Carbon Storage and Climate Change – The Case of Norway

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Abstract

The possibility of extracting and storing CO2 in a safe place to avoid emissions has for many years been considered a future remedy to the climate problem. The attractiveness of CO2 storage, and also its weakness in the eyes of its opponents, is that it offers a method to reduce emissions that does not require major changes in the energy supply system, at least for some time. Storage of CO2 in structures under the ocean floor is one promising option. Norway has taken a particular interest in this theme, due to its position as a CO2 emitter connected to offshore oil and gas production, as well as to the existence of geological formations suitable for storage. The purpose of this paper is to give an overview of the challenges related to carbon storage as a climate policy measure, exemplified by the case of Norway. Based on the experience of Norway, the paper winds up by discussing implications for the climate regime of bringing the issue into the formal channels of the UNFCCC and the Kyoto Protocol.

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Introduction

The possibility of extracting and storing CO_2 in a safe place to avoid emissions has for many years been considered a future remedy to the climate problem. Earlier referred to as one of several forms of CO_2 sequestration, it is now more commonly referred to as CO_2 capture and storage, leaving sequestration to only refer to terrestrial (biological) storage of CO_2. The attractiveness of CO_2 storage, and also its weakness in the eyes of its opponents, is that it offers a method to reduce emissions that does not require major changes in the energy supply system, at least for some time.

Storage of CO_2 in structures under the ocean floor has for several years been considered a promising option for handling CO_2. Norway has taken a particular interest in this theme, due to its position as a CO_2 emitter connected to offshore oil and gas production, as well as to the existence of geological formations suitable for storage. The purpose of this paper is to give an overview of the challenges related to carbon storage as a climate policy measure, exemplified by the case of Norway. Based on the experience of Norway, we wind up the paper by discussing implications for the climate regime of bringing the issue into the formal channels of the UNFCCC and the Kyoto Protocol.

Carbon Storage as a Climate Policy Measure – An Overview

CO_2 capture and storage embraces three steps. The first step is capture or separation of the CO_2. *Capture* of CO_2 generally refers to a process of capturing the CO_2 released from large emission sources like power generation. *Separation* of CO_2 refers to the process of separating CO_2 from a gas stream. While technologies for both capture and separation of CO_2 are available, there are significant cost differences. As will be discussed in the following sections, the cost of capturing CO_2 from power generation is a major challenge facing carbon capture and storage as a climate policy measure. There is also a cost issue with separation, but of a much smaller magnitude. Because of the different economic challenges concerning handling CO_2 from power generation and gas streams respectively, we find it useful to distinguish between capture and separation, but will include separation as part of the more general concept 'carbon capture and storage'.

The second step of carbon capture and storage is transportation of the CO_2 to the storage location. Pipelines and ship transport are the alternatives. The final step of carbon capture and storage is long-term disposal of the CO_2. Several options are available. Pure storage solutions include disposing of the CO_2 underground or in the ocean. Other options of long-term disposal are using the CO_2 as input in industrial processes or injecting the CO_2 in producing petroleum reservoirs to improve the recovery of oil. Pure storage and injection to improve oil recovery are the two disposal options today that can handle substantial volumes of CO_2, and we will hence limit the discussion to those alternatives (Norwegian Ministry of Petroleum and Energy 2003).

Pure storage of CO_2 can take place in the ocean or in geological formations.[1] Due to uncertainty about the permanency of ocean storage, this method has so far not been tried out, and following the present policy debate and technical R&D efforts we will focus on geological storage in this paper. Geological formations with potential for storage of CO_2 are aquifers (water reservoirs in the subsoil), producing and non-producing petroleum reservoirs, and non-mineable coal formations (NOU 2002, 7). Large-scale storage in aquifers is currently only taking place on the Norwegian Continental Shelf, but several small- as well as large-scale projects are in the pipeline in other countries, notably the In Salah gas project in Algeria which started in 2004, and the proposed development of the Gorgon offshore gas field in Australia (U.K. Department of Trade and Industry 2004). Note that these three projects all regard storage of CO_2 separated from the gas stream. Technology for storage of CO_2 in non-mineable coal formations is demonstrated at installations in the U.S.

