A Case Study from Norway on Gas-Fired Power Plants, Carbon Sequestration, and Politics

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INTRODUCTION

On Thursday 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. The government had been rejecting the building of the proposed plants for months. Bondevik and his coalition government wanted to hold off construction until new technology, such as carbon sequestration, allowed building more environmentally friendly plants. They argued that their 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 carbon-intensive coal-fired plants. Over Bondevik objections, the parliament voted 81-71 in favor of building Norway's first natural gas-fired power plant.[1] 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 paper, we analyze this event in more details and we uncover some of the underlying issues, such as national versus regional outlooks, conflicts of short-term versus long-term solutions, and the overriding role of economics. 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 these issues.

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?

To answer these questions, we must first understand the production and consumption of energy in Norway, along with their associated greenhouse gas emissions. Then we turn to the unprecedented political controversy that took place in Norway involving climate change mitigation policies.

[1] Source CNN & Reuters.

NORWAY'S ENERGY SECTOR

Norway is endowed with major petroleum resources, making it the second largest oil exporter the world. Over the last decade the production of oil and natural gas has been increasing steadily, essentially for export and revenue reasons (Figure 1). "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. In 2020, gas is predicted to outstrip oil as the major money-maker in the Norwegian oil and gas industry."[2]

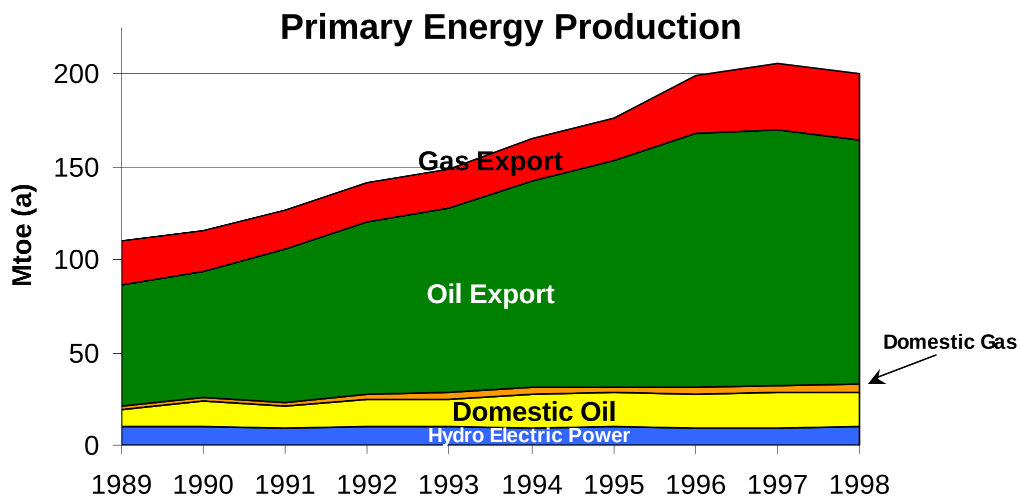

Figure 1. Time history of primary energy production in Norway[3]

In addition to energy purposes, domestic oil is used as feedstock for the petrochemical industry. Conversions are based on total heat content.

Electricity is almost exclusively produced from hydropower (over 99%), which results in essentially no greenhouse gases emissions to the atmosphere. Nonetheless the hydropower infrastructure has been developed to a point where it seems politically difficult to add significant new capacity. 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 the 175 TWhs of annual production potential[4] (Figure 2).

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[2] Source ODIN.
[3] Source Statistics Norway.
[4] Norwegian Ministry of Industry & Energy, 1995.

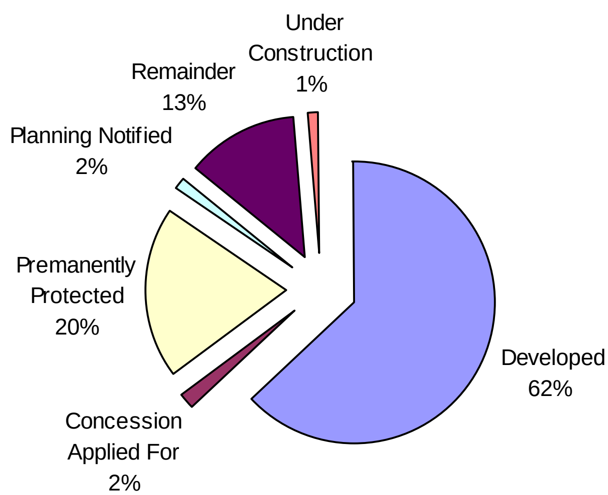

Figure 2. Hydropower exploitation of the hydropower resource in Norway[5]

Norway holds the record of the highest electricity consumption per capita in the world (see Figure 3), with demand on the rise at about 2% per year. This has come about due to historically low electricity prices combined with perceived low environmental impacts from hydropower. Norwegians have among the largest homes in the world and they rely to a significant extent 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”[6].

