# Building new power plants in a $CO_2$ constrained world: A Case Study from Norway on Gas-Fired Power Plants, Carbon Sequestration, and Politics

by

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# Abstract

On March 9, 2000, Norwegian Prime Minister Kjell Magne Bondevik's minority government resigned over a disagreement with the opposition about a controversial proposal to build two gas-fired power plants. A majority in the Stortinget, the Norwegian parliament, favored immediate construction of the power plants. Bondevik and his coalition government wanted to hold off construction until new environmentally friendly technologies were available, specifically including technologies for carbon sequestration.

Norway's primary energy production is dominated by oil and gas with most of its production going to export. Electricity production in Norway is exclusively from hydropower, but future expansion of the Norwegian hydro capacity is constrained. Low electricity prices- -from sources with very low environmental impacts contributed to Norway having the highest electricity consumption per capita in the world, with demand on the rise at about 2% per year. Consequently electricity demand is expected to outstrip the domestic supply in the near future.

Through the Kyoto Protocol, Norway has pledged to limit its greenhouse gas emissions to no more than one per cent of the 1990 level during the budget period of 2008-2012. However, its projected emissions are expected to be 19% above its Kyoto targets. In the past, Norway has successfully implemented an offshore carbon tax to reduce the GHG emissions of the oil sector. This made carbon sequestration a viable option to reduce GHG emissions in the North Sea, where Statoil has been depositing one million tonnes of $CO_2$ a year since 1996. The challenge for Norway is now to find a way to meet its domestic electricity demand without incurring extra burdens for reducing $CO_2$ emissions.

Gas-fired power plants have been proposed as an appropriate way to quickly increase the domestic power supply given Norway's huge national gas reserves, gas' relatively low impact on the local and regional environment, and the limited growth possibilities for hydropower. Recently, two controversial proposals to build gas-fired power plants in Norway have been debated. The first project, Naturkraft, features two combined cycle gas turbines (CCGT). The second project, Hydrokraft, involves the construction of a single CCGT power plant with carbon sequestration to limit GHG emissions. The controversy surrounding the proposed construction of gas-fired power plants in Norway has raised three fundamental issues:

1. Should GHG emissions be viewed from a national perspective, or is a regional perspective more appropriate? This can be generalized as "where flexibility".
2. Should state-of-the-art technology be adopted now, with cost considerations being secondary or should the adoption of available, but more expensive, be postponed? This can be generalized as "when flexibility".
3. What cost are people willing to pay to reduce greenhouse gas emissions?

The lessons we learn from this case study are important, in that most countries trying to seriously reduce their greenhouse gas emissions will have to face very similar issues.

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# Preface

Norway currently produces almost all of its electricity from hydroelectric power, which emits no greenhouse gases.

On March 9, 2000 Norwegian Prime Minister Kjell Magne Bondevik's minority government resigned in the wake of a disagreement with the opposition over a controversial proposal to build gas-fired power plants. A majority in Stortinget, the Norwegian Parliament, led by the Labour Party[1], favored immediate construction of gas power plants.
The government had been rejecting the building of the proposed two gas-fired plants for months. Bondevik and his coalition government wanted to hold off construction until new technology, such as carbon sequestration, allowed more environmentally friendly plants arguing that the government position was supported by European Union regulations and Norwegian pollution laws.

But the Labour Party and other opposition politicians insisted that regulations be changed to allow for the construction, a stand that led to the confidence vote. The opposition politicians contended the gas-fired plants would slow Norway's dependence on imported electricity from Denmark, which is generated from even more polluting coal-fired plants. On Thursday March 9, 2000, over Bondevik objections, the parliament voted 81-71 in favor of building Norway's first natural gas-fired power plant.[2]

As a result Bondevik's government, in office since 1997, became the first government to fall in a debate over how to address global warming concerns. In this thesis we will address these issues in more details. Two specific questions motivated the research:
Why, while the rest of the world looks at natural gas as a solution to climate change, is it so controversial in Norway?
Why, while in the US most politicians never heard of carbon sequestration, did it play such a key role in Norwegian politics?

[1] The Labour Party is the biggest party in parliament, with 65 of 165 seats
[2] Source CNN & Reuters

# Chapter 1

# The Norwegian Energy Sector

**ENERGY STRUCTURE**

Norway is one of Europe's largest energy producers, with most of its production going to export. "The energy situation in Norway is unique. Norway represents 1% of the population of Europe, and it enjoys 75% of the oil resources, 45% of the gas resources and 30% of the hydroelectric power."[3]

## Primary Energy Production

### Overview

Norway is endowed with major petroleum resources. Most of its oil and natural gas production is exported, making Norway the second largest oil exporter the world. Electricity is a major component of domestic primary energy supply, meeting as much as 45% of the domestic final energy demand. Electricity is almost exclusively made by hydropower (over 99%), which results in essentially no greenhouse gases emissions to the atmosphere.

Over the last decade the production of oil and natural gas has been increasing steadily essentially for export and revenue reasons (Figure 0.1), while electricity production has increased at a much smaller pace.

[3] Source Christopher Kloed, Norsk Hydro Electrolysers, Norway

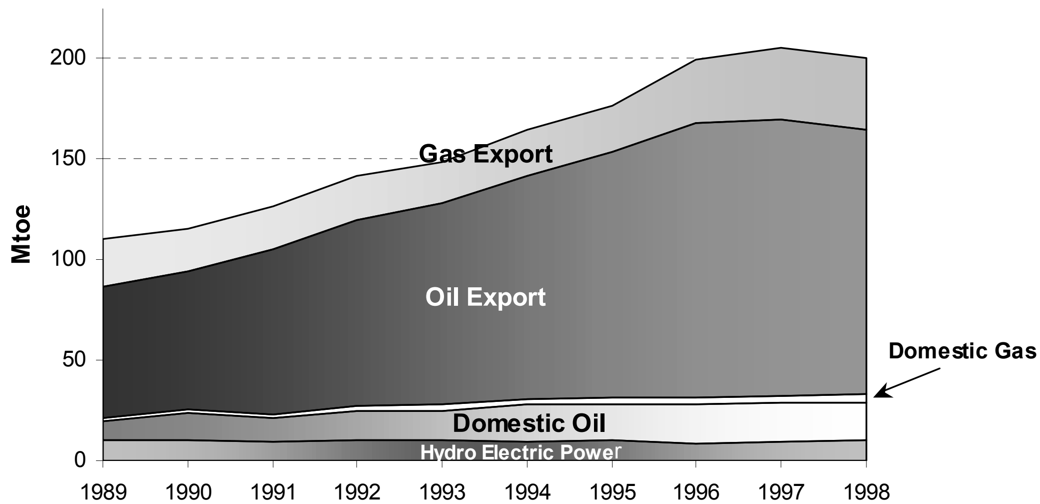


**Figure 0.1. Time history of primary energy production in Norway**[4]
*In addition to energy purposes, domestic oil is used as feedstock for the petrochemical industry. Conversions are based on total heat content throughout this thesis.*

Oil production is expected to peak in 2002 and then decline, as the oil and natural gas fields are aging. However reserve appreciation is typical in the North Sea. Oil and gas reserves have underwent a yearly 2% "growth" over the past three decades.[5]

Figure 0.2 below shows the make-up of primary energy production in Norway in 1998. Coal has never been a major energy source in Norway and is expected to remain at its marginal level over the coming decades. It is mainly used in the metallurgical processing of aluminum.

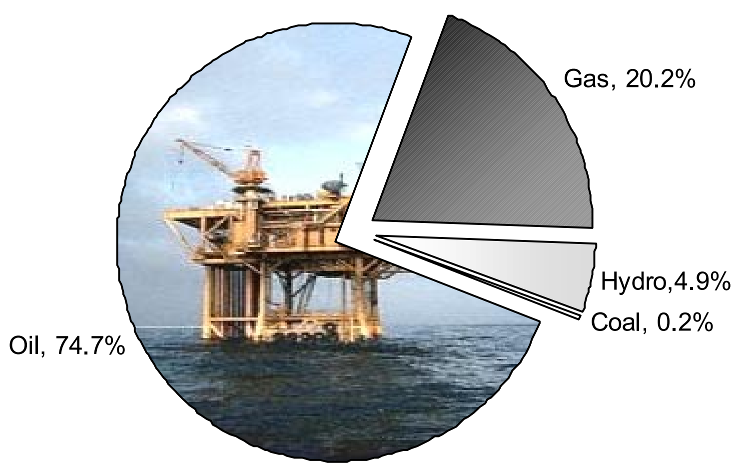


**Figure 0.2. Breakdown of Norwegian primary energy production in 1998**[6]

[4] Source Statistics Norway
[5] *North Sea Reserve Appreciation, Production and Depletion*, Tone Sem and Denny Ellerman, MIT-Center for Energy and Environmental Policy Research, October 1999, MIT-CEEPR 99-011 WP

Renewables (beyond hydro) remain at a very low level, while accounting for an expected 5% of final energy demand, they constitute a negligible share of primary energy production given the size of oil and gas production.

## Oil & Gas Production

The North Sea and the Norwegian continental shelf are endowed with massive oil and gas reserves and constitute the most significant oil reservoir in Europe[7]. This applies in particular to the Norwegian sector of the North Sea.[8] Norway exports 90 per cent of its entire oil production.

The North Sea became the third largest oil producer in the world (behind Saudi Arabia and the former Soviet Union) almost exactly two years after the huge Prudhoe Bay reserves were found in Alaska in 1967. These formed a significant counterweight to the dominance of the Middle East on an oil market that underwent dramatic growth in the 1950s and 1960s.

**Figure 0.3. Oil rig in the Ekofisk field**

The Ekofisk field was discovered in December 1969. It is still the biggest oil field in the North Sea, even if its production is now declining. Since all the oilfields are offshore, their

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[6] Source Energy Policies of IEA countries, 1998 Review, OECD

[7] There is no doubt at all that the world's largest oil reserves are to be found in the areas around the Persian Gulf: Country 1996 Reserves (millions of barrels), Source: *OPEC Annual Statistical Bulletin 1996*. Saudi Arabia 261,444, Iraq 112,000, United Arab Emirates 97,800, Kuwait 96,500, IR Iran 92,600

[8] Total proven reserves estimates at 38.5 billion barrels, Source Norwegian Petroleum Directorate

development required the aid of sophisticated technology (Figure 0.3) made possible by the high oil prices of the 1970s. Development continued until 1986 when the oil prices forced the Norwegian government to scale down part of the national oil production that year.

"Today, the situation on the Norwegian shelf has entered a new phase. The era of the gigantic oil finds is over. Norway's petroleum bank consists today of a number of small and medium-sized finds. Around one hundred oil and gas finds are awaiting development during the next 25 years and the expected investments during this period will be as great as those that have been made so far."[9]

Current levels of production (Table 0.1) coupled with its relatively low consumption due to its hydropower resources make Norway the second largest world exporter of oil after Saudi Arabia.

**Table 0.1. Norwegian production of oil and natural gas**[10]

| Year | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|
| Crude oil production (1000 tons) | 139 358 | 156 788 | 156 215 | 150 006 |
| Exports Crude oil (1000 tons) | 121 680 | 136 800 | 137 549 | 131 241 |
| Exports Natural gas (Million of standard $m^3$) | 27 598 | 37 825 | 42 286 | 42 665 |

"Today Norway sits on approximately half of the remaining reserves of oil and gas in Europe. It covers 10 per cent of Europe's gas consumption and within a few years will increase gas exports dramatically and account for 30 per cent of European gas imports. Norwegian gas pipelines go from the North Sea and the Norwegian Sea to England, Germany, Belgium and France. Norway is the world's biggest operator of submarine gas pipelines. In 2020, gas is predicted to outstrip oil as the major money-maker in the Norwegian oil and gas industry."[11]

"Norway is now preparing the development of the Ormen Lange field, a major gas field situated at a depth of 1,200 meters in the North Sea. This extends the gas perspective northwards on the Norwegian continental shelf. An even more extended perspective includes the Barents Sea, the arctic part of the Norwegian shelf. Plans are also in hand to develop the Snøhvit field on the Tromsøflaket off north Norway, bringing the arctic petroleum perspective even closer. But there is no doubt that significant finds of gas have already been discovered on the Russian side of the Barents Sea, while Norway again pushes forward on the front line of the Norwegian shelf."[12]

Since all the Norwegian oil is located in deep-sea regions, its development is heavily dependent on high oil prices. Norway has a clearly defined goal: to continually use improved technologies so that Norwegian oil and gas (which are becoming increasingly difficult to reach) are competitive even when oil prices are low.

[9] Source *ODIN*, Official Documentation and Information from Norway
[10] Source Statistics Norway
[11] Source ODIN
[12] Source Statistics Norway

## Electricity Production

Over 99% of Norwegian electricity is produced from hydropower. As compared to power production in other Nordic countries, its supply is much less diversified[13] (Figure 0.4).

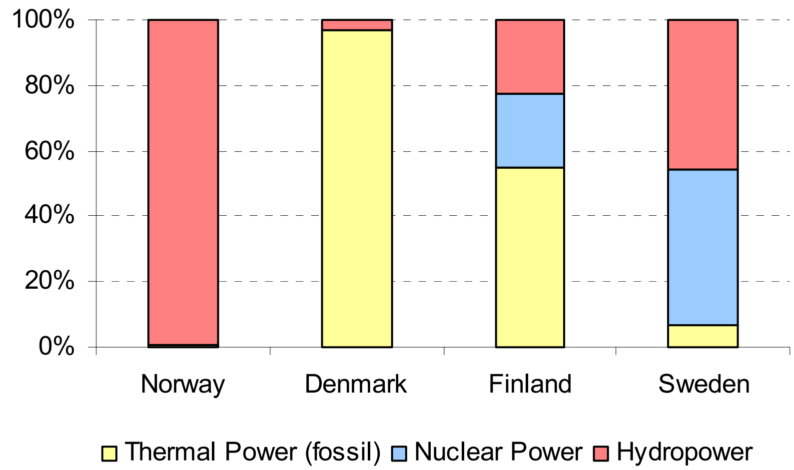


**Figure 0.4. Electricity Capacity make-up in the Scandinavian countries, in 1999** [13]

Moreover the hydropower infrastructure has been developed to a point where it seems politically difficult to add significant new capacity given that about 20% of the suitable hydropower sites are permanently protected in the wake of a steadily increasing conservation movement against river development that erupted in the 1960s[14]. In 1973, a strong environmental opposition to river development lead the government to permanently preserve designated rivers and leave aside as much as 35 out of 175 TWhs annual production capacity[15] (Figure 0.5).

[13] Source Statistics Norway
[14] Per Ove Eikeland, *Energy Policy*, Vol. 26, Num 12, 10/98
[15] Norwegian Ministry of Industry & Energy, 1995

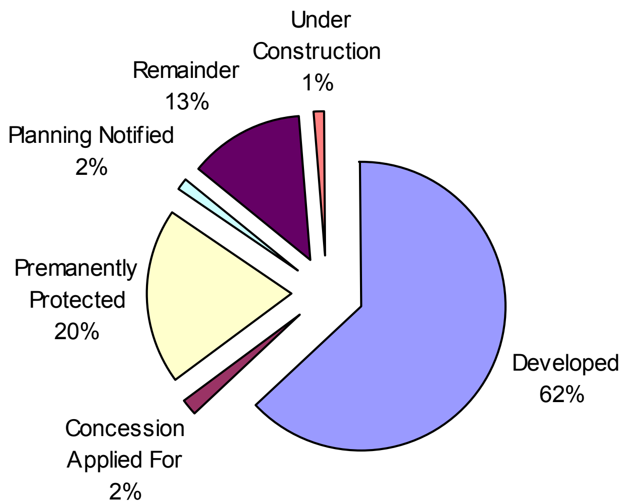


**Figure 0.5. Hydropower exploitation of the hydropower resource in Norway**[16]

Since 99% of its power is hydroelectricity, production varies considerably depending on variations in precipitations levels (Figure 0.6). Consequently even if new hydro capacity were added, this would not alleviate the Norwegian dependence on precipitation.

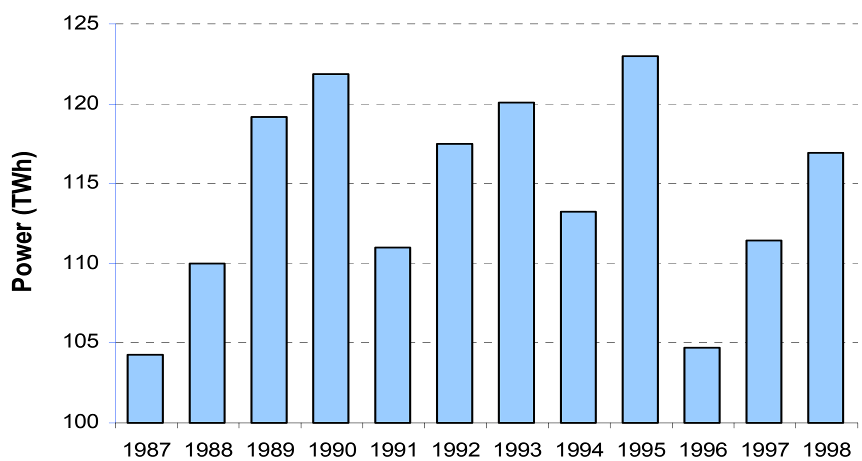


**Figure 0.6. Variations of the Norwegian Power production over the period 1987-1998**[17]

## Primary Energy Consumption

### Overview

[16] Source Statistics Norway
[17] Source Elektrisitetsstatistikk 1998, Statistics Norway

Oil and hydroelectricity are expected to meet 87 per cent of the domestic energy demand in 2000 (Figure 0.7). "Norway is in a special position in that renewable energy sources supply 70 per cent of stationary energy use"[18]. In a normal year, Norway covers all its onshore electricity needs from renewable energy (hydropower).

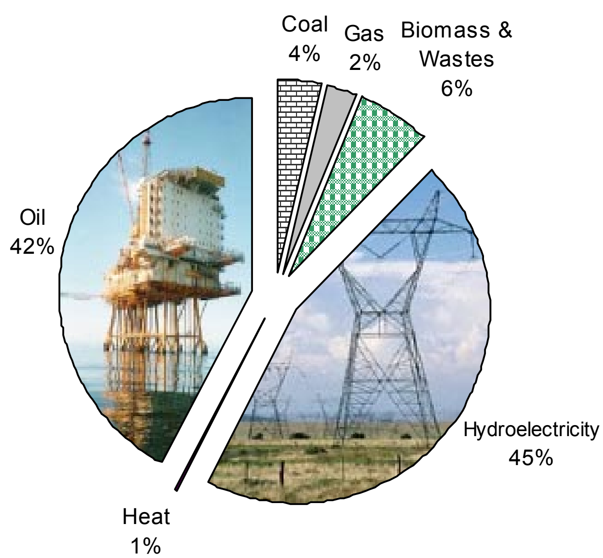


**Figure 0.7. Final energy consumption in Norway by fuel[19]**

Natural gas is hardly used at all onshore in Norway despite its huge and cheap availability. Almost all the domestic natural gas consumption stems from offshore use where it is used to enhance oil recovery by re-injection. It is also burned in gas-fired turbines to supply electricity to the oilrigs. Figure 0.8 shows the historical trends in primary energy consumption in Norway.

Norway desires to continue to supply a large proportion of the demand for stationary energy from hydro and other renewable sources, even though it cannot expect further hydropower development to provide satisfactory energy supplies. An alternative option is to increase its reliance on power trade, but this route is not risk-free either (see section 1.3).

[18] Report to the Stortinget (White Paper to the Norwegian parliament) No. 29 (1997-98) on Norwegian implementation of the Kyoto Protocol
[19] Source Energy Policies of IEA countries, 1998 Review, projections of IEA Secretariat

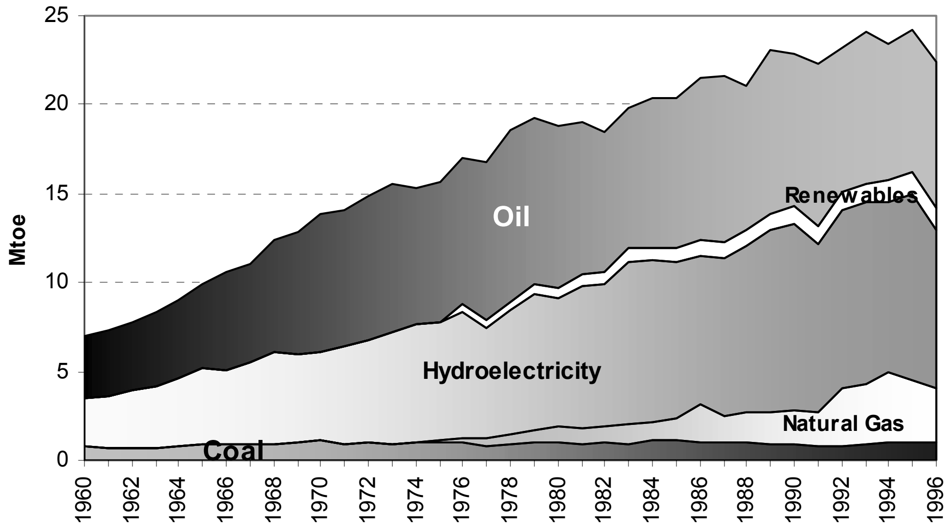


**Figure 0.8. Consumption patterns of primary energy sources in Norway[20]**

## Oil & Gas Consumption

Oil represents about 42% [21] of the total Norwegian energy consumption in 2000 with 53% of the oil going to transport.[22] Oil represented about one-third of the overall industry energy demand in 1995[23]. In spite of heavy taxes (Figure 0.1) on fossil fuels, consumption in Norway has increased (Figure 0.9). The greater part of the increase is accounted for by use of fuel in the offshore petroleum sector (oil and gas extraction). In addition “Norway has a decentralized settlement pattern and a relatively high demand for transport. The decentralized settlement pattern makes public transport systems costly to develop. Moreover, the demand for transport fuels is relatively insensitive to price changes.”[24] Households rely heavily on electricity for heating, thus individual oil consumption is basically limited to gasoline for transport.

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[20] Conversions are based on total heat content
[21] Projections IEA Secretariat, Energy Policies of IEA Countries, 1998 Review, IEA
[22] Source Statistics Norway
[23] Source ODIN
[24] Norway's second National Communication under the Framework Convention on Climate Change April 1997, T - 1186

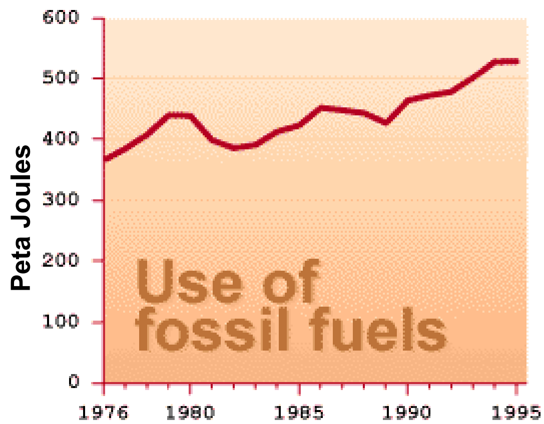


**Figure 0.9. Use of fossil fuels in Norway 1976-1995[25]**

Heavy industry (onshore) relies primarily on cheap hydropower. Moreover almost no electricity is produced from fossil energy. Consequently industrial natural gas consumption on the mainland is negligible.

Oil and gas production is very energy intensive[26]. Gas-based power generation is the only source of power on oilrigs offshore. The current increase in offshore activity (exploration and production resumed over the past few years in the wake of the increasing price of oil and relocation of oil activities northwards) has lead to greater consumption by the oil sector recently. In 1996 the use of natural gas based energy on the Norwegian shelf represented 10 TWh alone. It is expected to reach about 14 TWhs during 2002- 2003.[27]

Pipeline transport of natural gas to the European continent is energy demanding (huge compressors of several MW). Norwegian gas pipelines go from the North Sea and the Norwegian Sea to England, Germany, Belgium and France. Norway is the world's biggest operator of submarine gas pipelines. Burning of natural gas in flares constitutes a substantial consumption of natural gas even if regulatory measures now limit its usage to the strict security minimum. Non-commercial gas with high contents of $CO_2$ used to be flared on site. A carbon tax applied on $CO_2$ emissions has drastically reduced this usage since 1991 by creating an incentive to separate $CO_2$ from methane and reinject it underground.

## Electricity Consumption

Norway has the highest electricity consumption per capita in the world. In 1996, per capita electricity consumption was 25,200 $kWh_e$[28] (Figure 0.10). Norway's total electricity consumption

[25] Source Statistics Norway
[26] The overall oil consumption by the petroleum sector accounts for about 1-2% of the total oil production
[27] Source Bellona Norway
[28] Source Statistics Norway

will soon exceed 120 TWh per year[29] - with an estimated increase in demand of 32 TWh by 2020. Normal annual electricity production amounts to 113 TWh. A wider use of electricity for space heating than in most of the world, historically low prices and the cold, northern climate are responsible for this high electricity consumption.

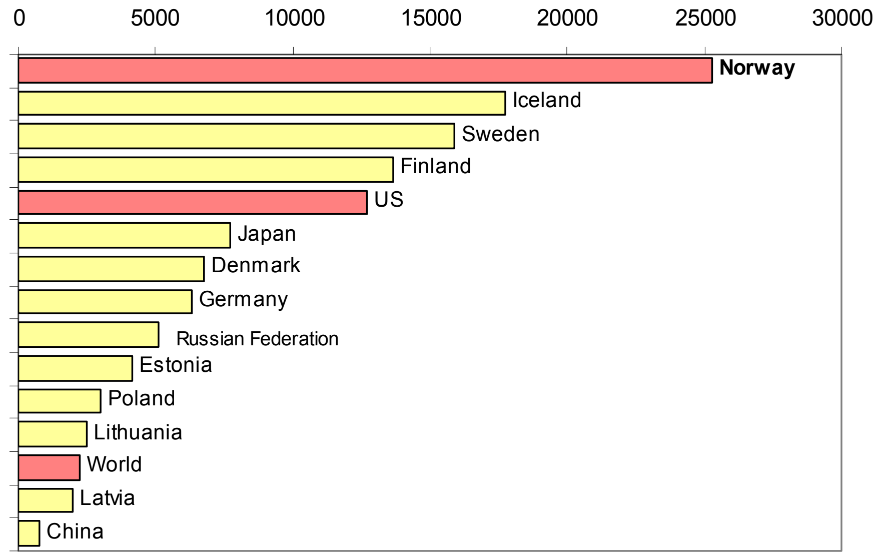


**Figure 0.10. Annual electricity consumption (kWh$_e$ per capita in 1997)[30]**

"Electricity consumption has doubled since 1970. The highest rates of increase have been in the service and residential sectors. Though industry accounted for 43% of electricity consumption in 1995, its rate of growth has been slower than in other sectors. Electricity use in the power intensive industries accounts for about 24% of overall electricity consumption. In the residential sector, space and water heating make up about 65% of energy consumption which is predominantly provided by electricity"[31] (Figure 0.11).

