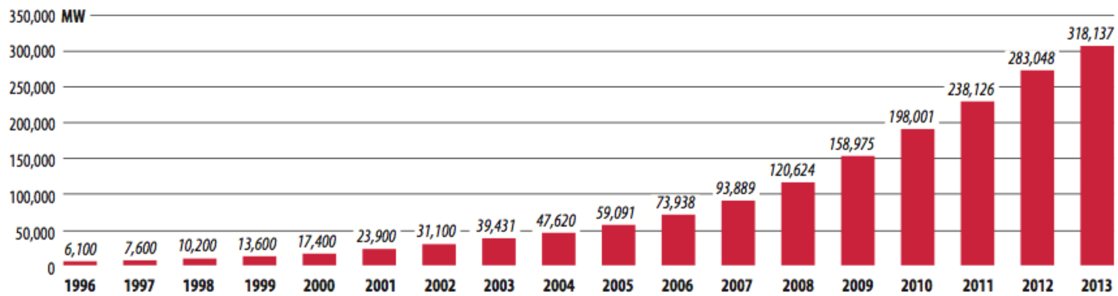

Figure 4 Global cumulative installed wind capacity 1996-2013.
Source: Global Wind Statistics (2013).

China has the largest and US the next largest wind capacity, which is seen in table 10.

Table 10 The 10 largest countries of global installed wind power capacity (MW) in 2013.

Country	Capacity
China	91 424
USA	61 091
Germany	34 250
Spain	22 959
India	20 150
UK	10 531
Italy	8 552
France	8 254
Denmark	4 772
Portugal	4 724

Note: The countries are ranked according to the production in 2013. Sweden is ranked as number 11. The Chinese figure is provisional.
Source: Global Wind Statistics (2013).

The total installed wind power capacity in the world is 318 137 MW of which the Chinese share is 29% and the US share is 19%.

3.7.3 Biofuels

Table 11 shows the biofuels production in 2003 and 2013.

Table 11 The 10 largest countries producing biofuels in 2003 and 2013. Thousand tonnes oil eqvivalent.

Country	Year 2003	Year 2013	Change
US	5 226	28 440	+23 214
Brazil	7 068	15 783	+ 8 715
Germany	613	2 615	+ 2 002
Argentina	9	1 884	+ 1 875
China	396	1 680	+ 1 284
Indonesia	-	1 608	+ 1 608
France	368	1 936	+ 1 568
Thailand	-	1 251	+ 1 251
Netherlands	-	1 182	+ 1 182
Canada	113	1 011	+ 898
Total	13 793	57 390	+ 43 597

Note: The countries are ranked according to the production in 2013. The total world production of biofuels in 2013 was 65 348 thousand tonnes oil eqvivalent.
Hydroelectricity and biofuels are shown separately.
Source: BP Statistical Review 2014.

The countries in table 11 account for 88% of the production of biofuels in the world. The production of these countries increased more than 3 times between 2003 and 2013. The largest production as well as increase of production are found in US, while Brazil is the second largest producer. The production of biofuels in the world grew from 14 682 to 65 348 thousand tonnes oil eqvivalent during the past decade. In 2013 the share of US of the world production was 44% and the Brazilian share was 24%.

4 EU - PERSPECTIVE

4.1 Introduction

The European Union has in recent years faced several important energy issues, such as the fluctuation of oil prices, interruptions of energy supply from non-member countries and difficulties of market access for suppliers in relation to electricity and gas markets, that have pushed energy towards the top of national and European political agendas. A major policy package was adopted in 2009 and became a binding legislation. These 20-20-20 targets include for 2020 a reduction in EU greenhouse gas emissions of at least 20% below 1990 levels, at least 20% of EU gross final energy consumption to come from renewable energy sources, at least 10% of transport final energy consumption to come from renewable energy sources and a 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency. In this policy the use of renewable resources is seen as a key factor (European Commission. Eurostat 2014-10-28a).

Another issue at focus is that EU, with the exception of peat and coke, is a net importer of energy products. In 2013 the total trade value of energy products imported into the EU was dominated by crude oil and natural gas; the share of oil was 73% (295 billion euro) and the share of natural gas in gaseous state 18% (73,4 billion euro) of all energy imports. Russia was the largest exporter of natural gas and petroleum oil to EU. The Russian share of the imports (in quantity) of natural gas (liquefied, gasous state) into EU in 2013 was 39%. Corresponding Norwegian share was 34% and the Algerian share 13%, while less quantities were imported from Qatar (7%), Libya (2%) and Nigeria (2%). The shares of imports from Russia were also largest concerning oil and coal; in volume 34% and 31% respectively[13](European Commission, Eurostat 2014-10-28b).

This dependency on energy imports means policy concerns related to the security of energy supplies. More than half (53,4%) of the EU-28´s energy consumption in 2012 was based on imported sources.

[13] Imports from Russia in terms of value were about 34% of total imports of crude oil and about 49% of total imports of natural gas in gaseous state (Commission, Eurostat 2014-10-28b).

The trend is increasing dependency on energy imports from non-member countries. In the EU-28 the production of primary energy was 794,3 Mtoe. In 2012 this production was 15,7% lower than a decade earlier. This downward trend should be seen in relation to the supplies of raw materials becoming exhausted and/or producers considering the exploitation of limited resources uneconomical. The main change during the decade was the fall of the production in U.K., while the largest expansions in the production of primary energy during the 10 years to 2012 were registered in Italy and Sweden (European Commission. Eurostat 2014-10-29). Figure 5 illustrates how the dependency of imports varied between countries of the EU-27 in 2011.

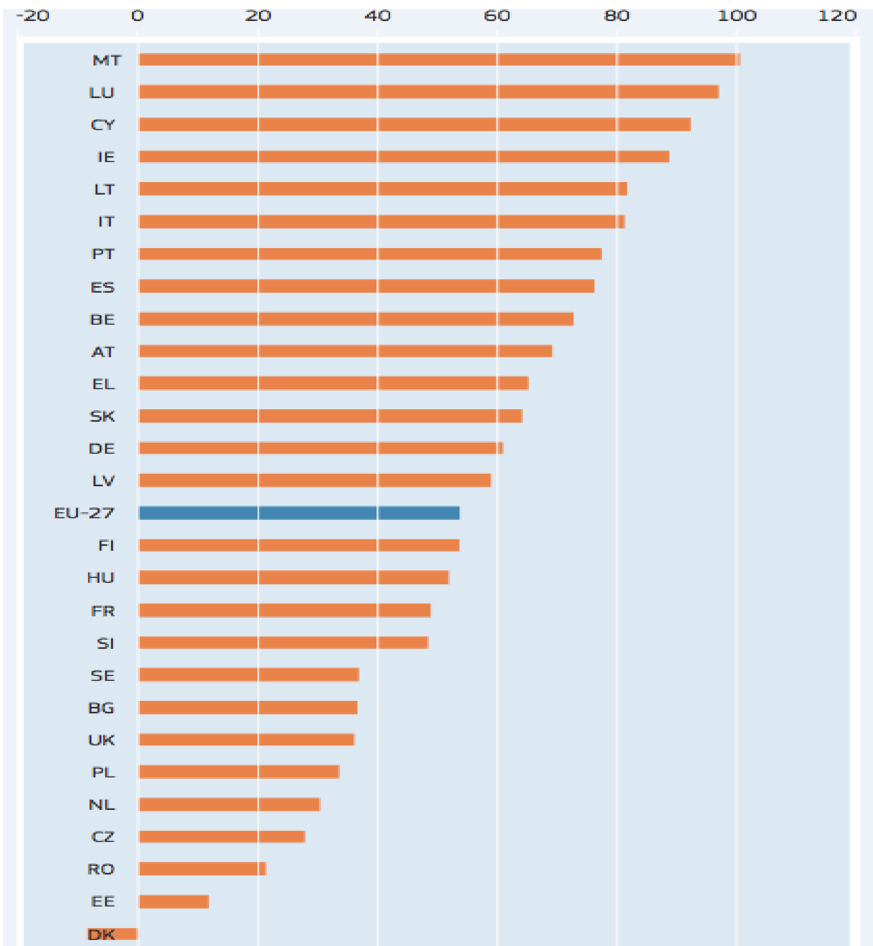

Figure 5 EU-27 Energy Import Dependency in 2011 (%). Source: EU Energy in figures (2013).

Denmark was the only EU-member in 2011 with a negative dependency rate. Low dependency rates were recorded for Estonia, Romania and the Czech Republic[14]. But Malta, Luxembourg and Cyprus were nearly entirely dependent on energy imports. This general strong dependency of imports and with regard to the economic muscle of Moscow combined with conflicts with Ukraine emphasize the seeks of EU to find alternative suppliers (FT 2014a).

An alternative perspective is to consider EU as export partner for Russia. The share of the EU as a partner in the total exports of Russia of petroleum oil is about 70%. The same share (about 70%) is also registered for the total estimated exports of Russia for natural gas in gaseous state. Furthermore, more than one third of Russia´s exports of coal and peat are bound for EU. During the period 2005-2012 the relative importance of EU in Russian exports of energy decreased (European Commission. Eurostat 2014-10-28b). This relative weakening of the EU-market is in accordance with Russian efforts to increase exports of energy products outside EU. However, to decrease the supply of energy to EU is a challenge as oil and gas make up more than 50% of the Russian government´s total revenue. Most of this revenue comes from Europe. A consequence is that any halt in supplies would cause problems not only for customers. But it would also leave big holes in the Russian budget (FT 2014a).

The dependence of imports of energy to EU becomes also evident when attention is paid to the consumption by fuel in EU-countries. See table 12.

[14] Sweden was also in this group of countries of low dependence rate in 2012 (European Commission, Eurostat 2014-10-29).

Table 12 Consumption (Mtoe) by fuel in EU-countries in 2013.

Country	Oil	Natural gas	Coal	Nuclear energy	Hydro electric	Renew able	Total
Austria	12,5	7,6	3,6	-	8,4	1,9	34
Belgium	31,0	15,1	2,9	9,6	0,1	2,8	62
Bulgaria	4,1	2,4	5,9	3,2	0,9	0,6	17
Czech Rep.	8,6	7,6	16,5	7,0	0,9	1,5	42
Denmark	7,8	3,4	3,2	-	-	3,7	18
Finland	8,9	2,6	3,7	5,4	2,9	2,7	26
France	80,3	38,6	12,2	95,9	15,5	5,9	248
Germany	112,1	75,3	81,3	22,0	4,6	29,7	325
Greece	14,0	3,2	7,1	-	1,5	1,4	27
Hungary	6,0	7,7	2,7	3,5	-	0,5	20
Rep. of Ireland	6,7	4,0	1,3	-	0,1	1,1	13
Italy	61,8	57,8	14,6	-	11,6	13,0	159
Lithuania	2,7	2,4	0,2	-	0,1	0,2	6
Netherlands	41,4	33,4	8,3	0,6	-	3,0	87
Poland	24,0	15,0	56,1	-	0,6	4,2	100
Portugal	10,8	3,7	2,7	-	3,1	3,6	24
Romania	9,0	11,2	5,6	2,6	3,4	1,1	33
Slovakia	3,5	4,9	3,1	3,6	1,2	0,3	17
Spain	59,3	26,1	10,3	12,8	8,3	16,8	134
Sweden	14,3	1,0	1,7	15,1	13,9	5,0	51
U.K	69,8	65,8	36,5	16,0	1,1	10,9	200
Total	589	389	280	197	78	110	1 643

Note: The table is based on figures presented in BP Statistical Review 2014. Figures for Croatia, Cyprus, Estonia, Latvia, Luxembourg, Malta and Slovenia are not shown.

Source: Processing of BP Statistical Review 2014.

Table 12 indicates that about 36% of the consumption of energy in average concerns oil and about 24% natural gas, while 17% is based on coal, 12% on nuclear energy, 7% on renewables and 5% on hydroelectricity. In comparison to the consumption in the world the share of EU is larger concerning oil (about 3%), nuclear energy (about 8%) and renewables (about 5%). On the other hand, in the total world the share of coal exceeds (about 13%) the European consumption as well as hydroelectricity (about 2%). The share of natural gas is the same in the total world and in EU (about 24%).

4.2 Coal

Coal has been an important factor enabling the industrial development of many countries. Thus coal resources were decisive for the creation and location of industries during the 18th and 19th centuries. Britain is observed as the break-through of the industrialization process. Several explanations have been offered concerning the issue ”why was Britain first?” The likelihood is that all contain an element of truth and that it is the conjunction of all of them which favoured Britain in such remarkable fashion. These included factors such as some valuable resources e.g. iron, copper, tin and coal of which coal probably was the most important factor in ensuring a British lead (Pollard 1998). The coal resources of Germany of which parts after World War ll belong to Poland were also important for the industrial development of these territories. The production of coal in EU is shown in table 13.

Table 13 Coal production in EU-28 in 2012. Million tonnes.

	Hard coal production	Lignite production
Austria		
Belgium		
Bulgaria	2.1	30.4
Croatia		
Czech Republic	11.4	43.5
Denmark		
Finland		
France		
Germany	10.8	185.4
Greece		62.2
Hungary		9.3
Ireland		
Italy	0.1	
Netherlands		
Poland	79.2	64.3
Portugal		
Romania	1.9	32.1
Slovakia		2.3
Slovenia		4.3
Spain	6.1	
Sweden		
United Kingdom	16.8	
others		
EU-28	128.4	433.8

Note: The production is in million tonnes of coal. In calorific eqvivalents one million tonnes of oil equals approximately 1,5 million tonnes of coal or 3,0 million tonnes of lignite (BP Statistical Review 1980).
Source: Euracoal 2013.

4.3 Oil

The production of oil in EU is limited to Denmark (8,7 Mtoe in 2013), Italy (5,6 Mtoe in 2013), Romania (4,1 Mtoe in 2013) and United Kingdom (40,6 Mtoe in 2013), while consumption of oil takes place everywhere (BP Statistical Review 2014). Table 14 shows the ten largest consumers of oil in EU.

Table 14 Consumption of oil (Mtoe); the 10 largest EU-countries in 2013.

Country	Mtoe
Germany	112,1
France	80,3
United Kingdom	69,8
Italy	61,8
Spain	59,3
Netherlands	41,4
Belgium	31,0
Poland	24,0
Sweden	14,3
Greece	14,0
Total	508,0

Note: The countries are ranked according to the consumption in 2013.
Source: BP Statistical Review 2014.

The countries in table 14 consume roughly 85% of the total consumption of oil in EU-28 (about 600 Mtoe in 2013). The production of oil in EU-28 is limited to 59 Mtoe. This difference between production and consumption of oil indicates a dependency rate of 90%.

All EU-countries imported petroleum oils and natural gas in 2013. For Bulgaria, Czech Republic, Finland, Hungary, Lithuania, Poland and Slovakia 75% of their imports of petroleum oils came from Russia. In contrast the share of Russian imports of national imports to Cyprus, Denmark, France, Ireland, Luxembourg, Malta, Portugal, Spain and the United kingdom was less than 25%. Russia is the largest exporter to EU of petroleum oil, crude and NLG with a share of 34% (net mass in 2013) of the EU-market. The Norwegian share is 11% followed by Nigeria and

Saudi Arabia with a share of 8% each[15](European Commission. Eurostat 2014-10-28b).

The transport of goods is dominated by the sea mode of all energy products with the exception of natural gas, which is transported by pipeline. Pipeline is also a significant mode for crude oil, which especially concerns imports to EU from Russia. See figure 6.

Figure 6 Regional oil infrastructure focusing suppliers to EU.
Source: International Energy Agenzie (2007).

But the Russian efforts to be less dependent on the European market has meant changes of the Russian export policy to more interest in conquering Asian markets such as China and India. In May 2006 China inaugurated its first transnational oil pipeline when it began receiving Kazakh and Russian oil from a pipeline originating in Kazakhstan.

[15] Other exporters to EU are Kazakhstan (6%), Libya (6%), Algeria (5%), Azerbaijan (4%), Iraq (4%), Angola (3%), Mexico (2%), Equatorial Guinea (1%), Egypt (1%) and Kuwait (1%).

Russia´s oil fields in East Siberia is another source for Chinese crude oil imports. This Eastern Siberian-Pacific Ocean Pipeline (ESPO) extends 3 000 miles from the Russian city of Taishet to the Pacific Coast (eia 2014).

These investments are related to the convergence of the Chinese and Russian energy interests. China needs energy supplies that do not have to pass through transit choke-points like the Strait of Malacca. Russia, on the other hand, needs to diversify the markets for its oil and gas underlined by the vulnerable position to pricing disputes with customers and pipeline disputes with transit countries as well as falling European demand and shifts in European energy policy (South China Morning Post 2014). The demand for oil in the Western market is volatile due to the crisis in the Eurocurrency zone. But If EU wants to put pressure on Moscow it can inrease its import of crude oil from North Sea, North Africa and the Gulf (US Message Board 2014).

4.4 Natural gas

The production of natural gas in EU takes place in Denmark (4,4 Mtoe), Germany (7,4), Italy (6,4Mtoe), Netherlands (61,8), Poland (3,8 Mtoe), Romania (9,9 Mtoe) and United Kingdom (32,8 Mtoe). Netherlands became a leading producer of natural gas when large quantities of gas were discovered in 1959 and production started in 1963 (OG 2014-11-04). But by the extraction of energy resources of the North Sea (since the beginning of the 1970´s) United Kingdom became the largest European producer. In 2009, however, Netherlands again took over the position as the leading producer of gas in EU; a consequence of that the sources of natural gas in the British sector of the North Sea run dry[16] (BP Statistical Review 2004). Table 15 shows the ten largest consumers of natural gas in EU.

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[16] In the European context is also observed that Norway in 2006 passed U.K. as the largest producer of natural gas (BP Statistical Review 2004).

Table 15 Consumption of natural gas (Mtoe); the 10 largest EU-countries in 2013.

Country	Mtoe
Germany	75,3
United Kingdom	65,8
Italy	57,8
France	38,6
Netherlands	33,4
Spain	26,1
Belgium	15,1
Poland	15,0
Romania	11,2
Hungary	7,7
Total	346,0

Note: The countries are ranked according to the consumption in 2013.

Source: BP Statistical Review 2014.

The countries in table 15 consume the same share of natural gas (about 85%) as the share of the 10 largest consumers of oil in EU. But the consumption of natural gas in EU (about 400 Mtoe) is less than the consumption of oil (about 600 Mtoe). Furthermore, the production of gas in EU-28 is more (127 Mtoe) than the production of oil (59 Mtoe). This indicates a dependency rate of about 70% in comparison to 90% concerning oil.

Even if EU is less dependent on imports of natural gas than imports of oil the supply of gas by pipelines is vulnerable as a large share is based on supply from Russia. The Russian supply (net mass) of gas to EU accounts for 39%. Norway accounts for 34%, Algeria 13%, Qatar 7%, Libya 2% and Nigeria 2% (European Commission. Eurostat 2014-10-28b). The net of pipelines of natural gas is shown in figure 7.