Injection of CO_2 in producing oil reservoirs to improve oil recovery has been used onshore in the U.S. and Canada for more than 30 years. A Canadian oil and gas company, Encana, has been operating a major CO_2 injection facility in their Weyburn, Saskatchewan, oil field for a number of years. The CO_2 is pipelined to the oil field from a syngas facility in the northern U.S. While this is a commercial enhanced oil recovery operation, it has also been the subject of a monitoring research study conducted with the support of the International Energy Agency Greenhouse Gas Research and Development Programme (IEA GHG). The IEA Weyburn Monitoring and Storage Project is an international research project intended to establish the degree of security with which greenhouse gases, particularly carbon dioxide, can be sequestered in geological formations during large scale, commercial, enhanced oil recovery operations. This will be accomplished through the scientific mapping of the movement of CO_2 in the reservoir, and technical prediction of the future long-term storage and migration characteristics of the CO_2. This monitoring project is managed by the Petroleum Technology Research Centre.[2]

According to the IEA greenhouse gas R&D program, the global storage potential in exploited oil and gas formations is about half of global emissions to 2050 (920 Gt CO_2) and 150 per cent of emissions to 2050 in deep saline aquifers (3,000 Gt CO_2).[3] Due to uncertainty about emission projections and varying safety of storage locations, these figures should be treated with care and understood as a rough indication of the huge potential of carbon storage sites actually existing. The technology applied for injection is well developed as numerous sites have been used for the temporary storage of natural gas for decades.

Environmental Challenges

There are two main environmental challenges facing carbon capture and storage: the first is, of course, whether it is possible to store the CO_2 safely in the geological formation in the long term—i.e., the technical risk. The second question is political: will investments in carbon storage replace investments in renewable energy and conservation, and accordingly be a barrier to de-carbonization of the energy systems? This last question seems to be the main reason why some environmental NGOs have taken a negative stand on carbon storage.[4] With respect to the technical risk, a conclusion from a workshop of the International Panel on Climate Change (IPCC) on carbon capture and storage in 2002 was that the environmental impacts of geological storage are likely to be small, but are not well characterized.[5] If huge amounts of CO_2 are stored, the release rates must be very low in order to prevent them from becoming a large source of future emissions (Bode and Jung 2004).

An underground deposit must display certain characteristics to be suitable for CO_2 storage. It has to be deep under the ocean surface to have high enough pressure, and the species of rock must be sufficiently porous to permit the gas to be pumped in. And of course, it is essential that the geological formation is stable and not earthquake prone. With reference to natural CO_2 fields[6] and studies of natural analogues, geologists conclude that under favourable circumstances geological formations with certain characteristics can hold CO_2 for millions of years.[7]

Establishment of procedures for risk assessment when selecting storage sites and monitoring systems are necessary both in order to ensure environmental performance and to build stakeholder confidence. The methods for risk assessment and monitoring are available: reservoir behaviour can be predicted with simulation tools based on reservoir information, and seismic and sediment samples are some of the available methods for monitoring.[8] There is extensive national and international research going on covering both risk assessments of leakage from geological formations and monitoring issues.[9]

In addition to the environmental challenges in the storage phase, there is also an environmental issue related to the capturing of $CO_{2,}$ often referred to as the energy penalty. Capturing CO_2 requires energy, and according to the IEA Greenhouse Gas R&D Program, capturing CO_2 reduces the energy efficiency in a power plant by as much as 10–15 per cent.

Economic Challenges

The IPCC estimates the costs of carbon capture and storage to be approximately US$40–60 per metric ton of CO_2 (IPCC 2001), while the International Energy Association estimates that capturing and storing CO_2 would cost from $50 to $100 per ton (Carbon Market News December 15, 2004). Several other studies estimate the total costs to range from about $20 per ton of CO_2 up to about $100, depending on the capture source, modes of transportation and types of reservoirs (Torvanger, Kalbekken and Rypdal 2004). Compared to current prices in the European emissions trading market of about 8.5 Euro, or about US$11, it is fair to conclude that the cost obstacle is at present significant, but there is probably scope for reduction of costs in the future through technical developments and wider application (IPCC 2001).

