CO_2-infrastructure on the Norwegian-British Shelf

Climate solutions across borders

ZERO-MEMO - December 2006

Berit Kristoffersen and Thomas Palm

Zero Emission
Resource Organisation

About ZERO

Zero Emission Resource Organisation is an environmental organisation set to reduce climate change by pointing out and gaining acceptance for emission free energy solutions. ZERO's perception is that it is possible to avoid climate emission whilst covering the world's energy demands. ZERO is a consistent advocate for these solutions and works to materalise these. www.zero.no

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Summary

There is a budding recognition on how future fossil energy consumption must be combined with the capture and permanent storing of CO2. The awareness of prospect large-scale climate changes has led to a call for action. As the world is already faced with climate changes, a cut-loss approach has been introduced, focusing on how reductions may be obtained.

In September 2005, ZERO launched the joint North Sea CO2- Infrastructure scheme, which outlines a would-be partnership between The UK and Norway. In this memo, we will present options concerning large-scale CO2-storage at The Norwegian-British Shelf. By mapping relevant CO2-sources and disposal options in the North Sea, it is ZERO's objective to help identify strategies enabling necessary and achievable CO2 reductions in Norway and Great Britain. A gradual development, with the implementation of new CO2 resources paired with new storage localities, may increase the total capacity.

The majority of foregoing studies have been isolated projects with a by or large general focus or not emphasized UK-related CO2-sources.

A bilateral CO2- implementation is likely to hold significant socio-economic effects. Furthermore, it can pay a regular contribution to noteworthy and measured drop in emissions and decarbonisation of fossil energy resources. While both countries have considerable fossil energy resources, Norway possess a greater CO2 disposal potential through the North Sea compared to the UK with its vast emissions from stationary CO2 sources (600% weighed against Norwegian emissions).

The UK and Norway are struggling to meet their climate commitments respectively. Therefore, we are now experiencing a probing move towards reducing CO2 emissions through clean energy solutions. The authorities in both the UK and Norway deem CO2 storage in the North Sea to be an important tactic to combine fossil energy production with methods that have major positive effects on climate accounts.

A joint effort from the two governments has already been initiated and established. Shared regulations and principles for regulating transport and disposal of CO2 in the North Sea are scheduled for presentation in the first half of 2007.
The authorities will then look into which infrastructure is required for transportation and storage.

With this memo, ZERO will help to provide authorities, companies and third parties with an improved platform for an assessment on how the realization of a Norwegian-British CO2-infrastructure may be reached.

In the UK, where stationary CO2 sources emit approximately 266 million tonnes annually, the potential for reducing emissions through capture, transportation and storage of CO2 in oil and gas fields is estimated to be 90 per cent.[1] The oil industry is basically favourably inclined, but few plans have progressed past the proposal stage. Estimates show that CO2 disposal will be profitable in several fields where injection of CO2 may increase oil recovery rates, even if projects are estimated based a conservative assessment of the oil price development. [2]

1. Stern Review on the economics of climate change
2. For instance EUR 32895:4, and in addition, the oil industry uses an oil price of no more than 30 dollars when

In this memo, our starting point is the most prospective activities in CO_2 capture and disposal which in turn may form the basis for a Norwegian-British infrastructure – Further, furnishing us with sufficient disposal solutions for greater emission sources.

The purpose:

- Provide a sufficient CO_2 quantity in order to dilate oil extraction.
- Provide accessible and sufficient buffer capacity.
- Realization of isolated projects, otherwise difficult to accomplish.
- Exploit scale advantages, thus reducing transportation and disposal costs.

Initially, a utilization of the short distance between the Sleipner and Miller fields, where the pioneering CO_2 projects in Norway and the UK, respectively, take place.

BP plans to capture 1.8 million tonnes of CO_2 annually from a power plant in Scotland and to use the CO_2 to increase oil recovery rates on the Miller field.[3] BP expects to operate the field for 15 to 20 years longer than originally scheduled due to the injection of CO_2.

The Miller field and Statoil's Sleipner field are situated 40km from each other. Since 1996, Statoil has disposed of 1 million tons (Utsira) of CO_2 on an annual basis .The Utsira formation is believed to offer an almost unlimited storage capacity.