[29] Dag Christensen, Hydro Energy, Norway
[30] Figures of 1996 for the Nordic countries (Sweden, Norway, Iceland, Denmark, Finland), 1995 for the other European countries, and 1994 for the rest of the world.
Source Statistics Norway and The International Energy Agency 1998
[31] Energy policies of IEA countries, Norway 1997 Review, p24

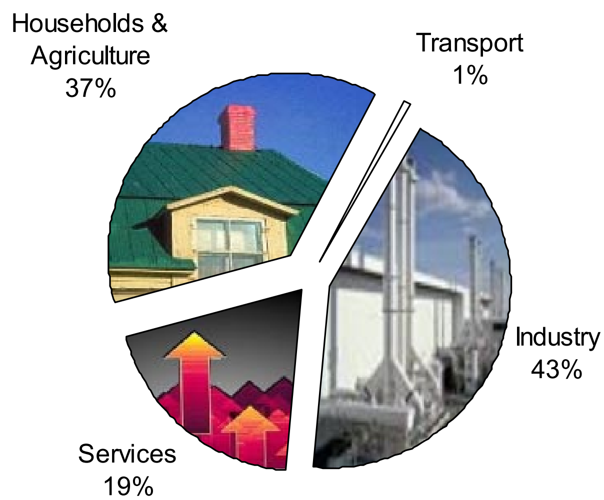


**Figure 0.11. Electricity consumption by sector in 1996** [32]

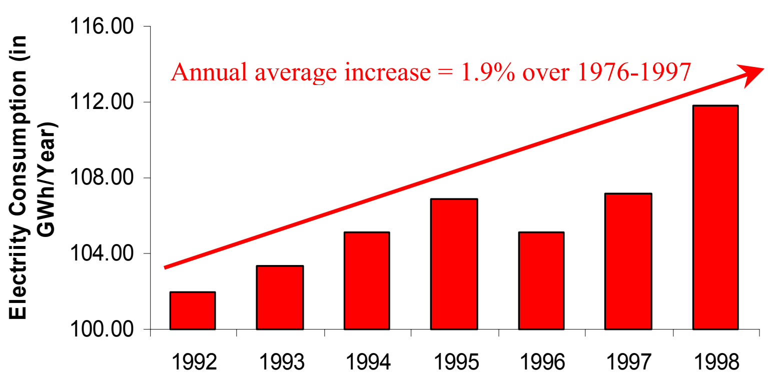


**Figure 0.12. Historical pattern of electricity consumption in Norway**[33]

The annual increase (Figure 0.12) in demand for electricity in Norway has been 1.9% in average over the period 1976-1997 (averaging about 1.9 TWh per year).[34] The Norwegian industry is heavily energy intensive due to the availability of inexpensive hydropower. The consumption pattern followed the same logic in households.

Energy efficiency in Norway is comparable to, and can even "be described as slightly better than the average for IEA Europe to that of IEA countries"[4]. The difference in the levels of power consumption with the rest of OECD countries comes essentially from the type of industry Norway has decided to develop. The sectoral make-up of industry (high percentage of energy-intensive industries) brings about an "excessive" use of electricity in Norway as compared to the

[32] Services cover essentially electricity conumed for heating building (other than households) Source Electricity Statistics 1996, Statistics Norway
[33] Source Statistics Norway
[34] Source Dag Christensen, Hydro Energy, Norway

OECD average consumption. Figure 0.13 shows a linear trend in electricity consumption/GDP on a Purchase Power Parity basis (PPP) from 1960 to 1996. There has been a steady increase in electricity use in the period corresponding to a decline in oil use outside of the transport sector. Consumption of oil for stationary use has fallen 64% over that period. A substantial shift from fuel oil to electricity in the heating market has contributed to an increase in electricity of about 36%.[35]

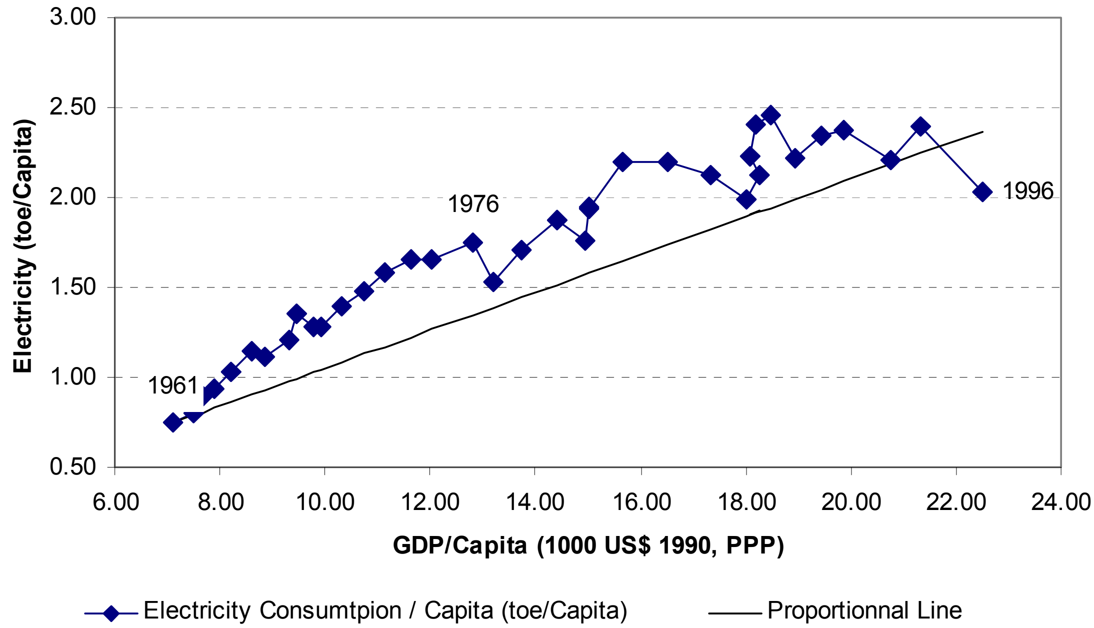


**Figure 0.13. Electricity Consumption vs. GDP (per capita) in Norway**

The growth in energy consumption appears to be the lowest in heavy industry. The growth in electricity consumption in Norway is unevenly distributed between the various consumer groups. Growth in consumption according to sector since 1970 is as follows[36]:

- Households: 250%
- Public and private service industry: 530%
- Small and medium sized industry: 175%
- Energy-intensive industry: 8%

An average household uses 16,000 kWh$_e$ per year[37]. "Norwegian homes are among the largest in Europe and more than 80% of them rely to a significant degree on electricity for space and water heating. Combined with the cold climate, this drives up household electricity use to the highest levels among IEA countries"[38]. Oil products are heavily taxed in Norway. High taxation on oil

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[35] Source IEA, Energy policies of IEA countries, Norway 1997 Review, Energy Balances of IEA countries, 1995-1996

[36] Source Norsk Hydro

[37] Source Statistics Norway

[38] Energy Policies of IEA countries, Norway 1997 review, p26

coupled with inexpensive hydropower resulted in an overwhelming fraction of households' energy consumption being electricity (Figure 0.14 and Figure 0.15).

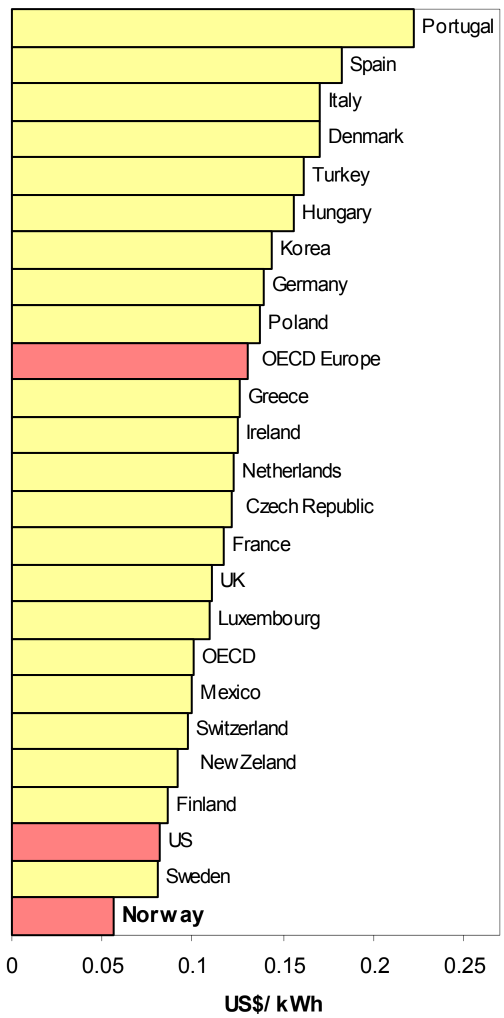


**Figure 0.14. Electricity prices for households in US$/kWh$_e$ in 1998[39]**

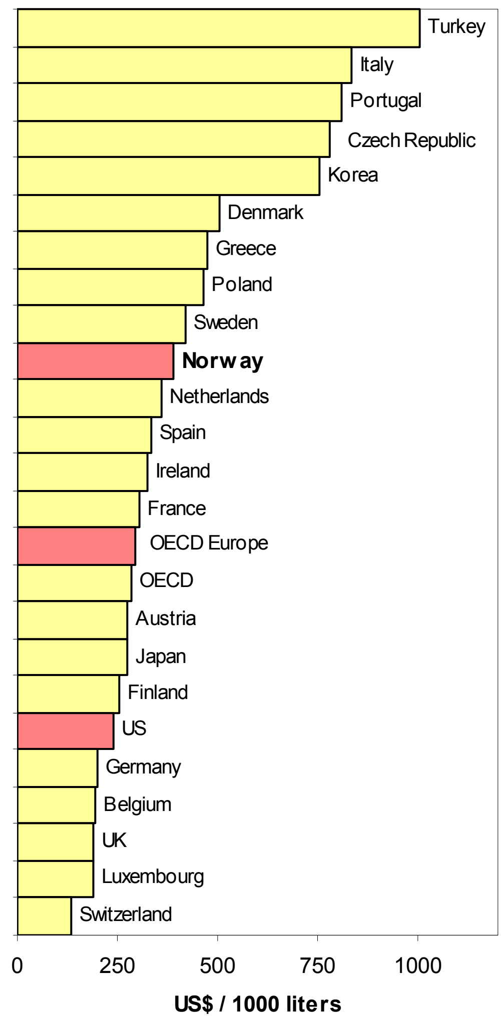


**Figure 0.15. Light fuel prices for households in US$/1000 liters in 1998[39]**

"Low prices also have fostered a large percentage of total electricity production being consumed in energy-intensive industries, i.e. in the manufacture of aluminum and ferro-alloy products (Figure 0.16, Figure 0.17). Norway has the most energy intensive mix of manufacturing output among IEA countries as a result of electricity-intensive ferro-alloy and non-ferrous metals and energy-intensive forest products manufacturing."[2]

[39] To avoid comparison irrelevances, these electricity prices are expressed in Purchase Power Parities. The PPPs are calculated by OECD
Source Energy Prices & Taxes, Quarterly statistics, second Quarter 1999, OECD

It is noticeable that manufacturing output significantly moved to electricity intensive output due to the availability of cheap hydropower after 1973. This shift accounts for the Norwegian lag in cutting industrial energy use over the last 20 years. Based on official statistics, industrial energy use per unit of added value fell by only 7% in Norway between 1973 and 1995 compared with 38.5% in the EU, 51% in the US and 41% in Japan.[40]

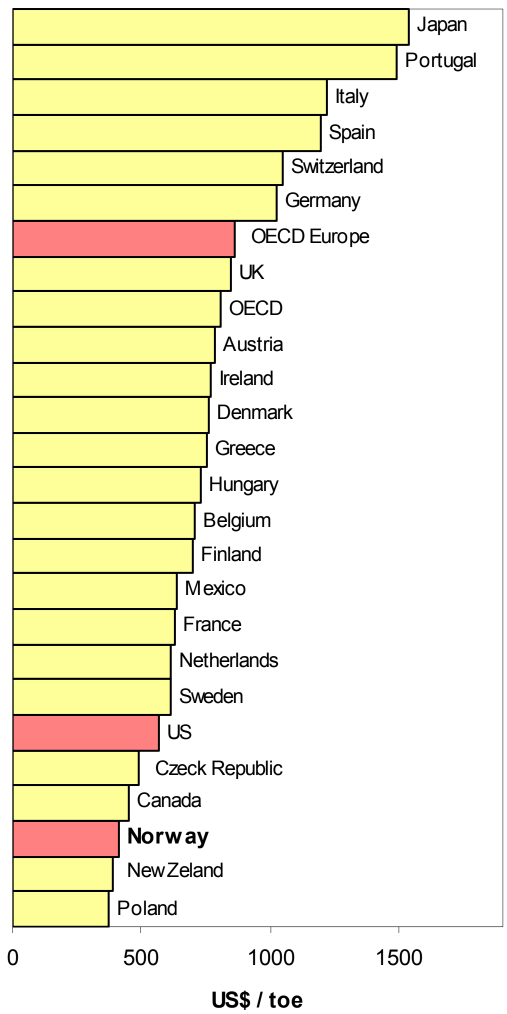


**Figure 0.16. Electricity prices for industry in US$/toe in 1998[39]**

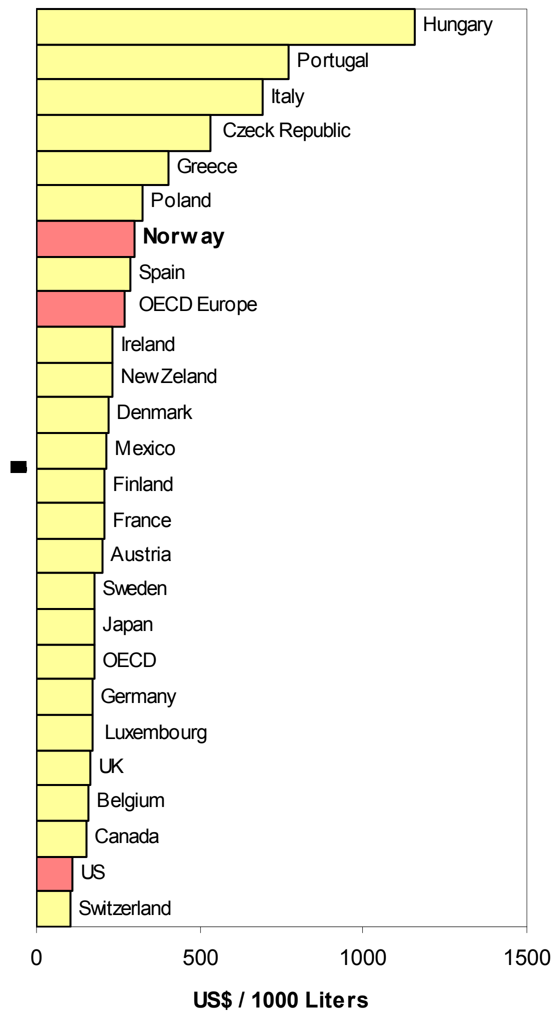


**Figure 0.17. Light fuel oil prices for industry in US$/1000 liters in 1998[39]**

## Electricity Trade

[40] *Source: Global Environmental Change Report*, Vol. X, NO.5, study from the NGO The Future in Our Hands

As shows Figure 0.18, Norway is usually a net exporter of electricity (7 TWh per year)[41]. It was an exceptionally dry year in 1996 (Figure 0.19), leading to substantial net importation of power. Due the return of normal hydro conditions in 1997 and 1998, the discrepancy between imports and exports diminished. Nevertheless Norway remained a net importer of power in those years.[42]

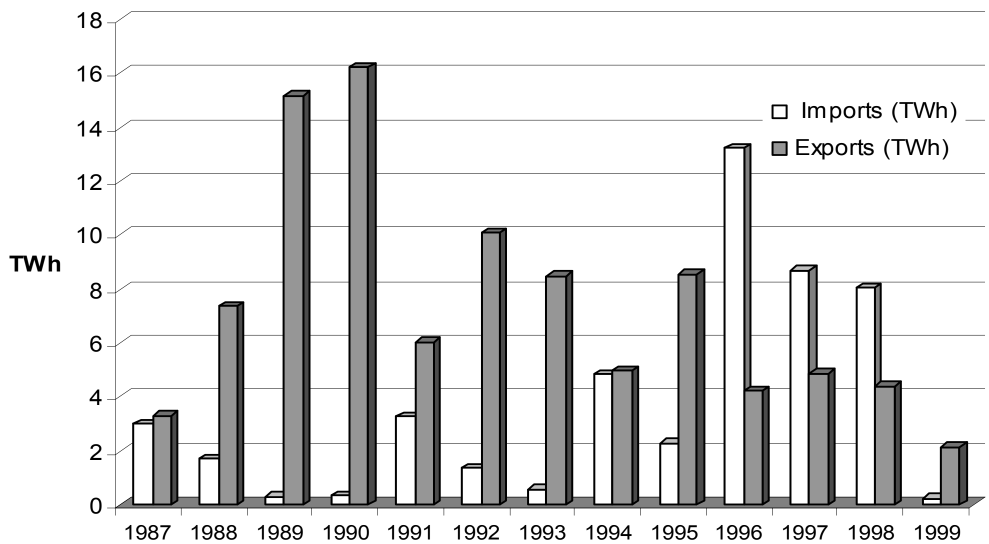


**Figure 0.18. Norwegian Electricity Imports-Exports over the period 1987-1999[43]**

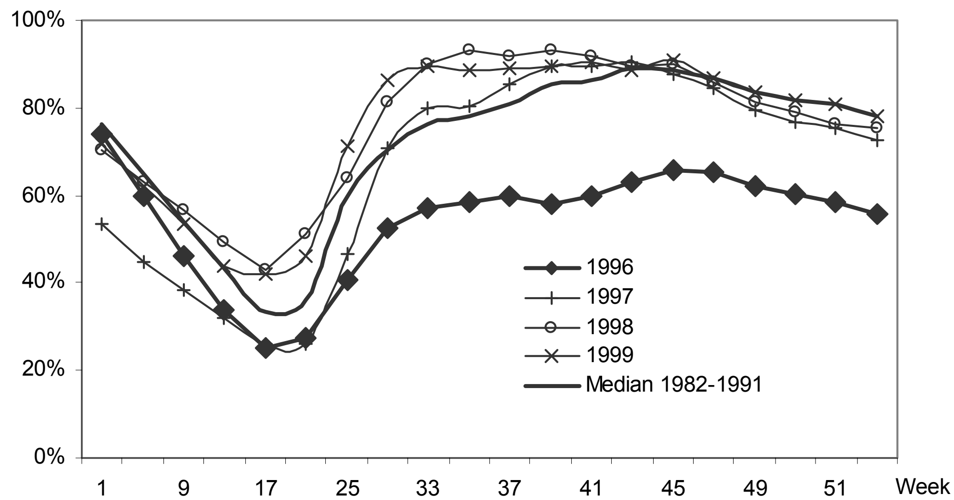


**Figure 0.19. Energy Content in Reservoirs in Norway[44]**

[41] Source Norway's second National Communication under the Framework Convention on Climate Change April 1997, T –1186, http://odin.dep.no/md/publ/climate/2.html
[42] Source Nordpool
[43] Source Elektrisitetsstatistikk 1998, Statistics Norway, and Nordpool
[44] Source Statistics Norway

The Norwegian topography production units (water falls and power stations) are located mainly in sparsely populated areas. The production units are linked together by a widespread national grid that is extensively interconnected with the Danish and the Swedish grids (Figure 0.20).

In view of the fact that its power production heavily fluctuates from year to year (Figure 0.6) and even from place to place, Norway has administered a spot market for electricity at the national level since 1971. This market was stringently regulated and only members of the regulatory monopoly association could trade in that market. The production variations in the hydropower system necessitate an efficient short-term trade in electricity, which enables entities to balance off their shortage or surplus volumes against contractual obligations. A complex set of deregulatory and reregulatory measures has taken place since 1985.

In 1991 the Scandinavian countries (Norway, Denmark, Sweden, Finland) have put in place a Scandinavian electricity exchange, Stattnet Marked. In 1996, Stattnet Marked was enlarged to a bi-national power exchange covering both the Norwegian and the Swedish power markets. This brought about a substantial degree of harmonization between the Norwegian and the Swedish regulation. On the same occasion the exchange changed its name to Nordpool.

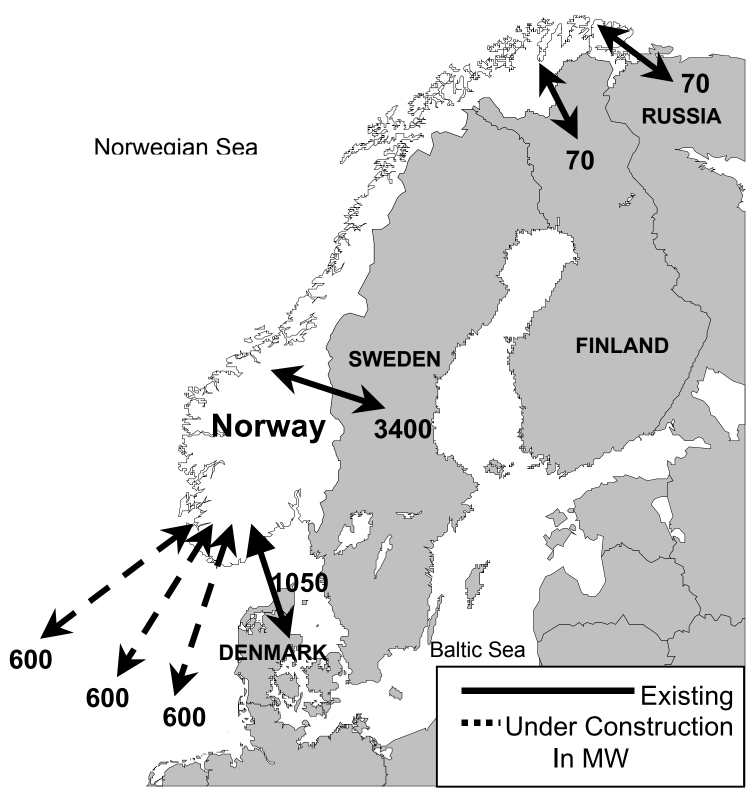


**Figure 0.20. Electricity transmission capacity between Norway and its neighbors**[45]

Today Norway and Sweden have implemented many interconnections between their national grid systems, and the spot market is managed as a common market. This common market greatly

[45] Source International Energy Agency

helps Sweden to smooth out its power consumption. Sweden produces about half of its power[46] from nuclear plants that are costly to turn on and off, and not appropriate to respond to peak-load consumption. Norway's electricity imports from Sweden allows the Swedish nuclear plants to smooth out their nuclear baseline power while Norway can easily export peak-load power to Sweden since the marginal cost of hydropower is practically nil and can be quickly turned on and off. The transboundary electricity exchange takes advantage of the complementary nature of the electricity infrastructures of these two countries.

Sweden and Norway now share a completely integrated market (consumers are entitled to chose their producer). Sweden is the most important (in volumes) electricity-trading partner for Norway today (Figure 0.21, 1.22, and 1.23).

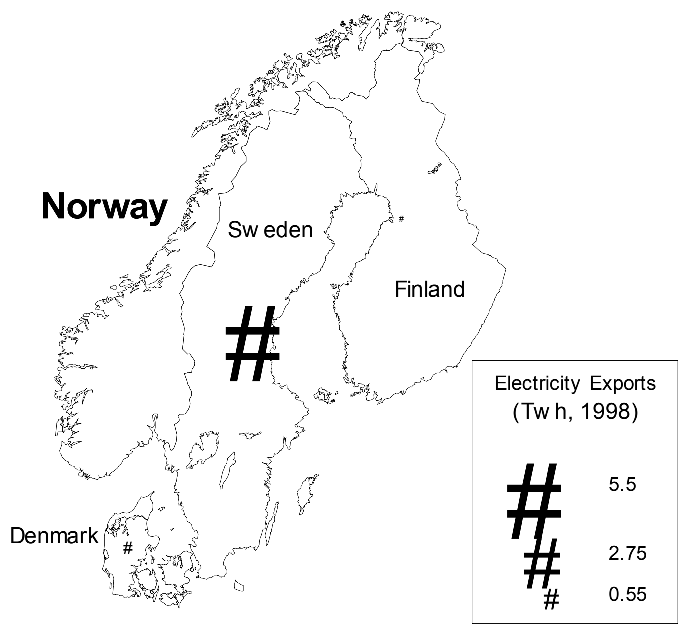


**Figure 0.21. Electricity Exports by Norway in 1998 [47]**

As for Denmark, the Danish regulatory framework and the state control had not allowed for such a common market to be operated. Nevertheless power trade had taking place between the two countries for years. Under pressure from Norway and Sweden, rather than from the preparation of the EU electricity market directive, which was finally passed in December 1996, Denmark opened its electricity market to partial competition (third-party access for large industrial consumers)[48]. This should develop power trade and exchanges between Norway and Denmark in the future.