Of the total costs, the capture costs are expected to constitute a much larger share than transport and storage, about 70–80 per cent according to some sources. Reducing capture costs is hence identified as the major economic challenge. But as noted above, this is only relevant with regard to CO_2 from large emission sources like power generation and not CO_2 separated from the gas stream.

Political and Legal Challenges

There are also legal barriers and potential political barriers on the international level with regard to disposal of CO_2. There is a need for clarification of the legal status of carbon storage in international conventions; simply because carbon capture and storage was not foreseen as a climate policy measure at the time the conventions were developed. Because of scepticism among several environmental NGOs and some states towards the measure as a climate policy measure, ongoing international processes aimed at solving the legal challenges might meet political barriers.

The first set of legal, and potential political, challenges stems from conventions developed to protect the marine environment. It has been maintained that injection of CO_2 is in conflict with the OSPAR convention, which was established to protect the marine environment in the northeast Atlantic area. This convention is far more concrete and operative than the UN Convention on the Law of the Sea, which also has provisions to protect the environment. The issue is whether injection of CO_2 can be considered dumping of a toxic. And since this process was not foreseen when both conventions were developed, there is scope for discussion and interpretation (Brubaker and Christiansen 2001). Dumping, which is defined as the discharge of waste or other substances into the ocean or the underground from ships, airplanes or offshore installations, is prohibited. But there are clauses that permit discharges from sources onshore as well as offshore if the precautionary principle and best available technology were employed.

A process, which might lead to the necessary revision of OSPAR, was started only recently within committees of the convention. There is also a need for clarification with regard to the London Convention on dumping (Gran 2004). To some extent these legal problems must be regarded as technicalities, and whereas they form obstacles to CO_2 injection today, the conventions can be adapted if consensus on the environmental safety issue can be established.

The other set of legal and political challenges at the international level comes from the treatment of the issue in the climate convention and the Kyoto Protocol, or the lack thereof. Carbon storage is not discussed directly and can only be inferred from general provisions about sequestration.[10] In the IPCC Third Assessment Report from 2001, CO_2 capture and storage is mentioned as a serious mitigation option alongside the more established options, but safety and verification are noted as problems. The IPCC is presently working on a report on carbon capture and storage to be finished during 2005. The report will include environmental, geological, technical as well as economic issues. The adoption of the report can become an important step towards clarification of the status of carbon storage as a climate policy instrument, but as will be discussed in the last section of the paper, it could also mean another complicating factor in the international climate negotiations.

How the issue is handled with respect to the EU emissions trading scheme (EU ETS) will also be important for the acceptance of the measure within the future climate regime, since the EU ETS has become somewhat of a benchmark for potential future GHG emissions trading schemes. According to the EU regulations on reporting and monitoring, the member states are allowed to report storage projects upon approval by the EU Commission, until permanent regulations have been developed.[11]

The major environmental, economic and legal/political challenges are summarized in Table 1.

Table 1. Carbon capture and storage as a climate policy measure – major challenges

	CHALLENGE			
STEP	**Environmental**	**Economic**	**Legal**	**Political**
Capture	Investments in capture technology replacing investments in renewables?	Capture technology is not commercial at present.		
Transportation		Establishment of new infrastructure		
Storage	Investments in storage technology replacing investments in renewables? Developing procedures for risk assessment and monitoring of storage sites to ensure safe storage.		Clarifications of the legal status of carbon storage as a climate policy measure in OSPAR, the London Convention, under the UNFCC and in the EU ETS.	Building confidence in storage as a safe and sound environmental measure.

The Case of Norway

Norway has no suitable structures for CO_2 storage on land, but storage in geological formations like aquifers and producing and non-producing petroleum reservoirs offshore is applicable in Norway.[12] Utsira alone, the aquifer where CO_2 from the gas field Sleipner is presently stored, has been estimated to have a capacity of 600 billion cubic meters of CO_2. The second storage option applicable in Norway is to inject CO_2 into non-producing and producing petroleum reservoirs. CO_2 can be stored in either oil or gas fields after production has ceased. About 20 fields on the Norwegian Continental Shelf with an estimated storage potential of just over 1000 million tonnes of carbon dioxide have either ceased production or are due to cease within the next 10 years (Norwegian Ministry of Petroleum and Energy 2003).