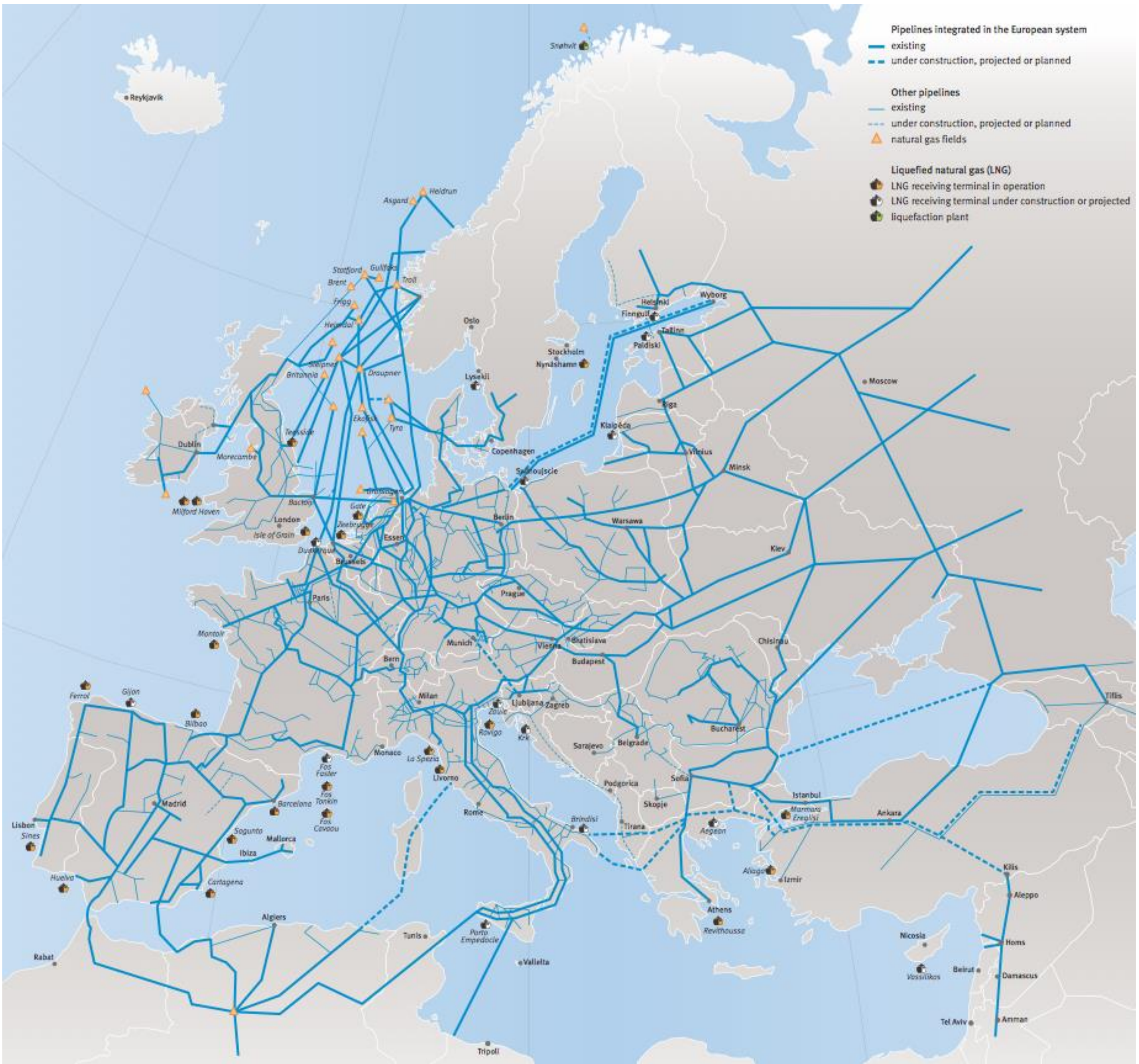


Figure 7 The net of pipelines of natural gas focusing the suppliers to the EU-market.

Note: The map also shows the location of LNG terminals.

Source: Statistical Report (2013).

The largest deposits of natural gas linked to the European gas net are found in Russia, North Sea and North Africa. But LNG-ships, enabled by freezing the gas to minus 162 C, bring also gas to the European market from countries such as Qatar and Nigeria. In total the LNG supply accounts for about 20% and the gaseous form for about 80% of the gas imports to EU-28[17].

The efforts to secure supply of Russian gas is related to the conflict between Russia and Ukraine. This problem is underlined by the fact that major routes of gas pipelines connecting natural gas fields in Western Siberia to export markets in Western Europe run via Ukraine. See figure 8.

Figure 8 Ukrainian gas pipelines.
Source: National Gas Union of Ukraine (2014).

4.5 Hydroelectricity

Hydropower is an efficient way to generate electricity. Furthermore, the storage capacity of hydropower and fast response characteristics are valuable to meet sudden fluctuations in electricity demand. This ability enables matching supply from less flexible electricity sources and

[17] In 2011 the LNG-share was 24% and in 2012 18% (Statistical Report 2013).

variable renewable sources (IEA 2014-11-05). Hydroelectricity accounts for 12% of the net electricity generation in EU-28. Most electricity is generated by conventional thermal power. See figure 9.

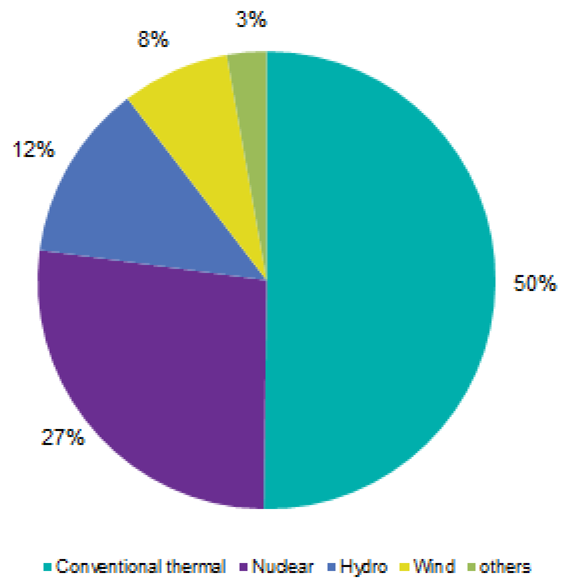


Figure 9 Electricity production by source in EU-28 in 2013.
Source: European Commission. Eurostat (2014-11-05a).

Table 16 shows the 10 largest consumers of hydroelectricity in EU.

Table 16 Consumption of hydroelectricity (Mtoe); the 10 largest EU-countries in 2013.

Country	Mtoe
France	15,5
Sweden	13,9
Italy	11,6
Austria	8,4
Spain	8,3
Germany	4,6
Romania	3,4
Portugal	3,1
Finland	2,9
Greece	1,5
Total	73,2

Note: The countries are ranked according to the consumption in 2013.
Source: BP Statistical Review 2014.

The countries in table 16 produce 94% of the hydroelectric energy in EU-28. France, Sweden and Italy are the largest producers and account for about half of the EU-production of hydroelectricity.

4.6 Nuclear energy

The share of nuclear energy at the production of electricity in EU is 27% (see figure 9). This is a low-carbon energy source. But there is a discussion about the necessary degree of safety and the final long-term storage method. Another issue concerns the location of radioactive nuclear waste materials. Furthermore, the development of nuclear energy is associated with the development of nuclear weapons (European Commission. Eurostat 2014-11-05b). Table 17 shows the 10 largest consumers of nuclear energy in EU.

Table 17 Consumption of nuclear energy (Mtoe); the 10 largest EU-countries in 2013.

Country	Mtoe
France	95,9
Germany	22,0
United Kingdom	16,0
Sweden	15,1
Spain	12,8
Czech Republic	7,0
Finland	5,4
Slovakia	3,6
Hungary	3,5
Bulgaria	3,2
Total	184,5

Note: The countries are ranked according to the consumption in 2013.
Source: BP Statistical Review 2014.

The countries in table 17 produce 94% of the nuclear energy in EU-28. About half of the production is French. The production of France is more than 4 times the volume produced by the second largest producer; Germany.

4.7 Renewable energy

4.7.1 Introduction

The renewable energy has increased dramatically in the world. This increase is also illustrated by an increase of nearly 4 times during the past decade in the largest EU-countries. See table 18.

Table 18 The 10 largest countries in EU consuming renewable energy, excluding hydroelectricity and biofuels, in 2003 and 2013. Consumption in Mtoe.[18]

Country	Year 2003	Year 2013	Change
Germany	6,3	29,7	+ 23,4
Spain	3,6	16,8	+ 13,2
Italy	2,6	13,0	+ 10,4
United Kingdom	1,7	10,9	+ 9,2
France	0,9	5,9	+ 5,0
Sweden	1,2	5,0	+ 3,8
Poland	0,1	4,2	+ 4,1
Denmark	1,8	3,7	+ 1,9
Portugal	0,5	3,6	+ 3,1
Netherlands	0,9	3,0	+ 2,1
Total	19,6	95,8	+ 76,2

Note: The countries are ranked according to the production in 2013.
The total world consumption of renewables in 2013 was 279 Mtoe.
Source: BP Statistical Review 2014.

The consumption in table 18 accounts for about 90% of the consumption of renewable energy in EU-28.

4.7.2 Wind

Wind power accounts for 8% of the net electricity generation in EU-28 (see figure 9). Germany has the largest capacity of wind power in EU; only China and USA have more capacity in the world. Table 19 shows the installed capacity of wind power at generating electricity in EU.

[18] Based on gross generation from renewable sources including wind, geothermal, solar, biomass and waste and not accounting for cross-border electricity supply. Converted on the basis of thermal equivalence assuming 38% conversion efficiency in a modern thermal power.

Table 19 The 10 largest countries of installed wind power capacity in EU (MW) in 2013.

Country	Capacity
Germany	34 250
Spain	22 959
UK	10 531
Italy	8 552
France	8 254
Denmark	4 772
Portugal	4 724
Sweden	4 470
Poland	3 390
Netherlands	2 693

Note: The countries are ranked according to the production in 2013.
Source: Global Wind Statistics (2013).

4.7.3 Biofuels

Table 20 shows the production of biofuels in EU in 2003 and 2013.

Table 20 The 10 largest countries in EU producing biofuels in 2003 and 2013. Thousand tonnes oil eqvivalent.

Country	Year 2003	Year 2013	Change
Germany	613	2 615	+ 2 002
France	368	1 936	+ 1 568
Netherlands	-	1 182	+ 1 182
Spain	173	674	+ 501
Poland	28	664	+ 636
Belgium	-	660	+ 660
United Kingdom	9	449	+ 440
Austria	26	378	+ 352
Finland	-	363	+ 363
Italy	232	292	+ 60
Total	1 449	9 213	+ 7 764

Note: The countries are ranked according to the production in 2013.
The world production of in 2013 was 65 348 thousand tonnes oil eqvivalent.
Hydroelectricity and biofuels are shown separately.
Source: BP Statistical Review 2014.

The countries in table 20 account for 95% of the production of biofuels in EU. Production increased more than 5 times during the past decade.

5 NORDIC COUNTRIES RELATED TO THE WORLD AND EU

5.1 Introduction

The overview above of production and consumption of commercial energy in the world identifies some Nordic international competitive sources with regard to production as well as presence on the energy market. Thus, Norway is ranked among the 10 largest countries of the world concerning production of natural gas and hydroelectricity. Sweden is ranked as number 10 on the list of the largest countries producing nuclear energy and on the list of countries producing renewable energy. Denmark is ranked as number 9 in the world as regards installed wind capacity. Furthermore, the production of gas in Norway increased with 32 Mtoe during the past decade, almost as much as Russia and Saudi Arabia. Only in US, Iran, Qatar and China the production grew considerably more than in Norway.

The Norwegian position is even stronger as actor on the global scene when production is compared with consumption. Six countries – US, Russian Federation, Iran, Qatar, Canada and China – produce more natural gas than Norway. But at reduction of the internal consumption Norway has the third largest surplus enabling export; only Russia and Qatar have larger export of natural gas than Norway. The location of the sources with access to the European market is another factor influencing the Norwegian competitiveness. On the other hand, the time of remaining reserves may become a problem. According to present knowledge of reserves and production the Norwegian gas reserves will remain less than 20 years, while this time for reserves located in Middle East is more than 100 years. The R/P relation for Russia is about 50 years. But the reserves in the world tend to increase.

Even if Norway is not ranked among the 10 largest producers of oil in the world it is an important competitor on the international oil market. The production is much larger than the consumption. The Norwegian oil surplus was about 70 Mtoe in 2013; the same volume as supply exceeds consumption in Iran, Kazakhstan and Qatar. Larger oil surplus than Norway is registered for Russian Federation, for Saudi Arabia, United Arab Emirates, Iraq and Kuwait in Middle East, for Angola and Nigeria in Africa, for Canada in North America and for Venezuela in South America (BP Statistical Review 2014).

But the European position is weak accentuated by the decline of oil production in the North Sea during the past decade. In 2003 the Norwegian oil production was 154 Mtoe to compare with 83 Mtoe in 2013, while the production in United Kingdom decreased from 106 to 41 Mtoe. This development is problematic; especially the English shift from exports to imports of oil (production of about 40 Mtoe and consumption of about 70 Mtoe). The R/P also indicates short remaining reserves of oil; about 10 years for United Kingdom and about 13 years for Norway (BP Statistical Review 2014).

During the past decade some remarkable changes of production and consumption of energy are also observed globally. Since many years oil is the largest energy source. But its position is threatened by the growth of coal. The share of coal increased from 26 to 30% of the total consumption of energy in the world, while the share of oil decreased from 38 to 33% during the past decade. The share of natural gas is the same (24%) and the renewable energy is growing fast albeit from a low base (from 0,1 to 2%). The generation of hydroelectricity tends to increase, while the generation of electricity by nuclear energy tends to decline (BP Statistical Review 2014).

Changing conditions of supply and demand for energy are decisive for the competitive ability of different sources. The changes are based on economic/political goals such as demand of energy for the economic development of China and strengthening of the competitiveness of the American economy. At present this kind of influence is exemplified by the fall of the oil price. Saudi Arabia tries to cut down the oil price to a level that makes it hard for producers with high costs to stay competitive (SvD 2014a). The figures in table 21 show the Nordic shares of the world of different sources as regards production and consumption of energy.

The Nordic countries have relative large shares of the world production and consumption of energy primarily based on resources of oil, natural gas and hydroelectricity in Norway. Largest share is registered for hydroelectricity. But this share (more than 5%) is less than the volumes produced of oil and gas. In 2013 the production of oil in the Nordic countries was 92 Mtoe, natural gas 102 Mtoe, hydroelectricity 46 Mtoe, nuclear energy 21 Mtoe and renewable energy 12 Mtoe (BP Statistical Review 2014).

Table 21 The shares of world production (oil and natural gas) and consumption (hydroelectricity, nuclear energy and renewables) of commercial energy in Denmark, Norway, Finland and Sweden 2013.

Type of energy	Share of total world (%)	Country (%)	
Oil	2,2	Denmark	0,2
		Norway	2,0
Natural gas	3,3	Denmark	0,1
		Norway	3,2
Hydroelectricity	5,3	Finland	0,3
		Norway	3,4
		Sweden	1,6
Nuclear energy	3,7	Finland	1,0
		Sweden	2,7
Renewable energy	4,3	Denmark	1,3
		Finland	1,0
		Norway	0,2
		Sweden	1,8

Note: Renewable energy is based on gross generation from renewable sources including wind, geothermal, solar, biomass and waste.
The share of production and consumption of energy in Iceland is too small to be registered at this comparison.
Source: Processing of BP Statistical Review 2014.

Producers of natural gas and oil act on the international markets, while generation of electricity by hydropower, nuclear energy and renewables mainly concern national markets even if the construction of the European network for transmission of electricity has facilitated integration of former national systems.

5.2 Oil and natural gas

Since the beginning of 1970´s the Nordic energy market is characterized by the Norwegian extraction of oil and natural gas in the North Sea. But the growth of the oil production was broken at the end of 1990´s and followed by decline. See figure 10.

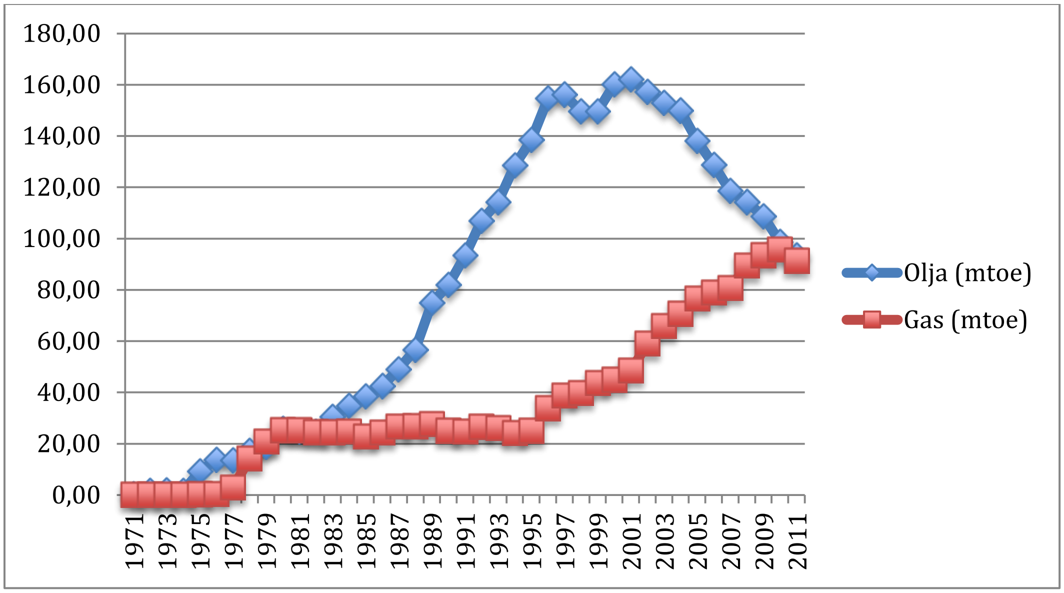


Figure 10 Production of oil and natural gas in Norway 1971 – 2011.
Source: Processing of BP Statistical Review.

In contrast to this decline of the oil production the production of natural gas has increased since the middle of 1990´s and reached the same level as oil about 2010. The last years (2010 to 2013), however, gas also shows instability in the growth of production. See figure 11.

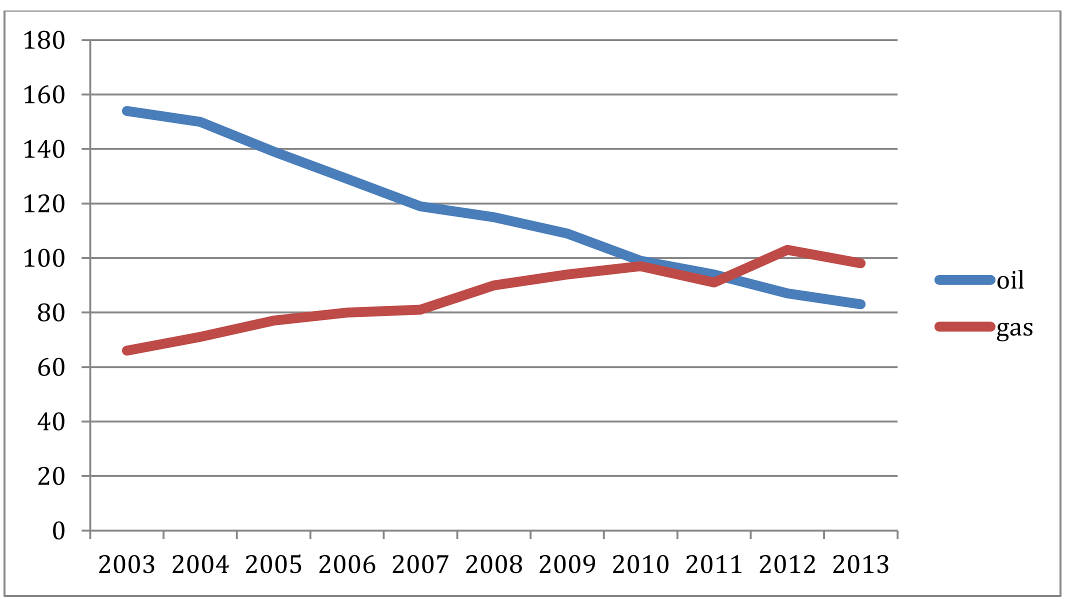


Figure 11 Production of oil and natural gas in Norway 2003 - 2013.
Source: Processing of BP Statistical Review 2014.

The production of oil during the period 2003 – 2013 decreased from 154 to 83 Mtoe, while the production of gas increased from 66 to 90 Mtoe in 2008 followed by volumes in the interval 90 to 103 Mtoe. Totally the production of oil and gas decreased from 220 to 181 Mtoe during the decade 2003 – 2013.

5.3 Unique geographical phenomena[19]

The extraction of energy in the North Sea is to large extent based on political, technological and entrepreneurial initiatives. This has created a unique geographical phenomena in sea environments. In general the interest to extract offshore is weak. But oil and gas are exceptions. Low prices on oil (and gas) during 1950´s and 1960´s gave few incitements to extract offshore. The activities were limited to shallow water, usually to areas that enabled extension of land based extraction. But the most important development offshore took place in Texas and Louisiana that should be seen in relation to restrictions to import oil between 1959 and 1971 (Odell 1986).