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[46] Sweden (GWh)
Total Production 147 035, Thermal 9 972, Hydro 67 128, Nuclear 69 935, Source Statistics Norway
[47] Source Statistics Norway
[48] Jarmo Vehmas and al., *Energy Policy*, Vol. 27, Num 1, 01/99

Norway has developed a good relationship with its Nordic neighbors and now trades a significant amount of power to compensate for shortages due to a lack of precipitation. This common market greatly reduces market inefficiencies. The marginal cost of the Norwegian hydropower is close to zero and its interconnection to the Scandinavian market supplies its neighboring countries with cheap peak-load power (thermal peak-load power is far more costly).

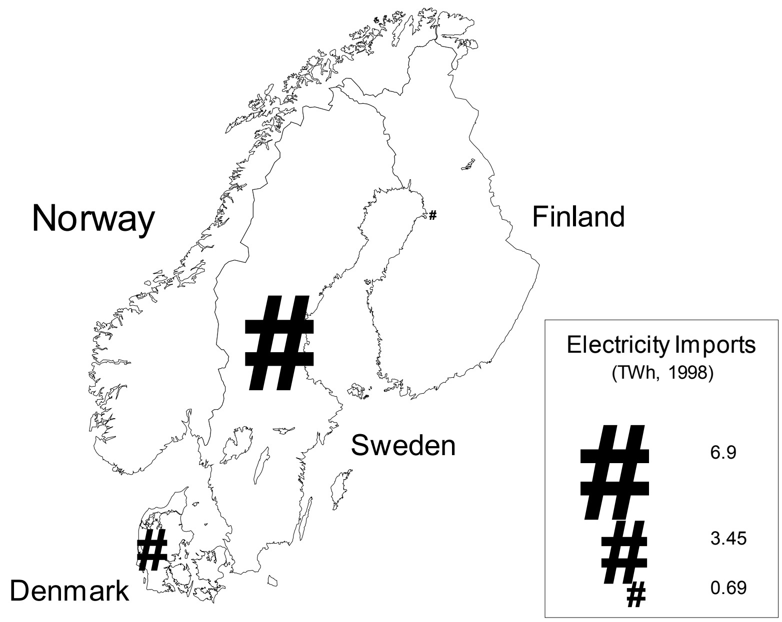


**Figure 0.22. Electricity imports in Norway in 1998** [49]

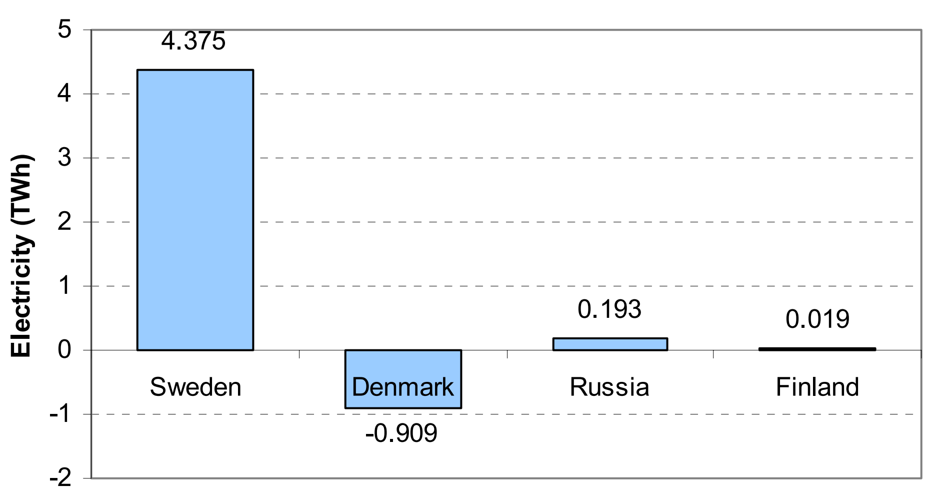


**Figure 0.23. Net imports of electricity by Norway in 1998**[49]

[49] Source Statistics Norway

Up to now power trade has helped Norway to supply electricity in a satisfactory manner by allowing for risk coverage of electricity shortages. Nevertheless, the ever-increasing consumption is posing a threat to its power supply security as its dependence on foreign electricity increases. Moreover hydropower requires a substantial capacity margin in order to ensure supply against variable rainfall.

## The case for the two gas-fired power plants

This ever increasing need of supply capacity to respond to an ever increasing demand and magnified by the hydro requirements is bound to conflict with the limited number of suitable sites available to this day (Figure 0.5). Consequently limiting the growth of electricity demand (redirecting demand and demand growth) and importing are the only available options without extra capacity.

This domestic power supply constraints combine with the energy policies implemented in power supplying partners. In 1980 Sweden expressed its will to phase out nuclear electricity by 2010[50] turning off the first reactor as soon as 2001. Even if that measure were to be left aside upon consideration of economic and environmental criteria[51] (global warming), this stresses the need for Norway to find suitable alternative power supply.

The expansion of electricity trade between Norway and its Scandinavian neighbors was essentially motivated by economic interests to reduce national economic inefficiencies (hydro in Norway, nuclear in Sweden). However this solution alone is no longer sufficient as Norway approaches its maximum hydro capacity and its neighbors' energy policies directly threaten its power supply. The competition in the European power market has driven down prices. Were Sweden to phase out nuclear electricity in the near future, it would have to either heavily subsidize other renewable energy supplies or increase its power imports not to deviate too much from the Kyoto targets.

Any demand side management would require Norway to reduce its consumption growth from households and redirect its industrial choices. Both are difficult to achieve. First households are not equipped for natural gas home heating. The widespread use of electric panel heaters in Norway necessitates a complete rebuilding of the household heating system. This would require either the slow adaptation of new housing or the costly retrofitting of the existing setup.

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[50] *Energy Policy*, Vol. 25, Num. 4, 04/97, p 383

[51] Initially Sweden was to shut down its first reactor by 1998, and the remaining 11 were to follow "at a constant pace", according to the governing Social Democratic Party. In fact the first nuclear reactor (Barsebäck 1) was shut down on November 30, 1999. The second one Barsebäck 2 is to be shut down by July 1, 2001. In the light of increasing Swedish $CO_2$ emissions, Sweden could postpone its nuclear phasing out indefinitely to meet or approach Kyoto targets. It is worth noting that Germany has decided to quit nuclear production by 2021 (press release, June 15, 2000). At a regional scale any phasing out country benefits from a "first mover advantage" since it increases pressure on the remaining countries for them to secure their power supply. These non coordinated energy policies show how much more difficult it is becoming for France, as the world first power exporter to quit nuclear power production. *Source Global Environmental Change Report*, Vol. VIII, NO. 7, and the French newspaper *Libération* June 15,2000

Moreover this would add to Norway's GHG emissions. As far as industry is concerned, any drastic change is bound to meet with outright political opposition and conservatism from the economic sphere.[52]

Any supply management aimed at meeting the increasing electricity demand implies the finding of new source of power supply to guarantee Norway's power supply security. Trade alone cannot guarantee a secured future power supply.

Opposition to nuclear power production dwarfs any other opposition to any other source of energy in Norway. The Parliament stated in 1986 that nuclear power will not be considered as a future alternative supply source.[53]

Wind power generation is characterized by many small (in the order of 1 $MW_e$ for the biggest ones) production windmills that must be sited in sufficiently windy areas (typically off-shore or along the coastline). This brings about visual pollution that may conflict with the tourist industry (Norway's preserved environment is an essential asset for the country). "An approximation of 10-15 TWh is considered realistic without causing major user conflicts. This is equivalent to between 2,500 and 4,000 of the largest windmills currently available."[54] Were the electricity demand to be met only by wind power, this would demand installing one or two big windmills in Norway every day.[54]

Other renewables (geothermal, solar, waste, combined heating) require infrastructures with which Norway is not massively equipped with (pipes, buildings equipped with hot water heaters, etc) even if their share is expected to marginally increase.

Consequently gas-fired power plants seem the most appropriate way of quickly increasing the domestic power supply given the huge national gas reserves, the relatively low impact on the environment if we set aside global warming, and the limited possible extension of the hydro capacity.[55]

[52] Sjur Kasa, Social & political barriers to green tax reform, Policy note 1999:5, CICERO, Oslo
[53] Source Energy Policies of IEA Countries, 1997 Norway Review, IEA
[54] Dag Christensen, Hydro Energy, Norway. Figures coming from a white paper to Stortinget
[55] Gas-fired plants can be designed to respond to two different needs: peak-load power demand or base load power demand. The projects proposed by the consortium Naturkraft and the alternative one proposed by Norsk Hydro are base load plants. Chapter 4 reviews these projects in more details

# Chapter 2

# Greenhouse Gases Emissions and Climate Change

GREENHOUSE GASES EMISSIONS AND CLIMATE CHANGE

## Introduction to the Greenhouse Effect

Human activities are emitting greenhouse gases into the atmosphere, where rising levels are expected to cause climate change. By absorbing infrared radiation, these gases control the radiative balance between incoming and outgoing energy. Their increasing atmospheric concentration is expected to make the average temperature of the earth increase. The international negotiations to control greenhouse gas emissions are concentrating on six gases ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$), with $CO_2$ accounting for over 60%[56] of today's anthropogenic greenhouse effect today.

Carbon dioxide is a by-product of the combustion of any carbon containing fuel, such as coal, oil, gas, or biomass. Methane and nitrous oxide are emitted from agricultural activities, changes in land use, and other sources. Chemicals called halocarbons (HFCs, PFCs) and other long-lived gases such as sulfur hexafluoride ($SF_6$) are released by industrial processes and uses.

[56] $CO_2$ emissions represent the bulk of greenhouse gases emissions, even adjusted for a chemical impact on the atmosphere that is smaller than most of the other greenhouse gases
Source UNFCC, information tool kit on climate change, http://www.unfccc.de/resource/iuckit/fact03.html

Climate change is likely to have a significant impact on the global environment. In general, the faster the climate changes, the greater will be the risk of damage. The mean sea level is expected to rise 15-95 cm by the year 2100, causing flooding of low-lying areas and other damage. Climatic zones (and thus ecosystems and agricultural zones) could shift towards the poles by 150-550 km in the mid-latitude regions[57]. Forests, deserts, rangelands, and other unmanaged ecosystems would face new climatic stresses. As a result, many will decline or fragment, and individual species will become extinct. While there remains a considerable number of uncertainties as regard to the extent and geographic distribution of the damage, the time horizon, and the global scope of the problem, there is enough evidence to cause concern.

Stabilizing atmospheric concentrations of greenhouse gases will demand a major effort. In a typical "non–intervention" scenario[58], greenhouse gas levels are equivalent[57] to a doubling of pre–industrial $CO_2$ concentrations by 2030, and a trebling by 2100[59]. Freezing global $CO_2$ emissions at their current levels would postpone $CO_2$-doubling to 2100; emissions would eventually have to fall to about 30% of their current levels for concentrations to stabilize at doubled-$CO_2$ levels sometime in the future. Given an expanding world economy and growing populations, this would require dramatic improvements in energy efficiency and fundamental changes in the way we use energy (changes in primary energy sources for instance).

In 1997, the conference of the Parties to the United Nations Framework Convention on Climate Change negotiated the Kyoto Protocol. This protocol contains targets for the developed countries to reduce their collective emissions of the six greenhouse gases aforementioned by an average of 5.2% compared to 1990 levels by the period 2008-2012. The Protocol is a first step towards achieving the Convention's ultimate objective of preventing "dangerous anthropogenic interference with the climate system". The following sections will mostly deal with reductions in carbon dioxide emissions.

## Reducing Carbon Dioxide Emissions

Since most greenhouse gas (GHG) emissions are a by-product of energy production and use, drastically reducing them will call for radical change in the way our economies rely on energy to thrive. One often resorts to the Kaya formulation to understand the economic mechanisms at play in carbon dioxide emissions:

$$\mathrm{CO_2} = \mathrm{P} \times \left(\frac{\mathrm{GDP}}{\mathrm{P}}\right) \times \left(\frac{\mathrm{E}}{\mathrm{GDP}}\right) \times \left(\frac{\mathrm{CO_2}}{\mathrm{E}}\right) - S$$

[57] Source UNFCC (United Nations Framework on Climate Change)

[58] "Non–intervention" means that no new policies are adopted to reduce emissions in response to the threat of climate change. This scenario assumes that world population doubles by 2100 while economic growth continues at 2–3% per year

[59] This takes into account all the greenhouse gases, translated into their carbon-dioxide equivalents

Where:

| | |
|---|---|
| $CO_2$ | = carbon dioxide emissions to the atmosphere |
| P | = population |
| GDP/P | = gross domestic product per capita |
| E/GDP | = energy intensity of the economy (energy consumption per unit of GDP) |
| $CO_2/E$ | = carbon intensity of the economy (mass of $CO_2$ emitted per energy unit consumed) |
| S | = sequestration of carbon dioxide (amount of produced $CO_2$ emissions that does not end up in the atmosphere, through offsets or carbon capture and sequestration) |

Since the standard of living (and economic growth) is associated with per capita GDP, and since population is not likely to significantly decrease in Norway over the next decades, any decrease in net emissions of $CO_2$ can be obtained through:

- a reduction in the energy intensity
- a reduction in the carbon intensity
- an increase in carbon sequestration

Reducing the energy intensity of the economy can be obtained through different channels: increasing the efficiency of primary energy conversion and use, or by modifying the make-up of the economy (turning from energy-intensive industries to service industries for example). Switching from high to low or no carbon fuels reduces the carbon intensity of the economy. Finally preventing carbon produced from fossil fuel combustion from getting into the atmosphere or from staying there can be obtained either through the enhancement of natural sequestrating ecosystems (also called offsets), or by industrial processes specifically designed for carbon capture and storage (technological carbon sequestration). We look at each of these options below.

## Reducing the Energy Intensity of the Norwegian Economy

The level of the energy intensity of the economy is linked to the efficiency of primary energy conversion, the sectoral make-up of Norwegian industry, and end-use efficiency. Figure 0.1 plots the energy intensity of the Norwegian economy over the past decades. Improvement in energy efficiency can be located at any stage of the fuel life cycle, from production to end-use. It not only has a direct effect on the environmental quality by diminishing ancillary effects of energy use (negative externality), but also it lessens the need for new energy sources (positive externality).

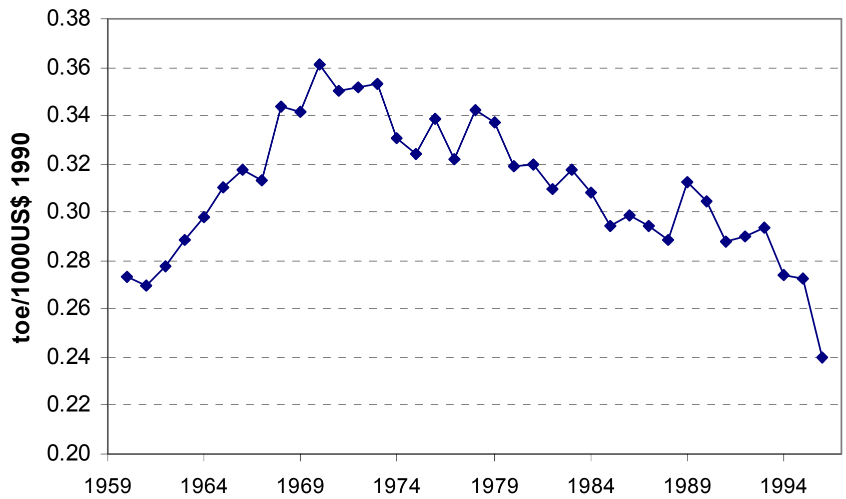


**Figure 0.1. Energy Intensity in Norway (toe/1000 US$ 1990)[60]**
*Energy intensity increased dramatically in the 1960s (due to the development of the Norwegian heavy industry) until the first oil shock in 1973. It has been decreasing since then.*

Note that energy intensity is not a direct measure of energy efficiency since structural changes have an effect on the energy intensity as well (e.g. switching from high to low energy-intensive industries). Energy efficiency has been steadily increasing over the past decades. Oil shocks have spurred technology improvements (spurring the redesign of more efficient industrial processes) in the 1970s as in the rest of the world. Nevertheless households heavily rely on electricity, 90% of them using electricity as the only source of energy for home heating. This certainly constitutes a terribly inefficient way to use energy[61]. But since 100% of electricity in Norway is hydroelectricity, this use does not directly lead to higher emissions of GHGs. Improvement margins are still to be found in the oil sector for instance, where many gas turbines are aging and do not meet with state of the art standard in term of energy efficiency.

Thanks to the availability of inexpensive hydropower, Norway dramatically developed its metallurgical industries in the 1960s. The swift development of the oil sector after 1970 lead to a dramatic increase in greenhouse gases emissions since industrial facilities rely on fossil fuels only to meet all their energy needs (gas turbines coupled with electric generators for electricity supply). Figure 0.2 below shows the relative growth of the various primary energies in Norway normalized to their 1996 level(1996 = 100). The growth of natural gas use stems from the expansion of the Norwegian oil sector.

[60] Source International Energy Agency
[61] For instance using electricity to power ground-source heat-pumps would be a much more efficient use of electricity to heat houses, rather than using it in electric resistance heaters

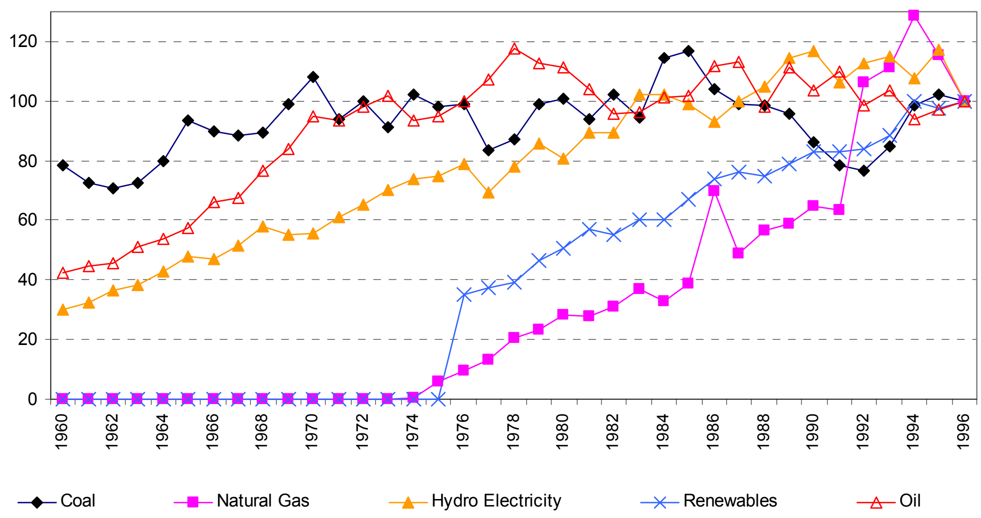


**Figure 0.2. Normalized primary energy consumption in Norway (1996 base 100)**
*This chart shows the rapid and late increase in natural gas consumption. Both the expansion of the oil sector and its energy intensity are embedded in this figure, since natural gas is only used offshore (it is difficult to separate the two since the energy intensity of the oil sector varies with the difficulty to reach geological formations containing oil). Coal consumption has remained pretty stable over the past decades.*

## Lowering carbon intensity

Fossil fuels are expected to supply 48% of Norway's energy needs in 2000 (Figure 0.7). The carbon intensity of the Norwegian economy has been decreasing since the end of the 1960s as Figure 0.3 illustrates. This stems from the fact that the expansion of the hydroelectric capacity has been more rapid than the offsetting effect of fossil fuels consumption both for transportation and energy purposes in the oil sector.

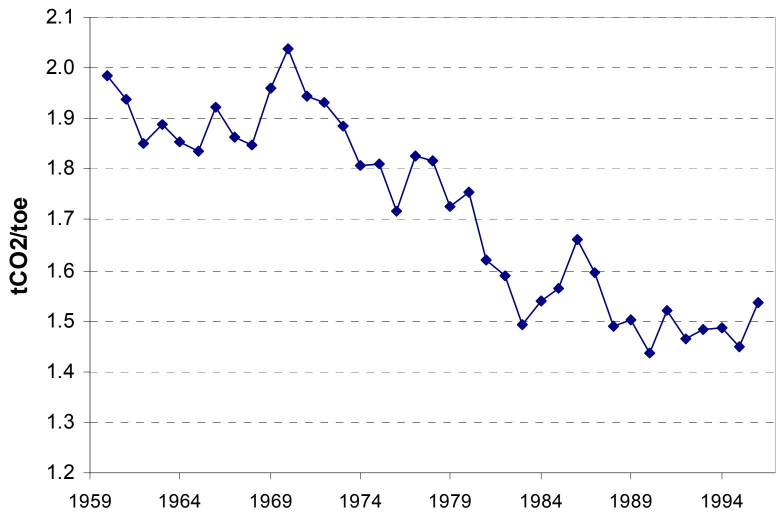


**Figure 0.3. Carbon intensity of the Norwegian economy (ton of $CO_2$/toe)[62]**
*The carbon intensity in Norway has been steadily decreasing after 1970. The oil shocks in 1973 and 1979 are visible on this chart.*

## Offsets

Offsets define the process of removing carbon in gas phase by natural ecosystems that secure its storage in a stable (often solid) form. Expanding forests constitute growing carbon sinks. Note that the dynamics of forests is critical since the overall carbon cycle intake in forests is close to zero due to natural decomposition that returns most of the stored carbon to the atmosphere. Enhancing the ability of natural ecosystems to capture and sequestrate carbon (increasing forest coverage, or modifying nutrient supply to ecosystems) is a route to reducing atmospheric carbon accumulation that still needs to be fully explored.

## Technological carbon capture and sequestration

One could prevent anthropogenic carbon dioxide from reaching the atmosphere by deploying technologies to capture it and securely store it in a stable form underground or in the deep ocean.[63] Carbon dioxide can be separated from power plant flue gases or from other gas by-products of industrial processes (metallurgical production plants, oil refineries release considerable amounts of carbon dioxide), and then be securely stored in gas or liquid form into geological formations (such as depleted oil wells, exhausted coal seams or deep brine aquifers). Figure 0.4 illustrates what the vision of the Norwegian oil company Statoil may be as regard to

[62] Source International Energy Agency
[63] Refer to Carbon Sequestration Research and Development, US Department of Energy, DOE/SC/FE-1

the future of the hydrogen energy.[64] Other chemical or biological process may convert carbon dioxide in other stable products (storage by seaweeds fed in $CO_2$ saturated water streams or microorganisms converting $CaCO_3$ for instance).

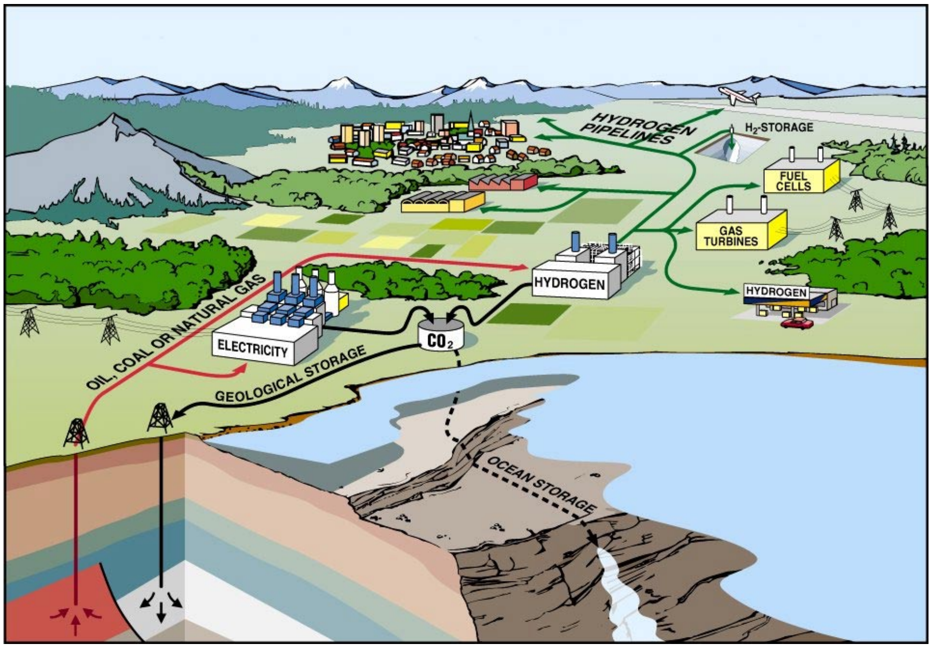


**Figure 0.4. $CO_2$-free electricity and hydrogen from fossil fuels**
*Sketch of one vision of the future where fossil fuels are decarbonized to produce electricity and/or hydrogen. The carbon by-product is then sequestered underground or into the deep ocean.*

## $CO_2$ Trading

Tradable permits have lately been given prominence as instruments for achieving environmental goals. In principle they rest on their expected ability to equalize marginal costs among all controlled sources and thereby to assure least-cost compliance with the particular environmental goal. This means, for a given cost, a maximum environmental benefit can be gained. This stems from the incentive for players with low abatement costs to reduce more than standards would compel them and to sell permits at a price that is above their marginal cost of abatement. Companies facing higher marginal abatement costs may prefer to buy emission permits to comply with their regulated emissions levels. Since global warming is a "tragedy of the common" (one ton emitted in Albania has the same effect than a ton emitted in Zambia), tradable permits are appealing since they are expected to level off abatement costs wherever they are used. This approach is preferred by the United States among others for its theoretical ability to allow for the most economic efficiency in reducing overall emissions. Trading can be implemented at the international level, at the national level, or both.

[64] Source Statoil, Norway

Very different technological approaches can help to reduce atmospheric carbon emissions: improving energy efficiency, reducing carbon intensity or sequestering carbon. Since any of these techniques is not likely to be able to solve the problem alone of increasing atmospheric carbon concentrations by itself, all options must be fully explored and assessed. International trading of $CO_2$ emission allowances is expected to equalize the abatement costs between the regulated sources. The farther the reach of such a system, the lower the overall cost of abatement, since the most inexpensive sources of reduction are expected to be tapped into first.