Since 1996, the partly state-owned Norwegian oil company Statoil has injected more than five million tons of CO_2 into a sandstone formation at the huge offshore gas field Sleipner—the so-called Utsira formation. This is considered to be the first full-scale project of its kind. The CO_2 has been separated out from natural gas produced at the Sleipner fields. To market the Sleipner gas, the high CO_2 content (nine per cent) must be drastically reduced. Thus, the *separation* of CO_2 is part of the industrial/ commercial solution for Sleipner. The separated CO_2 could have been emitted, but this would have incurred costs in the form of the Norwegian CO_2 tax. Consequently, *injection* of the gas becomes economically more attractive. The second major storage project on the Norwegian Continental Shelf is planned at the Snøhvit gas field in the Barents Sea. Production start at the field is scheduled early 2006. Like at Sleipner, CO_2 from the gas stream will be separated and injected into a sandstone formation at the field. The annual storage volume will be 700,000 tonnes of CO_2.

It is also possible to inject CO_2 into producing petroleum fields to enhance oil or gas recovery by increasing the pressure in the reservoir. Injection of CO_2 will then normally replace injection of water or natural gas. Since CO_2 injection offers the added advantage of storing CO_2, the method should also be discussed in a climate policy context. CO_2 for enhanced oil recovery has so far not been applied offshore, and based on 30 years of experience from the U.S. and Canada, onshore cannot be transferred directly to the petroleum fields offshore Norway. Nevertheless, Norwegian authorities as well as oil companies have been assessing the potential for injecting CO_2 for enhanced oil recovery in various fields on the continental shelf. According to those assessments, both technological and economic challenges remain to be solved before the option can be realized in Norway.[13]

Norway in the International Setting

The Norwegian government seems to increasingly arrange for CO_2 storage to become an accepted climate measure internationally. Norway's positive position on carbon storage has most strongly been expressed in the form of participation in international technological cooperation. The Norwegian companies Statoil and Hydro are participating in the technological cooperation that was established by the CO_2 Capture project (CCP) in 2000. The CCP is directed towards technology developments for all aspects of capture and geological storage of greenhouse gases, and comprises eight international energy companies.[14] Norwegian authorities provide some funding through the Research Council of Norway, and there has also been financial support for research from the European Union and the U.S. Department of Energy.

Another international cooperative effort, with stronger political overtones, was launched in 2003 with the establishment of the Carbon Sequestration Leadership Forum (CSLF). This was an American initiative and has 16 countries as members, as well as the EU. The Forum is 'an international climate change initiative that is focused on development of improved cost-effective technologies for the separation and capture of carbon dioxide for its transport and long-term safe storage. The purpose of the CSLF is to make these technologies broadly available internationally; and to identify and address wider issues relating to carbon capture and storage. This could include promoting the appropriate technical, political, and regulatory environments for the development of such technology'.[15] The Forum holds meetings on a minister or deputy minister level and can be regarded as a framework for international cooperation in research and an effort to focus public support to technology development.

Norway's support for the initiative can be understood both on the background of the country's natural conditions for CO_2 storage, but also as a way to find some common ground with the U.S. in climate politics and a forum for climate dialogue. Norwegian authorities are anxious to stress though, that "it is a precondition that the cooperation is not 'presented as an alternative to the Kyoto protocol or other international climate agreements with binding emission commitments'. (Norwegian Ministry of Petroleum and Energy 2004). The other pro-Kyoto members of the forum probably share this concern.

Norway has also developed a more pro-active policy within the climate negotiations, seeking to reduce or lift the barriers discussed above. The Norwegian Minister of Environment at COP-9 in Milan in 2003 highlighted the success of the Sleipner experience in order to promote the idea of carbon storage as a climate policy measure in a bridging period from fossil fuel-based economies to economies based on renewable energy (ENB 2003; Norwegian News Agency, December 11, 2003). At COP-10 in 2004, the minister also stressed technologies to capture and store CO_2 and pointed to the possibility of storing CO_2 from other European countries on the Norwegian Continental Shelf.[16]

Even though official pronouncements have been more supportive lately, Norway has been careful not to tout carbon storage as an established climate policy measure. Nevertheless the main carbon capture or, more precisely, separation and storage project in Norway is clearly connected to the climate regime. As described above, the economic stimulus for the injection of Sleipner gas into the Utsira formation is caused by the Norwegian CO_2 tax. By injecting the gas, companies avoid the tax. But if this procedure is to make sense in Norway's overall emissions accounting, the injected volumes must be subtracted from the country's CO_2 emissions when they are reported to the UNFCCC Secretariat. Thus, Norway presupposes that carbon storage will be recognized under the UNFCCC.