After the war in October 1973 (Yom-Kippur) the situation changed dramatically. The oil price went up 10 times between 1970 and 1981. At the same time the Multinationals´ resources were nationalised in nearly all important oil-exporting countries. This uncertainty brought about interest in seeking for oil in earlier not exploited areas. But lower oil price 1981 and 1986 meant hesitation about extraction of oil and gas offshore. This hesitation, however, was fading away by positive ingredients at the extraction in the North Sea. A consequence was continuing investments in offshore-activities.

A factor was the *phenomena in itself*. The first steps to extract oil and gas in the North Sea were taken before the first oil-shock. This shock meant larger revenues from oil and gas that increased the possibilities to make efforts to create new reserves and more production. The companies were in need of more production to compensate for the lost capacity by the expropriation of their facilities in OPEC-countries. At other conditions they would not have invested in such extent that they made in the North Sea. They would not have used that much of their competence to lead the companies and not so much at R&D.

[19] This section is mainly based on Odell (1997).

Some *processes of the development* are especially clear. These include the acceptance of the international companies of the political frame for extraction in the North See with partly ownership by the state, the complex systems of rules and demand on taxes of revenues. Many companies saw the location of the North Sea as attractive for investments. The technological development was pushed by the development of new products related to rough weather conditions combined with difficulties to work in deep water. These challenges brought about a stream of innovations contributing to more production at lower costs. Furthermore, the international oil industry has by innovations regarding methods to finance investments and by marketing of oil and gas linked the international oil industry to the North Sea.

The dramatic development of the extraction of energy in the North Sea has *changed the economic and geopolitical conditions of Europe*. Europe has become less sensitive for external pressure and eventual threats of suspension of deliveries. The freedom of Europe to act internationally has increased in relation to the extortionate situation following the reduction of the flows of oil in 1973/74 and 1979/80.

An issue is if there are similar possibilities of development in other parts of the world? Probably not as the location and what belongs to this location deviates. The resources of the North Sea are unique and related to a geographical concentrated energy market and the specific combination of political, social, financial and technological attributes. The timing of the resources at the North Sea was also unique. The reserves were verified when the structure of the international oil market changed and specified a market oriented towards oil and gas extraction.

The way the extraction of oil and gas in the North Sea is made reflects the tradition of involved countries; the policy is formed by participation between public and private oil companies. This approach deviates from the situation with private companies at the Mexican Gulf in USA. Europe has by the development in the North Sea shown a successful alternative, which includes cooperation between public and private companies and continuous interplay at extraction of oil and gas in large scale.

5.4 Unique Norway

Norway is ranked as the 7th country at the list of the largest producers of natural gas and as the 16th largest producer of oil in the world. Only China, Brazil, Canada, USA and Russia generate more electricity by water power than Norway (BP Statistical Review 2014).

The uniqueness of Norway becomes even more pronounced when production is related to the number of inhabitants. The production per capita based on water power is larger in Iceland, while Qatar and Brunei have larger production of natural gas than Norway. Kuwait, Qatar, United Arab Emirates and Equatorial Guinea have larger production of oil per capita than Norway. Table 22 shows the strong position of Norway as producer of energy related to per capita.

Table 22 The ranking of Norway with regard to production and production per capita 2013.

Source of energy	Production (rank)	Prod. per capita (rank)
Hydroelectricity	6	2
Natural gas	7	3
Oil	16	5

Source: Processing of BP Statistical Review 2013, Statistical Yearbook of Sweden 2014.

Norway has also a specific position at comparison of exported volumes of energy. Only Russia and Qatar export more natural gas than Norway. Russia and Saudi Arabia are dominant exporters of oil (about 400 Mtoe yearly from each country). Iran, Kuwait, United Arab Emirates and Venezuela export about 100 Mtoe, while the Norwegian oil export is about 80 Mtoe. At comparison of the total export volumes of oil and gas Norway is ranked as the third largest country in the world after Russia and Saudi Arabia (BP Statistical Review 2014).

Furthermore, Norway has a unique twin role as a major oil and gas producer and a strong global advocate of climate change mitigation. As large exporter of energy it contributes to energy security by providing reliable supplies to consuming countries. Norway also manages its petroleum resources in a commendable way. In European context the large potential for hydropower generation is of special interest as the electricity markets are integrating and renewable energy generation will increase. Accessibility to the Norwegian hydropower is a strategic asset to realise the full potential of hydropower for balancing variations in demand and supply in the regional market (Norway 2011).

5.5 Norwegian petroleum sector[20][21]

The petroleum activities on the Norwegian shelf were inspired by the discovery of gas in Groningen in the Netherlands in 1959. It led to new optimism regarding the petroleum potential of the North Sea. In October 1962 Norwegian authorities got a request from Philips Petroleum to get permission to explore for oil in the North Sea. But the Norwegian authorities refused to sign over the entire shelf to a single company; to be opened for exploration more than one company would be needed. In May 1963 the Government proclaimed sovereignty over the Norwegian continental shelf and a new act established the State as the landowner. By the discovery of the field Ekofisk in 1969 the Norwegian oil area started and in June 1971 production from the field started. At the beginning the exploration was in the North Sea and has gradually moved north as the knowledge has increased.

In 1979 the area north of 62nd parallel was opened and exploration was gradually initiated. A limited number of blocks were announced and the most promising areas were explored first. These large fields were given names such as Ekofisk, Statfjord, Oseberg, Gullfaks and Troll, which have been and still are very important for the development of petroleum activities in Norway. But several of the major fields are in decline. Nowadays, the trend is development of production from new smaller fields.

At the very beginning the authorities chose a model where petroleum activities were mainly performed by foreign companies. But Norwegian participation gradually grew by the addition of Norsk Hydro and Saga Petroleum. In 1972 Statoil was established with the State as the sole owner. Furthermore a principle was founded that gave the State 50% ownership in each production licence. This principle was changed in

[20] Oil and gas are organic materials transformed and deposited in ocean areas over millions years. The oil and gas deposits on the Norwegian continental shelf originate mainly from a thick layer of black clay that is currently several thousand metres under the seabed (Facts 2014).
[21] This section is based on Facts 2014.

1993; an assessment is made in each case whether there will be State participation and whether the ownership interest will be higher or lower. Saga was acquired by Norsk Hydro in 1999. In 2001 Statoil was partially privatised and in 2007 Statoil merged with Norsk Hydro´s oil and gas division.

The Norwegian petroleum management is based on the principle that exploration, development and operations must generate the greatest possible values for society. The petroleum industry is Norway´s largest industry measured in value creation and the State claims a large share of this creation through taxes, fees and the State´s Direct Financial Interest (SDFI). In 2012 the State´s total net cash flow from petroleum activities totalled NOK 401 billion. The petroleum sector´s share of state revenues amounts to about 29%. Figure 11 shows the shares of the petroleum sector of GDP, of state revenues, of total investment and of total exports.

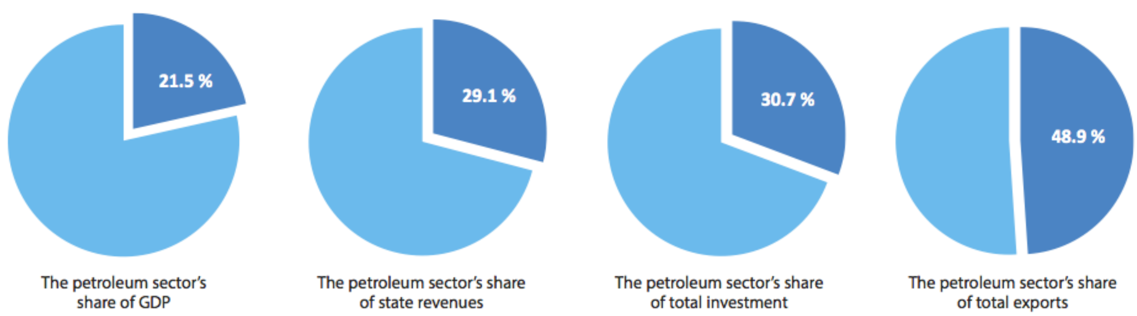


Figure 11 Macro-economic indicators for the petroleum sector 2013.

The petroleum industry also creates ripple effects locally and regionally. The roots of the industry is in Rogaland county. But along with the expansion of offshore activities the industry has developed northwards. Petroleum clusters and internationally competitive supplier services are established in many parts of the country. The number of employees in oil companies and companies that supply the petroleum industry is about 150 000. This number increases to about 250 000 when the effect of the petroleum industry´s demand on the overall economy is taken into account.

In the beginning only a few major international oil companies operated on the Norwegian shelf. Nowadays, however, there are more than 50 companies involved in exploration, production and infrastructure. Statoil is the largest company operating on the shelf followed by companies such as ExxonMobil, Total, Shell and ENI. Currently 78 fields are in production. In recent years investment and operation costs have grown, which is an international trend. In addition, the costs on the Norwegian shelf are somewhat higher than in other comparable petroleum provinces.

The Norwegian shelf includes vast ocean areas of the North Sea, Norwegian Sea and Barents Sea that still contain large amounts of oil and gas to be discovered. The shelf is divided into the North Sea (142 000 km^2), Norwegian Sea (287 000 km^2) and Barents Sea (772 000 km^2). The area opened for petroleum activities in the southern part of Barents Sea covers 313 000 km^2. But the main petroleum activities are still in the North Sea. Here, about 60 fields produce oil and gas, while the Norwegian Sea has 16 producing fields and the Barents Sea has one. Areas on the Norwegian continental shelf is shown in figure 12.

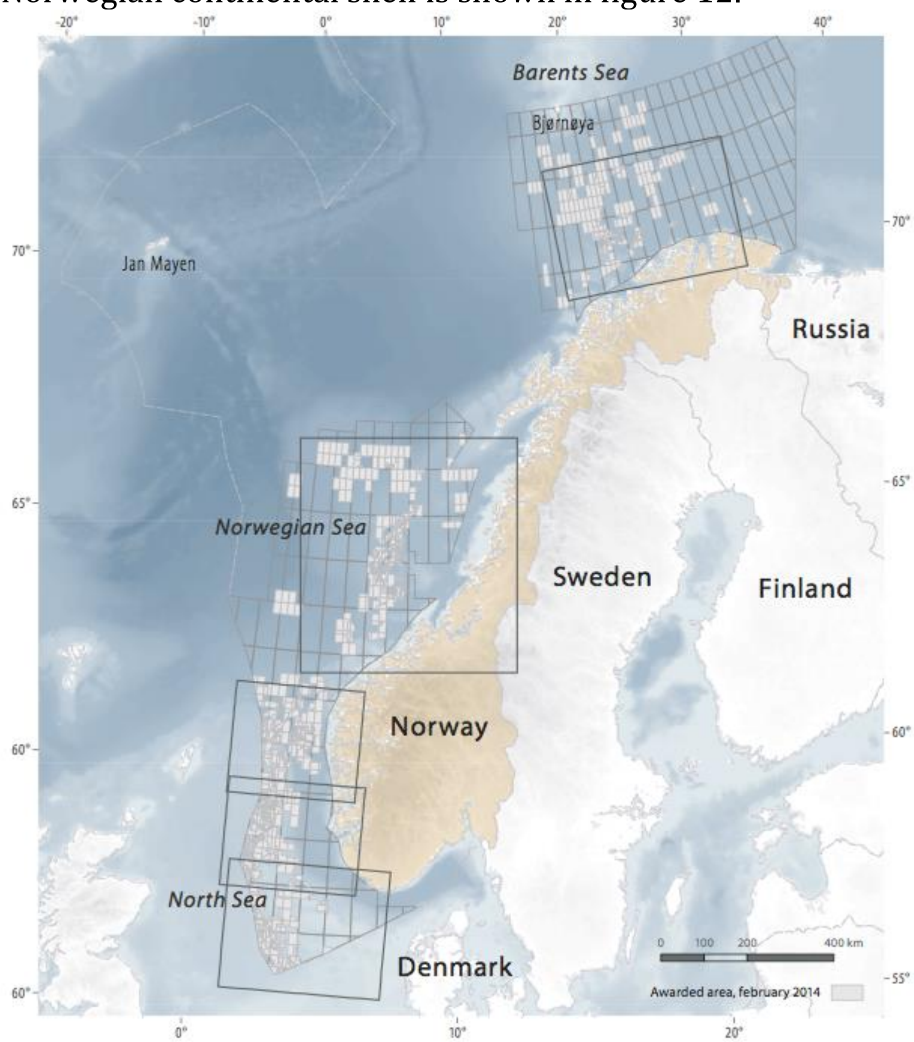


Figure 12 Areas of the continental shelf.

The *southern North Sea* is still an important production area even if extraction on the Ekofisk-field started more than 40 years ago. This part of the North Sea includes 13 producing fields. Ekofisk is a hub and many fields are tied to its infrastructure for further transport via the Norpipe system. In the *central North Sea* the Balder field was the first oil discovery on the Norwegian continental shelf in 1967. But it was not developed until 30 years later. Frigg gas field was the first producing field in the area and was in function during almost 30 years before it was shut down in 2004. Currently, 21 fields are producing and several discoveries are being planned for development over the next few years. The field of Heimdal is a gas hub at performing services for other fields in the North Sea. The *northern North Sea* includes 26 producing fields and after 30 years of extraction the resource potential is seen as substantial. The Troll field has an important function for the gas supply and is expected to become the primary source of Norwegian gas exports in this century. The production of the fields of the North Sea area is transported by vessels and via pipelines to onshore facilities on the Continent and in the UK.

Compared to the North Sea the *Norwegian Sea* is a less mature petroleum area. The first field – Draugen – came on stream in 1993. Nowadays, there are 16 fields producing in the area that also has substantial gas reserves. Extraction of gas from the fields is transported via the Åsgard Transport pipeline to Kårstö in Rogaland county and via Haltenpipe to Tjeldbergodden in Möre and Romsdal county. The production of gas at Ormen Lange is transported to Nyhamna and onward to Easington in the UK. The transportation of oil from the fields in the Norwegian Sea is performed by tankers.

Even if exploration in the *Barents Sea* has been carried out for more than 30 years the area is considered a frontier petroleum province. Only the field of Snöhvit, that came on stream in 2007, has been developed. By pipeline the gas is transported to Melköya. Here it is processed and cooled into LNG. After this process the gas is transported to the market by special vessels.

The Norwegian gas is mainly sold on the European market where a well-developed and efficient gas infrastructure and short transport distances make Norwegian gas competitive. By extension of the grid of pipelines Norwegian gas is exported to all the major consumer countries in Europe. Nearly all export is transported by pipelines while a small volume is delivered as LNG from the Snöhvit facility. The energy content of the

Norwegian gas production covers about 20% of the European gas consumption. In Germany, the UK, Belgium and France Norwegian gas accounts for 20 – 40% of total gas consumption. Figure 13 shows the Norwegian gas export.

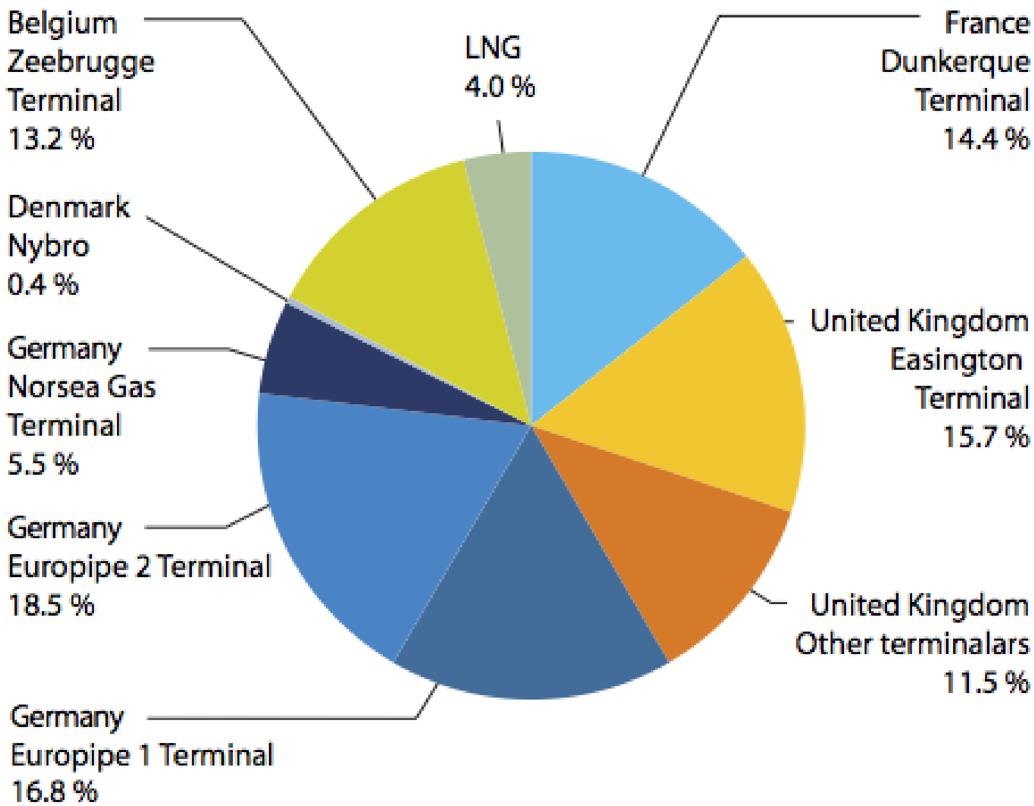


Figure 13 Norwegian natural gas exports in 2013 by delivery point.

The transport of gas by pipelines usually means major investments that need long depreciation periods. A network of pipelines for Norwegian gas with a total length of 8 000 km has been constructed. This transport system includes four terminals for Norwegian gas on the European continent and two terminals in the UK. See figure 14.

In the Nordic region the use of natural gas started 1974 in Finland by import of gas via pipeline from former USSR. Denmark received gas from Danish sources in 1984 and Sweden via pipelines was linked to Danish reserves in 1985 (Lorentzon och Olsson 1992).

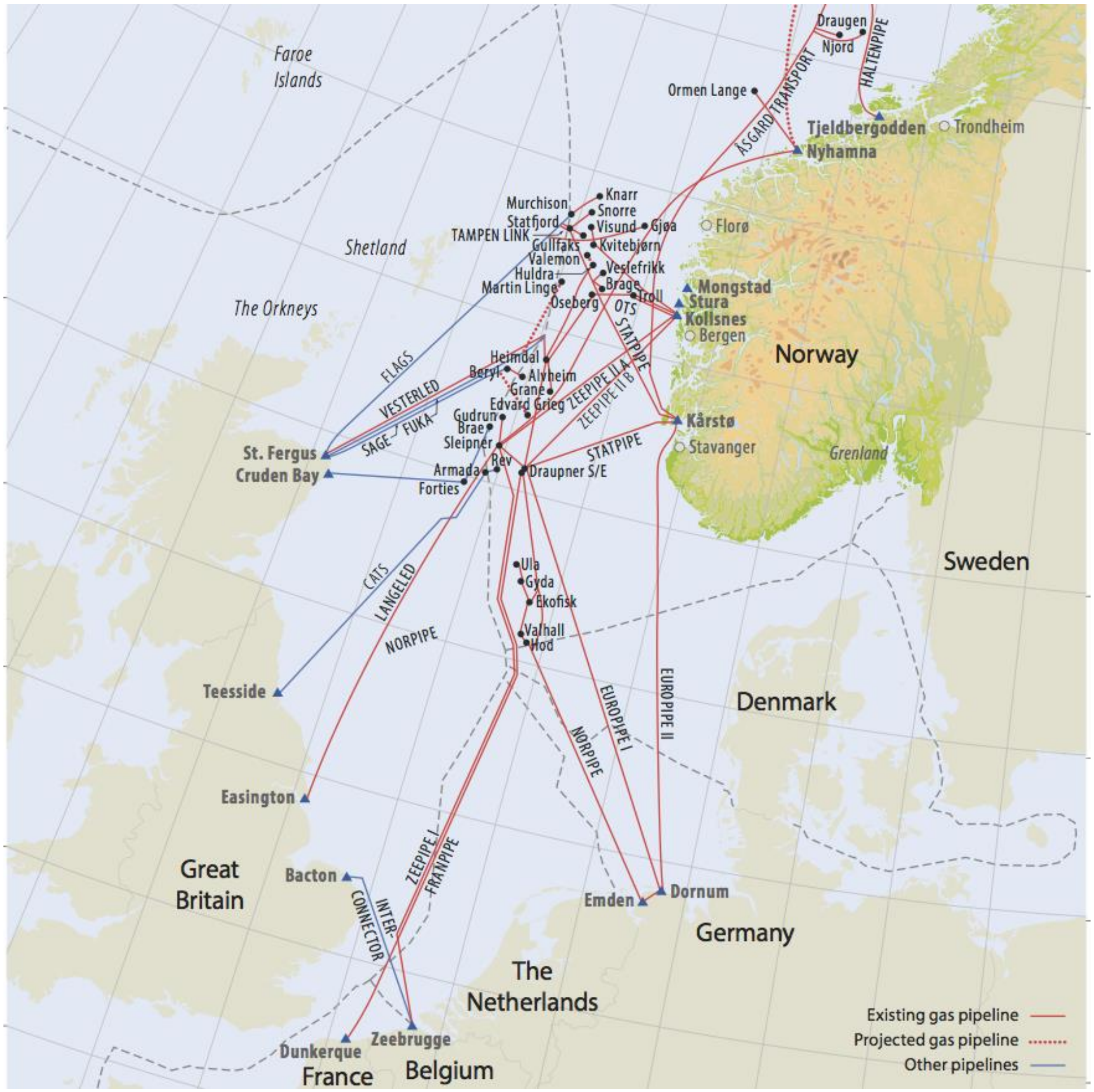


Figure 14 Pipelines linking Norwegian sources of gas with terminals on the European continent and UK.