Chapter

# 3

# Greenhouse Gases Emissions in Norway

## NORWEGIAN GHG EMISSIONS

### Past, Current and Projected Emissions

In 1999 Norway emitted 42.3 million metric ton of $CO_2$ (net emissions without land use change[65]. Counting all six greenhouse gases ($CO_2$, $CH_4$, $N_2O$, HFCs, PFCs, $SF_6$), emissions reached about 58 million tons of $CO_2$ equivalent in 1999 (without taking into account land use change). This corresponds to a 2% increase from 1998 and a 9% increase since 1990[66](Figure 0.1, Table 0.1).

[65] Land use change refer to the fact that changes in land use may lead to greater or lesser intakes of carbon by vegetation. The ways “carbon sinks” are taken into account into national inventories of GHG emissions are still debated to this day

[66] Source Statistic Norway and the Norwegian Pollution Control Authority

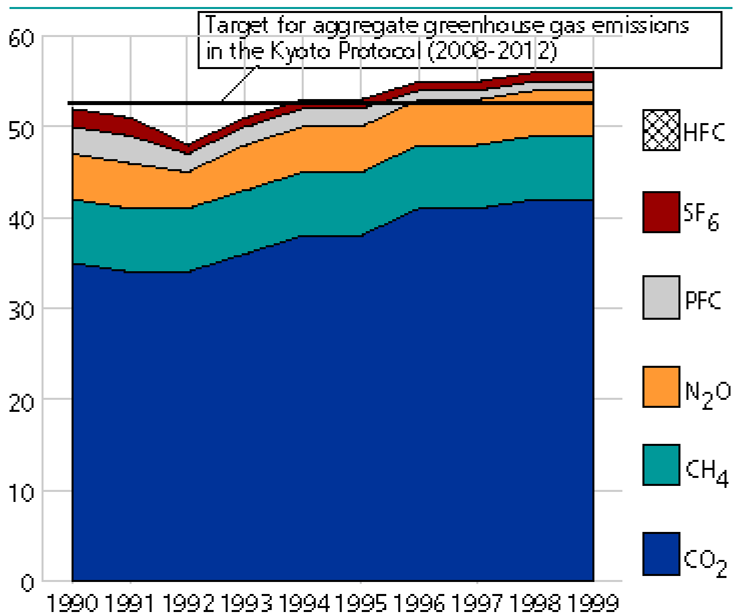


**Figure 0.1. Norwegian emissions of greenhouse gases for the period 1990-1999[67] (expressed in Million metric tons of $CO_2$ equivalent)**

**Table 0.1. GHG Emissions in Norway for the period 1991-1999[68] (in Mt of $CO_2$ equivalent)**

| GREENHOUSE GASES | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 |
|---|---|---|---|---|---|---|---|---|---|
| $CO_2$ emissions[69] | 33.605 | 34.267 | 35.918 | 37.940 | 38.157 | 41.119 | 41.426 | 41.700 | 42.300 |
| $CH_4$ | 6.717 | 6.858 | 6.966 | 7.143 | 7.200 | 7.264 | 7.374 | 7.265 | |
| $N_2O$ | 5.000 | 4.324 | 4.683 | 4.789 | 4.860 | 4.860 | 4.806 | 5.092 | |
| HFCs | 0 | 0 | 0.002 | 0.009 | 0.026 | 0.053 | 0.088 | 0.133 | |
| PFCs | 2.524 | 2.016 | 1.980 | 1.710 | 1.562 | 1.440 | 1.377 | 1.267 | |
| $SF_6$ | 2.070 | 0.697 | 0.754 | 0.765 | 0.582 | 0.590 | 0.552 | 0.698 | |
| Total | 49.915 | 48.162 | 50.303 | 52.357 | 52.387 | 55.326 | 55.624 | 56.154 | 58.000 |

67 Source Norwegian Pollution Control Authority and Statistics Norway
http://www.ssb.no/english/subjects/01/04/10/klimagassnf_en/
68 These estimates do take into account carbon uptakes resulting from land use changes
Source Statistics Norway
69 Note that $CO_2$ emissions do not include land use change

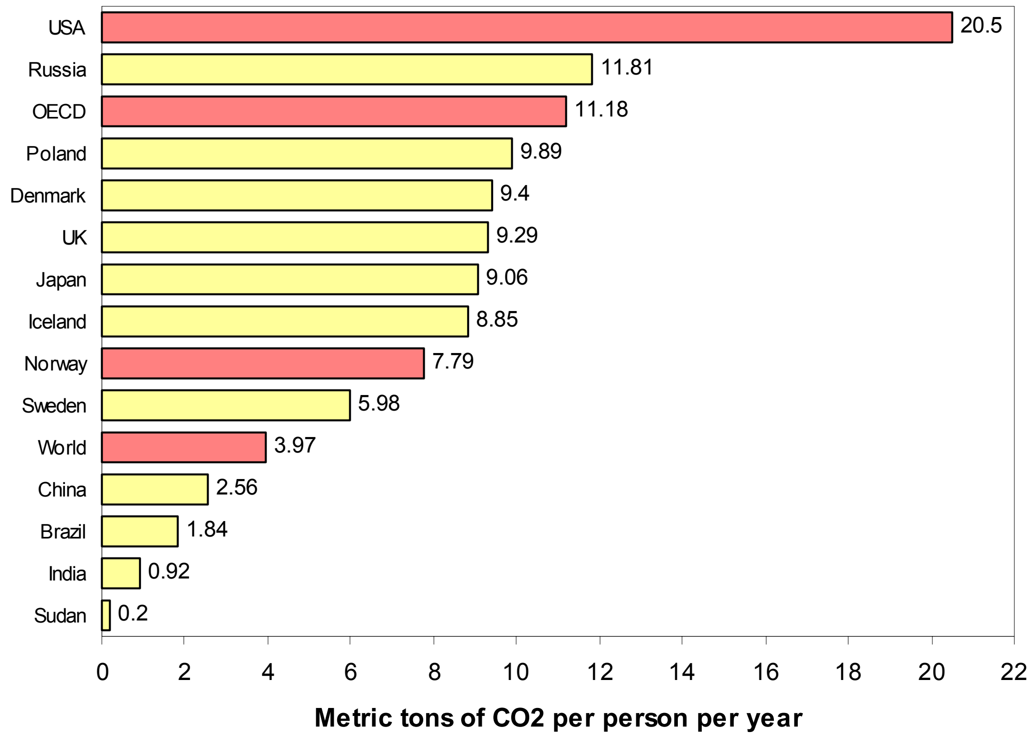


**Figure 0.2. $CO_2$ Emissions per capita in 1997**[70]

As Figure 0.2 shows, Norway's emissions are in the lower average of the developed countries. "Norway's $CO_2$ emissions increased steadily from 1960 to 1980, only interrupted by a drop during the increase in oil prices in the early1970s. Throughout the 1980s, $CO_2$ emissions were relatively stable, despite a steep increase in petroleum production and thus in the consumption of natural gas for energy purposes by this sector. This is primarily because the rise in emissions from the continental shelf has been offset by a drop in the consumption of fuel oils. From 1989 to 1992, precipitation levels were high and there were large supplies of cheap hydropower. This, combined with lower economic activity and the introduction of $CO_2$ taxes, kept $CO_2$ emissions below the 1989 level. In 1993, emissions reached about the same level as in 1989, and in 1994 they increased further, mainly as a result of higher consumption of fuel oils, particularly by the wood-processing industry."[71]. The substantial increase over the past 3 years is due to the combined emissions of the oil sector and the increase from the transport sector.

[70] Source IEA Statistics, $CO_2$ Emissions from Fuel Combustion 1971-1997, OECD Editions
[71] Source Report to the Stortinget No. 41 (1994-95) on Norwegian policy to mitigate climate changes and reduce emissions of nitrogen oxides ($NO_x$) - Summary

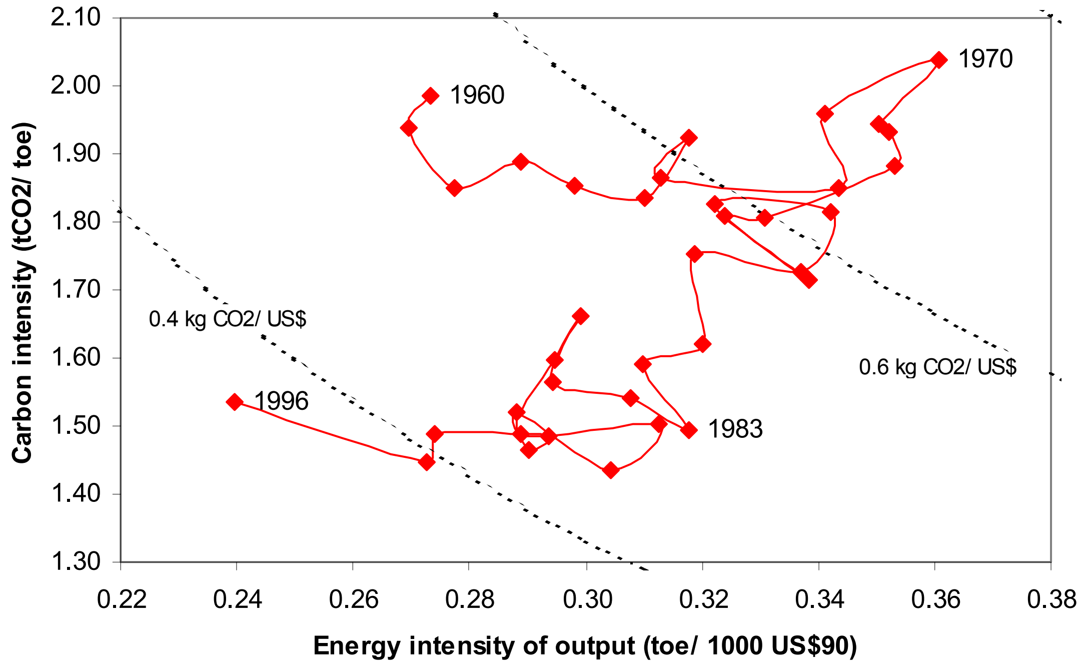


**Figure 0.3. Energy intensity vs. carbon intensity in Norway over the past 4 decades**[72]

Three distinct periods[73] are clearly visible from Figure 0.3:

1. During the 1960s Norway developed its heavy metallurgical industries, resorting mostly to electricity as a source of energy. This lead to an increase in the energy intensity of the economy while the carbon intensity remains pretty stable.

2. During the 1970s hydroelectricity developed more rapidly than other sources of energy. This dominance lead to a “dilution” of the energy share of carbon-based energies and resulted in lower carbon intensities, despite the dramatic rise of natural gas use on the continental shelf.

3. The 1980s and 1990s show a stabilization on the carbon intensity of the Norwegian economy due to improved efficiencies and the leveling off of hydropower development. Note that the 1996 deterioration is essentially due to the lack of hydroelectricity (because of dry conditions that year).

Through the Kyoto Protocol, Norway has pledged not to let its greenhouse gas emissions increase by more than one per cent of the 1990 level over the period 2008-2012. However, its projected future emissions are way above its Kyoto targets.

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[72] Constructed from data of the International Energy Agency. I am indebted to Laurent Viguier, from the Energy Laboratory, CNRS, Grenoble, France, who first proposed this representation in June 2000

[73] Refer to Figure 0.8 that shows the dynamics of the energy growth in Norway over the same period

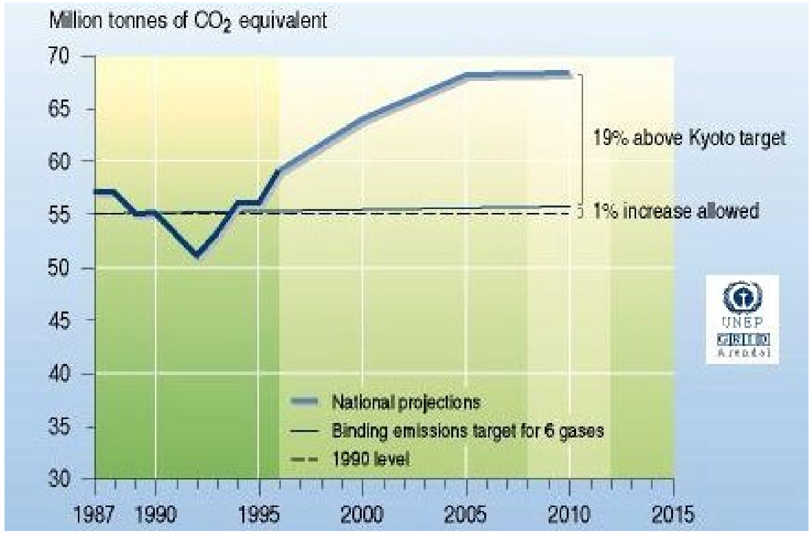


**Figure 0.4. Emissions of Greenhouse Gases in Norway ($CO_2$, $CH_4$, $N_2O$, $SF_6$, HFC's and PFC's)**

Without new measures, Norwegian GHG emissions are expected to increase by 20% from 1990 to 2010". Norway needs to take new measures to reduce the projected 2010 GHG-emissions by 19 per cent to fulfill the Kyoto protocol (Figure 0.4).[74]

This average level of $CO_2$ emissions per capita actually masks a sector-based composition of $CO_2$ emissions which is somewhat different from that pertaining in most other countries. "Norway is in a special position in that renewable energy sources supply 70 per cent of stationary energy use"[75]. In a normal year, Norway covers all its electricity needs from renewable energy (hydroelectricity). Most of the remainder of stationary consumption comes from the petroleum sector.

## Sectoral GHG Emissions

As already mentioned more than 99 per cent of Norwegian electricity is hydroelectricity. Power generation is not a source of greenhouse gases in Norway.

In 1999, the largest $CO_2$ emissions were from stationary combustion (40%), including both the offshore and the onshore industry, and mobile sources (39%) (Figure 0.5). Gas turbines offshore accounted for 16% of Norwegian emissions of $CO_2$ in 1995[76]. The figure for 1999 is likely to be much the same. Road traffic contributed about 22%, while coastal traffic and fishing accounted

[74] Source GRID Arendal, UNEP
[75] Report to the Stortinget (White Paper to the Norwegian parliament) No. 29 (1997-98) on Norwegian implementation of the Kyoto Protocol
[76] Source Inventories of anthropogenic greenhouse gas emissions and removals Ministry of the environment, http://odin.dep.no/md/publ/climate/3.html

for 9%. Industrial processes, i.e. production of metals, carbides, cement etc., constituted 20.6% of total $CO_2$ emissions in 1999.

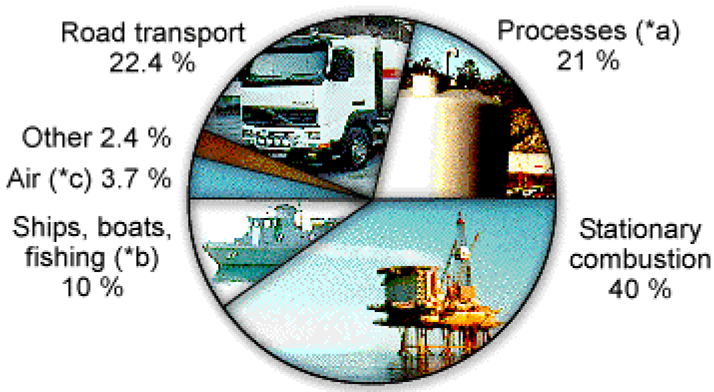


**Figure 0.5. Emissions of GHG in Norway in 1999**[77]

*Notes: *a: Emissions other than combustion*

**b: International maritime transport excluded.*

**c: International flights excluded*

The following sections address the three main sectors that account for significant the most part of GHG emissions in Norway: processes, transport, and stationary combustion.

## Processes

This term covers many different industries, ranging from the well-known energy-intensive ones such as the aluminum industry to the wood industry. Over the past decades, Norway has specialized in energy intensive industries given the availability of cheap hydro electricity. Nevertheless these industries are not GHG emission free. For example Norway is a major aluminum producer and perfluorocarbons (greenhouse gases with a very high global warming potential and exceptionally long atmospheric lifetimes) are primarily formed during aluminum production. Nevertheless even if this adds to Norway's emissions, greenhouse gases emissions per ton of aluminum from Norwegian production plants appear to be much smaller than those reported from other countries.[78]

"Emissions of perfluoridized carbons ($CF_4$ and $C_2F_6$) from Norwegian aluminum refineries are estimated to have been reduced by about 40 per cent since 1985. The main source of emissions

[77] Source United Nations Environment Programme, GRID (Global Resource Information Database) Arendal, Norway, figures Statistics Norway 2000

[78] Source Inventories of anthropogenic greenhouse gas emissions and removals Ministry of the environment

of sulfur hexafluoride ($SF_6$) is magnesium production, and Norwegian emissions were estimated at 31 tons in 1993"[79]

The recent increases in GHG emissions in 1993 and 1994 can be attributed to higher consumption of fuel oils, particularly by the wood-processing industry.[80] Figure 0.6 below shows the constant increase of GHG emissions by the process sector.

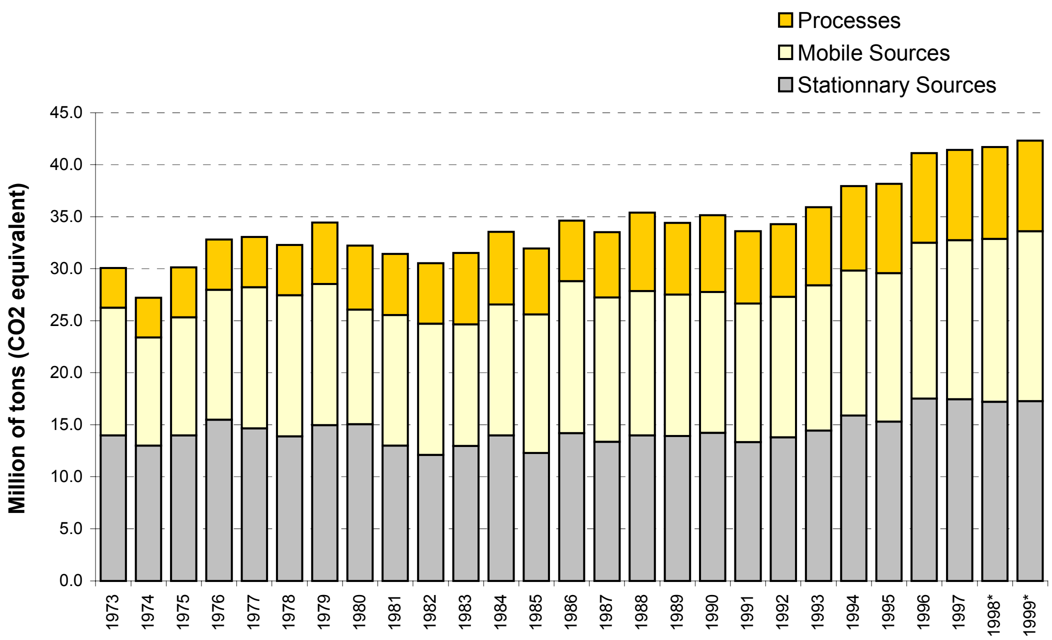


**Figure 0.6. GHG emissions by sources in Norway[81]**

## Transport

In 1999 transport accounted for a little more that 36% of total GHG emissions. Road traffic was responsible for about 22% of GHG emissions in 1999. The demand in this sector, as in the rest of the developed countries, is fairly inelastic and on the increase. Again this is due to the scattered population pattern of the country, which is widespread and not densely inhabited. Domestic commercial aviation accounted for approximately 3.7% of GHG emissions in 1999. International flights are excluded. All other mobile sources (domestic shipping industry, fishing fleet, agricultural mobile sources, etc.) emitted about 10% of the total.

[79] Source Report to the Stortinget No. 41 (1994-95) on Norwegian policy to mitigate climate changes and reduce emissions of nitrogen oxides ($NO_x$) - Summary
[80] Source Report to the Stortinget No. 41 (1994-95) on Norwegian policy to mitigate climate changes and reduce emissions of nitrogen oxides ($NO_x$) - Summary
[81] Source Statistics Norway

### Stationary combustion (Oil sector)

"The petroleum sector alone (production and transport of petroleum) accounted for about 23% of total $CO_2$ emissions in 1995. These emissions come from different sources (refer to Figure 0.7): (a) Pipeline transport of natural gas to the European continent is energy demanding and therefore generates $CO_2$ emissions."[82], (b) Gas fired turbines are the only energy source on oil rigs offshore, (c) burning of natural gas in flares.

Other $CO_2$ and GHG emissions are connected with exploration activities, gas terminals onshore and indirectly with non methane volatile organic compound (nmVOC) emissions from the loading of crude oil. NmVOCs contribute indirectly to the greenhouse effect because $CO_2$ and ozone are formed when nmVOCs react with air in the atmosphere.[83]

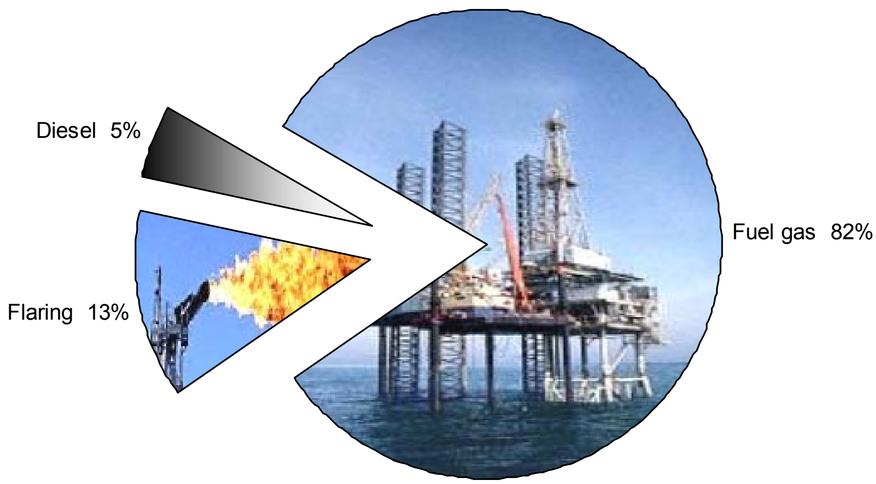


**Figure 0.7. Sources of GHG emissions in the Norwegian oil industry[84]**

Emissions from oil and gas production have made the greatest contribution to the increase in $CO_2$ emissions since 1990[85]. GHG emissions have been steadily increasing since 1990 (15% from 1989 to 1996[86]). This is due to the increasing activity of that sector which has not been altogether offset by improvement in efficiency ($CO_2$ emissions per produced oil equivalent have

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[82] Norway's second National Communication under the Framework Convention on Climate Change April 1997, T - 1186
[83] Environment 1999, The Norwegian Petroleum Sector, Ministry of Petroleum and Energy
[84] Source Environment 1999, Ministry of Petroleum & Energy
[85] Source Statistics Norway, Emissions to air
[86] Source GRIDA Arendal http://www.grida.no/prog/norway/soeno98/climate/co2goal.htm

been reduced by about 30% from 1990 to 1996[87]). In 2000, the oil sector will emit approximately 10 million tons of $CO_2$.

GHG emissions are expected to grow in the future as oil fields are aging and hence, requiring more energy per unit of produced output (declining pressure in the reservoirs). Moreover, the relocation of activities northwards (at a longer distance from shore hence higher transportation costs of compressed natural gas) is bound to accentuate this trend since these new activities are more energy-intensive (exploration, drilling and transport over longer distances, etc.). GHG emissions are expecting to peak around the year 2006, when they are expected to reach 16 million tons of $CO_2$ equivalent.[88]

It is worth noting that Norwegian emissions of greenhouse gases from oil and natural gas production, as well as natural gas transmission are among the lowest in the world (Figure 0.8.). GHG emissions from oil production per $m^3$ of oil produced in Norway are about half the British emissions, and one eighth of the Russian emissions.[88]

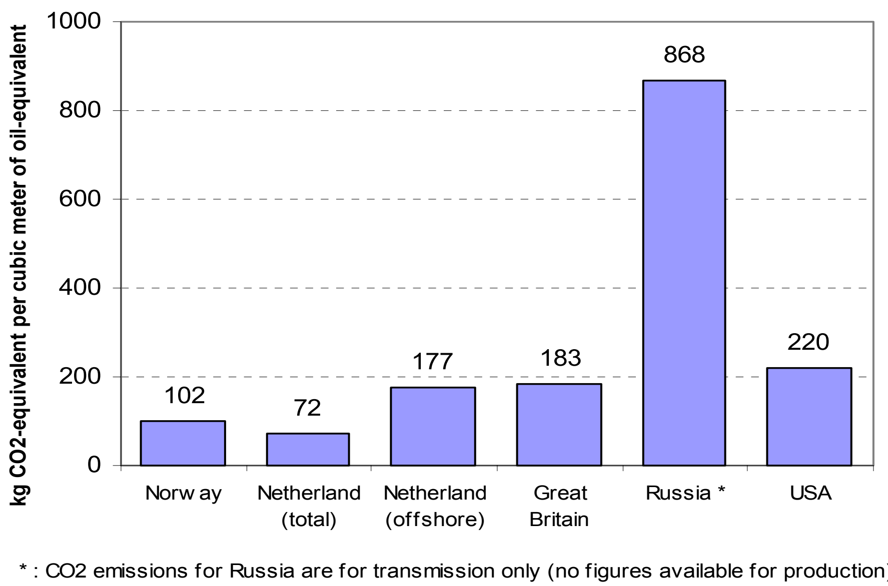


**Figure 0.8.[88] Emissions of greenhouse gases from natural gas production and transmission**

The progressive exhaustion of oil reserves and the phasing in of more energy intensive natural gas exploitation all lead to increases in GHG emissions. Natural gas production is more energy intensive due to its physical features (compressing and pumping a compressible fluid is more energy demanding than doing the same with an uncompressible fluid such as oil).

[87] Environment 1999, The Norwegian Petroleum Sector, Ministry of Petroleum and Energy
[88] Source Courtesy of Statoil

### Electricity Generation

Over 99% of Norwegian electricity comes from hydropower, where GHG emissions are negligible. However Norway is increasingly in need for new power generation capacity to secure its power supplies. Diversifying its electricity production calls for the construction of new power plants.