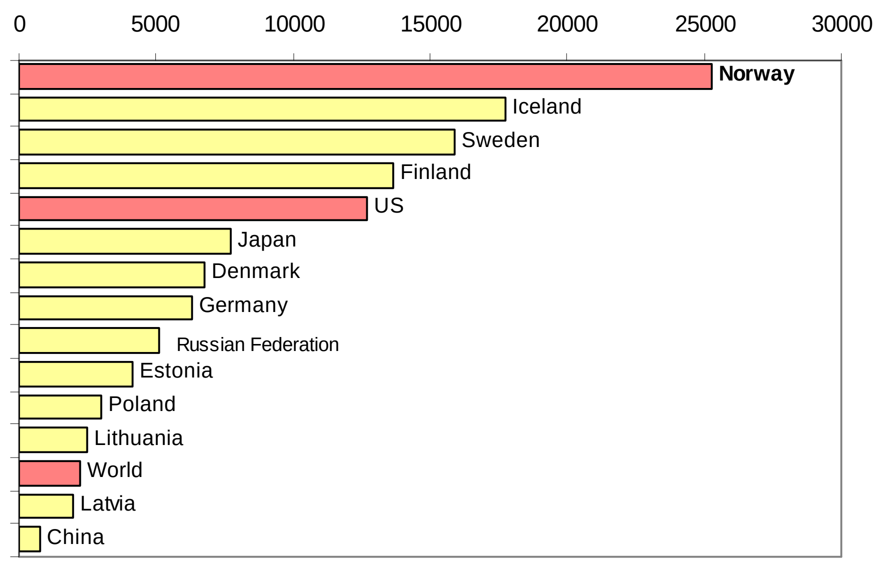

Figure 3. Annual electricity consumption (kWh$_e$ per capita in 1997)[7]

[5] Source Statistics Norway.
[6] Energy Policies of IEA countries, Norway 1997 review, p 26.
[7] 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.

The difference in the levels of industrial 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 a greater use of electricity in Norway as compared to the OECD average consumption. "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."[8].

In view of the fact that its power production heavily fluctuates from year to year and even from place to place, Norway has administered a spot market for electricity at the national level since 1971. In 1996, this national market was enlarged to a bi-national power exchange covering both the Norwegian and the Swedish power markets. The transboundary electricity exchange takes advantage of the complementary nature of the electricity infrastructures of these two countries. 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 hydropower can be quickly turned on and off. Sweden and Norway now share a completely integrated market (consumers are entitled to chose their producer). This market has been further enlarged and now accepts third-party suppliers from countries such as Denmark and Finland.

Hydropower requires a substantial capacity margin in order to ensure supply against variable rainfall. Up to now, the power trade has helped Norway to cover any risk of electricity shortages caused by a lack of precipitation. Nevertheless, the ever-increasing consumption is posing a threat to its power supply security as its dependence on foreign electricity increases. This point has been dramatically illustrated in 1996, an exceptionally dry year, where Norway had to import substantial amounts of power. Beyond the difficulties posed by the variability in hydroelectricity production, demand is expected to outstrip the domestic supply in the near future, even in "normal" years.

This sudden dependence on foreign power revived Norway's interest in building new power plants, since the ever increasing need of supply capacity to respond to an ever increasing demand is bound to conflict with the limited number of suitable hydroelectric sites available. Slowing the growth of electricity demand and importing are the only available alternatives to building additional capacity.

The tight integration of the country within the Scandinavian electricity market makes Norway's electricity imports vulnerable to its trading partners' energy policies. In 1980 Sweden expressed its will to phase out nuclear electricity by 2010,[9] 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[10] (global warming), this stresses the need for Norway to find suitable alternative power

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[8] Energy Policies of IEA countries, Norway 1997 review.

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

[10] 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

supplies. The expansion of electricity trade between Norway and its Scandinavian neighbors was essentially motivated by economic interests to reduce inefficiencies and take advantage of complementary energy sources (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.

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 in new housing or the costly retrofitting of the existing setup. Moreover this would add to Norway's GHG emissions. And as far as industry is concerned, any drastic change is bound to meet with outright political opposition and conservatism based on economic concerns.[11]

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 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.[12] Wind power generation would bring about visual pollution that may conflict with the tourist industry (Norway's preserved environment is an essential asset for the country). Other renewables (geothermal, solar, waste, combined heating) require infrastructures with which Norway is not massively equipped with (pipes, building 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.[13] 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.