Specific Norwegian prerequisites such as rough weather conditons, stringent regulations and demanding operators at the extraction of oil and gas have contributed to the development of Norway´s technologically world-leading petroleum service and supply industry. Currently, the Norwegian shelf is the world´s largest offshore market that provides Norwegian service and supply companies with a vast home market. The shelf has become a technological laboratory in pushing the development of innovative solutions indicating further contribution to the industry´s opportunity to boost its competitiveness. Figure 15 shows the number of employees in different regions in Norway.

Note: In addition 3 thousand are employed in Northern Norway.

Figure 15 Number of employees (in thousands) in Norwegian service and supply companies 2012.

The State´s tax revenues are transferred to the Government Pension Fund – Global (SPU), which was established in 1990 for the purpose of ensuring a long term perspective when using the State´s petroleum revenues. In 1996 the first transfer to the SPU took place. At the end of 2013 the Fund was valued to NOK 5 038 billion (NBIM 2013).

5.6 Renewable energies

5.6.1 Introduction

The use of renewable sources of energy in the Nordic countries has increased considerably during the last two decades[22]. But the geographical prerequisites of resources vary. In Norway hydropower stands for nearly 100% of electricity generation from renewables. Corresponding share of hydropower in Sweden is about 85%, in Iceland about 76% and in Finland nearly 60%. In Sweden and Finland biomass is an important renewable source of energy for electricity. In Iceland the electricity generation is also based on geothermal energy, while electricity from renewables in Denmark is mainly related to wind power (about 2/3). The rest comes from solid biomass and municipal waste[23](Nordregio 2014-11-27). The production of renewable energies for electricity in the Nordic countries is shown in figure 16.

Norway is by far the largest producer of renewable energies by its hydroelectricity. But, at generating electricity Sweden and Finland also use nuclear power. In global and European perspectives the Nordic countries have a strong position as producers of electricity based on hydropower, nuclear energy and renewables. Furthermore, the Nordic region is and has been at the forefront in developing technology enabling transmission of electricity. For example, the electrification of Sweden started during the end of 1880´s. At the beginning investments were made in small plants to meet local demand. But new technology and increasing demand led to investments in larger units. Transmission of power from the big rivers in the North was introduced during the 1930´s. This extension was followed by demand for investments in the electricity grid.

[22] Here renewable energy includes hydroelectricity.

[23] Greenland is a relative newcomer in terms of renewable energy production; almost half of the electricity generation is based on hydropower.

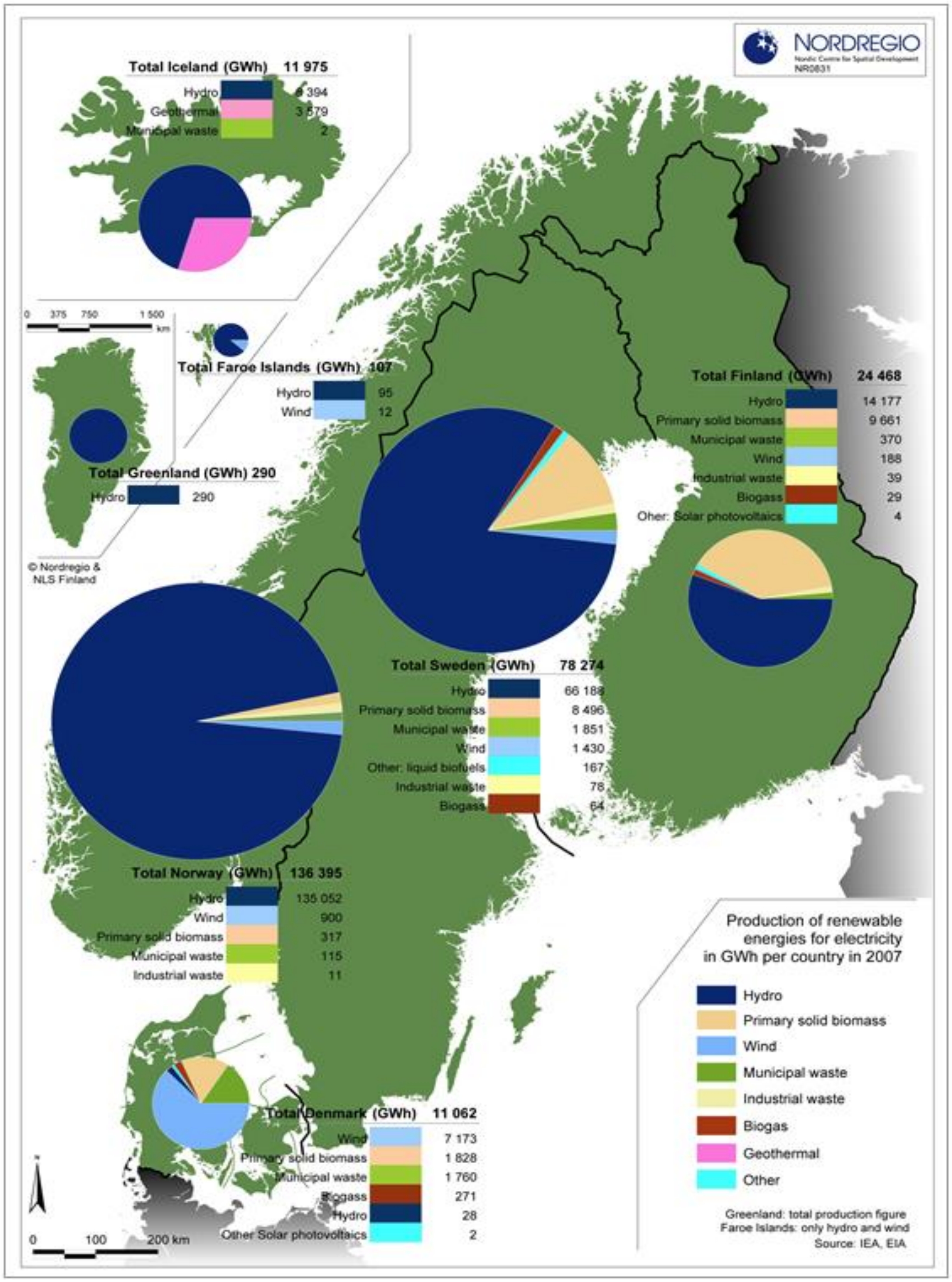


Figure 16 Production of renewable energies for electricity by sources in GWh in the Nordic countries in 2007.
Source: Nordregio 2014-11-27.

The production of electricity in Sweden is based on rich flows of water in the North, investments in dams and introduction of new transmission technology enabling distribution of electricity in the South. These prerequisites have formed the business structure. Representatives of different interests such as the state, the public and private businesses have been involved in different activities. The Swedish electricity grid is divided into different levels. These levels are transmission, subtransmission (or regional) and distributional (local level)(Nordreg 2011). The number of businesses in distribution of electricity has decreased dramatically. This concerns especially economic associations originally established to support farmers with electricity. The state has played a key role and is the owner of the backbone (SOU 1978).

In the Nordic countries the operators of the Transmission System have the responsibility for both the security of supply and the high voltage grid (the transmission grid). The operators are Statnett SF in Norway, Svenska Kraftnät in Sweden, Fingrid in Finland and Energinet.dk in Denmark (Nordpool spot 2014-11-27).

The systems of electricity in Denmark, Finland, Norway and Sweden are linked to each other and are founded by cooperation since the beginning of 20th century. Lately the Nordic countries have been linked to other countries such as Germany and Poland. This extension means more demand of transmission capacity. In general the Nordic countries are well integrated by long experience of transmission of electricity based on production by hydropower. But independent of energy source at generating electricity there is demand for grid capacity enabling efficient systems of electricity. For example, efficient transmission technology facilitates exchange of electricity produced by hydropower and wind. The Nordic transmission grid is shown in figure 17.

This section pays attention to the generation of electricity by hydropower and wind. Hydroelectricity is the largest renewable source and the use of wind for generation of electricity is fast growing. Furthermore, the use of biofuels at generating electricity is observed.

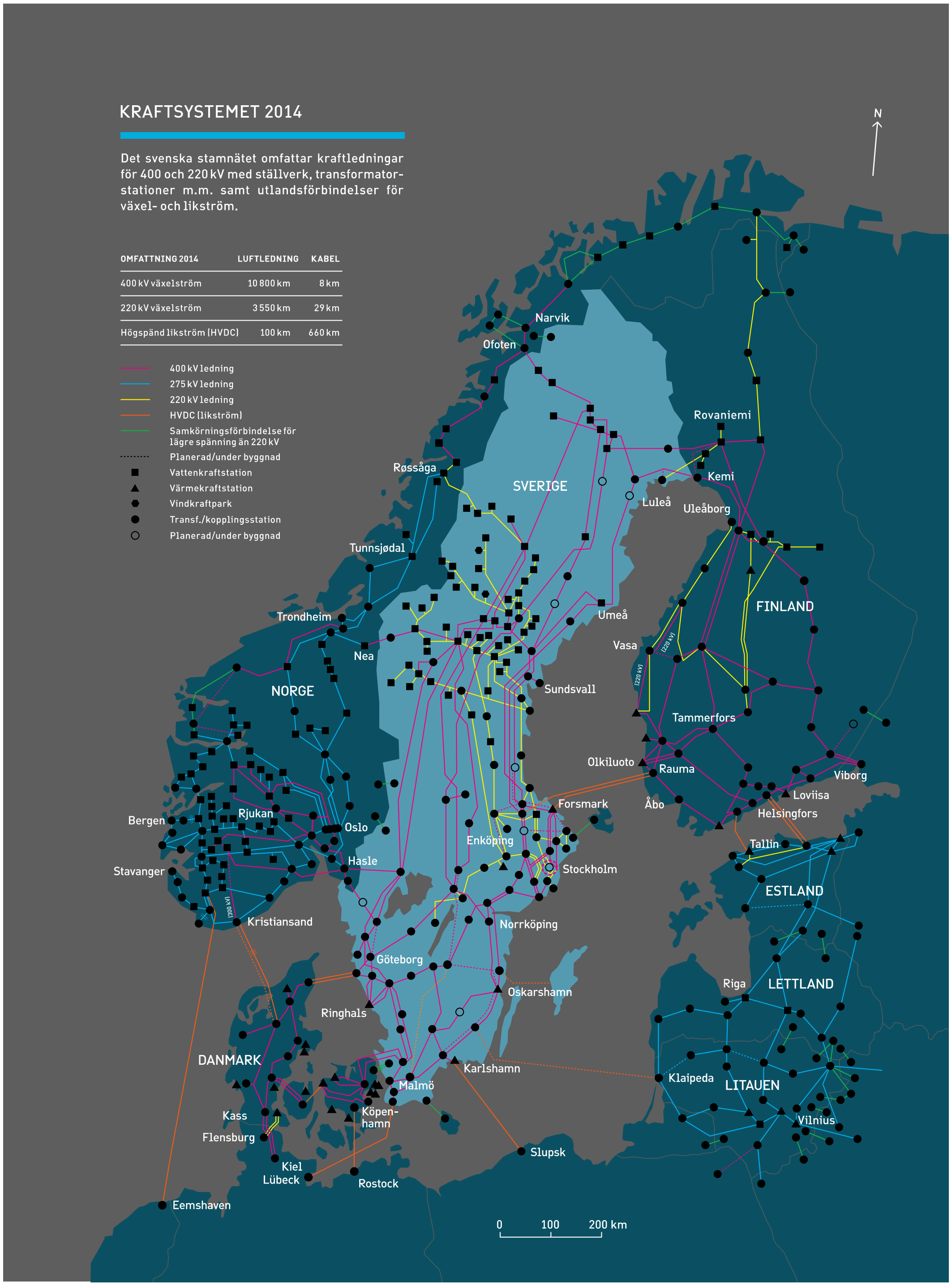


Figure 17 Transmission nets in and between the Nordic countries and links to surrounding countries.
Source: Kraftsystemet (2014-11-26).

5.6.2 Hydroelectricity

Generation of electricity in Norway by hydropower was about 135 000 GWh, in Sweden about 66 000 GWh, in Finland about 14 000 GWh and in Iceland about 8 000 GWh in 2007 (see fig. 16). The large production in ***Norway*** is based on favourable geographical conditions. The Norwegian relief map is characterized by mountains, valleys and fjords from the South to the North where 20% of the mainland lies at an elevation of more than 900 meters. See figure 18.

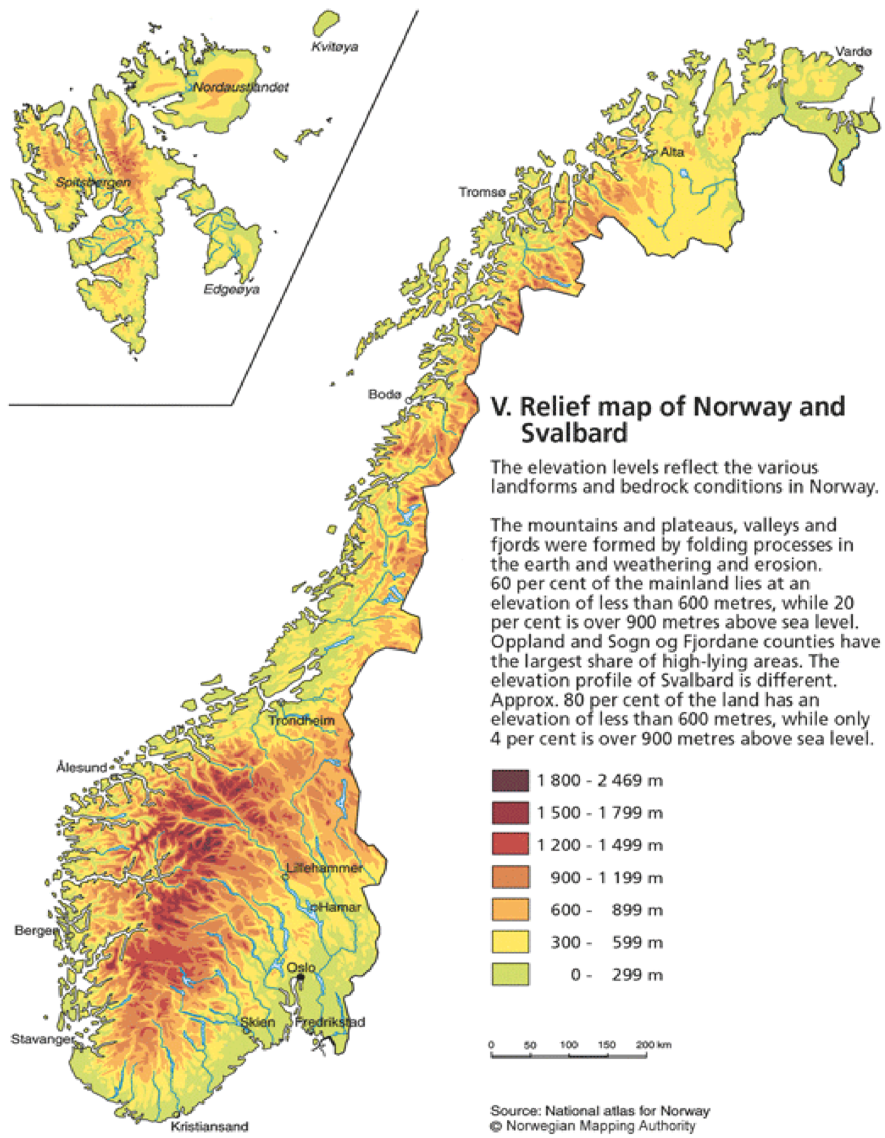


Figure 18 Relief map of Norway and Svalbard.
Source: Statistical Yearbook of Norway 2013b.

The precipitation varies between 500 and 3 000 mm/year and falls mainly along the coastal areas (WeatherOnline 2014-12-02). The Norwegian topography enables construction of environment-friendly hydropower stations located high-up in remote mountain areas which often benefit from a glacier as second level storage facility. Usually the melting water is either directed through tunnels into underground plants with outlet direct into a fjord, or into a river system. Hydropower with storage capacity will be even more useful in the context of meeting the effects of climate change as the reservoirs will become more important to mitigate floods and droughts and generate renewable energy. Furthermore, hydropower with reservoirs provides the required backup energy and ensures electricity supply in times when there is no wind or sun. Nearly half of the European reservoir capacity is located to Norway (Statkraft 2014-12-03).

There are different types of hydroelectric power stations. One is unregulated stations with no storage capacity. This type of station is typically located at rivers and are small plants. The flows of water are hard to regulate and must be used when it comes. Regulated hydroelectric power stations are, on the other hand, linked to dams enabling regulation of the water flows. Table 23 shows the largest plants in Norway.

Table 23 The 10 largest hydroelectric power stations in Norway ranked after installed capacity per 1.1 2012.

Power station	Fylke	Capacity MW	Average prod. GWh/year
Kvilldal	Rogaland	1 240	3 583
Tonstad	Vest-Agder	960	4 357
Aurland 1	Sogn og Fjordane	840	2 508
Saurdal	Rogaland	640	1 334
Sy-Sima	Hordaland	620	2 158
Lang-Sima	Hordaland	500	1 358
Rana	Nordland	500	2 168
Tokke	Telemark	430	2 328
Tyin	Sogn og Fjordane	374	1 450
Svartisen	Nordland	350	2 430

Source: Fakta (2013).

The plant located to Kvilldal in Rogaland has the largest capacity, while the plant in Tonstad generate more electricity. Here should also be observed the regulation enabled by the special type of power stations; pumped-storage hydroelectricity. At this type of plants water is pumped from a low to a higher located reservoir and can be used to production during periods of high prices. Furthermore, there is potential water power for generation of more electricity even if license for establishing plants mainly concerns small stations and investments in upgrading of existent plants (Fakta 2013).

In ***Sweden*** about 45% of the consumption of electricity is based on hydropower (Svensk energi 2014-12-04b). The precipitation in forms of rain and snow is decisive for the production. Normally the generation of electricity is 65 TWh/year. The hydroelectrical plants may be used both as producer of basic power and as regulator of the production when the demand of electricity increases or decreases. They may also be used as regulators to compensate fast changes of production in other types of electrical power stations (Svensk energi 2014-12-05).