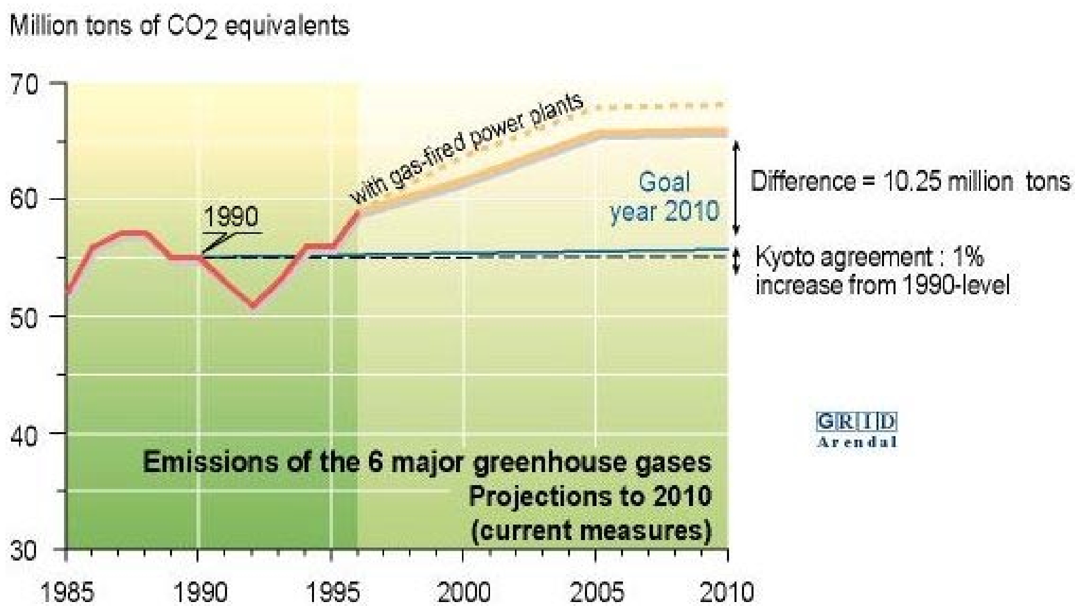


**Figure 0.9. Projections of GHG emissions in Norway**
(Including the proposed two gas-fired power plants)

Two gas-fired plants have been contemplated supplementing the current hydro capacity. "If the two planned gas-fired plants are built, this figure (19% increase of GHG emissions over the Kyoto target) is expected to increase by 23%"[89] (Figure 0.9). These two plants alone would increase the Norwegian emissions by 3 to 5% over the 1990 baseline. They would emit approximately 2.1 million tons of $CO_2$ a year (this is equivalent to emissions produced by 700,000 cars, half the Norwegian fleet[90]).

## Emissions Overview

Any substantial reduction for Norway to meet its Kyoto targets will require a significant effort. Most of the different sectors (transport, oil) are expected to increase their emissions even if devices such as tax or permit systems were introduced to deter fossil fuel usage (because of a relatively inelastic usage from households and weak dependence of industry on oil products).

[89] Source GRID Arendal, UNEP
[90] Source Alexander's Gas & Oil Connections

Nevertheless some successful attempts have been made to curb $CO_2$ emissions in the gas extraction activity: flaring limited to safety reasons, separation of $CO_2$ from natural gas (to comply with sale specifications) and reinjection of one million tons of $CO_2$ emissions annually into a subsea reservoir. [91]

Because of the increasing need for Norway to secure its power supplies and to diversify its electricity production, coupled with the local cheap and secured supply of natural gas and its positive environmental attributes (except for $CO_2$), serious consideration has for some time been given to gas-fired power plants. However, the construction of such power plants would drastically increase the Norwegian $CO_2$ emissions and make the meeting of the Kyoto targets even more difficult to attain. We will explore these issues in more detail in chapter 5 and 6. First chapter 4 will address the policies Norway has already implemented and that contributed to limit its GHG emissions.

[91] Environment 1999, The Norwegian Petroleum Sector, Ministry of Petroleum and Energy

# Chapter 4

# GHG Emissions Control in Norway

**HISTORY OF GHG EMISSIONS CONTROL IN NORWAY**

This chapter reviews Norway's history of GHG emissions control. Section 1 analyzes the roots and the nature of environmental concerns in Norway. Section 2 and 3 address the past actions Norway took that contributed to limit its emissions. Section 4 reviews the $CO_2$ tradable system Norway has designed at the national level.

## Norway's Relationship to the Environment

The American political scientist Langdon Winner[92] distinguishes three main schools of thought as regard the human relationship to the environment: 1) Nature as an economic asset, 2) Nature as a threatened ecosystem and 3) Nature as a source of harmony and ethical examples. The three of them are often intimately entangled in the "environmentalist discourse".[92] A disciple of one these schools frequently borrows arguments from the others to hammer out and give extra weight or credibility to its point of view.

[92] For an exhaustive and very intelligent approach of these ideologies please refer to, Langdon Winner, *The Whale and the Reactor, A Search for Limits in an Age of High Technology*, The University of Chicago Press, 1977. The arguments presented here have been mostly borrowed from Winner's work

## Nature as an Economic Asset

This school of thought affirms the fundamental right of the human species to colonize, dominate and exploit Nature to its own advantage. The undesirable by-products or side-effects of this exploitation (industrialization, urbanization, pollution) are never allowed to call this right into question. The economic paradigm (the model of the "market") allocates environment goods (clean air, clean water, etc.) according to a monetary metrics. Trade-off (in other words market-based allocation) is the leitmotiv in this environmental policy approach. Economists have long been dominating this approach. "Would you prefer to have condos or condors? You may not be able to offer both."[92]

The environmental movement in the United States is deeply rooted in this economic strand. The rest of the world is now adopting this conceptual framework when it comes to solving such environment threats as global warming.

## Nature as a Threatened Ecosystem

This group considers Nature as the ultimate judge of human behavior. The advancing degree of nature's destruction directly threatens the human race. "If we are faced with extinction, what sense does it make to worry about nickels and dimes?"[92] The endangering of the full ecosystem (of which the human being is only a part) is a prelude to the full destruction of the biosphere.

"Eco-catastrophes" are at our doorstep. This Ecology shelters our most terrible fears (doomsday), hence the calls for a centralized, absolute authority as a means of regulating our blinkered individual behaviors. Laissez-faire and selfish interests all lead in the wrong and lethal direction. These concepts have aroused substantial interest in centralized countries such as France (preponderance of the state role in all the economic life of the nation).

## Nature as a Source of Harmony and Ethical Examples

Around 1970 a new ecological philosophy made its appearance in Norway.[92] The Norwegian author Arne Naess identified two degrees of environmental concern[93]. In his terms, "shallow environmentalism" tackles the harmful side-effects of industrialization, remedying to the adverse effects of industrialized society. This rather limited approach turns out to fall short of the philosophical approach required by Nature. The second degree focuses on resource conservation and pollution reduction as well, but it invites the human race to find a new ethical relationship to the biosphere. He named this second degree of environmental concern "deep ecology".

This approach to ecology has gained a lot of support in Northern Europe, especially in Norway; given that this approach originated in Scandinavia, this is hardly surprising. Indeed in Norway

[93] Arne Naess, The Shallow and the Deep, Long-Range Ecology Movement, Inquiry 16:95, 1973

the environment is often considered to be a fragile, vulnerable, defenseless, and voiceless person ("Nature can't vote"). Consequently this calls for preventive measures in the first place, and drastic corrective measures if necessary, with little concern for costs.

## Today's Norwegian ecological sensibility

The merging of environmental concerns with philosophical questions is less visible today but its influence may still be discerned in the leading environmental role Norway is trying to play on the international stage. Norway prides itself on being "a driving force in international environmental cooperation"[94]. This probably stems from the "ecological philosophy" and the fact that Norway has been a victim of transboundary pollution, which it has been actively combating on the international stage for decades.[95]

Norway suffers serious harm from acid rain. Seventy thousand square kilometers of land area–an area about the size of Ireland–are currently too acidic for fish to breed there. Half the lakes are empty of fish. In response to this, notable reductions in sulfur oxide emissions have taken place in this area in recent years.[94]

Today Norway's ecological approach is also influenced by the "economic ecology" arguments. The official discourse often mentions the possibility of economic damage resulting from the extinction of potentially useful and lucrative substances. Today, species are becoming extinct at a much higher tempo than at any other time — from 100 to 1,000 times faster than two or three generations ago. This is a threat to man's need for inspiration, beauty, recreation and solitude. The natural environment also contains large economic resources, keys that can help secure food for a steadily increasing population and solutions to medical and nutritional problems hidden in the biological diversity."[94] At the same time doomsday arguments are given more and more prominence. "The danger of major climate change caused by human activity is perhaps the most serious threat the world has ever faced.[96]

In a word there is no longer a prevailing ecological approach in the official discourse. However Norwegian Non-Governmental-Organizations still bolster their ecological discourse with "philosophical arguments". This may explain why any departure from this line is systematically rejected and often considered "pure rethoric".[98] Nevertheless ecology is still a primary pillar of the Norwegian political culture. "Nimby" attitudes are rejected with force and energy.

Global warming is certainly one of the most important ecological issues in Norway today. The global warming threat is not questioned and it is one of the most important issues on the Parliament agenda in Norway.[97] Nevertheless it is not clear whether everybody in Norway is

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[94] Tone Bratteli, former adviser at the Ministry of Environment, Source ODIN

[95] Historically transboundary pollution has meant acid rain. Refer to Gareth Porter and Janet Welsh Brown, *Global Environmental Politics*, Westview Press, Boulder 1996, p.69

[96] Source Norwegian Climate Change Policy, White Paper to the Stortinget (Norwegian Parliament) No.29, 1997-98

[97] Source Interview with Mrs. Hilde Frafjord-Johnson, former Minister of Development in the "Center Government", August 2000. Political consensus, except for the Fremskrittspartiet (FRP, the Progress Party)

fully aware of the potential adverse effect of global warming for Norway. For instance a major threat to Norway might be a chilling effect brought about by a slow down or a complete halt of the thermohaline circulation in the North Atlantic.

“Since the 1980s there has been a growing concern as to the impact of energy production. In 1985, a White Paper elevated environmental conservation to a major objective of future energy policies. Another one in 1988 concluded that the electricity supply industry should have a central role in implementing energy savings and that energy-efficiency measure would have a positive impact on the environment.”[98]

For many Norwegians, clean hydropower is a symbol of the environmental virtue of their country. The decline in the availability of new hydro capacity may soon force Norway to import electricity on a massive scale from abroad and consequently produce transnational and global pollution.[99]

The following sections look at the different actions Norway has taken in order to secure tighter controls and more drastic limitations on its GHG emissions together with other measures taken that indirectly limit GHG emissions.

## Liberalization of the Electricity Market

Originally the Norwegian Parliament stipulated electricity prices and other contract terms. The governmental pricing control was essential for the long term planning of the electricity sector. “Future demand patterns were forecasted to allow for planning the new production and transmission capacity. Prices were set so as to communicate the need for efficient use of hydropower while taking into account supply security and environment concern”[100].

However the fragmentation of the production capacity (most of the hydroelectric power stations were owned by local or regional utilities who were allowed to set their own prices following the governmental guidelines) led to a limited effect of this centralized environmental management. The electricity prices varied substantially from place to place and the resources management (economic resources) was inefficient due to a lack of competition.[100]

Notwithstanding the pervasive environmental concern in Norway, the reform of the electricity market in Norway was motivated by economic concerns. Academic criticism about the centralized system, where prices were set by the government led to the Electricity Act in 1990 (reform passed on June 29, 1990)[100]. Since the Norwegian market was characterized by government control, this reform constituted a significant departure from the public controlled market organization typical of the Scandinavian economic model. This paved the way for a shift from a centralized macro-planned market to market governance (micro management).

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[98] Per Ove Eikeland, Electricity market liberalization and environmental performance: Norway and the UK*, Energy Policy Review*, Vol. 26, No. 12, p. 917-927
[99] Source Energy Polices of IEA Countries, Norway 1997 Review, IEA
[100] Ulf Hammer, Structuring of the electricity market. A study in the regulation of the coordinating grid functions, Oslo, Norway

Undoubtedly, the reform of the electricity market led to better organization of the supply chain by removing most of the economic inefficiencies attached to the previously centralized production. It reduced the overall excess capacity of the power supply infrastructure [101]. This reform delayed the need for extra power capacity until 1996 (the first dry year) by reorganizing the existing production and distributing it better.

The environmental benefits brought about by the Energy Act were very much a side-effect of the reform, for little attention was paid to either environment concern or any other potential consequences in the course of the regulatory reshuffle. "A minor passage in the law states that an effective electricity market will lead to efficient investment, production and use of the electricity. The Act places the major responsibility for end-use efficiency on the consumers – assumed to make the right choice of whether to consume or not."[98]

## Taxation

Norway has been relying on economic instruments to implement environmental policies for years. This policy approach has been implemented through the use of taxes on products (excise tax, VAT, and $CO_2$ tax). The overall tax level on fossil fuel is amongst the highest in the world. This strategy is part of a more global strategy consisting of progressively shifting the burden of taxation from labor and income towards green taxation levying fees on pollution and environmentally harmful forms of energies and activities.[102]

### Fossil Fuel Taxes

Norwegian fossil fuel taxes are amongst the highest in the world. One of the highest VAT rates (23% in Norway compared to 7% in Canada and a fixed federal-state tax ranging from 2 to 6 cents per liter in the US) combined with the highest and still increasing excise tax make Norwegian gasoline the most expensive gasoline in the OECD countries. Figure 0.1 below compares the price of unleaded gasoline in most OECD countries.[103]

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[101] Norway experienced a halt in new development of hydro-capacity in 1990 and after. Originally the regional licensing system led the local utilities to meet local demand by expanding the hydro-capacity. This turned out to have produced excess capacity at the national level

[102] For more details consult Report to the Stortinget, White Paper No. 29 (1997-98) on Norwegian implementation of the Kyoto Protocol

[103] Source Energy Prices & Taxes, Quarterly Statistics, Third Quarter 1999, IEA

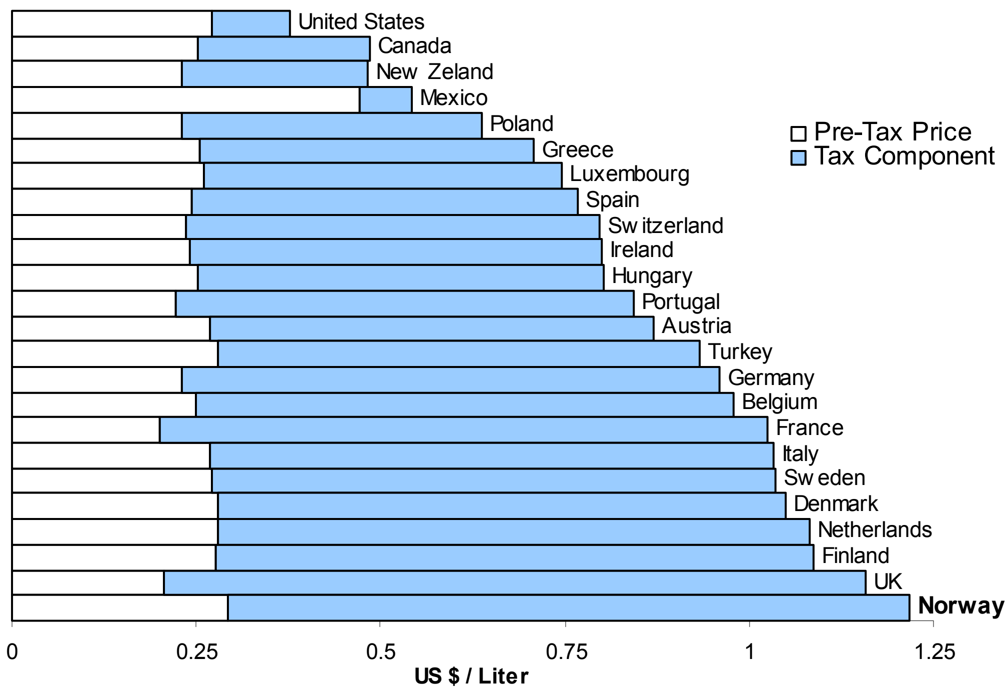


**Figure 0.1. Premium Unleaded Gasoline (RON 95) Prices And Taxes (US$/Liter)[103]**

Like most taxes in Norway, excise taxes are set by the Parliament in the budgetary process. Excise taxes on gasoline have approximately doubled since 1989. Note that excise taxes on automotive diesel for commercial use (not subject to VAT) have skyrocketed by almost a factor of 20 over the last decade (Figure 0.2), while VAT has remained constant. In 2000 gasoline excise taxes alone are equivalent to NOK 1835 (about US$ 210[104]) per ton of $CO_2$.[105]

[104] Exchange Rate used : US$ 1 = NOK 8.605, Source Banque de France, June 2000
[105] Source Energy Prices & Taxes, Quarterly Statistics, Third Quarter 1999, and Report to the Stortinget (Norwegian Parliament) on Norwegian GHG emissions, Executive Summary, 1996 (as a reference for GHG emissions per unit of tax)

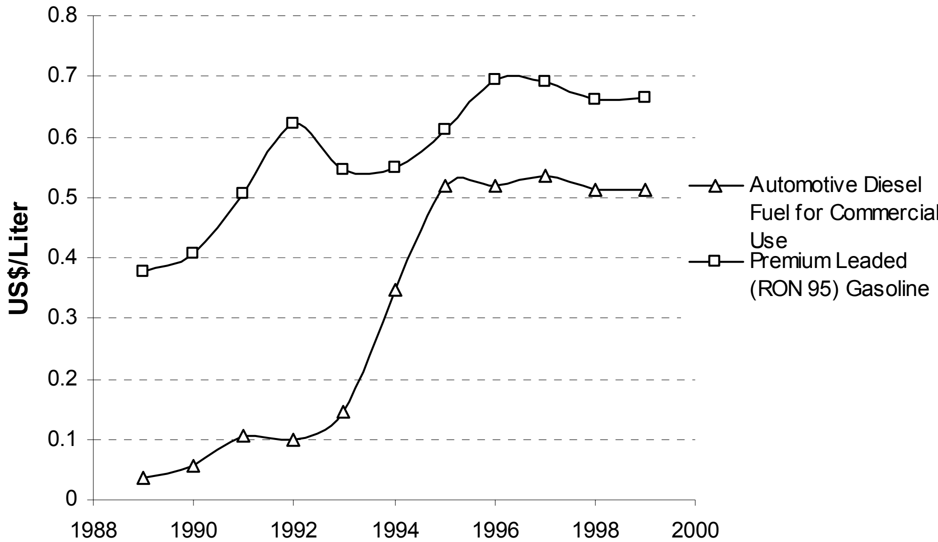


**Figure 0.2. Excise Tax in Norway (US$/Liter)[106]**
*The observed fluctuations stem from fluctuations in exchange rates over the last decade*

## $CO_2$ Tax

In 1991 Norway introduced a comprehensive taxation scheme to specifically tackle $CO_2$ emissions and deter fossil fuel combustion (excise taxes and VAT were part of a more general scheme aimed at income redistribution and social benefit allotment). This system of $CO_2$ tax is notable in that it covers about 60% of national $CO_2$ emissions and applies very high rates. Parliament sets $CO_2$ tax rates on a yearly basis. The rates are regularly reviewed. A $CO_2$ tax was added on top of the existing excise tax levied on gasoline and oil. In 2000 gasoline $CO_2$ taxes alone are equivalent to NOK 398 (about US$ 46[107]) per ton of $CO_2$ (Figure 0.3).

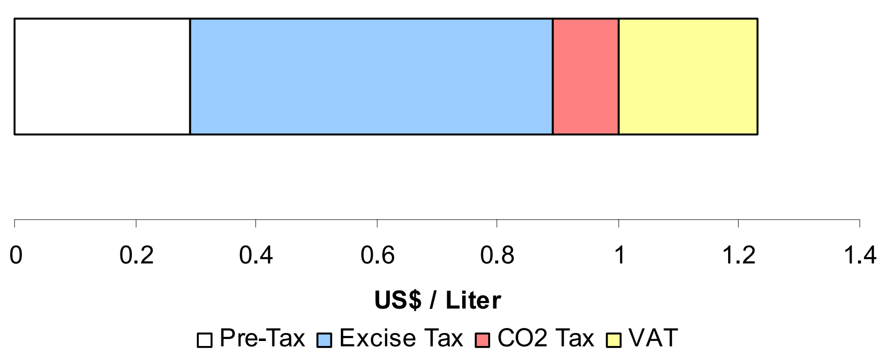


**Figure 0.3. Premium Unleaded Gasoline Price Components in 1999[108]**

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106 Source Energy Prices and Taxes, Quarterly Statistics, Third Quarter 1999, IEA
107 Exchange Rate used : US$ 1 = NOK 8.605, Source Banque de France, June 2000
108 Source Energy Prices & Taxes, Quarterly Statistics, Third Quarter 1999, IEA

Figure 0.4 and Figure 0.5 below[109] show the $CO_2$ tax rate levied on oil activities on the Norwegian continental shelf (coal is consumed on the mainland by the metallurgical sector), in US$ and Norwegian Krone respectively (to distinguish between policy changes and exchange rates fluctuations). Table 0.1 lists the different taxes levied on a sample of petroleum products in Norway.

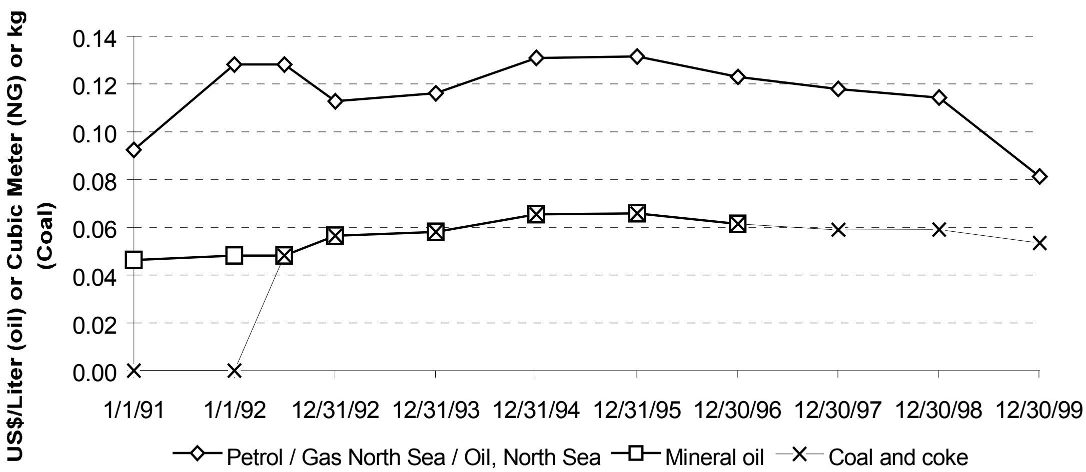


**Figure 0.4. $CO_2$ Tax for the Petroleum Sector (US$)**
*Most of the observed fluctuations stem from fluctuations in exchange rates.*

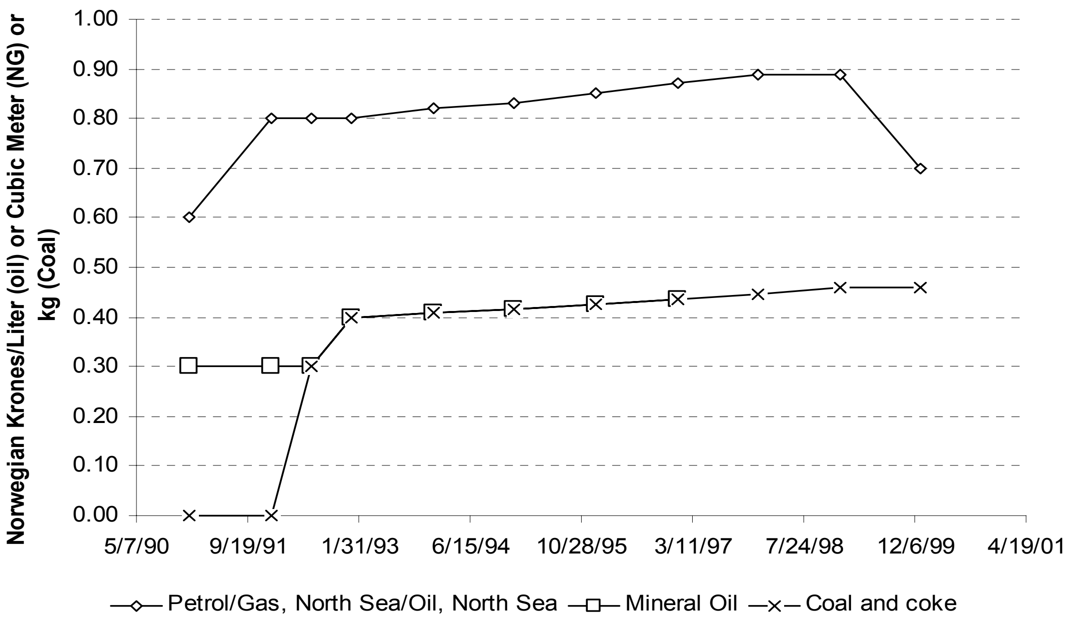


**Figure 0.5. $CO_2$ Tax for the petroleum sector, expressed in Norwegian Krone (NOK)**

109 Source Fact Sheet Norwegian Petroleum Activity, Ministry of Petroleum & Energy, Energy Prices & Taxes, Quarterly Statistics, Third Quarter 1999 and Norway 1990-94 (SFT 96:06) (White Paper)

**Table 0.1. Tax rates for petroleum products, gas, coal and coke in US$ in 2000**[110]

| | Basic Tax | $CO_2$ Tax | Total | $CO_2$ tax per ton $CO_2$ emitted (US$/metric ton of emitted $CO_2$) |
|---|---|---|---|---|
| Unleaded petrol ($/liter) | 0.47 | 0.107 | 0.57 | 46.25 |
| Leaded petrol (<0.05g/l lead, $/liter) | 0.50 | 0.107 | 0.60 | 46.25 |
| Leaded petrol,(>0.05g/l lead, $/liter) | 0.55 | 0.107 | 0.66 | 46.25 |
| Diesel, North Sea ($/liter) | 0.00 | 0.081 | 0.08 | 30.67 |
| Gas, North Sea ($/Sm$^3$) | 0.00 | 0.081 | 0.08 | 34.88 |
| Coal ($/kg) | 0.00 | 0.053 | 0.05 | 22.00 |
| Coke ($/kg) | 0.00 | 0.053 | 0.05 | 16.71 |

## Historical review of green taxes in Norway

In the 1970s command-and-control policies and subsidies for cleaner industrial equipment were the primary tools at the disposal of the Norwegian government to implement environmental policies. However, this Keynesian approach that prevailed in most OECD countries after the oil crises lost its backing at the start of the 1980s when pure environmental concerns were then perceived as obstacles to economic growth and the national efficiency.