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 in 2010 are expected to be 19% above its Kyoto targets. Most of the growth in emissions is expected to come from the oil sector and the transportation sector.

Two gas-fired plants have been contemplated supplementing the current hydro capacity. If the two planned gas-fired plants were built, they would emit approximately 2.1 million tons of CO_2 a year. This would add an additional 4% to Norway's GHG emissions (Figure 4). The question now boils down to how to increase electricity supply without burdening GHG emissions?

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production. *Source Global Environmental Change Report*, Vol. VIII, NO. 7, and the French newspaper *Libération* June 15,2000.

[11] Sjur Kasa, Social & political barriers to green tax reform, Policy note 1999:5, CICERO, Oslo.

[12] Source Energy Policies of IEA Countries, 1997 Norway Review, IEA.

[13] 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.

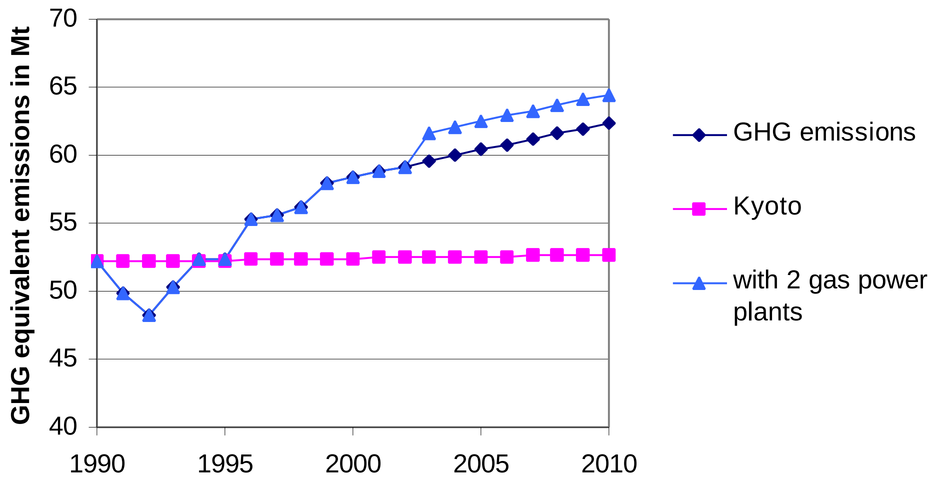

Figure 4. Projections of GHG emissions in Norway

OPTIONS FOR GAS-FIRED POWER PLANTS

Proposals involving gas-fired power plants in Norway have been around for more than 15 years.[14] 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. The reform instigated new rules governing the definition of electricity generation supply (less politically influenced and more market-oriented) and provided new opportunities for gas-fired power plants in Norway.

Recently, two specific proposals to build gas-fired power plants in Norway have been debated. The first project, Naturkraft, led by the industrial company Norsk Hydro, the state-owned oil company Statoil, and the state-owned electric utility Statkraft, features two combined cycle gas turbines (CCGT). It was first proposed in 1994. In 1998, a second project, Hydrokraft, proposed by Norsk Hydro alone, involves the construction of a single CCGT power plant with carbon sequestration to limit GHG emissions. The two plants were expected to satisfy domestic electricity demand and increase Norway's electricity exports.

Despite the clear support of the majority in Parliament, Naturkraft has been facing fierce opposition since its first proposal in 1994. When Norsk Hydro released its intention to launch its Hydrokraft project, associating carbon sequestration and electricity generation, it weakened any political support behind Naturkraft. Natural gas fired capacity was originally said to contribute to lower emissions abroad (in countries importing Norway's electricity, especially Denmark) but it is bound to increase GHG emissions in Norway. Moreover, neither Naturkraft nor Hydrokraft could compete in today's integrated Scandinavian electricity market, since their price of electricity is about 225 and 325 NOK/MW respectively, as compared to an average price of 125 NOK/MW on the wholesale electricity market in the region. On the other hand, as seen in California, economics can change dramatically when demand outpaces supply.

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

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 technologies were available. To give time for cleaner technologies 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 program coupled with a strong effort to develop renewables would avoid the need for 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[15] 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 significantly increase Norway's GHG emissions, making it more difficult for Norway to meet its Kyoto targets. Economic assessments of carbon sequestration have shown it to be an economically unattractive technological route to reducing emissions today.

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[16] both at the public and the political level.

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[15] Equipping 6 ferries with gas-fired engines was expected to offset NO_x emissions from the two power plants.

[16] 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.