The Swedish and the Norwegian topographies differ. Even if there are some high mountains in northern Sweden along the Norwegian border the Swedish landscape is flat and low in comparison to the high Norwegian elevation and mountain areas. The large Swedish watercourses used for generation of electricity are mostly stretching from areas close to the Norwegian border and southeast into the Baltic. Luleälven is the most important of these rivers. The watercourses have been of decisive importance at location of hydroelectrical power plants. See figure 19.

There are about 2 000 hydroelectrical power plants in Sweden of which about 200 have a capacity of 10 MW or more. The largest station is Harsprånget (830 MW) located at Lule älv. Table 24 shows the largest plants in Sweden.

Figure 19 Location of hydroelectric plants with installed capacity of more than 20 MW in Sweden.

Note: Four big rivers in the North are not regulated: Torneälven, Kalixälven, Piteälven and Vindelälven.

Source: Svensk energi (2014-12-04a).

Table 24 The 10 largest hydroelectric power stations in Sweden ranked after installed capacity.

Power station	River	Capacity (MW)
Harsprånget	Luleälven	830
Stornorrfors	Umeälven	591
Messaure	Luleälven	452
Porjus	Luleälven	440
Letsi	Luleälven	440
Ligga	Luleälven	343
Vietas	Luleälven	325
Ritsem	Luleälven	320
Trängslet	Dalälven	300
Porsi	Luleälven	275

Source: Svensk energi (2014-12-04a)

The installed capacity in Sweden is about 16 200 MW. About 80% of the generated electricity by hydropower is produced in Norrland of which a large share at stations along Luleälv (Svensk energi 2014-12-05).

Generation of electricity in ***Finland*** is based on many different sources of energy and forms of production. The most important sources are nuclear energy, hydropower, coal, natural gas, wood and peat.

The physical geography of Finland for generation of electricity by hydropower is less favourable than in Norway and Sweden. The Finnish landscape is characterized by lakes and watercourses even if the number of lakes varies. Thus, the coast areas have few lakes, while the density of lakes in the inland is impressive. In all Finland the number of lakes are nearly 190 000. But the lakes are in general small with a surface of less than 1 km^2. Usually the lakes are ground and many islands are linked to each other by different systems of lakes (Uppslagsverket Finland 2014-12-07).

In 2012 wood as fuel passed oil and became the largest source of energy in Finland (Statistikcentralen 2014-12-07). The rich resources of wood also reflect the large use of electricity within the forest industry; nearly 25% of the consumption of electricity in Finnish industrial activities (Fingrid 2014-12-07).

Hydro- and geothermal resources have made ***Iceland*** the largest producer of green energy/capita. In 2011 the electricity industry produced 17,2 TWh. This is close to 54 MWh/capita, which is much more than the average production of electricity in countries in OECD and EU (about 9 MWh and 6 MWh respectively). Furthermore, nearly all the electricity in Iceland is produced by harnessing only renewable resources of hydro and geothermal energy. In addition, approximately 86% of Iceland´s consumption of primary energy comes from renewable sources of which 66% comes from geothermal sources and 20% from hydropower. This means that Iceland has the largest share of renewable energy of any national energy budget in the world (Askja Energy 2014-12-10).

Iceland is an island of 103 000 km^2 and one of the youngest landmasses on the planet. A consequence is that Iceland is the home to some of the world´s most active volcanoes. In addition, Iceland is located where the Eurasian and American tectonic plates meet (Iceland 2014-12-07). The country consists mainly of a central volcanic plateau with elevations of 700 to 800 meters. But there are also higher mountains of which Havannadalshnúkur is the highest (2 119 meters). Glaciers cover almost 12% and lava fields cover almost 11% of the surface. Vatnajökull, the largest glacier in Europe, is located in southeastern parts of Iceland. Furthermore, there are many lakes, snowfields, hot springs and geysers. Even if most rivers are short there are swift currents and waterfalls that create important waterpower potential (Iceland topography 2014-12-10).

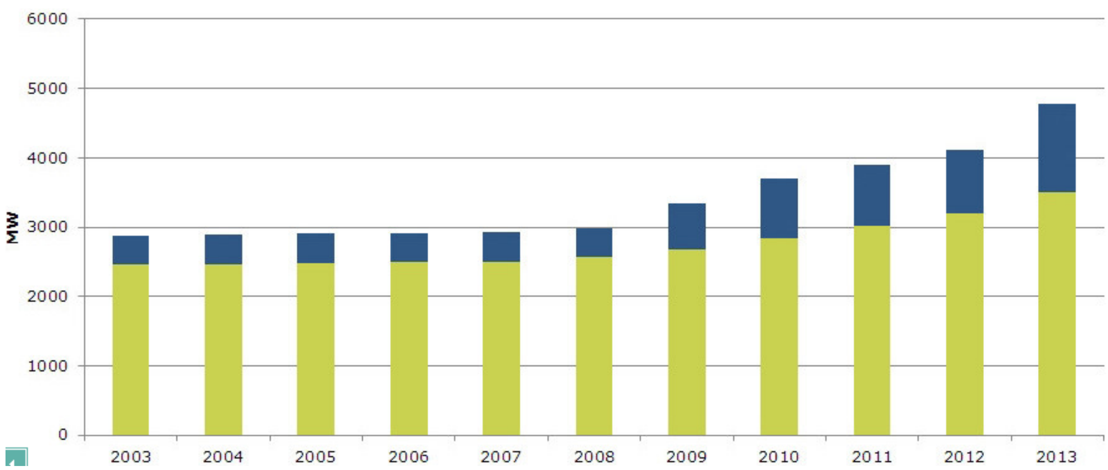
5.6.3 Wind

With regard to installed wind power capacity ***Denmark*** has a strong position; number 9 in the world, number 6 in Europe and the largest capacity among the Nordic countries. Sweden is ranked as number 11 in the world and number 8 in Europe. China has the largest capacity in the world, Germany in Europe, while Denmark has the largest capacity per capita in the world. About a third of the Danish electricity consumption in 2013 was covered by wind. This is the highest share in the world (Danish Wind 2014-12-09)[24]. The installed capacity in Denmark was 4

[24] In the first part of 2014 wind power provided a record - 41,2% - of Denmark´s electricity (Wall Street Journal 2014-12-09).

808 MW in 2013 and in Sweden 4 459 MW, while the Norwegian capacity of installed wind power was 811 MW and the Finnish capacity was 448 MW (IEA 2014-12-02).

Denmark has been an important first-mover in both onshore and offshore wind power. This ability to capture the power of the wind is based on the fact that Denmark is a windy country. But there are many factors explaining why Denmark is leading the way in integrating wind power into the electricity system. Innovative thinking and experience have enabled creation of core competence in production, design and installation of wind turbines worldwide. More than 90% of the world´s offshore wind turbines have been installed by Danish companies and Denmark expects to remain the dominant player in the offshore wind turbine market (Wind Energy 2014-12-09). Figure 20 illustrates the development of wind energy capacity in Denmark.



Note: Green colour onshore capacity; blue colour offshore capacity.

Figure 20 Accumulated wind energy capacity (MW) onshore and offshore in Denmark 2003 – 2013.

Source: Danish Wind (2014-12-09).

Denmark´s position in the offshore wind turbine market is underlined by its installed capacity; second largest in Europe after UK. UK has about 60% of the total installed European capacity offshore, while the Danish share is about 20%. The Swedish share is about 3%. The Finnish and Norwegian shares are less than 1% respectively. At ranking of the 10 countries that have installed and connected turbines to the electricity grid the Nordic countries are found as number 1 (Denmark), 6 (Sweden), 7 (Finland) and 9 (Norway)(EWEA 2013).

The total installed capacity and connected to the electricity grid in offshore wind farms in Europe was at the end of 2012 about 5 000 MW. This capacity enabled production of 18 TWh in a normal wind year and covers 0,5% of the EU´s total electricity consumption. In the world the installed wind energy capacity offshore is about 5 500 MW of which 90% is in Europe. This gap (about 500 MW) is explained by installation of wind energy offshore in mainly China (about 500 MW) and to some extent Japan (about 30 MW). The investments in offshore wind capacity in Europe are mainly made in the North Sea (65%), in the Atlantic Ocean (19%) and in the Baltic Sea (16%). Siemens is the leading offshore wind turbine supplier with about 60% of total installed capacity in Europe followed by Vestas (about 30%)(EWEA 2013).

Figure 21 illustrates the dramatic development of wind power in ***Sweden*** stressed by the increasing production of electricity since 2006.

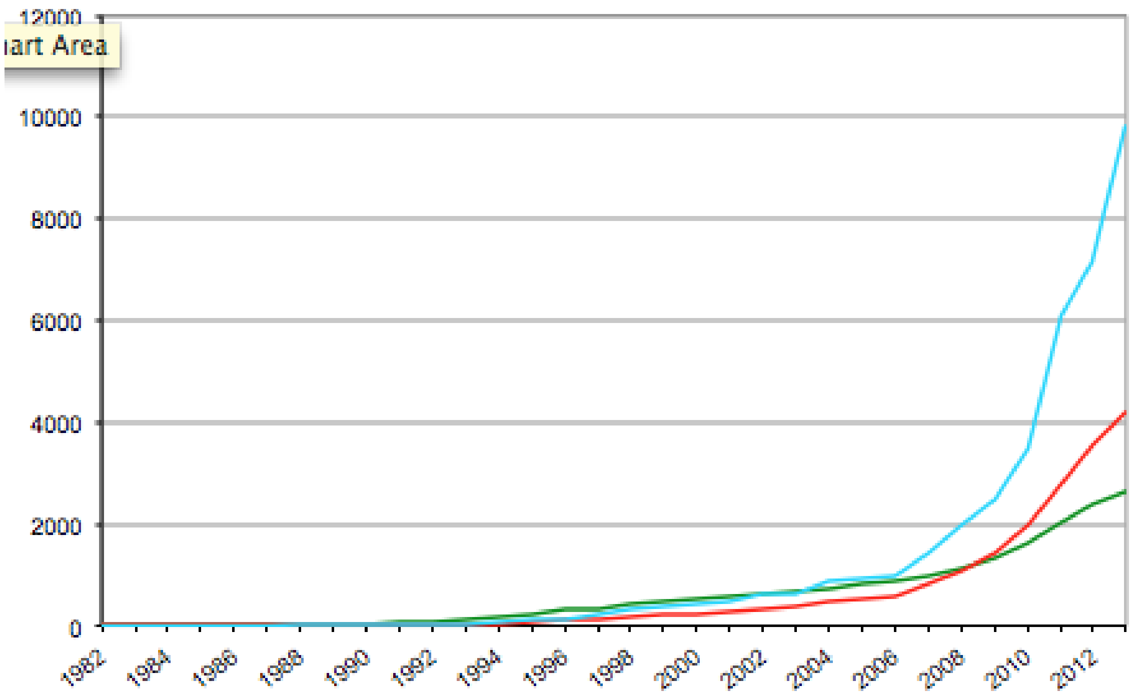


Figure 21 The development of the wind power in Sweden 1982-2013.
Note: Number of units (green), installed effect (MW; red) and production of electricity (GWh; blue).
Source: Statens energimyndighet (2014-12-11).

In 2006 the Swedish production of electricity by wind power was 988 GWh that in 2013 had grown to 9 842 GWh (9,9 TWh)(SCB 2014-12-11). Lately Sweden has become a net exporter of electricity. This development is explained by the ability to increase the generation of electricity combined with stagnation and even decreasing use of electricity. The increase of production depends on more efficient nuclear power stations and the extension of wind power capacity, small scale water power and promotion of cogeneration of heat and power based on biofuels. In 2013 the generation of electricity by wind power covered 7% of the Swedish electricity market and was the third largest source of electricity in Sweden. Nuclear energy (43%) and hydroelectricity (41%) dominate the market[25](Statens energimyndighet 2013).

Sweden is located in the zone of west winds and large parts of the country are windy, especially along the coasts and offshore. The best location for wind power stations are found on the islands of Gotland and Öland, at the West Coast and along the coast of Skåne. Lillgrund at Öresund was the third largest wind power station offshore at the start in 2007 (Svensk energi 2014-12-16). The counties of Västra Götaland, Västerbotten and Skåne contributed to more than 1 TWh each of the total generation of electricity of 10 TWh in 2013 (Statens energimyndighet 2013).

The primary source of electricity in ***Norway*** is hydropower. This source stood for about 96% of the generation of electricity in the country in 2013. But in recent years attention has been paid to wind power as a commercial source of energy. Some of the best prerequisites in Europe for generation of electricity by wind power are found in Norway with windy places spread over big areas (NVE 2014-12-15). These resources in combination of technological advances and renewable energy support schemes indicate investments in new wind power installations in the coming years. At present the Norwegian capacity and generation of electricity of wind power are lagging behind Denmark and Sweden (IEA 2014-12-02). Installed capacity in the end of 2013 was 811 MW that in 2014 has increased to 860 MW enabling production of 2,2-2,4

[25] According to preliminary figures from ”Svenska kraftnät” the generation of electricity by wind power was 11 TWh during the 12 months period; April 2013 to March 2014 (Statens energimyndighet 2013).

TWh a normal windy year. This corresponds to about 1,8% of the supply of electricity in Norway (Vindkraft i Norge 2014-12-16).

The interplay between accessibility to hydropower and new wind power in the future is one of the most important reasons for the ranking of Norway as the best country in Europe for renewable energy. Norway has about 50% of the European capacity in reservoirs enabling regulation of production of electricity by wind and water power. The suppliers of electricity in Norway have experience of this kind of cooperation. For example, the Danish need for regulation of wind power has to large extent been performed by use of Norwegian water power stations (Vindkraft i Norge 2014-12-15).

Rogaland county is seen as the best Norwegian county for wind power. This position is explained by good wind, enough capacity of the net and proximity to both the Norwegian market and the export market (Norsk Vind Energi 2014-12-16). But nowadays attention is paid to the big investments made in construction of wind power stations on eight places around “Trondheimsfjorden”. The costs are calculated to 20 billion Norwegian crowns and the project has a total capacity of 3,7 TWh (SWID 2014-12-17). Expectations of authorities to increase the production of electricity by wind power to 6-8 TWh in 2020 also indicate more investments in wind power in the future (Vindportalen 2014-12-17).

In 2013 29% of electricity consumption in ***Finland*** was provided by renewables; 15% by hydropower, 13% by biomass and 1% by wind power. The wind produced about 0,8 TWh. A target is to reach the production of 6 TWh per year in 2020 (IEA 2014-12-02). The number of wind turbines was 211 at the end of 2013 and the capacity of wind power was 448 MW (Miljo. Utbyggnad av vindkraft 2014-12-18).

5.6.4 Biofuels

Biofuels have become more important as a source at generating electricity and for heating but also for transportation. In global and European perspectives the Nordic countries are in the forefront of using biofuels.

The geographical conditions are decisive for the efforts made to invest in biofuels. Sweden and Finland are mainly covered by forest enabling production of electricity and heating, while biofuels in Denmark is based on agricultural products. The forest sector is the main supplier for solid fuels in northern Europe even if the agricultural sector has potential to increase considerably. But in Norway rich resources of hydropower may hamper investments in biofuels as source of energy for production of electricity. Increasing bioenergy production is also seen as a tool to reduce negative environmental impacts at production of energy. Furthermore, these efforts are linked to proposals at the EU level to promote the use of renewable energy resources and thereby contribute to climate change mitigation (Sustainable Production of Bioenergy from Agriculture and Forestry in the Nordic countries 2008).

The Nordic countries have also used different policy instruments for the development of biofuels for transportation means. The countries envisage a future where an increasing proportion of transport energy is derived from biofuels and contribute with different inputs to the production process such as agriculture and food waste in Denmark and municipal waste and forestry residuals in Finland and Norway or municipal waste, forestry and agriculture residuals in Sweden. An observation is that in Norway the desire to replace gasoline and diesel with biofuels is less prominent; electric mobility is an avenue which is more supported. This should be seen with regard to the accessibility to cheap renewable electricity. Local and regional projects e.g. busses in cities or the usage of local waste for biogas and biofuel production have been implemented in all the Nordic countries (Olsen et al 2013).

Bioenergy is the main renewable resource in heat generation in Denmark, Finland, Norway and Sweden. Sweden leads in terms of absolute application of bioenergy with most municipalities with district heating systems use bioenergy. In Iceland the use of biomass for heating is limited to municipal solid waste (Pöyry 2008).

5.7 Nuclear energy

Electricity by nuclear energy in the Nordic countries is produced at plants in Sweden and Finland. At the list of EU-countries with regard to the use of nuclear energy Sweden is ranked as number 4 and Finland as number 7. The consumption per capita in Sweden and France is considerably more than other EU-countries. Finland has per capita the third largest consumption of electricity generated by nuclear power.

During the period 1972 – 1985 12 reactors started in ***Sweden***; 4 in Ringhals, 3 in Oskarshamn, 3 in Forsmark and 2 in Barsebäck. Table 25 shows when the reactors started.

After the closure of the Barsebäck plant in 2005 there are 10 reactors in Sweden located to 3 places. Ringhals has a total electrical net effect of circa 3 700 MW, while corresponding effect at Forsmark is 3 140 MW and nearly 2 600 MW at Oskarshamn. These reactors account for circa 40% of the total production of electricity in Sweden (Energimyndigheten 2014-12-19). An observation is that two of the oldest reactors, but also one of the youngest reactors are located to Oskarshamn.

Table 25 Launching of reactors in Sweden.

Year	Reactor
1972	Oskarshamn 1
1974	Oskarshamn 2
1975	Barsebäck 1
1975	Ringhals 2
1976	Ringhals 1
1977	Barsebäck 2
1980	Forsmark 1
1981	Forsmark 2
1981	Ringhals 3
1984	Ringhals 4
1985	Forsmark 3
1985	Oskarshamn 3

Note: Barsebäck 1 was closed in 1999 and Barsebäck 2 in 2005.
Source: Processing of Swedish Radiation Safety Authority 2014-12-18.

The production of electricity by nuclear power is dependent on activities performed in many countries based on specific competence of the nuclear fuel cycle. See figure 22.

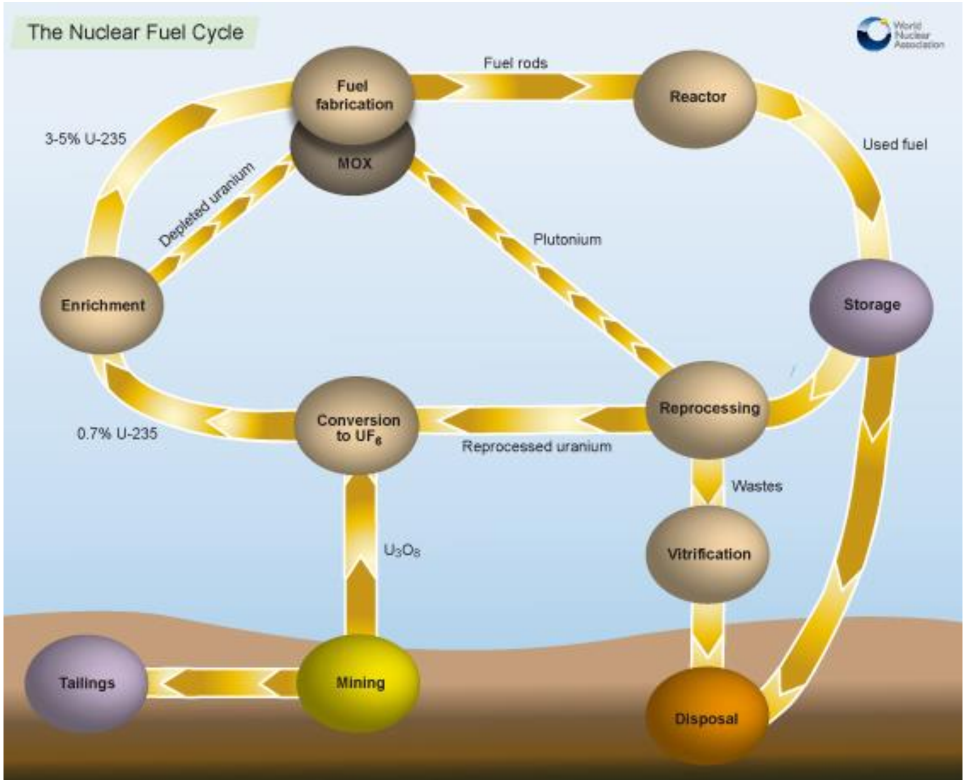


Figure 22 The nuclear fuel cycle.
Source: World Nuclear Association 2014-12-20.