The idea of Norway offering a solution to CO_2 emissions from other European countries by injecting the gas for enhanced oil recovery in Norwegian oil fields has also recently been communicated to the European Union by the Norwegian government. An expert group consisting of representatives of various European countries has been set up.[17]

Carbon Storage and the International Climate Negotiations

So far, international processes on carbon storage have been developing separately from the negotiations on the climate regime, and the processes have mainly taken place in technical, not political arenas. Even so, some countries, i.e., Norway, but also Canada, have brought the issue to the attention in the climate negotiations from time to time unilaterally. Carbon storage has, however, not been on the official agenda. Thus the status of the measure in relation to the UNFCC and the Kyoto Protocol has not been clarified. With the launching of the IPCC report on the issue in autumn 2005, carbon storage will formally be brought into the international climate regime. This does not necessarily mean that the issue will be high on the political agenda in the international negotiations. The report as an input to policy-makers will probably first be discussed at a SBSTA meeting, which attracts much less political attention than the Conferences of the Parties do. Whether the IPCC report will contribute to clarification of the status of carbon storage within the climate regime, will hence depend on how the process develops from the initial SBSTA discussions, and also on whether actors within the climate regime see it in their interest to obtain guidelines.

If, as a consequence of the IPCC report and increasing international attention, the issue is put high on the agenda in the international climate negotiations in the near future, it is possible to outline, at least, two opposite scenarios. One possibility is that this will advance the international negotiations one step further; the other is the opposite, namely that the international climate diplomacy will be further complicated.

It seems possible that carbon storage might constitute some common ground between the parties on the Kyoto track and the U.S. It is an option compatible with the U.S. emphasis on technology development and a measure that does not threaten the fundamental interests of important domestic actors within the U.S., i.e., the coal and the oil industries. It is also important that the U.S. was the initiator of the Carbon Sequestration Leadership Forum. The EU, also a member of the CSLF, is like the U.S. in emphasizing research and development on carbon capture and storage, and several R&D programs are ongoing or in the pipeline.

Unfortunately, the scenario of carbon storage complicating the climate negotiations seems more realistic. As has been stated above, there are still many unresolved questions regarding the overall feasibility of carbon storage as a measure to combat climate change on a large scale. There is also a list of more specific issues, which will have to be solved if carbon storage should be accepted as a climate measure. One such issue is whether it should be treated as a sink, with all that implies in the climate regime, or whether it should be counted as emission reductions (Bode and Jung 2004). Another set of problems will be connected to certification and verification procedures for storage sites.[18] And third, as would be highly relevant for Norway, it is necessary to determine how to share credits for CO_2 reductions in situations where capture and storage are taking place in different countries.

What will be the consequences of bringing these issues into the climate negotiations in the near future? Carbon storage is still very uncertain, and a lot of new controversies are likely to erupt. Furthermore, if carbon storage is brought into the negotiations, the discussions will have a conditional character since there are still fundamental technical uncertainties. To clarify and develop the option, considerable economic resources are needed. It is easy to imagine that these efforts will be at the expense of other options that are already at hand, i.e., energy conservation and renewable energy. This will create tension in the negotiations.

We will argue that bringing the issue of carbon capture and storage into the climate negotiations at this time will probably do more bad than good. The questions of monitoring, verification, selection of storage sites and public confidence should be allowed to mature outside the climate negotiations before the issue is fully discussed within the framework of the UNFCCC. Also the potential to constitute common ground between the U.S. and the Kyoto Parties would probably be higher if these issues are allowed to develop further outside the climate negotiations.