Combining classic gas turbines with carbon sequestration was certainly premature in light of the economic assessment conducted by Norsk Hydro. The 1991 CO_2 tax that is levied 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. So the economic conditions that would allow Hydrokraft to be competitive do not exist today and are dependant on future international CO_2 policies.

FRAMING THE DEBATE

The controversy surrounding the proposed construction of gas-fired power plants in Norway has raised three fundamental issues:

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

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 favored 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". It has been suggested that a minimum of 50% of the emissions reductions be made at home, without any clear economic reasoning. 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.[17]

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 5 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.

[17] This stand might have been motivated by political opportunism.

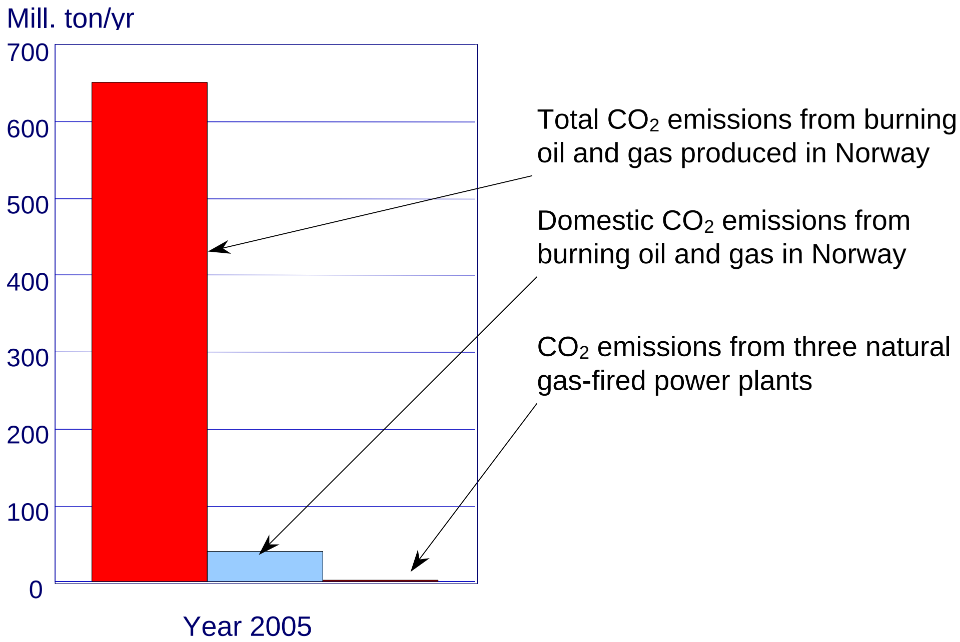

Figure 5. CO_2 emissions "originating" from Norway[18]

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 to 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.

[18] 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 between domestic and export would condition the amount of reduction Norway could claim. Consequently to make it an effective route to reducing Norwegian emissions, electricity exports should dominate the domestic use of 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. 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 market forces.

- *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[19] 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-based environmental group Bellona has been strongly pushing for carbon sequestration, leaning on the wording of the law to back its position.[20] 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 Norwegian industrial interests.

[19] For example, Norsk Hydro's first technological assessment stating the technical feasibility followed by its economic assessment that put the project to a standstill months later.
[20] Cato Buch, Bellona Norway.

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.[21]

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 (e.g. safe offshore storage option and credits for CO_2 used for enhanced oil recovery) in the future. The economic future of sequestration is now tied to future CO_2 policies in Norway and abroad.

CONCLUSIONS

Reducing GHG emissions in Norway is a difficult task. This stems from the fact that electricity production in Norway is almost exclusively from hydropower, which is expansion-constrained. Contrary to some other countries[22], 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 policies to meet its GHG emissions targets. We have seen that the issues raised in implementation of GHG emission controls are universal, including "where flexibility", "when flexibility" and the overriding importance of costs.

For the first time, carbon sequestration has been given serious consideration in formulating a strategy to reduce GHG emissions. Returning to the questions which motivated our research, we suggest some answers below.

- *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.

[21] Note that the direct subsidy per kW_e installed is very low compared to subsidies aimed at promoting the development of renewables in Norway.
[22] For example, 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.

- *Why, while in the US most politicians have never heard of carbon sequestration, did it play such a key role in Norwegian politics recently?*
  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 on the Norwegian continental shelf has successfully made carbon sequestration a viable, cost-effective, technological solution to limit CO_2 emissions from the oil sector in Norway. The carbon sequestration experience that started in the Sleipner field in the North Sea 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!

ACKNOWLEDGMENTS

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FURTHER READING

This paper is a summary of Guillaume Quiviger's Masters' thesis. The full thesis may be downloaded at <http://sequestration.mit.edu/bibliography>.