The mining of uranium starts the nuclear fuel cycle that ends with the disposal of nuclear waste. In Sweden *mining of uranium* took place at Ranstadverket in Västergötland at the end of 1960s. But local opinion stopped at an early stage this mining. Thus, Sweden has imported uranium from countries such as Canada, Australia, USA and Gabon (SNA 1992).

The *conversion* to UF6 has e.g. been performed in Canada, UK and France, while *enrichment* has taken place in the nuclear countries of USA and former Sovietunion. *Fuel fabrication* has mainly been accomplished in Sweden even if some fabrication of competitive reasons has been made abroad. The fuel rods are used for power generation in the *reactor.* When removed from a reactor the fuel will be emitting both radiation and heat and is unloaded into a storage pond adjacent to the reactor to allow the radiation levels to decrease. But ultimately used fuel must either be reprocessed or prepared for permanent disposal (World Nuclear Association 2014-12-20).

Here, the dependence of other countries at production of electricty by nuclear power is observed. The Swedish dependence mainly concerns the first steps of the nuclear fuel cycle; mining, conversion and enrichment. At an early stage of the Swedish use of nuclear power for generating electricity the reprocessing of used fuel also meant dependence on plants abroad. Nowadays, however, the waste of Swedish reactors are taken care of in Sweden. Sweden has chosen the alternative with long-term storage and final disposal without reprocessing of used fuel and left the alternative reprocessing to recover and recycle the usable portion of it. The waste is managed by SKB (Swedish Nuclear Fuel and Waste Management Co). A site for the Spent Fuel Repository was selected in 2009 and SKB has submitted the applications to build the repository in Forsmark (SKB 2014-12-22).

Finland has 4 reactors of which 2 are located to Lovisa in the southern and 2 are located to Olkiluoto in the soutwestern parts of the country. These reactors provide nearly 30% of Finland´s electricity. In addition a fifth reactor is under construction in Olkiluoto and 2 more are planned. The decision in Finland´s parliament in 2002 to approve building of the fifth nuclear reactor was seen as very significant as it was the first decision of this kind for more than 10 years in Western Europe[26].

But the construction of the reactor (Olkiluoto 3) has been delayed and can be started first in 2018, 9 years later than planned (NyTeknik 2014-12-22). Like Sweden Finland makes efforts to prepare used fuel for permanent disposal (SKB 2014-12-23). In 2013 nuclear power provided 23,6 TWh, coal 14,6 TWh, hydropower 12,9 TWh, gas 7,0 TWh and biofuels 11,5 TWh of Finland´s electricity production (World Nuclear Association 2014-12-22).

The production of electricity by nuclear power has been criticized concerning the ability fo find long-term solutions for nuclear radiation waste and the risk for accidents. In Sweden this criticism has been intensive, especially after the accidents in Harrisburg 1979 and in Tjernobyl in 1986. A consequence of the accident at Harrisburg was the referendum in Sweden in 1980 concerning the use of nuclear power for generation of electricity. After this referendum the parliament made the

[26] The Finnish parliament has also decided to accept the request to construct another reactor in the North of Finland but it has met strong protests (DN 2014).

decision to accept 12 reactors if the reactors were closed in 2010 (Swedish Radiation Safety Authority 2014-12-18)[27]. Furthermore, the accident at Fukushima in March 2011 meant more criticism of the use of nuclear power at production of electricity and led to more efforts in security of the nuclear fuel cycle as well as more investments in renewables. A remarkable example is the immediate decision by the German chancellor Angela Merkel to close seven reactors (Economist 2014). These efforts emphasize the use of nuclear power at generating electricity as a global issue.

5.8 Generation of electricity – all energy sources

The overview above indicates the strong position of the Nordic area as energy producer. But the natural conditions vary among the countries. The Norwegian situation is unique with rich resources of oil and natural gas as well as hydropower. Denmark with few energy sources has invested in wind power for production of electricity, while Sweden and Finland have used hydropower, nuclear energy and biofuels as important energy sources. Iceland has hydropower and geothermal energy as basic sources. The generation of electricity is identified as a Nordic production profile. This section pays attention to the production of electricity enabled by other energy sources not illustrated above.

Sweden is the largest producer of electricity among the Nordic countries. Norway is the second largest producer followed by Finland, Denmark and Iceland. The Swedish production of electricity reaches the same level as the Norwegian when hydropower and nuclear power are combined. But the generation in Sweden comprise more production based on wind power, Combined Heat and Power (CHP) and contribution of condensing power[28]. CHP and condensing power account for an important share of the generation of electricity in Finland. In Iceland hydroelectricity dominates. Figure 23 shows the generation of electricity in the Nordic countries.

[27] In 2014 Sweden has 10 reactors in function after the closure of 2 reactors at the plant of Barsebäck.
[28] CHP is used both in municipalities and in industry.

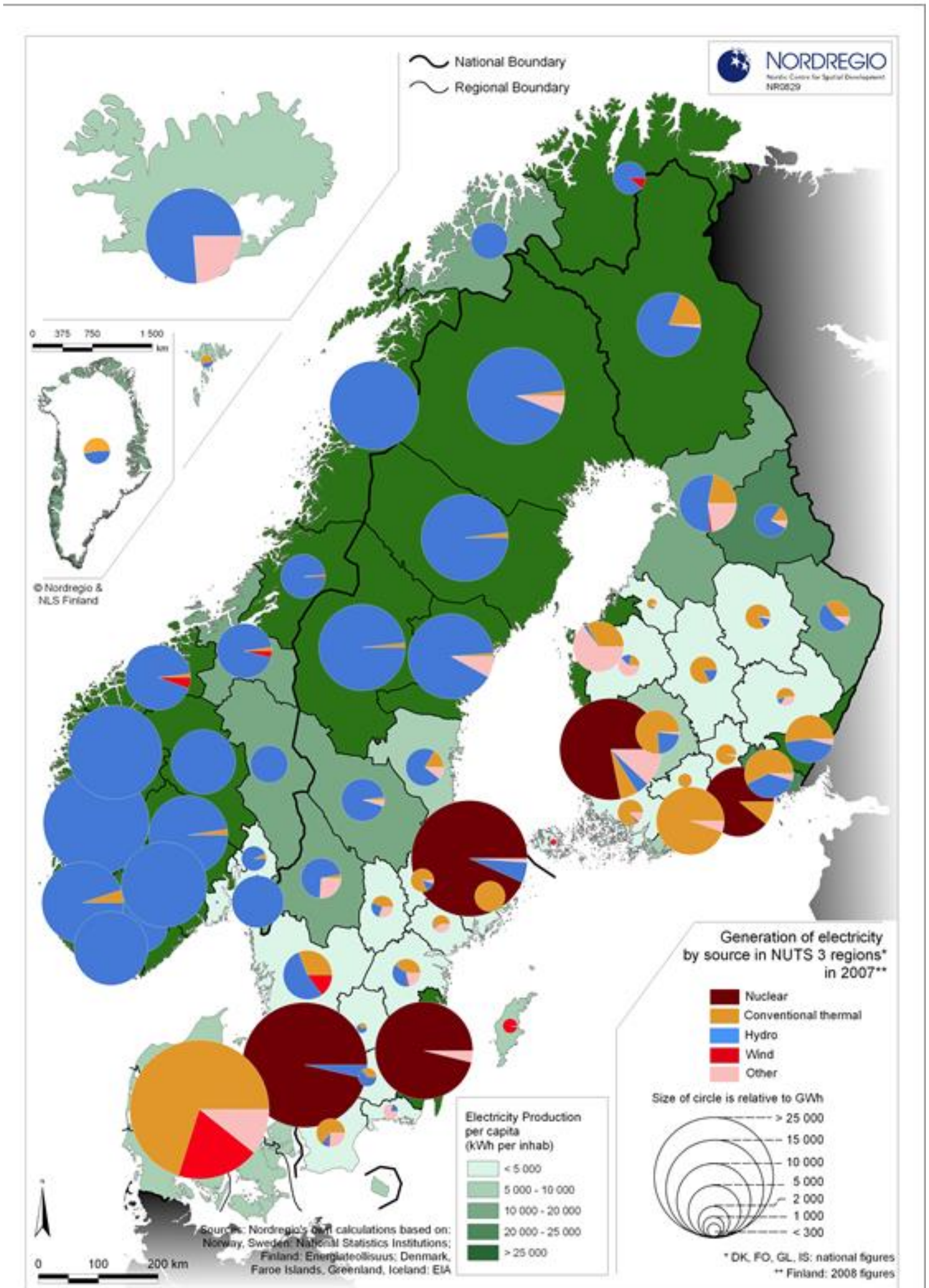


Figure 23 Generation of electricity by source in GWh in NUTS 3 regions in the Nordic countries in 2007.
Source: Nordregio (2015-01-16).

6 USE OF ENERGY[29]

6.1 Consumption regarding energy sources

The Nordic countries are characterized by a large share of renewable sources; about a third of the Nordic region´s energy supply. Biomass and waste are the largest of these and are used to generate electricity, heat and transport fuels. Hydropower is the second largest renewable source of energy used at generating electricity in the region. Substantial production of electricity is also based on nuclear energy. Still oil is the largest energy source. Figure 24 shows the energy supply in 2013.

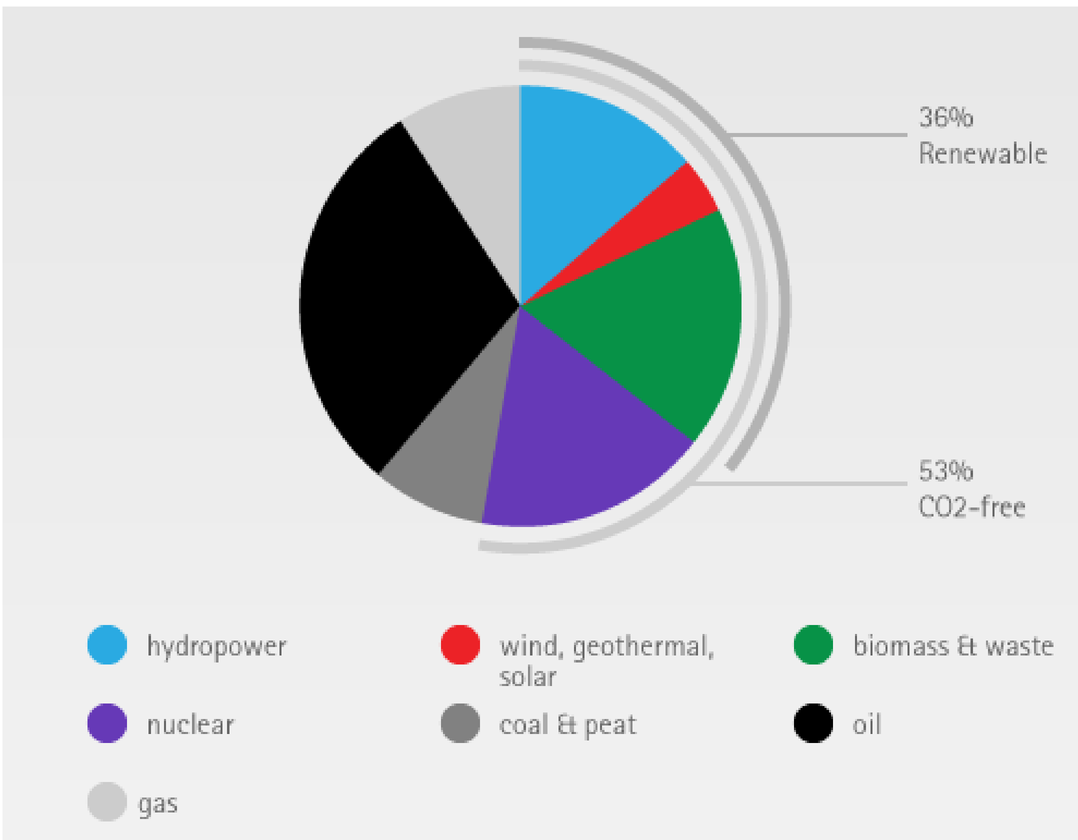


Figure 24 Nordic total primary energy supply as regards energy sources 2013.

[29] This chapter is mainly based on Energy Systems (2015-01-09).

A consequence of the oil crisis in 1970s was increasing interest in using alternative energy sources to oil at generating electricity. The use of nuclear energy in Sweden and Finland and the increasing use of coal in Finland and Denmark should be seen in this context. Thus, oil today principally is used in the transport sector. But, in spite of increasing use of renewable and nuclear energy the absolute demand for fossil fuels is roughly the same as it was at the beginning of 1970´s. Growth of the population and the economies are some reasons behind this development. See figure 25.

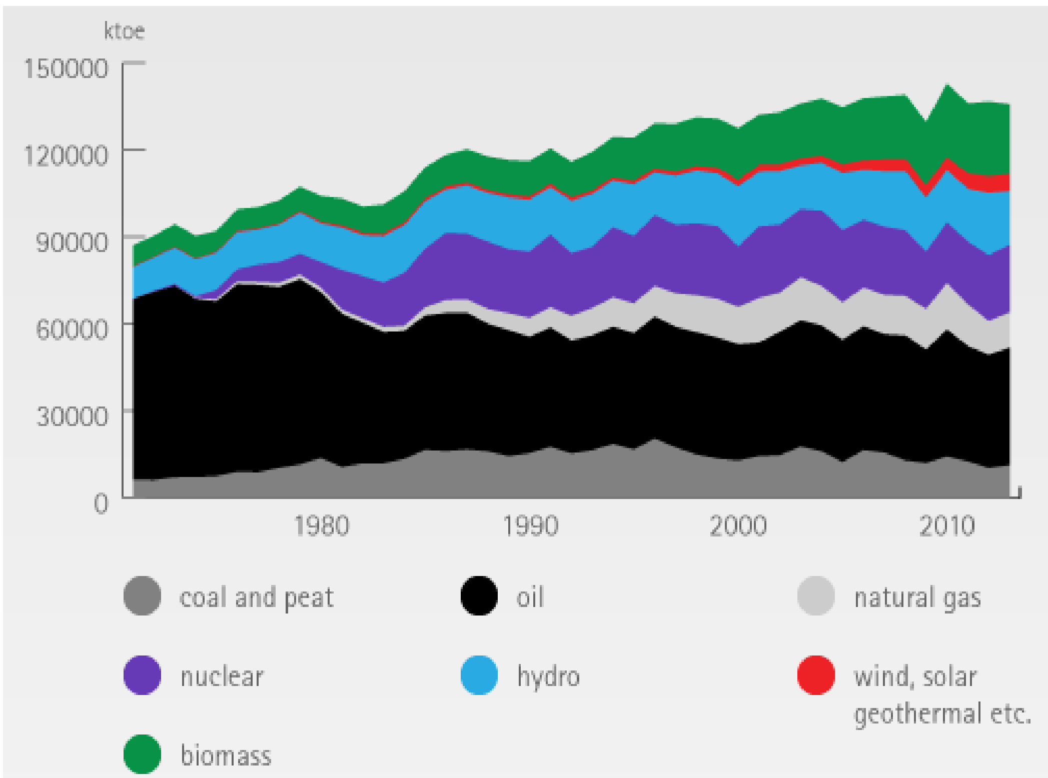


Figure 25 Nordic total primary energy supply as regards energy sources 1971-2013.

Two thirds of the generation of electricity in the Nordic region is based on renewables including hydropower in Norway and Sweden. Combined Heat and Power plants across Finland and Sweden burn biomass. Denmark has the largest share of wind power in the world at production of electricity, while in Iceland a substantial share of electricity is produced by the use of geothermal sources. Besides, by adding the use of nuclear power in Sweden and Finland to the renewables the region´s electricity is 85% CO_2 free. The production of the Nordic electricity is shown in figure 26.

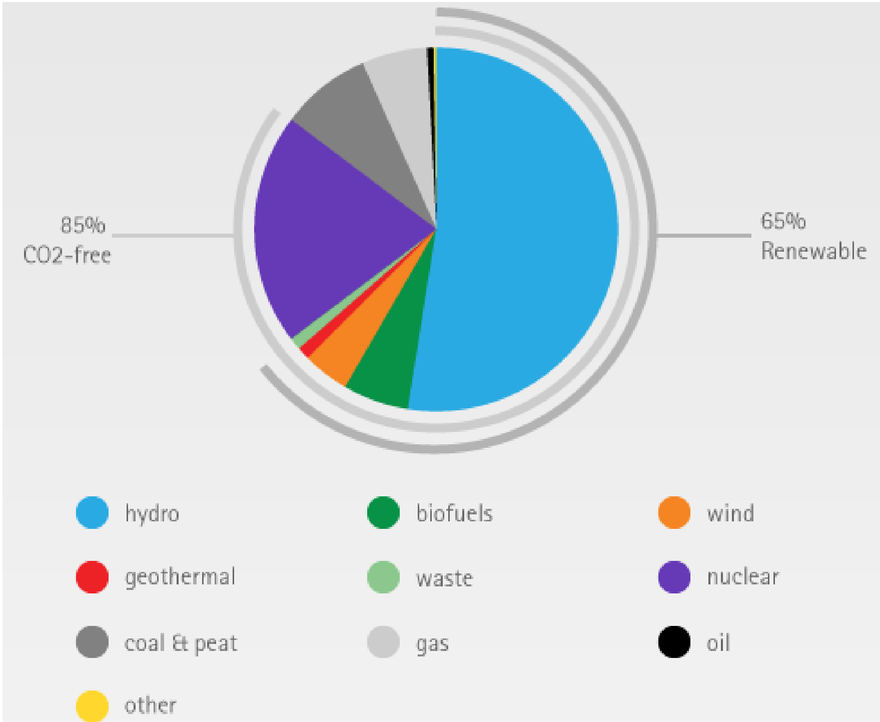


Figure 26 Nordic electricity production as regards energy sources 2011.

The Nordic countries have different but complementary electricity mixes enabled by the common Nordic grid linking Denmark, Finland, Norway and Sweden. The use of varying energy sources is shown in figure 27.

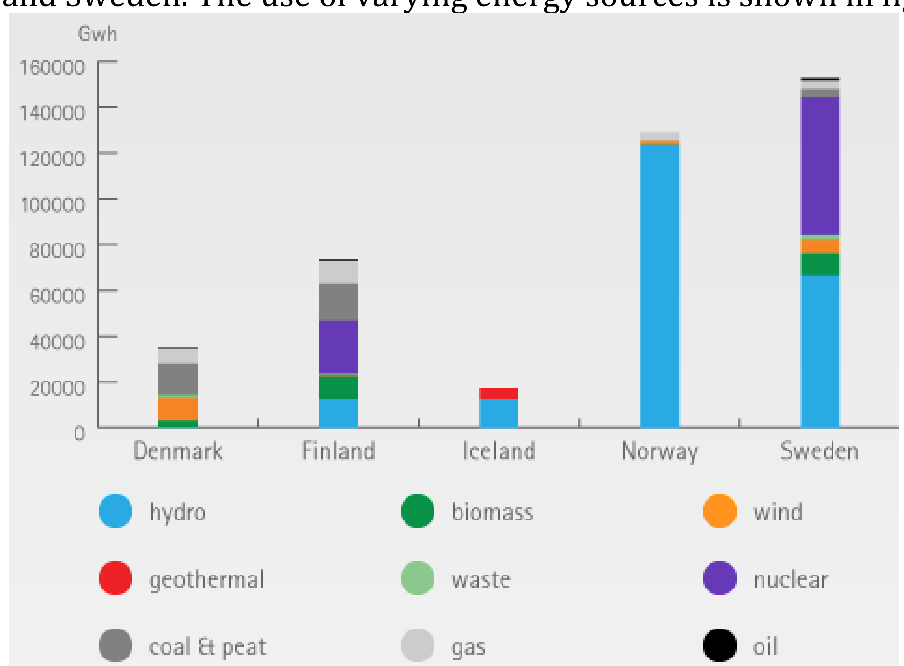


Figure 27 Electricity production in the Nordic countries related to source of energy 2011.