This argument does not disregard carbon storage as a possible future option. According to the most optimistic analyses, carbon storage offers a possibility to deal with a substantial share of the world's CO_2 emissions over many years. This 'service' can, in principle, be made available to many emitters and many countries. But there are a limited number of countries where the required geological structures can be found. These countries, which include Norway, will have an additional interest in developing carbon capture and storage as a feasible technology. They will be able to charge customers for the use of storage capacity. Thus it can be argued that they will have a strong economic self-interest in developing solutions for carbon capture and storage, and that it should not be necessary to use mechanisms negotiated at the global level to support research and development for this purpose. In other words, the collective action problem associated with several forms of development and transfer of technology will be much less pronounced in the case of carbon capture and storage, since the number of users will be limited by the natural distribution of storage sites. Nevertheless, the need for international cooperation—among storage 'owners' to reduce costs is there, and also to develop environmentally solid methods for selection of storage sites and monitoring.

To a large extent such a 'regionalization' of carbon capture and storage development outside the global climate negotiations is actually what has happened, with the establishment of various fora, as mentioned above. The argument here is that the development should continue along these lines until sufficient certainty about environmental as well as economic aspects of carbon storage has been reached. The prospects for realization of carbon storage as a climate policy measure might in fact be better if the issue is not brought into the framework of COPs/MOPs for the time being. In other words, carbon capture and storage belongs in the *debate* and research efforts about future climate policy measures, but not yet in the *negotiations* about a post-Kyoto climate regime.

Notes

[1] It is also possibe to store mineralized CO_2 as a solid substance, but this option is presently not high on the agenda of carbon capture and storage as a climate policy measure, and we will hence not include it in the further analysis.

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[2] www.nrcan.gc.ca/es/etb/cetc/combustion/co2trm/pdfs/co2trm1_cpreston.pdf

[3] 'Technical options for placement of CO_2 in the maritime area.' Presentation by Paul Freund, the IEA Greenhouse Gas R&D Programme, at Ospar workshop, October 27, 2004.

[4] www.cslforum.org/documents/von_Goerne_Gabriella_mon_Pal_AB_1330.pdf

[5] Presentation by Heleen de Coninck with the IPCC on an OSPAR workshop, October 26, 2004.

[6] Workshop report: Ospar workshop on the environmental impact of placement of carbon dioxide in geological structures in the maritime area, October 26-27, 2004.

[7] Workshop report: Ospar workshop on the environmental impact of placement of carbon dioxide in geological structures in the maritime area, October 26-27, 2004.

[8] 'Safe storage of CO_2'. Presentation by Erik Lindeberg, Sintef, at Ospar workshop October 27, 2004. 'How can injected CO_2 be monitored'. Presentation by Barthold Schroot, TNO's Institute of Applied Geoscience, at Ospar workshop October 27, 2004.

[9] An updated overview of projects can be accessed via the IEA Greenhouse Gas R&D Programme's Web site: http://www.co2captureandstorage.info/

[10] The issues related to the Convention, as well as key technological challenges are discussed in (Torvanger, Kallbekken and Rypdal 2004)

[11] Commission decision of January 29, 2004, establishing guidelines for the monitoring and reporting of greenhouse gas emissions pursuant to Directive 2003/87/EC of the European Parliament and of the Council.

[12] Storage of CO_2 in the ocean is also a theoretical possibility, but due to scientific uncertainty about the permanency of such storage, the method is controversial and has so far not been tried out. The Norwegian Ministry of Environment stopped an experiment of releasing about five tons of CO_2 in deep water in the Norwegian Sea in 2002. The Norwegian Institute for Water Research had first been admitted a permit to carry through the experiment from the Norwegian Pollution Control Authority, but Greenpeace and WWF submitted a complaint of the decision to the Ministry of the Environment, which consequently altered the decision.

[13] Report No 38 to the Storting (2003–2004).

[14] BP, Chevron, Eni, Hydro, Suncor, ConocoPhillips, Shell, Petrobras.
www.CO2captureproject.com/index.htm

[15] www.cslforum.org/intro.htm

[16] Statement by Mr Knut Arild Hareide, Minister of the Environment, Norway, Panel Discussion, COP-10, Buenos Aires, December 16, 2004

[17] Press release from the Norwegian Ministry of Petroleum and Energy, May 23, 2004.

[18] Some of those issues are discussed in (Torvanger, Kalbekken and Rypdal 2004)

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