In the mid 1980s the Brundtland commission from the United Nations Environmental Program constituted a departure from the laissez-faire “policy consensus”. Its report advocated nothing less than the complete reshaping of environment polices in the world by emphasizing the need to consider “sustainability” as the corner-stone of any economic policy. Led by a prominent Norwegian political leader, this Commission has had a considerable impact on the Norwegian political spectrum. Environmental taxation emerged as a new environmental policy approach and was backed by the Brundtland Report and post-Keynesian economists. Green taxation was advocated to shift the burden of taxation from Labour to harmful forms of energy.

Following proposals by the center-right-Syse government of $CO_2$ taxes on mineral oil and gasoline in 1991, the Labour government implemented a $CO_2$ tax on these items and extended it to oil and gas consumption by the petroleum sector off-shore.[111] It is worth noting that the tax levels were not based on the carbon contents. This was considered to be an environmental inconsistency but was said to be a first step in the “right” direction. These taxes faced fierce hostility from the Conservative parties in Parliament.[112]

$CO_2$ tax exemptions were granted since neither the pulp & paper industries nor the metallurgical sector were covered by the $CO_2$ tax. The aforementioned environmental inconsistency was now

[110] Source Energy Prices & Taxes, third quarter 1999; Report to the Stortinget on Norwegian GHG emissions, Executive Summary. Exchange Rate used : US$ 1 = NOK 8.605, Source Banque de France, June 2000
[111] An initial tax of NOK 0.6 per m$^3$ of natural gas or liter of oil consumed by the off-shore petroleum industry (US$0.09) was then introduced
[112] The Norwegian Parliament sets all the tax levels and keeps the initiative to introduce new ones either after proposals from the government or on its own

compounded by an economic inconsistency since these industries were the most energy intensive in Norway.

In 1996 the metallurgical sector emitted 11% of Norway GHG and it represented 1.1% of GDP and 9.6% of the Norwegian total exports.[113] Its manning level had been steadily decreasing since the 1970s and the sector employed less than 20,000 people in 1990.[114]

Sjur Kasa[115] underlines at least five reasons for this tax treatment discrepancy. Social and political barriers are mostly liable for this tax inequality:

1. Historically, the exempted industries have long been very well organized. Thanks to their active and powerful lobbying they had been able to secure favorable electricity rates for decades.

2. These energy-intensive industries are located in rural and often remote places and still dominate the local economic activity. Any $CO_2$ tax would severely affect their competitiveness and put entire rural communities on the dole. These industries have long wielded the relocation threat to curb any political will to change the status quo. Moreover the metallurgical sector (which includes Norsk Hydro) had plans to expand aluminum and electricity production by resorting to new gas-fired power plants.

3. The Norwegian system of political representation gives a net advantage to rural areas.

4. These "big businesses" have been successful in mobilizing the conservative wing against any attempt to reform.

5. The Norwegian Confederation of Trade Unions (LO) has long dominated these industries.[116] LO rejected any broadening of the $CO_2$ tax on the basis of relative weight and political influence inside the trade union. The Labour Party (ruling from 1990 to 1997) had many close and strong links to LO and was extremely vulnerable to trade union pressure when conducting its economic policy at the beginning of the 1990s (income moderation was a political vow to regain international competitiveness after the 1990 recession in Norway).[117] Trade unions and energy intensive lobbying efforts managed to keep the status quo alive and to avoid any reform of the $CO_2$ tax until 1997, despite governmental reform attempts over that period from 1994 to 1998.

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[113] Godal, O. Oslo: Center for International Climate and Environmental Research, CICERO Working paper 1998:13
[114] Godal, O. CICERO Working paper 1998:6
[115] Most of the facts related here have been borrowed from Sjur Kasa's CICERO Policy paper(1999:5). I am very much indebted to his work on green taxation in Norway, especially Sjur Kasa (1999): *Social and Political barriers to green tax reform*. Oslo: Center for International Climate and Environmental Research, CICERO Policy Note paper 1999:5
[116] The industrial branch of LO had approximately 200,000 (April 1999)members and dominated the other branches (the Service branch would have benefited from the extension of the $CO_2$ tax, but it had "only" 100,000 members). Refer to 115
[117] Note that this approach had been adopted in the Netherlands as well at the same time. Schumpeterian arguments seem to contradict the economic hopes that were then the key-stone of economic policies in the Nordic countries in the 1990s. Refer to Alfred Kleinknecht, *Is labor market flexibility harmful to innovation?*, Cambridge Journal of Economics 1998, 22, 387-396

1997 constituted a turning point. That year, general elections brought a new minority coalition (called "Center Government" and composed of the Center Party, the Christian Democratic and the Liberal Party [118]) to power. This coalition was much less linked to the major unions and the big industries that had paralyzed the previous government. Other groups of interests, especially small businesses heavily dependent on distribution, had close links to the Liberal Party. A limited $CO_2$ tax was affecting them in a disproportional manner given its high rate on gasoline.[119] Also since the $CO_2$ tax was to alleviate labor taxes, its broadening would have reduced labor costs for many small and medium-sized businesses.

The legislative agenda did not allow for governmental initiatives in that field to appear before the Parliament before 1998. In the meantime the Kyoto Protocol was signed. It greatly helped the minority government to sustain its position on the $CO_2$ tax. In April 1998 the government proposed a NOK 100 tax (US$ 13.25) per ton of $CO_2$ covering the previously exempted sectors.[120] The energy intensive industries counter proposed a domestic scheme for tradable $CO_2$ quotas. They launched simultaneously a very intensive and aggressive lobbying and political campaign targeting representatives from rural areas that were the most dependant on energy intensive industries. In June 1998 the governmental proposal was defeated by the Stortinget (Norwegian Parliament). In March 2000 the "Center Government" fell after Parliament passed a vote of no confidence following its refusal to grant the building of the two gas-fired power plants by the Naturkraft consortium.

## A Political Explanation

The relative economic weight of the energy-intensive sector alone is not an explanation for its success to prevent a $CO_2$ tax broadening, since it even defeated a government. Other factors might be considered.

According to Sjur Kasa "the exceptional strength of the links between the mainland emission industry organizations (NHO) and the Norwegian Confederation of Trade Unions (LO), as well as the strength of their links to the most important political parties and parts of the government bureaucracy are very important explanatory elements."[115]

Kasa suggests that the efficient forces behind the blockage of attempts to broaden the $CO_2$ tax may be described as a "policy community". "Policy communities are highly cohesive groups of actors characterized by a limited amount of members (NHO, LO, bureaucracy), a high level of interaction and high agreement about values, a relative balance of power between its members as well a close relationship to government and legislature".[121] A common industrial culture

[118] Senterpartiet, Kristelig Folkeparti and Venstre
[119] NOK 380 tax (US$ 48.50) per ton of $CO_2$ on gasoline, and NOK 170 tax (US$ 23) per ton of $CO_2$ on auto diesel. Exchange rates are averaged 1999 rates
[120] Report to the Stortinget, White Paper to the Norwegian Parliament No.29 (1997-98) on Norwegian implementation of the Kyoto Protocol
[121] Marsh, D. and R.A.W. Rhodes: *Policy networks in British Government*, 1992, Oxford University Press

dominated and welded together all the major stakeholders involved in the decision making process. The roots of this culture go deep in the Norwegian industrial history and organization. Historically the central government settled and organized the energy intensive sector during the post war era. The bureaucracy is undoubtedly still closely linked to that sector which benefits from a privileged access to the circle of power.[122] These close ties raise questions about the capture of the regulatory process by the energy intensive industrial interests.

The 1997 ruling minority coalition (the "Center Government") was less penetrated by this "policy community"[123] and its closer links to small businesses made it less prone to act in the best direct interests of the big industry. Consequently it tried to expand the $CO_2$ tax coverage to all the previously exempted sectors. It was defeated by the Norwegian Parliament who was undoubtedly under the strong political influence of this "policy community".

It is worth noting that the $CO_2$ tax levied on oil activity on the Norwegian shelf has declined for the first time in a decade this year (23% decline in 2000 compared to 1999). According to Mrs. Hilde Frafjord-Johnson, former Minister of Development in the Bondevik government, this tax cut is the result of successful lobbying of the oil industry combined with pressures from trade unions (who were themselves encouraged by the oil companies). The Norwegians were not used to layoffs in the oil sector. The threat of layoffs in that sector was sufficient to make the previous government do something symbolic. No significant layoffs have been reported to this day.

The oil industry has been using the threat of decreasing investment on the Norwegian continental shelf for years. The "tax barrier" was to be alleviated for the oil companies to pursue their investment efforts and sustain their current level of production. Some executives in the oil sector acknowledged that the previous tax level was not sufficiently high to deter oil companies from pursuing their investments on the Norwegian continental shelf.

## The National Norwegian GHG Emissions Trading System

The Norwegian officials are well aware of the very constraining conditions regarding GHG emissions reductions in Norway. The country cannot easily switch to natural gas and scrap coal-fired power plants like UK. Consequently emissions trading as a way to reduce overall GHG emissions is rather well perceived at the political level in Norway. The Norwegian Parliament (Stortinget) expressed its clear interest in developing a comprehensive cap and trade system for Norway to comply with its commitment made at the Kyoto summit in 1998. On 23 October 1998 a "Quota commission" was appointed by Royal Decree to draw up a national trading system for greenhouse gases using quotas and based on the Kyoto Protocol.[124]

On 17 December 1999 the Commission delivered its report to the Ministry of the Environment. It recommended that an extensive national quota system be introduced with regulation by quotas starting in 2008. This system is to cover 88% of all Norwegian GHG emissions.

[122] The industry group Norsk Hydro is owned at 43.8% by the Norwegian State (source Norsk Hydro), the oil company Statoil is 100% state owned
[123] The Ministry of Finance was inaccessible to the industry lobby at that time. Refer to 115
[124] Source Report T-1328 A quota system for greenhouse gases, Minister of Environment, Norway

The Commission decided that "$N_2O$ or $CH_4$ from combustion, $CO_2$ from agricultural liming and from solvents, $CH_4$ and $N_2O$ from agriculture, HFCs/PFCs as substitutes for CFCs and halons, and $SF_6$ other than from magnesium production emissions are not suitable for the time being, but that their inclusion should be considered and/or actively sought."[124]

This proposed national system is far more comprehensive than the trade system proposed by the European Commission in its Green Paper released in March 2000 (system limited to large industrial sources). It is expected to be hooked up to a forthcoming international trading system if such a system were to be put in place.

Nevertheless, the supplementary clause of the Kyoto Protocol has not yet been seriously debated at the political level in Norway. A popular symbolic threshold often cited is 50%, meaning that Norway "should" do at least 50% of its reductions "at home". This stand is widespread, irrespective of the very high costs Norway would endure if it were to effectively reduce its national GHG emissions.

# Chapter 5

# Gas-Fired Power Plants in Norway

## GAS-FIRED PLANTS IN NORWAY

### Historical perspective

Proposals involving gas-fired power plants in Norway have been around for more than 15 years.[125] Poor economics and political opposition have put a halt to all these projects in the past. The major reform of the electricity market that took place in Norway in 1991 completely reorganized the Norwegian electricity market and drastically modified the political and economic environment. Before the electricity market liberalization, prices were set by the government. The price was set so as to meet the costs of the least efficient power-producing units (the least effective dams). Consequently no gas power station would get the governmental green light since all the needs were met by the current hydro-capacity, even at the expense of economic efficiency. The reform instigated new rules governing the definition of electricity generation supply (less politically influenced and more market-oriented) and it may provide new opportunities for gas-fired power plants in Norway.

#### The 1990 Energy Act: the reform of the electricity market

[125] In 1984 Norsk Hydro had plans for a 700 $MW_e$ gas-fired power plant. Overcapacity in power production in Norway put an end to this project. Source: Olav Kaarstad, Statoil, Interview August 2000

Historically the electricity market in Norway has been characterized by a high number of small productive entities owned and developed by local municipalities.[126] Essentially the electricity structure was publicly owned and scattered. Licenses were granted on a regional basis. The prices were set by the Norwegian government for each type of consumers (large industries, households, etc.).

In 1990 Norway was the second country in Europe (after the United Kingdom in 1989) to reform and liberalize its electricity supply market. This reform constituted a significant departure from the public controlled market organization that epitomized the Scandinavian economic model. This paved the way from a centralized macro-planned market-to-market governance (micro management). This reform was essentially an economic reform. The system of politically set prices and regional licenses came under their fire and brought about this major reform[127].

The key events in the reform process were:

1. An Energy commission was appointed in 1980 to review the electricity regulatory framework. In 1985 it released a first proposal recommending the merger of the scattered supply companies into 20 vertically integrated companies. In April 1989 the Brundtland government (Labour Party) expressed its intention to use this report as a basis for the looming future reforms of the Norwegian electricity market. A U-turn in governmental policy left aside this first centralizing reform two months later (in the wake of the UK market liberalization in 1989).

2. In September 1989 the Brundtland government proposed a new reform advocating some market based approaches.

3. In October 1989 a new coalition (Center Party / Conservative / Christian Democratic) came to power. The new Energy minister (former executive from the energy consortium Norsk Hydro) withdrew the energy law considering the reform too much limited.

4. In March 1990 a new reform proposal came before Stortinget (Norwegian Parliament). This new law was much more market oriented and was passed on June 29, 1990. Despite the return of the Labour Party to power in November 1990 (the Labour Party had expressed its hostility to this market-oriented reform previously), the reform was implemented as passed by the Parliament.[128]

In 1991, Norway, Denmark, Sweden, and Finland put in place a Scandinavian electricity exchange, Stattnet Marked. In 1996 Stattnet Marked was enlarged to a bi-national power exchange covering both the Norwegian and the Swedish power markets. At the same occasion the exchange changed its name to Nordpool. This exchange also accepts third party suppliers from Finland and Denmark. As a result, electricity prices have been reduced.

[126] Ulf Hammer, Structuring of the electricity market. A study in the regulation of the coordinating grid functions

[127] Source Per Ove Eikeland, Electricity market liberalization and environmental performance: Norway and UK, *Energy Policy, Vol. 26, No 12, p 917-927*

[128] Source Atle Midttun, Electricity liberalization policies in Norway and Sweden, *Energy Policy, Vol. 24, No 1, p55*

## Electricity trade as an "Environment Protection"

The Electricity reform rationalized power production in the Scandinavian countries by geographically reallocating production sources and consumption timing. "The Norwegian industry and the Minister of Energy have praised this trade as beneficial not only commercially, but also environmentally, by claiming that Norwegian hydropower would replace coal-based capacity abroad."[127] The Labour government gave prominence to environmental beneficial side-effects of power trade to have this major reform passed and accepted by the Labour party and its constituency. Norway was about to become the green power supplier for the rest of Scandinavia. The overall Scandinavian emissions would be reduced since some of its neighboring countries (especially Denmark who has been the main peak-load supplier for Norway in 1996) were producing "dirty" power from coal-fired power plants.[129]

In the 1990s, forecasting the steady increase in domestic electricity demand, the Norwegian electricity production industry proposed the construction of gas-fired power plants in Norway. Naturkraft (power of nature in Norwegian) was the first project of this nature. It involved the construction of gas-fired power plants. It has faced fierce political hostility, especially from the environmental groups, since its public release in 1994. The opponents of new gas-fired power plants emphasized the increase in both the Norwegian GHG and $NO_x$[130] emissions such a project would bring about. The project stood still until 1996, which constituted a turning point.

The year 1996 was an extraordinarily dry year in Norway leading the country to massively import power from Denmark. While continuously increasing power consumption and highly variable domestic production have sporadically imposed net electricity imports, the magnitude of electricity imports in 1996 was unprecedented. The Ministry of Energy reversed itself and now argued then that trade was threatening the environment, since Norway may well have to import more and more coal-based electricity given its increasing demand, its expansion-constrained hydro capacity and its high level of integration in the Scandinavian electricity market. Since river development was constrained by the significant extent of protected suitable areas, expanding the domestic electricity supply by resorting to natural gas-based capacity made a return in the political agendas that year. As a result 1996 renewed the interest in the Naturkraft project.

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[129] It is worth noting this constitutes a new approach within the Kyoto Protocol, which sets national targets, but not a new approach in Norway. Norway has always advocated a global approach for global environment threat (Acid rains in Norway originated UK essentially. Norway successfully instigated international agreements to cut $SO_2$ emissions) "Norway's climate policy is to ensure that targets are met at the lowest possible cost in society, through an international strategy which seeks to find the most cost effective solutions for all countries, sectors, and greenhouse gases, considered jointly". Source: Energy Policies of IEA Countries, Norway 1997 Review, International Energy Agency

[130] Remember that Norway has been suffering from acid rains for decades and has been an early active proponent of international regulations to cut $SO_2$ emissions

## The Naturkraft Project

### First Stage

In 1994 the industrial company Norsk Hydro, the state-owned oil company Statoil, and the state-owned electric utility Statkraft formed the Naturkraft consortium. Naturkraft proposed the construction of gas-fired power capacity to respond to increasing electricity consumption in Norway. In early 1997, the government (the Labour Party was then the ruling party) supported by a majority vote in the Stortinget gave its agreement to the construction of two large gas-fired power plants by the consortium Naturkraft.[127]

Naturkraft was pursuing plans to build these two gas-fired power stations in association with the pipeline landfalls (Figure 0.1, Figure 0.2) at Karstoe, north of Stavanger, and Kollsnes, near Bergen.[131] These relatively remote locations had been chosen for their closeness to natural gas fields (hence gas transportation costs would be minimized). These two gas-fired power plants were expected to emit a total of 2.2 million tons of $CO_2$ a year.[132]


**Figure 0.1. Map of Norway showing potential sites for the Naturkraft power plants**

[131] Source: AFP/FT
[132] Source GRIDA Arendal, UNEP

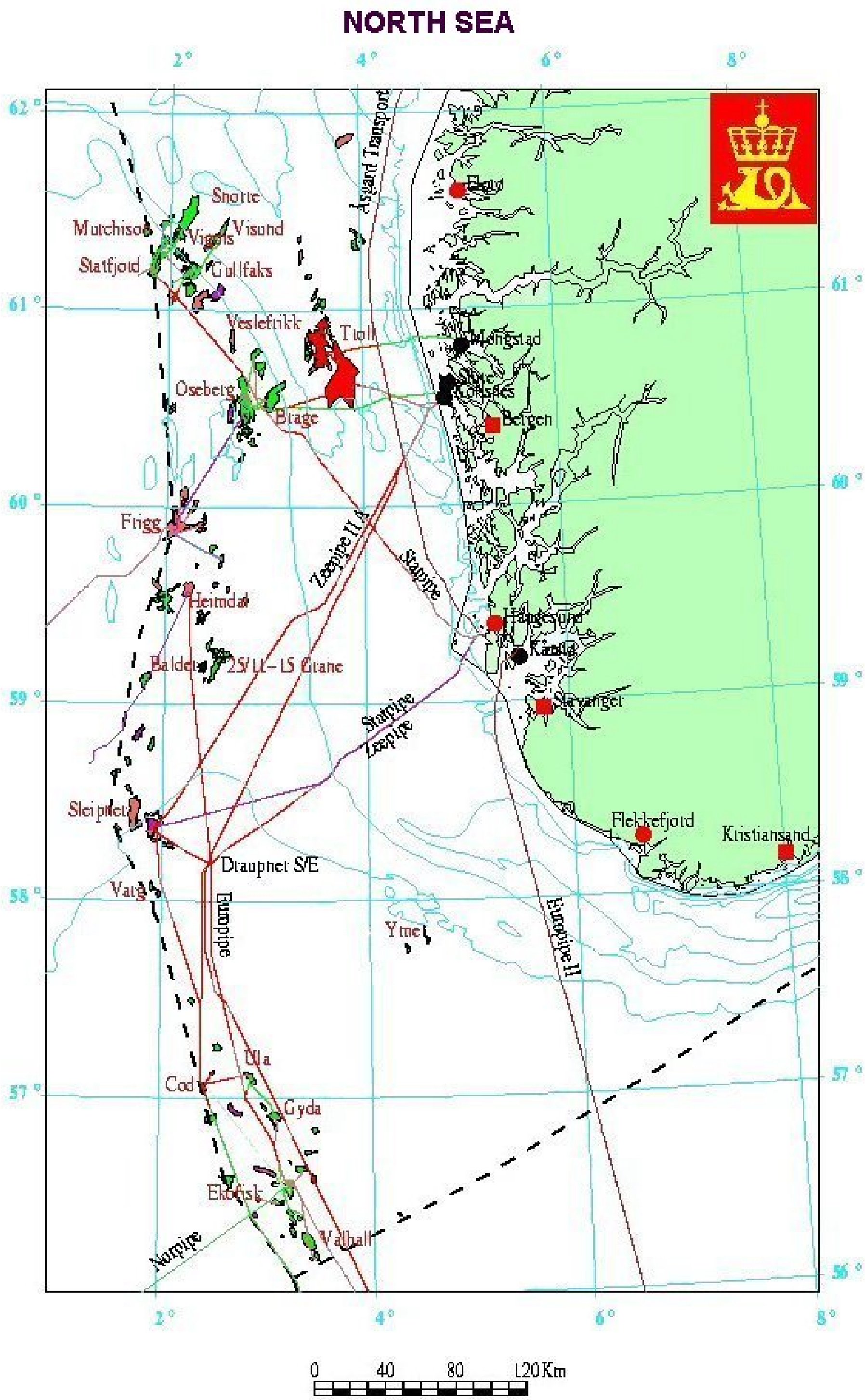


**Figure 0.2. Oil fields in North Sea**[133]

*Main gas oil and natural gas pipes in the North Sea. The two gas fired power plants were to be located near the gas terminals at Kollsnes and Kåstoø (near the outlet of Statpipe and SeepipeIIA respectively).*

[133] Source Norwegian Petroleum Directorate

## Second stage

The 1997 General Election brought to power a new minority coalition. This “Center Government”[134] had expressed its opposition to these plants and managed to delay the granting of emissions licenses for months.[127]

By the end of 1997, the Kyoto Protocol forced the Norwegian authorities to question the rationale behind the construction of the two plants. Since Norway was already way behind its Kyoto targets, the two gas-fired plants would make the meeting of the targets even more difficult, adding an extra 5% excess to 1990 baseline. This is equivalent to emissions produced by 700,000 cars, half the Norwegian fleet.[135]

In spring 1998, Norsk Hydro, a member of the Naturkraft consortium, took everybody by surprise. It released its own plan for a project called Hydrokraft (literally “power from hydrogen” in Norwegian), featuring "$CO_2$-free" power plants[127] (see Section 5.3). This caused Naturkraft to lose all its political backing since Norsk Hydro was proposing to meet the same energy demand with essentially no greenhouse gas emissions.

## Last Stage

In January 1999, Naturkraft was granted an emissions permit to build two gas-fired power plants in western Norway by SFT (Statens Foruensningstilsyn, the Norwegian counterpart of the US Environmental Protection Agency), but under strong restrictions on releases of greenhouse gases and $NO_x$. Its GHG emissions are to be reduced by 90% over the original application. Nitrogen oxide emissions must be almost halved (from 500 t/year down to 300 t/year). Naturkraft said it might try to meet the demands by buying $CO_2$ emissions quotas from another country.

The Pollution Control Authority based the strict emissions requirements on Norway's greenhouse gas targets agreed at the Kyoto meeting on climate change in 1997. That meeting also opened the door for trading in emissions quotas, a strategy Naturkraft said it is considering and that is allowed by SFT.[136] The company decided to postpone its final investment decision by two years expecting a clearer international regulatory framework to emerge in the meantime.[137]

The restrictions imposed on Naturkraft concerning its emissions have brought this project to a standstill. Naturkraft has proposed to offset its excess $NO_x$ emissions by reducing $NO_x$ emissions of Norwegian ferries. It has been calculated that equipping 6 ferries with gas-fired engines would suffice to make-up for the two power plants emissions. This proposal has been probed by lawyers and political executives. It is expected to comply with Norway’s air law.

[134] Composed of the Center Party, the Christian Democratic and the Liberal Party, Senterpartiet, Kristelig Folkeparti and Venstre
[135] Source Alexander’s Gas & Oil Connections
[136] Source The Norwegian Pollution Control Authority, 99-01-22
[137] Source *Global Environmental Change Report*, Vol. XI, No 18, 24 September 1999

It is worth noting that the Labour Party (who came back to power after the Kjell Magne Bondevik's minority government resigned) expressed its preferences for this offsetting mechanism. Moreover it officially consider $NO_x$ emissions to be the main obstacle for Naturkraft to go ahead. Solving this difficulty is likely to give the project its needed political green light. The official Labour Party position is now to circumscribe the Naturkraft controversy to this technical issue, whereas all the other involved parties (former government, environmentalists, industry) still argues that all the Naturkraft controversy revolves around GHG emissions.[138]

## Future Development of the Naturkraft Project

- ***Naturkraft is Standing Still***

  When Norsk Hydro released its intention to launch its own Hydrokraft project, it blew away any political support behind Naturkraft. Natural gas fired capacity was originally said to contribute to lower emissions abroad (especially Denmark) but it will undoubtedly increase GHG emissions in Norway since 99% of its electricity is based upon hydro electricity. Moreover the new coal-plants installed in Denmark and Sweden combine heat and power technologies so as to reuse the heat generated by the fuel combustion in the turbines during the electricity generation for district heating (heating of neighboring households or commercial premises). Whereas the sites for the two natural gas fired power plants (the Naturkraft project) in Norway were chosen for their proximity to natural gas fields. They ended up in rather remote locations where there is little demand for cogenerated heat due to a lack of local population.139

  Scant analyses have been conducted so far on this combined heating but this could seriously question the asserted argument that the overall emissions per unit of useful energy are significantly lower in the gas-fired power plants in Norway than in the coal-fired cogeneration plants in Denmark.