Sweden is the leading producer of electricity mainly based on hydro and nuclear power. The Norwegian production is nearly all based on hydroelectricity, while Finland and Denmark generate electricity from many energy sources.

The differences in the use of energy are related to varying energy resources and industrial activities. Iceland and Norway have electricity intensive industries enabled by abundant sources of electricity. For example, aluminium smelting plants explain the relatively high energy consumption per capita in Iceland. In Norway the use of electricity in heating of space and water is used to larger extent than in other Nordic countries, which have more developed district heating systems. This kind of distribution is much more spread in the Nordic than in other regions. Figure 28 shows the energy consumption per capita.

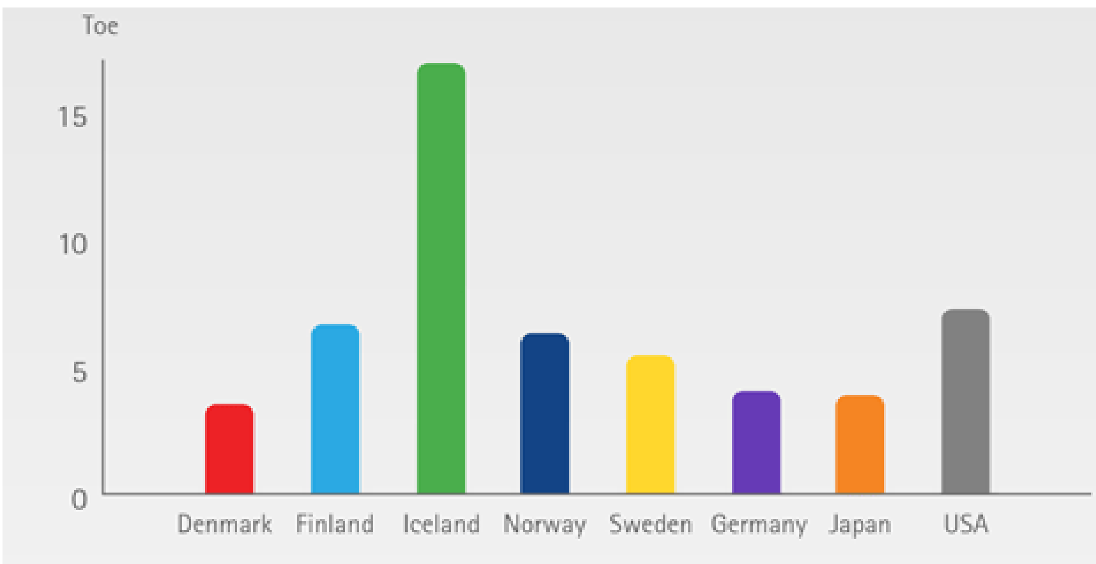


Figure 28 Energy consumption per capita in the Nordic countries 2010.

The Nordic region has one of the largest share of renewable electricity consumption in the world and all the Nordic countries have shares above the average of EU.

6.2 Consumption by sector

The Nordic countries account for about 8% of the energy consumption in EU. On average industry accounts for about a third of the energy used in the Nordic countries. This is substantially more than in most other countries. Rich endowment of raw materials and large capacity of hydroelectricity are important factors explaining the development of energy intensive industries in the region. Figure 29 illustrates the Nordic energy consumption by sector.

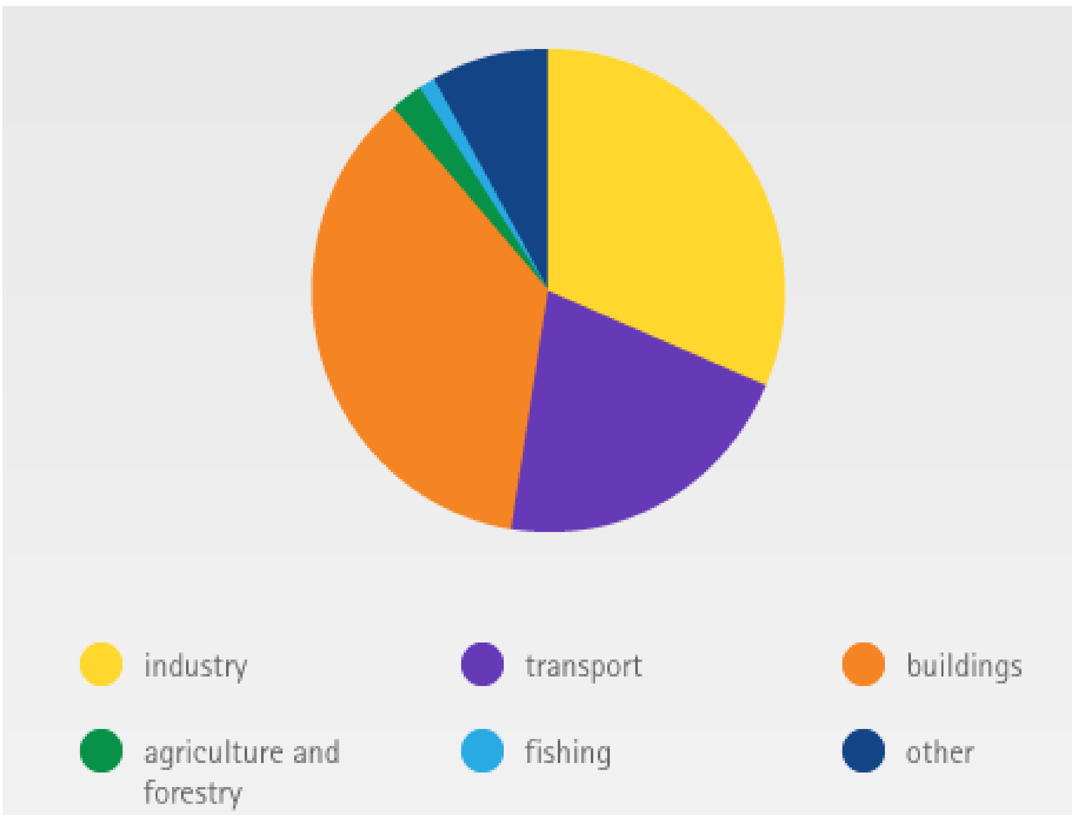


Figure 29 Nordic energy consumption by sector 2012.

Forest-based industries are especially important in Finland and Sweden, while Iceland and Norway have significant metal manufacturing developed by cheap and plentiful hydroelectricity. Denmark, on the other hand, has not the same access to energy resources. This situation is verified by small share of industrial energy use. See figure 30.

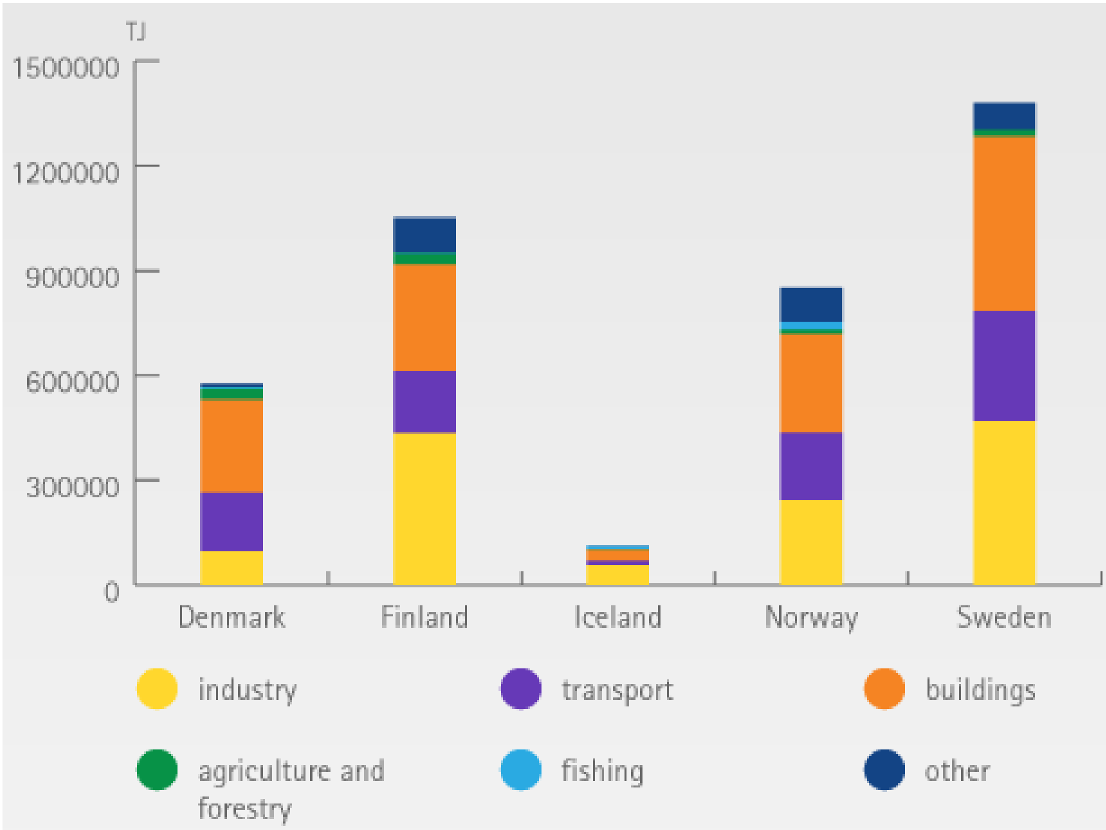


Figure 30 Nordic energy consumption by sector and country 2012.

At studies of regional differences of consumption of electric energy the metropolitan regions are identified as regions of high consumption; especially within the service sector. The industrial sector, on the other hand, dominates the consumption of electricity in many regions. The availability of natural resources for industrial production this kind of industrial activities has led to location to regions in northern Sweden, across Finland and along the Norwegian coast. See figure 31.

Iceland has the largest and Denmark the lowest consumption of energy per capita. These positions are related to high consumption in industry, transport and households in Iceland, while the low Danish consumption is mainly explained by the small industrial sector. See table 22.

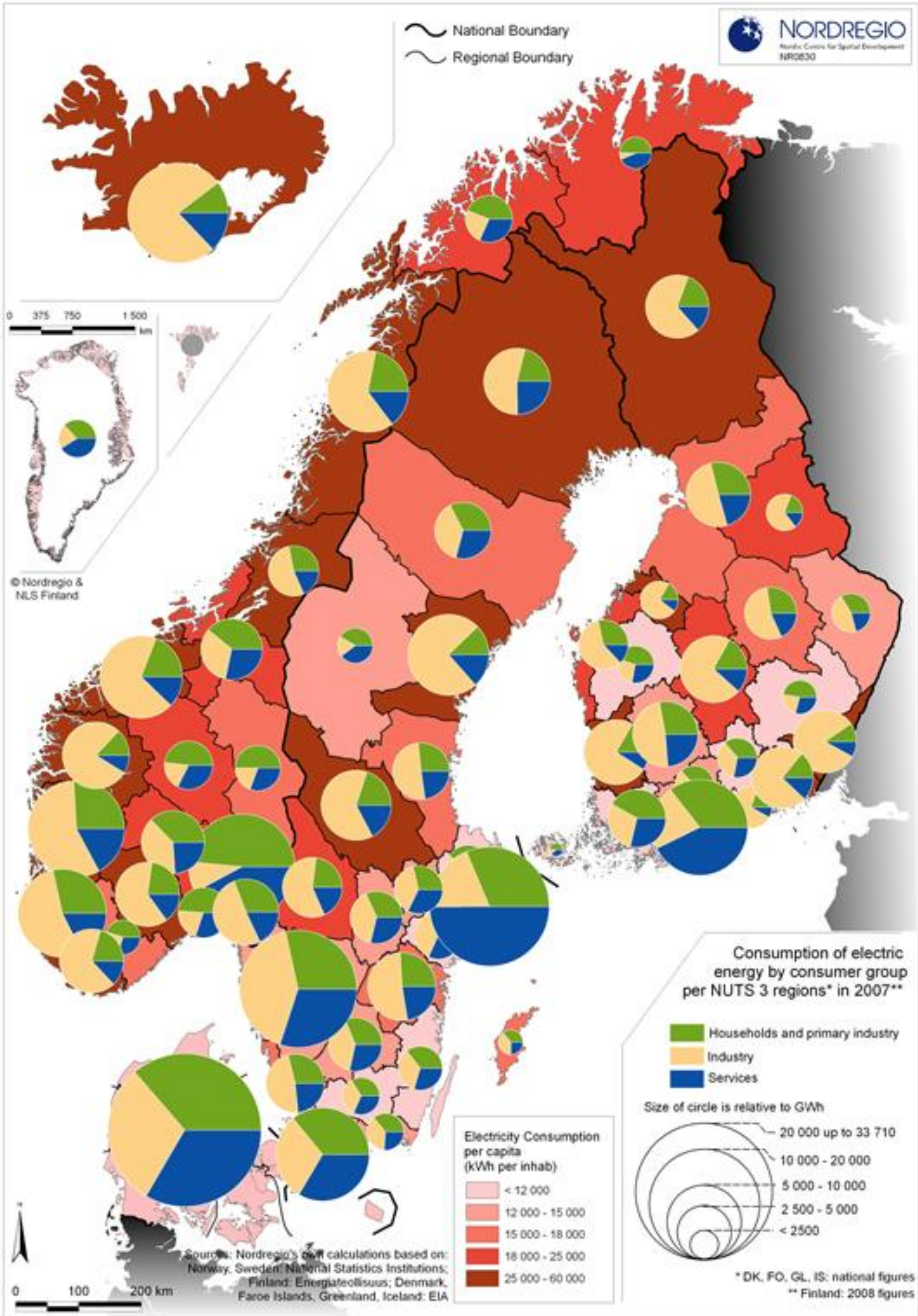


Figure 31 Consumption of electric energy in the Nordic countries by consumer group per NUTS 3 regions in 2007.

Source: Nordregio 2015-01-12.

Table 22 Final consumption of energy in the Nordic countries 2012.

	Denmark	Finland	Iceland	Norway	Sweden
Tonnes oil equivalents per person					
Total	**2.6**	**4.7**	**7.8**	**3.8**	**3.4**
Per cent of total final energy consumption					
Industry	16.2	43.2	35.8	34.5	36.0
Transport	32.6	19.1	20.1	27.1	25.7
Households	31.2	21.5	44.1	20.6	22.8
Fishery	0.8	0.1	0.0	2.6	0.1
Agriculture	5.4	2.9	0.0	1.7	1.4
Services and other sectors	13.8	13.2	0.0	13.6	14.0

Source: Nordic Statistical Yearbook 2014.

6.3 Energy intensity

Energy intensity indicates how much energy it takes to create one unit of GDP. Countries with heavy industries will have higher energy intensity than countries primarily based on services. As seen in figure 32 Denmark has the lowest ratio reflecting its lack of energy intensive industries but also energy efficiency.

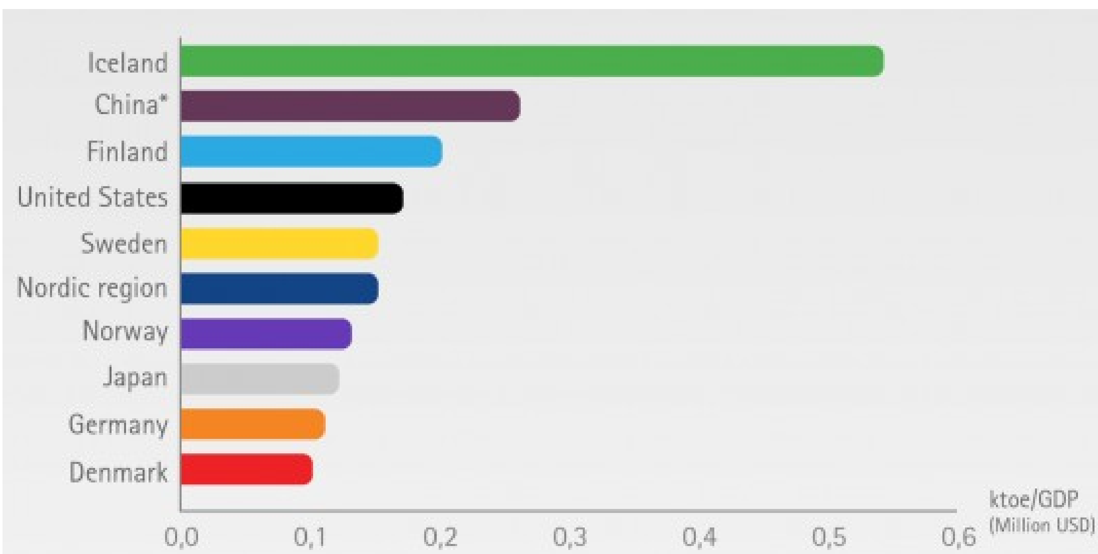


Figure 32 Energy intensity in 2011.

Iceland, on the other hand, has high energy intensity due to the dependence on energy intensive industries such as aluminium smelting. This dependence should be seen in relation to that all of Iceland´s electricity and about 80% of its energy supply are renewable.

Surveys of the development of the energy intensity during the period 1990 – 2011 show that the major economies have reduced their energy intensity. This trend is most evident in China, which has increased its GDP much faster than its energy consumption. Iceland deviates; its energy-intensive aluminiun industries have grown faster than its economy. But, to this should be added that in a globalised economy with substantial trade of goods, workforce, energy and capital the correlation between economy and energy system weakens. This makes energy intensity less relevant as a nation specific parameter.

6.4 Greenhouse gas emissions

The Nordic region has slightly higher per capita GHG (Greenhouse Gas) emissions than other industrialised countries in spite of having a relatively decarbonised electricity supply. The cold climate and energy-intensive industry are important factors explaining this situation.

Denmark has relatively carbon-intensive electric production. But this is counteracted by its lack of energy-intensive industry. The Danes have been successful at decoupling emissions and energy use from economic growth. Emissions of CO_2 have been reduced, while the economy has grown. This is a result of increasing energy efficiency and more use of wind and biomass in heat production and at generation of electricity.

The use of fossil fuels in the electricity mix and substantial industrial activity mean that Finland has one of the highest per capita emissions of the region. Pulp and paper, metal and chemical industries are main Finnish energy consumers.

Highest per capita emissions of the region, which has a unique composition, are found in Iceland. Transport and fishing vessels account for almost 80% of the emissions. After transport emissions from aluminium production are the most pronounced. The use of hydropower and geothermal energy make low emissions from generation of electricity and for heating.

Renewable supply of electricity gives Norway relatively high per capita energy consumption. But petroleum extraction also accounts for about 16% of Norway´s emissions. If the exported oil and gas were included the total Norwegian emissions would be much more.

The Swedish emissions are the lowest in the Nordic region. Despite economic growth the emissions have been reduced substantially during the last decades. This reduction is explained by two important factors: the introduction of nuclear energy and the change from oil to biofuels in the production of district heat. Figure 33 illustrates the greenhouse emissions per capita in different countries.

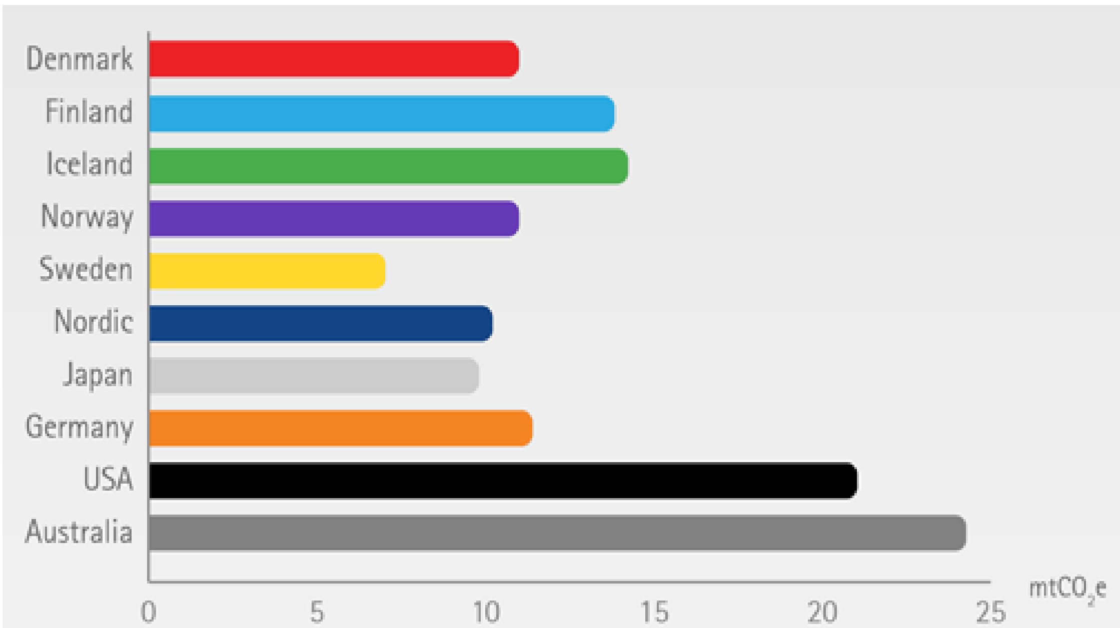


Figure 33 Greenhouse gas emissions per capita in different countries 2010.