- ***Political and judicial development***

  The SFT decision to issue permits is currently under review by the ruling labor government. It is expected by almost everybody that the SFT decision will be broken down. Naturkraft is expecting to get formal approval for the two gas-fired power plants. Nevertheless such a decision by SFT is bound to be brought to court by environmental NGOs.[140] The final outcome is not determined yet.

- ***Industrial Development***

  The current price of electricity on the wholesale Nordic market would not allow for a project such as Naturkraft to be profitable today (Figure 0.3). Naturkraft may not have fully considered or expected the decline of electricity prices in the wake of the electricity

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[138] Source: interview with Mr. Øyvind Slåke, political advisor for energy questions for the Labour Party group in Parliament

[139] Source Per Ove Eikeland, Electricity market liberalization and environmental performance: Norway and UK, *Energy Policy, Vol. 26, No 12, p 917-927*

[140] Bellona and Friends of the Earth have expressed their will to stop Naturkraft by all possible legal means at their disposal

market liberalization in 1994.[141] Nevertheless the expected retirement of power plants in Europe combined with the Kyoto incentive to switch to natural gas instead of coal may make this project more economically attractive in the future.

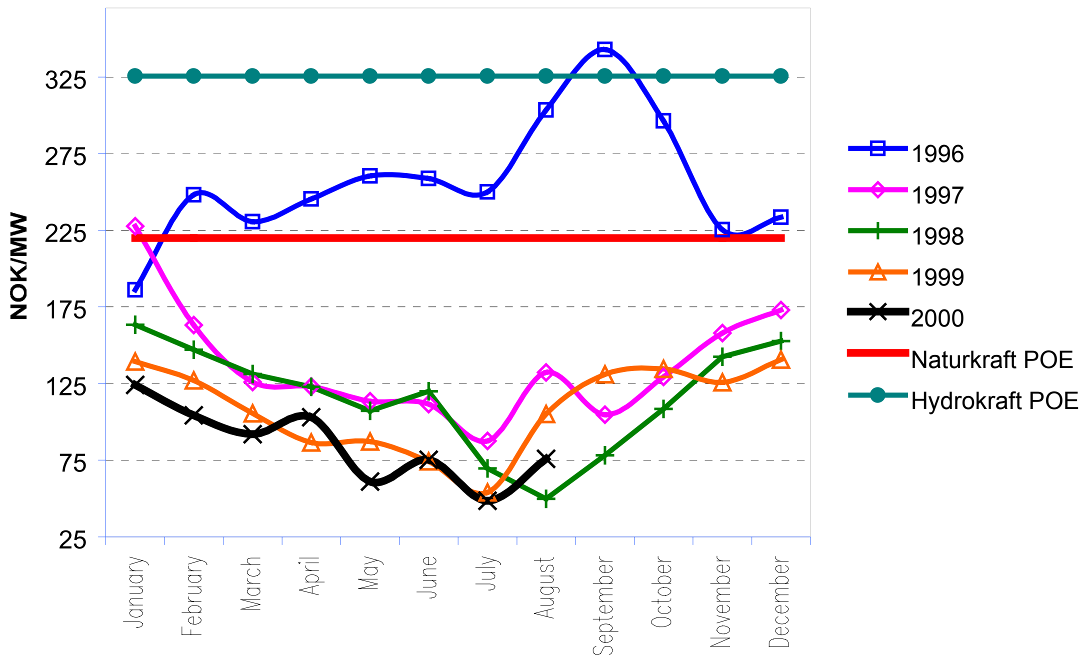


**Figure 0.3. Wholesale electricity spot price in Oslo on the Nordpool market** *(smoothed variations)*

## The Hydrokraft project: electricity generation, enhanced oil recovery and carbon sequestration

### Enhanced oil recovery and Carbon sequestration

Enhanced oil recovery (EOR) techniques include the use of water, natural gas, nitrogen, or $CO_2$. On the Norwegian shelf, water and natural gas have been primarily used.[142] In 1997, a total of 22.6 billion $Sm^3$ of natural gas was injected for this purpose in Norway. This is equivalent to 53% of the annual Norwegian gas export. The volume is expected to increase to 40 billion $Sm^3$. $CO_2$ has been used for enhanced oil recovery at some 70 oil fields in the USA. It is especially well suited to recover viscous oil, as $CO_2$ greatly reduces its viscosity.

Carbon sequestration is a promising technique to reduce GHG emissions. In the Scandinavian area since underneath the Norwegian seabed, it may be possible to deposit the amount of $CO_2$

[141] Its proposed two gas-fired power plants are competing with older and amortized capacity abroad
[142] Using a compressible fluid is often preferred because the pressure into the reservoirs is more stable. Nitrogen might be used for this purpose as well. The choice of the fluid is conditioned by its physical and chemical properties, by the physical and chemical properties of the oil in place, and by the shape of the reservoir

generated by every power plant in Western Europe through the next 500 years. [143] It is estimated that Norway controls about two thirds of the total European $CO_2$ storage capacity offshore.[143]

Carbon sequestration has been successfully implemented in Norway to reduce GHG emissions. The Norwegian oil company Statoil has been depositing one million ton of $CO_2$ a year at the Sleipner field[143] since 1996 in response to a carbon tax levied by the Norwegian government on the continental shelf. Instead of flaring the non-commercial gas produced at that field (it contained too much $CO_2$ to be sold as is), Statoil has built a platform devoted to processing the non-commercial gas, and reinjecting the concentrated $CO_2$ into the Utsira Formation, an underground saline aquifer (Figure 0.4).

EOR and carbon sequestration can be coupled in order to make an economic use of the produced $CO_2$, instead of reinjecting it in an aquifer. In that case it is possible to mitigate climate change while getting credit for EOR use of $CO_2$. This is exactly what Norsk Hydro envisioned when it proposed its Hydrokraft project in 1998.

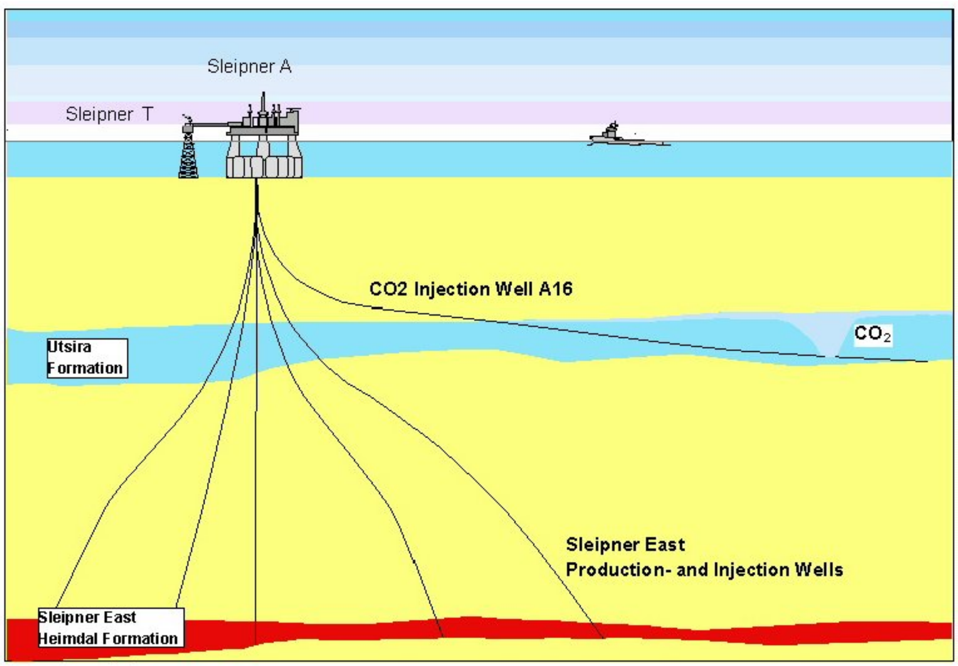


**Figure 0.4. Sleipner aquifer $CO_2$ storage[144]**

[143] A study by the European Commission made in 1996 shows that the capacity for depositing $CO_2$ in Europe is about 806 billion metric tons. The greater part of this capacity is located under the Norwegian continental shelf. It is possible to deposit 470 billion metric tons in aquifers, and an extra 10.3 billion metric tons in depleted oil and gas reservoirs. Source Bellona Norway
[144] Source courtesy of Statoil

Electricity Generation by Hydrokraft

In spring 1998, Norsk Hydro announced a project to build a hydrogen fueled power plant in Karmøy[145], on the west coast: the Hydrokraft project. The process involves reforming and processing natural gas to produce $CO_2$ and hydrogen. The hydrogen-rich fuel[146] is then burned with air in modified combined cycle gas turbines to produce electricity. Norsk Hydro wants to reuse the separated $CO_2$ for enhanced oil recovery[147]. The project is dimensioned to meet the EOR $CO_2$ requirements in the Grane oil field[148] (Figure 0.6) and is expected to reduce $CO_2$ emissions by 90%[149] compared to conventional gas-fired power plants.

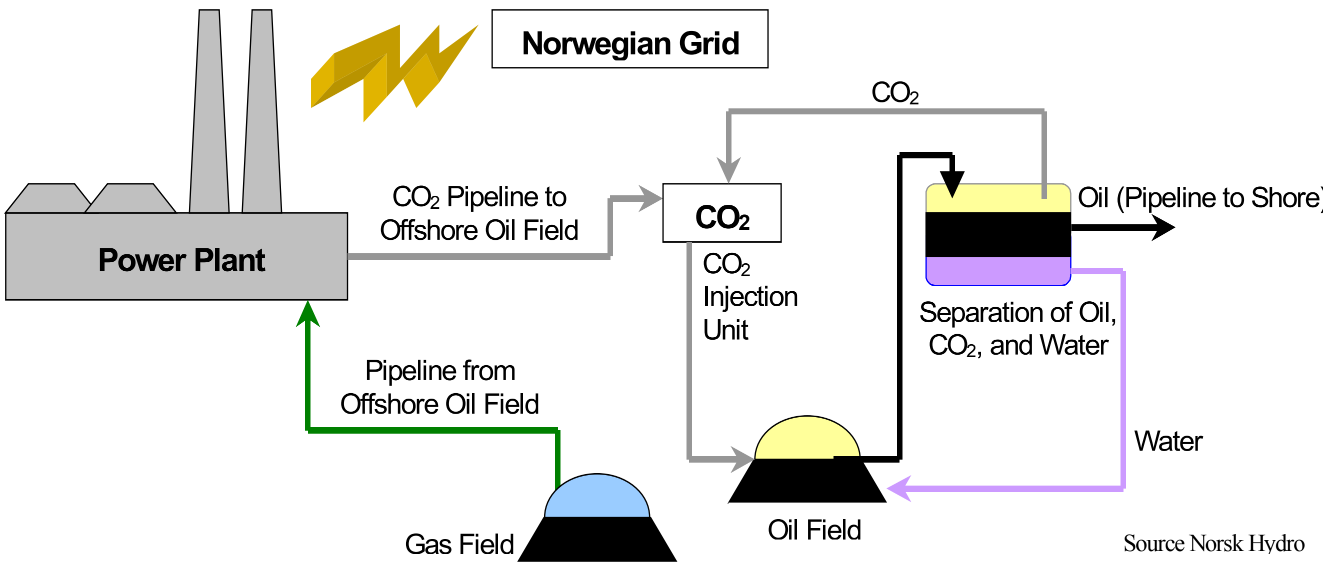


**Figure 0.5. Sketch of Hydrokraft**
*This project features a 1200 $MW_e$ gas-fired power plant and supplying an oil field with $CO_2$ for enhanced oil recovery*

[145] The choice of Karmøy was dictated by the proximity of an aluminum plant Norsk Hydro was operating there. The two facilities could be integrated with respect to energy. Source Bellona. Refer to footnote [149]
[146] The fuel is expected to be composed of about 54% $H_2$, 42% $N_2$, and 3% $CH_4$. Source Bellona
[147] The $CO_2$ is compressed and injected into oil wells, raising pressure in the wells and increasing output
[148] Grane is a shallow field containing viscous oil. It has been discovered in 1991. The plan for development and operation of the deposit was submitted in December 1999
[149] Even if in principle almost all of the CO2 can be removed, energy efficiency makes it optimal to limit the purification process to 90%. Source: Green Heat and Power, Eco-effective Energy Solutions in the 21$^{st}$ Century, Bellona Report No 3:1999, T. Palm, C. Buch, B. Kruse, E. Sauar

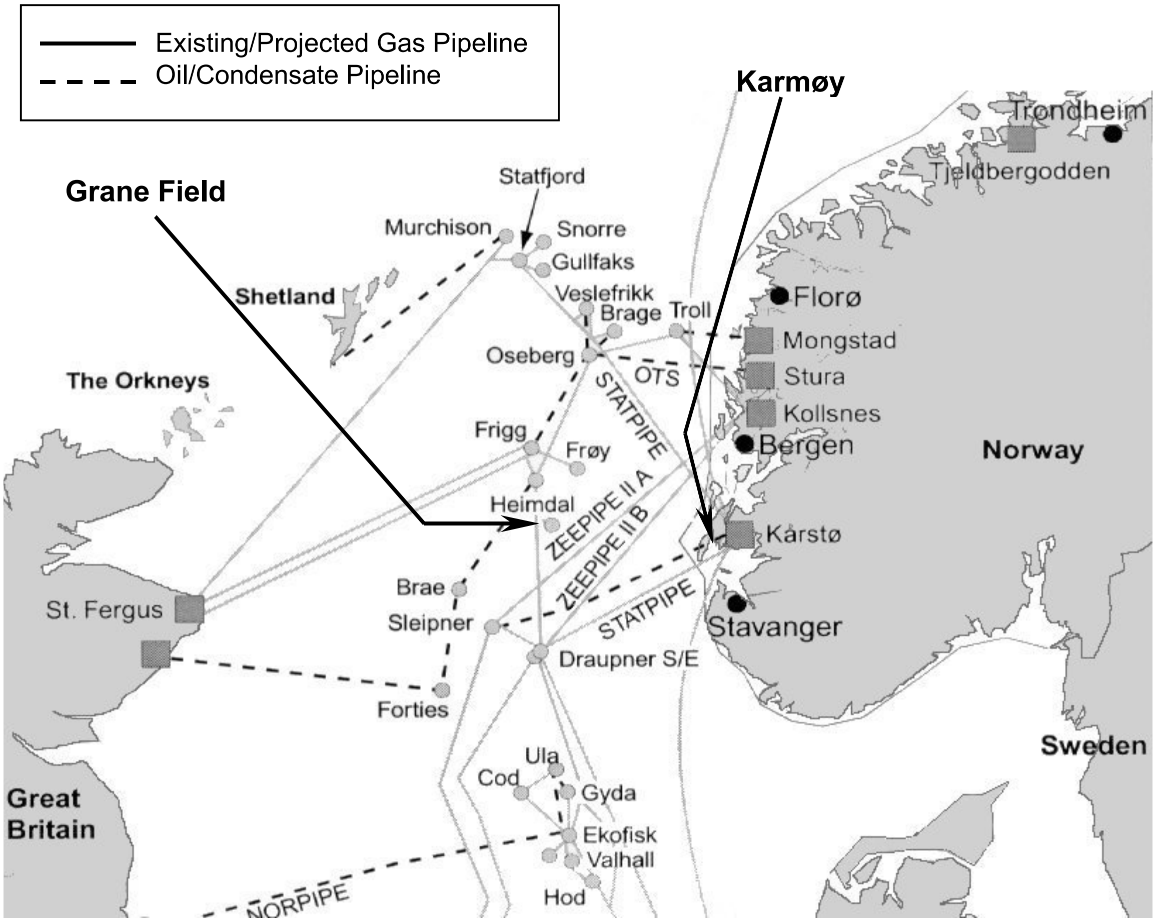


**Figure 0.6. Location of the Grane field.**
*This field has been discovered in 1991*

Norsk Hydro's experience in natural gas reforming stems from its industrial production of ammonia that is used as feedstock for its fertilizer business.[150] Bridging the oil and fertilizer activities within Norsk Hydro constituted a very attractive opportunity of economies of scope. For the first time $CO_2$ sequestration "kills two birds with one stone", since it was used in the hope of enjoying a new business opportunity while limiting GHG emissions.

One of the technical challenges of the Hydrokraft project is that the use of hydrogen instead of natural gas tends to lead to higher $NO_x$ emissions.[151] Nevertheless, General Electric, the gas turbine supplier, had been confident in his ability to supply a well functioning turbine modified to meet the $NO_x$ emissions standards set by the Norwegian government. By the end of 1999, laboratory tests conducted by GE showed that the proposed modified turbines complied with

[150] Ammoniac is an essential reactant in the process of many fertilizers. The reforming of natural gas produces $H_2$ which then reacts with nitrogen from air to produce $NH_3$

[151] The use of modified gas turbines was necessary. Norsk Hydro wants to utilize air in the reforming process, leading to high nitrogen content in the fuel. The presence of nitrogen has a cooling effect in the turbine reducing the flammability of the hydrogen rich fuel and allowing for reduced $NO_x$.emissions

$NO_x$ emissions levels (10 ppm). To achieve this, about 10% of the $CO_2$ is to be left in the hydrogen-rich fuel.[152]

The amount of $CO_2$ needed for enhanced oil recovery (EOR) varies with time. However, the power plant supplies $CO_2$ in a linear fashion (Figure 0.7). The Hydrokraft $CO_2$ production pattern does not seem to fit the $CO_2$ needs for enhanced oil recovery. Hydrokraft has not resolved this timing discrepancy yet.

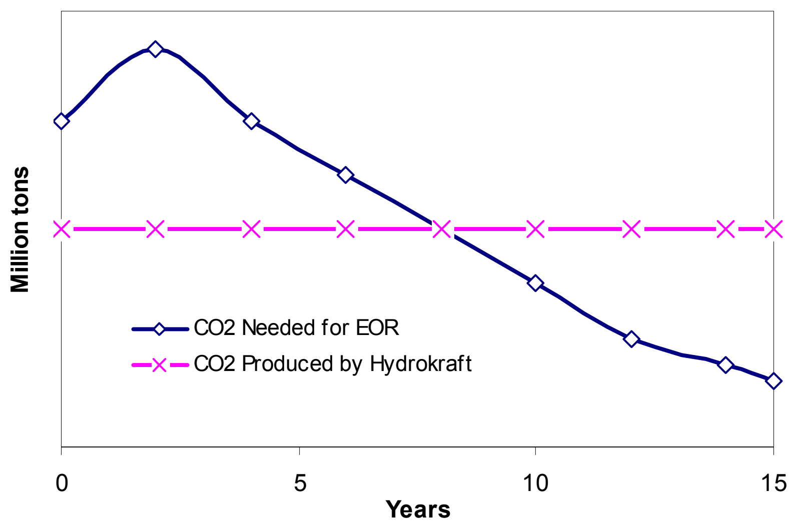


**Figure 0.7. $CO_2$ Needed vs. $CO_2$ produced**
*This figure shows the production pattern of $CO_2$ at the Hydrokraft plant as well as the expected consumption pattern of $CO_2$ at the Grane oil field. How to deal with the discrepancy between the two rates has not been resolved yet. The sketch does not feature any scale, this is a qualitative example.*

## Economics of Hydrokraft

Norsk Hydro's first estimates for the investment cost of Hydrokraft amounted to 10 billion Norwegian Krones. Sometime later, it revised its estimates to 11.8 billion and finally up to 12.7 billion Krones. This figure includes the costs of the power plant (a 1375 $MW_e$ Combined Cycle Gas Turbine, NOK 5.7 Billion) the $CO_2$ separation unit to produce the hydrogen-rich fuel (NOK 4.5 Billion), the compressors (NOK 800 Million), and the pipeline to carry the separated $CO_2$ to the Grane field (NOK 800 Million). Given the risks associated with such an activity never undertaken before, these figures may be underestimated.[153]

[152] The 10% $CO_2$ left in the fuel allows to optimize energy production while limiting $NO_x$ emissions. This explains why the Hydrokraft process releases some $CO_2$ emissions.
[153] Some sources estimate that the total cost should be around 14.7 billions. The 10% discount rate used by Norsk Hydro seems for example very low when one takes into account the new and unknown risks associated with this project

Using natural gas for enhanced oil recovery implies facing the opportunity cost of not selling it until the oil is depleted (it is recovered afterwards), plus the fraction of natural gas that is not recoverable at the very end of the exploitation of the oil field. This lost fraction ranges from 10% to 40%. Consequently the value of $CO_2$ is equal to the present value of the fraction of natural gas lost after the 15-year exploitation of the field plus the present value of the stream of revenue forgone by the use of natural gas. One can then estimate the commercial value of the $CO_2$ to be in the range from 14 to 18 US$ per metric ton.[154]

The use of the "best case" economics (e.g. low discount rate, low contingency on investment costs) shows that the Hydrokraft project is still away from economic feasibility (Figure 0.8, see also Figure 0.3).

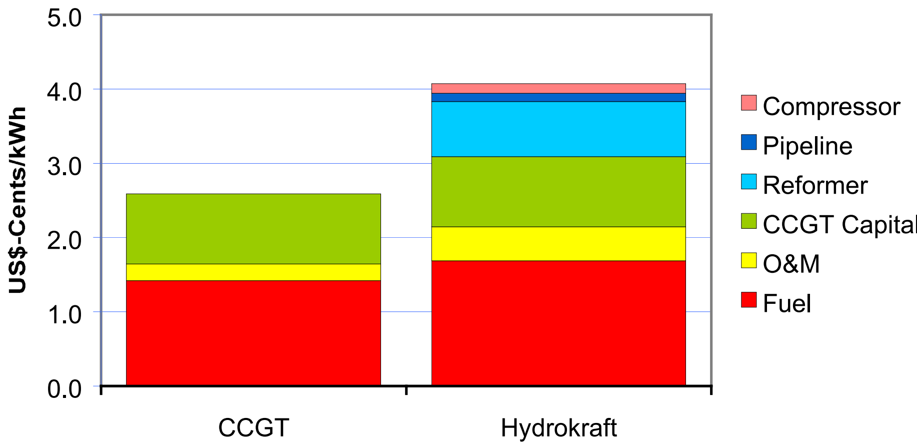


**Figure 0.8. Hydrokraft price of electricity vs. CCGT price of electricity**
*This figure shows the comparative prices of the price of electricity produced by a Combined Cycle Gas Turbine and by Hydrokraft. This chart is for illustrative purpose only. It has been obtained through assumptions and approximation by the author, based on public information released by Norsk hydro. However, it is close to the official estimate released by Norsk Hydro.*

## Current Status and Future Development of Hydrokraft

The Bondevik government clearly expressed its preference for sequestration over classic CCGT.[155] This type of solution would have allowed Norway to meet its needs for electricity

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[154] In the Grane field Norsk Hydro estimated that the recoverable oil amounted to 88 million $m^3$ without the use of any enhanced oil recovery technique, 129 million $m^3$ by the use of natural gas, 125 million $m^3$ by the use of $CO_2$, and 115 million $m^3$ by the use of nitrogen.

[155] Mrs. Hilde F. Johnson, former Minister of Development, favored this solution over the Naturkraft project. The previous government hoped that waiting (instead of building new power capacity) would force this kind of technologies that were hoped to be "around the corner"

while only marginally increasing its GHG emissions. Therefore, it was no surprise that Naturkraft lost all political support after the release of the Hydrokraft project. Today, while the Labour Party[156] has expressed its interest in the Hydrokraft project, it has not given the idea clear-cut political support.

In 1998 Norsk Hydro announced that its power plant would not reduce $CO_2$ as much as originally forecasted. The life span of the underground reservoir was estimated to be only 15-20 years whereas the power plant has an expected lifespan of 25 years. When the oil fields become exhausted, Norsk Hydro plans to emit the captured $CO_2$ to the atmosphere, thus increasing the overall lifetime emissions of the power plant.[157]

In 1999, Norsk Hydro released the results of its market study that revealed the technical feasibility of Hydrokraft. Nevertheless the market study showed that the resulting $kWh_e$ produced this way could not compete with other power plants (especially hydro and coal) in the Scandinavian market (Figure 0.3).

Economic considerations have delayed this project indefinitely. Economies of scale characterize sequestration. Nevertheless Hydrokraft was size-constrained and could not fully exploit the economies of scale advantage for two reasons:

1. Hydrokraft was dimensioned according to the EOR needs of the Grane field, which is one of the only few “thick” oil fields well suited for $CO_2$ EOR in the North Sea.
2. The power output of Hydrokraft was limited by the Norwegian electric grid that exhibits bottlenecks on the west coats.[158] So even if $CO_2$ EOR were suitable for other oil fields, the grid capacity would limit the size of the plant.

The future of innovative projects implementing carbon sequestration may rest outside Norway. Norsk Hydro is currently applying for “Green Certification” for an installation implementing carbon sequestration in the Netherlands. Getting this certification would allow Norsk Hydro to get government subsidies to improve project economics. The Dutch decision on this project has not been made yet.

[156] Source Mr. Øyvind Slåke, political advisor for the Labour Group in Parliament, interview, August 2000
[157] Source *Global Environment Change Report*, Vol. X, No. 24, 24 December 1998
[158] There was a grid bottleneck on the west coast that limited Hydrokraft’s maximum size

Chapter

# 6

# Policy Approaches to Climate Change in Norway

## CLIMATE CHANGE POLICY IN NORWAY

Much importance is given to the climate change threat on the Norwegian policy agenda. This chapter reviews briefly the situation in Norway with regard to climate change policy, while trying to extract some valuable lessons for the rest of the world, since it is likely to face comparable issues in the future. The reader's attention is focused specifically on the opportunity that carbon sequestration offers in the future, given the lessons learned on the Norwegian continental shelf.