7 CONCLUDING REMARKS

The starting point of this chapter is the issues formulated in section 1.2:

* Changes in extracting energy chiefly during 2003 – 2013. Impact on competitiveness regarding Nordic energy sources.

* Conditions in EU concerning production and consumption of energy. Impact on competitiveness regarding Nordic energy sources.

* The Nordic competitiveness regarding production and consumption of energy in relation to the world and EU?

* Are there strategic advantages in the current political and economic situation enabling Nordic competitiveness as producer and consumer of energy?

Changes in extracting energy chiefly during 2003 – 2013. Impact on competitiveness regarding Nordic energy sources.

Since the oil crisis in 1973 conflicts in the Middle East have influenced the energy market. A consequence is volatile oil prices. These changes of the oil prices have had a decisive influence on the Nordic economic development. High oil and gas prices have enabled investments in extraction offshore. Primarily Norway but also Denmark have become oil and gas producers. Furthermore, the nationalization of the Multinationals´ resources in nearly all oil-exporting countries brought interest in looking for oil in not exploited areas. But there were also processes favouring acceptance of extraction in the North Sea with partly ownership by the state. The technological development was pushed by demand for extraction in rough weather and from deep water.

The present Norwegian competitiveness is linked to this unique technological development. High extraction costs have forced Norwegian actors to innovate tools enabling production offshore and has created a competitive profile: Norway has thus conquered a leading position in offshore technology. The oil prices have led to a cash flow, facilitating both investments and savings. The State´s tax revenues are transferred to the Government Pension Fund – Global and its development reflects successful Norwegian investments in offshore activities.

The production and consumption of energy in the world increased during the past decade. One remarkable change is the drastic increase of the production of gas and oil in US due to the introduction of fracking enabling extraction of energy at lower costs. But the technique is controversial by its environmental impact, which may hinder expansion of this type of extraction. Norway also increased its production of gas considerably and is the only European country among the largest gas producers in the world.

Nowadays (February 2015) the oil prices have gone down to a level making oil extraction hard to justify as regards offshore activities. Factors that may explain the fall include Saudi Arabias rich flow of oil which has led to low oil prices and thus is a means of eliminating competitors. In Norway this decline has meant some discharges and decreasing rig activities. A factor delaying changes of the Norwegian production of oil and gas is investments made in offshore equipment. On the other hand, in areas enabling low production costs such as Middle East the budgets are based on oil revenues. Speculations of this kind indicate a price level enabling extraction offshore as well as keeping budgets in balance. *In Norwegian perspective the knowledge of producing offshore seems to be one of the most competitive edges.*

Depending on oil and gas production the Norwegian economy is vulnerable to changes of the energy market. But weakening of the Norwegian currency (”krona”) should facilitate Norwegian export. Furthermore, the Government Pension Fund – Global enables protection against dramatic changes of the Norwegian economy. In addition, if the demand of oil and gas increases Norway has large resources offshore; mainly natural gas. *These resources will, at higher prices, become reserves indicating Norwegian competitiveness during many years.*

Conditions in EU concerning production and consumption of energy. Impact on competitiveness regarding Nordic energy sources.

Characteristic for EU is the dependence on imports of energy. Russia is the largest exporter of oil and natural gas to EU. This leads to policy concern related to security of energy supply. Another issue regards difficulties of market access for suppliers to electricity and gas markets. Furhermore, a major policy has been adopted to reduce greenhouse gas emissions as well as aims to increase the use of renewable energy sources.

The production of oil in EU is about 60 Mtoe, while the consumption is about 600 Mtoe (2013). This gap means imports of which 34% comes from Russia and 11% from Norway. There is a mutual wish of Russia and EU to become less dependent on each other. Thus, the Russian export policy is more directed to the possibilities to conquer Asian markets and the European policy has become more focused on imports from other areas.

The production of natural gas in EU is nearly 130 Mto and the consumption about 400 Mtoe. Even if the import of gas is less than that of oil the supply of gas is vulnerable as nearly 40% is Russian gas furnished via pipelines. There are also large deposits of gas linked to the European gas net in North Sea and North Africa. Norway accounts for about a third of EU´s gas import. But gas is also brought to EU by LNG-ships. In total the supply in gaseous form account for about 80% and LNG for about 20% of the gas imports to the EU market. This need for import of oil and gas to EU combined with the aim of both EU and Russia to reduce their dependence on each other indicate stronger competitiveness of the Nordic region. *This should lead to new possibilities of the Nordic region to increase its market shares of many energy sources on the EU-market even if Norway is not a member of EU.*

The generation of electricity by hydropower is of special interest as a strategic factor for balancing variations in demand and supply of electricity. Otherwise, hydroelectricity traditionally has the nation as market. But the Nordic countries have since many years established cross-border grids. The fall of the wall and the extension of EU have brought new possibilities to construct grids. Political aims of more investments in renewable energy stress the need for transmission capacity at balancing varying production and consumption of electricity. The ability to store large volumes of water in reservoirs in especially Norway but also in Sweden and Finland is in this context a Nordic advantage. *More integration of electricity generated by hydropower and wind power tends to strengthen the position of the Nordic region as producer of electricity by renewables.*

The Nordic competitiveness regarding production and consumption of energy in relation to the world and EU?

There are some Nordic features as regards the size of different sources of energy and the presence of these sources on the world market. Norway is ranked among the 10 largest countries regarding production of natural gas and hydroelectricity, while Sweden is ranked number 10 on the list of the largest producers of electricity by nuclear energy as well as on the list of countries generating electricity by renewable energy. Denmark is ranked as number 9 in the world as regards installed wind capacity. Norway belongs to the countries which have had a substantial growth in the production of gas during the past decade. A favourable Nordic feature is the access to the European market located in short distance from Norwegian oil and gas sources.

The Norwegian position as producer of energy is impressive. At global comparison Norway is ranked as number 6 regarding hydroelectricity, regarding natural gas as number 7 and concerning oil as number 16. Related to per capita the production becomes even more impressive. On the ranking list of hydroelectricity the position is number 2, while the position of natural gas is number 3 and of oil number 5. The position is also strong concerning exports. Norway is the third largest country in the world after Russia and Saudi Arabia with respect to total export volumes of oil and gas; Norway is the third largest gas-exporting country in the world after Russia and Qatar. Norwegian extraction is, mainly regarding natural gas, by pipelines linked to European terminals. *Considering security the suppliers of energy from the North Sea have a competitive advantage as activities are performed in "stable" political territories.*

Sweden and Finland are among the leading producers of electricity by nuclear energy in the world. But the attitudes towards the use of nuclear energy differ. In Sweden a strong opinion is critical to nuclear energy verified by the closure of two reactors. In Finland a reactor is under construction. These different attitudes are related to conditions regarding supply of energy. Sweden has more hydropower than Finland. Furthermore, Finland is dependent on Russian import of natural gas and has tried to reduce this dependence by a gas pipeline from Norway via Sweden to Finland. The Swedish interest is weak, which is related to investments made in nuclear energy. The competitiveness of nuclear energy is related to the ability to avoid accidents and hinder introduction of more security rules that may lead to higher investment costs. *The future of nuclear energy is to large extent a political issue.*

Are there strategic advantages in the current political and economic situation enabling Nordic competitiveness as producer and consumer of energy?

The importance of hydroelectricity, nuclear energy and windpower as generators of electricity emphasizes the need for strong grids enabling transmission of electricity within and between countries. Furthermore, high capacity of the grids admits regulation of the flows adapted to differences in demand and supply as well as a varying flow of water and wind. The production by hydropower is of special interest as the reservoirs can be used as storage. In Nordic perspective, with its mixture of energy sources, producing electricity *investments in grids enabling transmission of big volumes seem to become an even more valuable factor to stay competitive on global, regional and local/regional energy markets.*

The relatively large Nordic shares of production and consumption of energy in the world are primarily based on resources of natural gas, oil and hydroelectricity in Norway. The oil and gas markets are mainly international, while electricity generated by hydropower, nuclear energy and renewables chiefly furnish national markets. But the opening of the electricity market and the construction of the European network for transmission of electricity have led to better access to former national markets.

The extraction of energy in the North Sea is to a large extent based on political, technological and entrepreneurial initiatives, which has created unique geographical sea environments. Along with the expansion of offshore activities the industry has developed northwards and petroleum clusters and competitive supplier services have been established at many places. A network of pipelines for Norwegian gas has been constructed enabling exports to major countries in Europe. The Norwegian shelf is the world´s largest offshore market that provides Norwegian service and supply companies with a vast home market. *The activities of the shelf is pushing the development of innovative solutions indicating further contribution to the industry´s opportunity to boost its competitiveness.*

The geographical conditions for generation of electricity by hydropower in Finland is less favourable than that of Norway and Sweden. But rich resources of forest have led to large use of wood at production of electricity within the forest industry. Hydropower and geothermal resources have made Iceland the largest producer of green energy/capita in the world. Low prices of electricity in Iceland attract energy intensive industries.

Denmark has a strong position regarding installed wind power capacity with the largest capacity among the Nordic countries and the largest capacity per capita in the world. Denmark has been an important first-mover in both onshore and offshore wind power. This development has created core competence in production, design and installation of wind turbines worldwide. *The Danish competitiveness is especially strong concerning offshore activities and Denmark is the dominant actor installing wind turbines offshore*.

In Sweden the production of wind power has increased drastically during the past decade. In Norway the conditions for generating electricity are some of the best in Europe with windy places spread over big areas. *By the combination of hydropower and new wind power Norway is seen as the best country in Europe for renewable energy.*

In global and European perspectives the Nordic region is in the forefront using biofuels for generating electricity, for heating and for transportation. Investments in biofuels vary with respect to geographical prerequisites. The forest sector is the main supplier of solid fuels in the Nordic region. Production of bioenergy is seen as a tool to reduce negative environmental impact at producing electricity and as a way to mitigate climate change.

REFERENCES

BP Statistical Review (1980) BP Statistical review of the world oil industry 1980.

BP Statistical Review (2004) BP Statistical Review of World Energy June 2004.

BP Statistical Review (2014) BP Statistical Review of World Energy June 2014.

Economist (2014) Germany´s energy transformation. Energiewende. The *Economist 2014-12-22.*

eia (2014) U.S. Energy Information Administration. *Independent Statistics & Analysis*. Last updated: February 4 2014. Full report.

Energy in Sweden (2013) *Swedish Energy Agency.*

Euracoal (2013) *European Association for Coal and Lignite.* Coal Industry across Europe. 5th edition.

EU Energy in figures (2013) *Statistical Pocketbook*.

EWEA (2013) The European offshore wind industry – key trends and statistics 2012. January 2013. *A report by the European Wind Energy Association.*

Facts (2014) The Norwegian petroleum sector, *Norwegian Petroleum Directorate.*

Fakta (2013) Energi- og vannressurser i Norge. *Olje- og Energidepartementet.*

FT (2014a) European Energy. EU seeks alternative suppliers. FT Special Report. *Financial Times 2014-10-23*.

FT (2014b) Energy. The "age of abundance" poses fresh dilemmas. FT Special Report. *Financial Times 2014-11-24*.

Global Wind Statistics (2013) *GWEC-Global Wind Energy Council*. 05.02.2014.

International Energy Agenzie (2007). Oil supply security. *Emergency response of IEA countries.*

Lorentzon, S och Olsson, S-O (1992). Historisk bakgrund och geografiska förutsättningar i Olsson, S-O (red.) *Naturgas i Norden. Förutsättningar för ett integrerat gasnät.* BAS. Göteborg.

National Gas Union of Ukraine (2014) *EEG East 2014-11-02*. European Gas Analysis. Consulting Services on Natural Gas sector of Russia.

NBIM (2013) Norges Bank Investment Management. *Government Pension Fund Global. Annual Report.*

Nordreg (2011) Economic regulation of electricity grids in Nordic countries. *Nordic Energy Regulators. Report 7/2011.*

Nordic Statistical Yearbook 2014.

Norway (2011) Energy Policies of IEA countries – Norway 2011 Review.

Odell, P.R (1986) *Oil and World Power.* Eighth edition. Penguin Books Ltd. Harmondsworth, Middlesex, England.

Odell, P.R (1997) The exploitation of offshore mineral resources. *GeoJournal 42.1: 17-26.*

Odell, P.R (2004) *Why Carbon Fuels will Dominate 21st Century´s Global Energy Economy*. MultiScience publishing Co, Ltd. Brentwood, Essex.

Odell, P.R (2010) *An Energetic Life.* The memoirs of Peter R. Odell from 1930 to 2010. British Library Cataloguing in Publications Data.

Olsen, D, Klitkou, A and A. Eerola & VTT colleagues (2013) Analysis of Biofuels Policy in the Nordic Countries. TOP-NEST (Nordic pathways for sustainable transport and energy) *Contribution to TOP NEST WP3.*

Pollard, S (1998) Industrialization, 1740 to the Present in Butlin, R.A and Dodgshon, R.A (editors) *An Historical Geography of Europe*. Clarendon Press. Oxford.

Pöyry (2008) Status and Potentials of Bioenergy in the Nordic Countries. Commissioned by Nordic Energy Research. *ECON Pöyri-Report no. 2008-057.*

SNA (1992) *Infrastructure*. National Atlas of Sweden.

SNA (1995) *Manufacturing and Services*. National Atlas of Sweden.

SOU (1978) Energi. Betänkande av energikommissionen. *SOU 1978:17*.

South China Morning Post (2014) Why China and Russia are ready to deal on oil and gas. *South China Morning Post 2014-10-29.*

Statens energimyndighet (2013) *Vindkraftstatistik 2013*. Tema: Systemeffekter. ES 2014:02.

Statistical Report (2013) Eurogas. *Fuelling the future. December 2013.*

Statistical Yearbook of Norway (2013a) Energy and manufacturing. Coal mining Svalbard. *Statistics Norway.*

Statistical Yearbook of Norway (2013b) *Statistics Norway*.

Statistical Yearbook of Sweden (2014) *Statistics Sweden.*

Sustainable Production of Bioenergy from Agriculture and Forestry in the Nordic countries (2008) *Nordic Council of Ministers, Swedish Board of Agriculture, Swedish Forestry Agency.*

SvD (2014a) Lindahl, B Snålblåst i norsk oljeindustri. *Svenska Dagbladet 2014-11-10.*

SvD (2014b) Hellekant, J Oljedippen ger norsk varselvåg. *Svenska Dagbladet 2014-12-24.*

US Message Board (2014) *Political Discussion Forum 2014-11-03.* Oil Pipeline to be Built from Russia to India through Northwest China.

Internet

Askja Energy (2014-12-10) The independent Icelandic Energy Portal.

BBC News (2014-09-23) What is fracking and why is it controversial?

Canadian Association of Petroleum Producers (2014-09-23) What are Oil Sands?

Danish Wind (2014-12-09) Industry Association.

DN (2014) Finland bygger kärnkraftverk – 15 mil från Skellefteå. Dagens Nyheter 2014-12-22.

Energimyndigheten (2014-12-19) Kärnbränsle.

Energy Systems (2015-01-09) Nordic Energy Research.

European Commission. Eurostat (2014-10-28a) Energy.

European Commission. Eurostat (2014-10-28b) Trade in energy products – Statistics Explained. Statistical analysis of EU trade in energy products, with focus on trade with the Russian Federation.

European Commission. Eurostat (2014-10-29). Energy production and imports. From Statistics Explained.

European Commission. Eurostat (2014-11-05a). Electricity production and supply statistics.

European Commission. Eurostat (2014-11-05b) Nuclear energy.

Facts about hydropower (2014-10-01) Wisconsin Valley Improvement Company.

Fingrid (2014-12-07). Förbrukning och produktion i elsystemet.

Government of Canada (2014-09-23) Natural Resources Canada. The Importance of Crude Oil. October 2010.

Government.no (2015-01-21). The Government Pension Fund.

Iceland (2014-12-07) The official Gateway to Iceland. Geography.

Iceland topography (2014-12-10) Encyclopedia of the nations. Europe. Iceland

IEA (2014-09-23). History.

IEA (2014-09-25) Iraq Energy Outlook. World Energy Outlook Special Report. Iraq domestic energy balance.

IEA (2014-10-02) Nuclear energy´s rebirth is not robust enough to limit climate change.

IEA (2014-11-05). Renewable Energy Essentials: Hydropower.

IEA (2014-12-02) Wind.

Kraftsystemet (2014-11-26) Kraftsystemet 2014.

Miljo. Utbyggnad av vindkraft (2014-12-18). Miljöförvaltningens gemensamma webtjänst.

Nordpool spot (2014-11-27) Transmission System Operators.

Nordregio (2014-11-27) Production of renewable energies for electricity in the Nordic countries. Production of renewable energies for electricity by sources in GWh per country in 2007 in the Nordic Countries.

Nordregio (2015-01-12) Consumption of electric energy in the Nordic Countries. Consumption of electricity by main consumer groups (household, industry, services) and electricity consumption per capita in NUTS 3 regions in 2007.

Nordregio (2015-01-16) Generation of electricity in the Nordic Countries. Generation of electricity by main sources (nuclear, thermo, hydro, wind, other) and electricity production per capita (KWh per inhab.) in NUTS 3 regions in 2007.

Norsk Vind Energi (2014-12-16) Vindkraft.

NVE (2014-12-15) Norges vassdrags- og energidirektorat. Vindkraft.

NyTeknik (2014-12-22) Olkiluoto 3 nu nio år försenad.

OG (2014-11-04) Olie-en Gasportaal.

OPEC (2014-09-23) OPEC: Brief History.

Power Technology (2014-10-01) The 10 biggest hydroelectric power plants in the world. 28 October 2013.

Ruhrgas (2011-01-03). Transmission Systems.

SCB (2014-12-11) Tillförsel och användning av el 2001-2013 (GWh).

SKB (2014-12-22) Swedish Nuclear Fuel and Waste Management Co.

SKB (2014-12-23) Finland bygger slutförvar.

Statens energimyndighet (2014-12-11) Wind power production, 1982-2013.

Statistikcentralen (2014-12-07). Energianskaffning och -förbrukning 2012.

Statkraft (2014-12-03) Hydropower, Statkraft Pure Energy.

Svensk energi (2014-12-04a) De största vattenkraftstationerna.

Svensk energi (2014-12-04b) Vattenkraft.

Svensk energi (2014-12-05) Vattenkraftsproduktion.

Svensk energi (2014-12-16) Vindkraft.

Swedish Radiation Safety Authority (2014-12-18).

SWID (2014-12-17) Swedish Wind Industry Database.

Uppslagsverket Finland (2014-12-07) Sjöar och vattendrag.

Wall Street Journal (2014-12-09) Denmark´s Wind Power Output Rises to Record in First Half.

WeatherOnline (2014-12-02).

Wind Energy (2014-12-09) The official website of Denmark.

Vindkraft i Norge (2014-12-15) Överföringsnett i Nordsjön

Vindkraft i Norge (2014-12-16) Vindkraftverk i Norge.

Vindportalen (2014-12-17) Vindkraft I Norge.

World Nuclear Association (2014-12-20) The Nuclear Fuel Cycle.

World Nuclear Association (2014-12-22) Nuclear power in Finland.