## The Challenge of Global Climate Change in Norway

Climate change presents the decision maker with a set of formidable complications. A considerable number of uncertainties remain with regard to the extent and geographic distribution of the damages and the time horizon. The problem is further complicated by its global scope, its requiring international cooperation, and the irreducibility of the equity question, i.e. who should bear the costs and how to share these costs.

The Norwegian approach as regard to environmental polices has been extremely "conservative", always leaning on the cautious side and promoting the application of the precautionary principle and international cooperation. In 1998 human activities in Norway resulted in carbon dioxide equivalent emissions totaling around 56 million metric tons. As previously shown in Chapters 1 and 2, these emissions stem primarily from stationary combustion for energy purposes in the oil sector offshore (40%), industrial processes (21%) and road transport (22.4%). GHG emissions are on the rise by about 1.9%[159] per year. In addition, while electricity production is GHG-free today, electricity demands is climbing up by 1 to 2% a year. This may force the adoption of new electricity sources, which do emit greenhouse gases.

Norway enjoys very inexpensive electricity (analogous to gasoline in the US). These low prices brought about a rather poor end-use efficiency, which is difficult to remedy due to lack of existing infrastructure (centralized heating systems and the like). Low prices combined with very low environmental impacts have encouraged Norway to have the highest electricity consumption per capita in the world.

Public acceptance of non-hydro electricity sources is low due to the perception of environmental soundness of hydropower. Norwegians pride themselves on producing very clean electricity and on having amongst the most environmentally friendly way of living. This makes it very difficult to market alternative sources of clean energies (e.g. biomass) despite high environmental concerns in Norway.

The lack of extra hydroelectric capacity has led Norway to turn to power imports from the integrated Scandinavian market to make its demand meet its fluctuating supply. Nevertheless the increasing electricity demand is bound to outstrip national supply in the future. Electricity trade might not be a satisfactory buffer in the long term for it could pose a substantial threat to the security of the Norwegian electricity supply.

The challenge for Norway is now to find a way to meet its domestic electricity demand without extra burdens for $CO_2$ emissions. Since hydro-electricity is size-constrained and since Norway is endowed with huge natural gas resources, building gas-fired power plants to fill the projected gap between demand and supply was considered a serious option, which is analyzed in the following section.

## Norway's Options for Gas-Fired Power

Three main options are now at the disposal of the Norwegian government with respect to building (or not building) gas-fired power plants. A quick review of each of them will try to sort out their relative advantages.

### The Wait-&-See Option: Building Nothing Now

The Bondevik government preferred to delay any action on building gas-fired power plants until new environmentally friendly technology was available. Instead, to give time for cleaner

[159] Average increase emissions over the past decade

technology to develop, they proposed both a demand-side and supply-side management approach. This included developing renewable electricity sources (wind power, geothermal) and improving energy efficiency (by taxing electricity and subsidizing energy efficiency improvements). Beyond the electricity sector, they proposed an array of actions to reduce GHG emissions: taxing car use (peak hours road taxation schemes) to curb transport emissions, or promoting the use of natural gas for public transportation for instance.

It was hoped that a vigorous electricity demand-side management to slow down the increase in electricity consumption in Norway coupled with a strong effort to develop renewables would avoid the construction of gas-fired power plants over the next decade. If this approach was not sufficient, the previous government expressed its clear preference for the carbon sequestration technique coupled with electricity generation, explicitly leaning for a technology forcing approach.

### Building classical gas-fired power plants (Naturkraft-type plant)

Combined cycle gas turbines allow for energy conversion efficiencies close to 60% today. The two proposed gas fired power plants proposed by Naturkraft were state of the art power plants. $NO_x$ emissions were expected to find an appropriate solution[160] for the project to meet the stringent $NO_x$ emissions standards and get the governmental approval.

These gas-fired power plants would alleviate most of the pressure that electricity demand is putting on domestic supply. Moreover this would contribute to add value to hydrocarbon resources in Norway. On the negative side this would dramatically increase Norway's GHG emissions, making it more and more difficult for Norway to meet its Kyoto targets. Economic assessment of carbon sequestration eliminated the technique as an economically attractive technological route to reducing emissions.

### Building Gas-fired Power Plants coupled with Carbon Sequestration

Coupling gas-fired power plants with carbon sequestration would allow Norway to meet its increasing electricity demand. Without extra burdens on its GHG emissions, side-benefits included adding value to its natural gas and avoiding the risk associated with electricity imports. Moreover carbon sequestration is well accepted in Norway[161] both at the public and the political level.

Combining classic gas turbines with carbon sequestration was certainly premature in light of the economic assessment conducted by Norsk Hydro (Figure 0.3). The 1991 $CO_2$ tax that is levied

[160] Equipping 6 ferries with gas-fired engines was expected to suffice to make-up for the two power plants emissions
[161] Environmentalists are split on that issue: Bellona supports it as long as it is considered to be a transitory solution towards an hydrogen economy whereas Greenpeace opposes it. However carbon sequestration does not face major opposition outside some environmental groups in Norway

on the continental shelf was a pigouvian tax that made oil companies reinternalize environmental externalities and triggered such initiatives as the carbon sequestration project at the Sleipner field. Such a tax does not exist on the mainland today. Levying a comparable tax on the domestic electricity generation sector would prove ineffective since 99% of Norway's electricity is hydro and since in would not apply to producers outside Norway (Norway is tightly integrated into the Scandinavian electricity market). So the economic conditions that would allow Hydrokraft to be competitive do not exist today and are dependant on future international $CO_2$ policies.

## Policy Tools Available

Policy mechanisms can be classified as either direct or incentive-based regulation. Direct regulation is often referred to as "command-&-control" regulation. "Command-&-Control" regulation usually resort to quotas, limits, bans on activities deemed to be undesirable, and/or standards. Quotas, limits and bans often address the problem brought about by ancillary effects of the technology or practice subject to regulation. On the other hand standards often require the use of a particular process or technology the regulator has deemed to be the most adequate to conduct the specific activity at stake.

Direct regulation has been the primary tool used by regulators for decades. After much criticism of this single approach and pressures from the academic sphere essentially in the United States, the regulatory body started to implement a new set of market-based tools. Market-based approaches essentially resort to economic incentives or disincentives: taxes, tax credits, subsidies, and/or tradable permits (or allowances). The Pigouvian principle just calls for the re-internalization of externalities in the economic calculus of individuals trying to maximize their individual wealth.

These market-based approaches have been given much prominence recently. A tradable permit system to regulate $CO_2$ emissions has been on the international political agenda since the third Conference of the Parties in Kyoto in 1997. This approach is preferred by the United States for its theoretical ability to allow for the most economic efficiency in reducing overall emissions. This stems from the incentive for players with low abatement costs to reduce more than standards would compel them and to sell permits at a price that is above their marginal cost of abatement. Companies facing higher marginal abatement costs may prefer to buy emission permits to meet their regulated emission levels.

Moreover the Kyoto protocol[162] allows Annex B countries to engage in Joint Implementation. Any party is allowed to finance emissions reductions in another Annex B country and earn credit for these reductions. This project-by-project approach can be considered an extension of national approaches to reductions without resorting to formal trade of greenhouse gases.

[162] Article 6 of the Protocol

## Reframing the debate

The controversy surrounding the proposed construction of gas-fired power plants in Norway essentially centered on three questions:

1. "Where Flexibility": Where should the GHG emissions reductions be made, within Norway or outside Norway?
2. "When Flexibility": When should they be done?
3. At what cost?

We now turn to these universal questions that have been strongly debated in Norway.

### National vs. Regional Action: Where to reduce?

The proponents of national action stress the need for Norway to reduce its national GHG emissions before resorting to any supplementary mechanisms, such as emissions trading, Joint Implementation, and the clean development mechanisms. The previous center Government did favor this approach by refusing to go ahead with the two gas-fired power plants and relying on a tightened supply to force technology and improve efficiency.

Moreover the Bondevik government claimed that its position was supported by the "spirit" of the Kyoto Protocol, which is negotiated around national targets and in which flexible mechanisms are considered to be "supplementary tools". A threshold of 50% of reduction to be made at home has been suggested without any clear economic reasoning in Norway for some time. Nevertheless, for symbolic purposes (that are particularly relevant given the historical and sociological roots of the Norwegian environmental concerns) and certainly political purposes, the previous government seemed to give prominence to this approach.[163]

The advocates of a regional approach stress that it could be much less costly for Norway to work simultaneously with its neighbors in reducing emissions in the Scandinavian region as a whole. In principle this would call for coordinating emissions reduction efforts at the regional level instead of the national level. Figure 0.1 below shows the expected $CO_2$ emissions (in 2005) resulting from the burning of oil and natural gas produced in Norway both at the "global level" and at the national level, and then compares it to the $CO_2$ emissions from three natural gas fired power plants, similar to the ones Naturkraft is pursuing to build in Norway.

[163] This stand might have been motivated by political exploitation opportunism

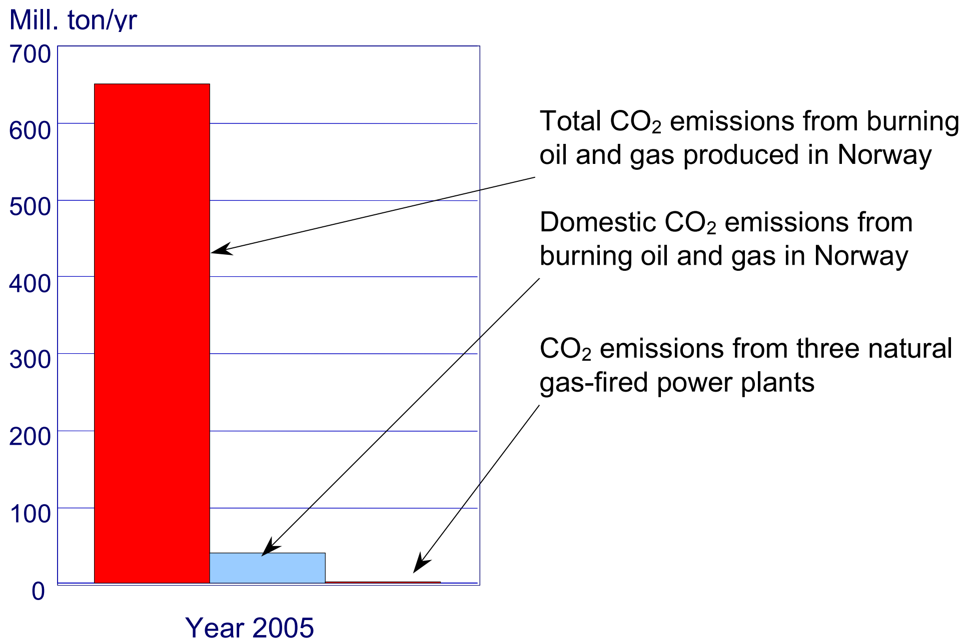


**Figure 0.1. $CO_2$ emissions "originating" from Norway**[164]

This change of perspective tends to weaken the arguments of the proponents of strict emissions reductions in Norway. This approach may even call for increasing emissions in Norway to reduce overall emissions in the region. Norway could produce electricity from natural gas and export it to countries that currently resort to coal-based electricity generation.

Reasons why the regional approach is attractive to Norway include:

1. Since there is limited scope for Norway to reduce national emissions, implementing reductions at the regional level might be able to reduce compliance costs substantially.
2. Norway is endowed with huge natural gas resources that it currently exports "as is". Producing and exporting electricity would add value to Norwegian natural resources.
3. Norway is well suited to carry out carbon sequestration if necessary given its past experience, its topography, and its economic use of the sequestrated $CO_2$. Moreover, carbon sequestration enjoys large public and political support in Norway.
4. It might be easier to reduce emissions at the regional level than for Norway's neighboring countries be forced to reduce their national emissions alone (e.g. Denmark).

For the first time, Norway has proposed a "Reversed Joint Implementation" scheme, with increased emissions in the country (in this case Norway) undertaking the capital investments. While GHG emissions are increasing in Norway, this triggers emission reductions in countries importing Norwegian electricity resulting in an overall net decline in GHG emissions. This differs from France producing GHG emission-free electricity for export, because there are no added emissions associated with nuclear electricity.

[164] Courtesy of Mr. Hans Jørgen Dahl, Statoil

This scheme would need to be subject to constraints in order to be successful in reducing emissions: the electricity produced by natural gas fired power plants in Norway should be primarily produced to displace dirtier (coal-based electricity for instance) electricity production abroad, otherwise those new GHG emissions would just add to the current ones. Actually the mix of electricity domestic-export would condition the amount of reduction Norway could claim using this method. Consequently to make it an effective route to reducing Norwegian emissions, electricity exports should dominate the production of domestic electricity from natural gas.

Since Joint Implementation is based on contractual engagements between two parties, Norway and its partner would have to negotiate an agreement that serves the interests of the two parties. This negotiation is bound to be a zero-sum game since any reduction in emissions credited to one party is not credited to the other. For the scheme to be attractive for Denmark, for example, it would require something more attractive than simply importing natural gas and producing electricity in Denmark. Thus, it is likely that Norway will not be able to get full credit for the emissions reductions and that it would have to share part of it with the countries importing its electricity. Still, since Norway has no easy path for reducing GHG emissions, this approach might be an attractive alternative for all the parties involved.

### Timing of Technology: When to reduce?

One can distinguish two major ways of selecting a technological response to a given problem:

- ***Use "best" available economic approach***
  While this approach might discard carbon sequestration as an immediate response to GHG emissions in Norway, it can "buy" time for the development of technology. But at the same time it might lessen the incentives to develop and improve the technology, since it reduces immediate need for the new technology and it does not stimulate innovation driven by economic competition.

- ***Technology forcing approach***
  This approach strongly advocates the use of the most effective technology available today, with cost considerations being secondary. This approach would increase the incentives to develop and improve the technology. Competition would be lured into the development of the technology given the assurance of economic viability guaranteed by the political support the technology enjoys.

The previous Norwegian government had a belief in the economic and technological feasibility of carbon sequestration in the medium term. Contradictory signals came from the industry[165] that may have induced the government into overrelying on this technique. Nevertheless, the Bondevik government was favoring a technology forcing approach.

It is worth noting that the Norwegian air pollution regulation stipulates that the "most effective technology must be used to prevent or diminish releases to the air of pollutants". The Norway-

[165] Norsk Hydro's first technological assessment stating the technical feasibility followed by its economic assessment that put the project to a standstill months later

based environmental group Bellona has been strongly pushing for carbon sequestration, leaning on the wording of the law to back its position.[166] Today, while the ruling Labour Party expressed its interest in the technique, no clear-cut political support has been given yet. Nevertheless it is likely that the current government will support future proposals to implement carbon sequestration in Norway to the extent it does not hurt direct Norwegian industrial interests.

### Economics have the Final Word: At what cost to reduce?

Ultimately economics controls the final choice. Industry stepped back in light of its economic assessments. Carbon sequestration was not viable given the prevailing regulatory framework. Some people proposed direct subsidies - Norsk Hydro is looking for Green Certification in Netherlands – to pay for the extra capital needed for sequestration. Nevertheless investing billions of Norwegian Krones into one single (let alone private) project was a deterrent enough for that argument to be short-lived.[167]

Past experiences (Sleipner Field) have demonstrated that economic incentives (e.g. the offshore carbon tax) are needed to make carbon sequestration economically viable and attractive. Nevertheless, Norway appears to be well suited to implement such a technique (Safe offshore options, credits for EOR use) in the future. The economic future of sequestration is now tied to future $CO_2$ policies in Norway and abroad.

## Stakeholders

The controversy surrounding the construction of the two proposed gas-fired power plants resulted from the political opposition of Stortinget.[168] As a matter of fact the Labour Party's official position is now to circumscribe the Naturkraft controversy to a mere political issue rooted in the definition of the balance of power in Norway (Parliament vs. Government).

All the parties involved in the political decision-making process can be considered stakeholders in this issue. This includes the previous government, the former opposition-current ruling party (the Labour Party), the Norwegian Parliament, the oil industry, the public utility players, the environmentalists, the neighboring countries who intervene on the regional electricity market, and more generally the international community through the setting up of international measures within the framework of the Kyoto Protocol.

- ***Ruling Government***
  The Labour Party's official position is now to circumscribe the Naturkraft controversy to a mere political issue rooted in the definition of the balance of power in Norway (Parliament

[166] Cato Buch, Bellona Norway
[167] Note that the direct subsidy per $kW_e$ installed is very low compared to subsidies aimed at promoting the development of renewables in Norway
[168] Stortinget is the Norway's Parliament

vs. Government). By claiming that the whole controversy revolving around the Naturkraft project and the Hydrokraft project boils down to the technical problem of reducing the NOx emissions induced by the two proposed gas-fired power plants, the government endeavors to stifle the political opposition surrounding the proposed reshuffle of the "air" law aimed at making sure the current legislative framework would not put a halt to the construction of the Naturkraft project. It is likely that the ruling government will break down the previous decision of the Norwegian Environmental Protection Agency[169] that put very stringent limitations on both NOx and CO2 emissions. To appease the public opposition to bending the current law to the political needs of the moment, the Labour Party now asserts that the air law in its current version does cover CO2 emissions.

- ***Opposition***

  The opposition is scattered today in Norway. Unlike in the US, there is no clear dichotomy between parties in Norway, and most of the previous governments have been minority governments that have made labile alliances to get a ruling majority. Even the former center-right coalition is split on this issue (as well as the current ruling government). Nevertheless the prevailing opinion among the members of the former government is still to block the construction of gas-fired capacity in Norway, except if it implements carbon sequestration.

- ***The Norwegian Parliament***

  As previously mentioned, Stortinget already expressed twice its intention to give a green light to building gas-fired power plants in Norway. This majority opinion still holds in Parliament.

- ***The oil industry***

  The oil industry does certainly favor the opportunity to develop these new domestic outlets for Norway's natural gas. This is underlined by the fact that the two Norwegian oil companies have been involved in three of the last proposals to build gas-fired power plants in Norway. However, they stepped back given the poor economics of the technology when associated with electricity generation in Norway today.

- ***The public utilities***

  Since the hydro capacity is constrained in Norway today, public utilities are very inclined to develop new generation capacity. Consequently, the industry is expected to back such a move to expand electricity generation capacity beyond the existing hydro capacity.

- ***The metallurgical industry***

  Norsk Hydro has been given formal approval by the ruling government to expand its metallurgical activities. Developing the aluminum sector is bound to require more and more electricity since the energy intensity has been pretty stable in that sector in Norway. Moreover the heavy industry in Norway has been cultivating strong links with the Labour Party for decades. The interests of the metallurgy sector are likely to be better taken into account under the new Labour administration than they have been under the center

[169] SFT

administration in recent years. This is expected to increase pressure on the electricity supply side.

- ***Norway's neighboring countries***
  The energy policies of Norway's neighbors will play a crucial role in the definition of Norway's energy strategy. Since all the Scandinavian electricity markets are now interwoven by the setting up of a common wholesale electricity market, the degrees of freedom exercised by Norway have been drastically reduced over the last decade. Sweden is Norway's primary electricity trade partner. In 1980 Sweden expressed its intention to phase out nuclear power and to turn off the first reactors as soon as 2001. Even if Sweden was to renounce to this measure, this underlines the vulnerability of Norway to its neighbor's energy policy.

  Moreover most of Norway's "electric" partners (Sweden, Denmark) are members of the European Community. The EU member states have agreed to form a "bubble" so as to facilitate reductions in GHG emissions at the European level. Since Norway is not part of that scheme, this may lessen the incentives for its partners to undertake common actions with it first.

- ***Norway's environmental community***
  As already mentioned, environmental concerns have been on the political agenda in Norway for decades. The environmentalists are strong influence brokers in Norway. It seems clear that the vast majority of nature protectionists do oppose the construction of the two gas-fired power plants proposed by Naturkraft. Nevertheless the environmentalists are split as regard to carbon sequestration.170 It is not clear which position dominates the environmental thought in Norway today.

The Labour government is now in charge of defining the future role of natural gas-fired electricity generation in Norway. Its action is somewhat limited by Norway's commitment to limit its GHG emissions and by the strength of its coalition. The Labour Party government is expected to give final approval to the construction of the two gas-fired power plants proposed by Naturkraft. Economic arguments have not been given much prominence under the previous administration that favored the delaying of the construction of gas-fired power plants. The previous government put much more emphasis on "moral duties". Nevertheless it is not clear whether a clear macro-economic rational has been articulated to support the decision to grant permission for Naturkraft to proceed as well.

## Definition of Strategy

[170] Greenpeace strongly oppose any new source of fossil-based electricity (relying on renewables) whereas Bellona does support carbon sequestration as a necessary intermediate step toward an $H_2$ economy

In the short term, implementing a portfolio of actions, both on the demand side and the supply side, might be the most efficient way to curb GHG emissions in Norway. Promoting renewables, end-use efficiency, energy savings, and the implementation of new taxation schemes aimed at better incorporating the environmental externality are directions Norway has endeavored to follow.[171]

Carbon sequestration might be considered a medium to long-term option given its current costs and the uncertainties surrounding the future $CO_2$ policies, both in Norway and at the international level. This does not mean that sequestration should be discarded right away. Norway is endowed with the vast majority of suitable sites to implement carbon sequestration in Europe.[172] It is unlikely that carbon sequestration - that has enjoyed a broad political support in Norway so far [173]– is going to be forgotten soon in Norway. Nevertheless there remain some uncertainties with regard to the extent of the popular support behind this technique. Were Norway to take care of the $CO_2$ produced by the generation of electricity that is then exported abroad, would it still be popular in Norway to become the "$CO_2$ dumpster" of Europe? Moreover many Norwegian environmentalists perceive carbon sequestration as a necessary intermediate step towards the development of hydrogen as the fuel of choice of the future. The environmentalists may precondition their support for the technique on a political commitment that this will ultimately lead to an economy of hydrogen.[174]

In order to stabilize and reduce its GHG emissions, Norway might resort to carbon sequestration, once all the other less expensive options have been exhausted (to the extent they are politically feasible and to the extent of Norway's strength of commitment to reducing its GHG emissions). In the meantime, a technology surveillance approach, including pursuing research and experiments in carbon sequestration, certainly constitutes a valuable option for Norway.[175]

Carbon sequestration is too expensive today, if one only uses a "best" economic approach. Any measure aimed at decreasing the cost of carbon sequestration should be welcomed. Consequently, one may wonder if the last governmental decision to reduce the carbon tax on the Norwegian continental shelf is well suited to help Norway meet its GHG emissions reductions target, since its lessens the incentives to both reduce the energy intensity of the oil sector and to implement carbon sequestration soon.

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[171] As already mentioned this strategy is consistent with the expressed intention of progressively shifting the burden of taxation from labor and income towards green taxation

[172] Source Olav Kaarstad, and European Commission

[173] Even the Labour Party in now expressing its interest in the technique
Source: Øyvind Slåke, political counselor for the Labour group in Parliament

[174] Source Bellona Norway

[175] For instance Schlumberger expressed its interests in this technique: it launched a major R&D effort to better assess the technical feasibility (geological stability, safety…) of carbon sequestration recently in 2000. Source: Philippe Lacour-Gayet, Chief Scientist, Schlumberger
At the same time Statoil believes that some major oil players may become $CO_2$ storage operators in the long term. Source Olav Kaarstad, Statoil

# Chapter 7

# Conclusion

**CONCLUSION**

In this thesis we have found that Norway's electricity consumption has been on the rise for decades. At the same time Norway evolves in a constrained electricity market since:

1. Over 99% of Norwegian electricity is produced from hydropower
2. Its generation capacity is highly dependant on precipitation levels
3. The hydro capacity is constrained today (for political and environmental reasons)
4. The Norwegian electricity market is well integrated into the Scandinavian market, hence its limited ability to enforce its own policies without any concern for the situation in its neighboring countries

Reducing GHG emissions in Norway is a difficult task. This stems from the fact that electricity in Norway is 100% hydroelectricity and expansion-constrained. Contrary to other countries[176], Norway does not benefit from any "easy" paths for reducing its GHG emissions.

Norway has been one of the first countries to try to adapt its industry policies to its GHG emissions targets. We have seen that the issues raised in implementation of GHG emission controls are universal. It includes:

- "Where flexibility"
- "When flexibility"
- Cost

[176] The United Kingdom is expected to meet its Kyoto targets. To do this, UK retired many of its coal-based power plants and heavily promoted gas-fired power plants to meet its electricity demand

But for the first time, carbon sequestration has been given much consideration in formulating Norway's approach to reducing its GHG emissions.

**Answers to my initial questions:**

- *Why, while the rest of the world looks at natural gas as a solution to climate change, is it so controversial in Norway?*
  This stems essentially from the GHG emissions structure and the nature of the electricity sector in Norway. Specifically, in most countries the average GHG emissions per $kWh_e$ produced decrease when adding new natural gas capacity to produce electricity. This is not the case in Norway, since 100% of its electricity is GHG emission-free. Moreover some countries manage to reduce their emissions by retiring coal-based power plants while building gas-fired power plants. This is not an option in Norway. On top of that Norway has few "easy" ways to reduce GHG emissions in other sectors to offset increased GHG emissions from electricity production. Finally, building gas-fired power plants coupled with carbon sequestration is not economically attractive today.

- *Why, while in the US most politicians have never heard of carbon sequestration, did it play such a key role in Norwegian politics?*
  Sequestration enjoys a broad political and public support in Norway. Sorting out the politics from the policy implications of societal choices is no easy task when it comes to understand what role played GHG emissions and carbon sequestration in the fall of the previous government. However, the Pigouvian $CO_2$ tax Norway has imposed in 1991 has successfully made carbon sequestration a viable, cost-effective, technological solution to limit $CO_2$ emissions on the Norwegian continental shelf. The carbon sequestration experience that started in the Sleipner field in 1996 remains a powerful and convincing example that shows that carbon sequestration can be a workable solution to reduce GHG emissions. Consequently carbon sequestration might be a long-lasting political wish in Norway: once politicians are familiar with the technique, they keep dreaming of it!