Sleipner is also the most relevant recipient for CO_2 from the gas power plant under construction at Kårstø, where the Norwegian government has decided to build a capture facility, which is at present in planning. Not far from Sleipner is also the Volve field, where turn-key is scheduled to 2007. Statoil is considering the possibilities of using CO_2 for increased oil recovery rates at Volve, but this is only an option for a few years, and getting CO_2 for such a project is urgent.

A would-be piping of the distance between Sleipner and Miller may connect Norway and the UK, creating an unparalleled and necessary hub for further capture, utilization and disposal of CO_2. ZERO has built a good rapport with both BP and Statoil, and they are seemingly postive to the idea.

The subsequent phase may focus on the major pollution sources along Norway's west coast, and not the least, sources originating from Scotland should be included, as several power plants and oil-related activities operates along the coast line. As a result, CO_2 will be avaliable for substantial additional oil recovery projects, E.g Statoil's Gullfaks field.

A sufficient quatity of CO_2 can be obtained in Norway and Scotland, and either be forwarded through the Sleipner hub, or gathered at – and shipped from Kårstø.

Transportation from the latter may be routed via Mongstad, where Statoil is building a gas power plant (set to introduce CO_2 capture by 2014). Regardless if it proves impossible to obtain a decision in favour of introducing CO_2 at Gullfaks, Mongstad would still be in need of a solution dealing

considering long-term profitability for various projects

3. The power plant will transform gas into hydrogen and CO_2

with both transportation and disposal. The said solution may include a pipe extension leading to Kårstø and further to be hooked on the Sleipner hub.

Third phase might entail tying English emission sources (mainly coal power plants) and prospective large-scale Norwegian power plants to the CO2 infrastructure.

During this period, CO2 may also be introduced in several southern parts of the North Sea.
At the same time, ZERO may point out other domestic (Norwegian) or regional (European) CO2 sources deemed feasible for the above mentioned CO2 infrastructure; however, we will not discuss this further in this memo.

The competence from Sleipner and the enormous storage capacity in the Utsira formation will remain the key factor all along, as it, in addition to representing a desirable buffer capacity in the CO2-structure, guarantees that there is somewhere to store all CO2.

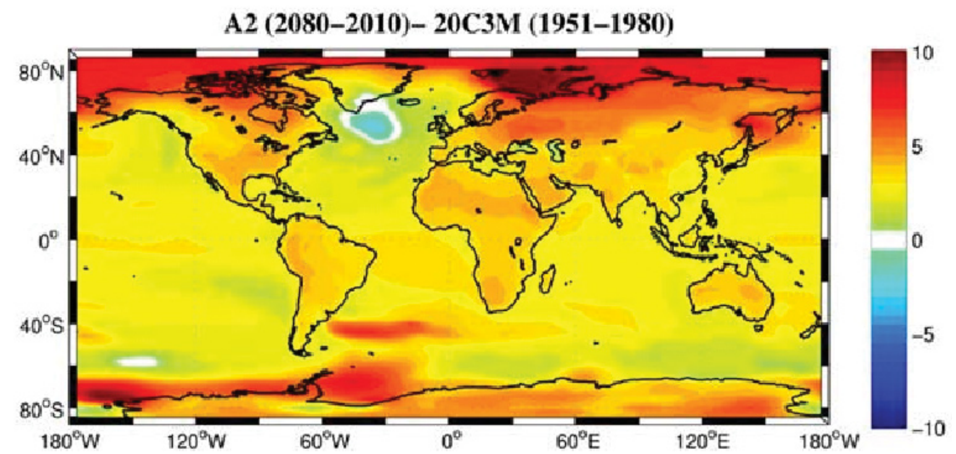
We do not regard an implementation of CO2 in oil production as crucial to realization of the infrastructure; nevertheless, it would be a driving factor even to our neighbours.

Large-scale capture and storage of CO2 must be carried out in any event for environmental reasons.

In the course of our work with this memo, we have been in touch with the British Department of Trade and Ministry and the Committee on Science and Technology, Scottish and English pollution authorities, as well as the mentioned companies. They have all been helpful and positive towards this project.

1. The Climate Challenges

Due to the enormously accelerated use of the non-renewable energy sources, mainly oil, coal and gas, the CO2 concentration in the atmosphere is at its highest level in 650,000 years. If the growth continues, it will be the highest level in 20 million years, in 2100. Even if all emissions were to be cut today, they have already lead to such high CO2 concentrations in the atmosphere that the temperature will rise regardless of action.



In the period from 1979 to 2005, the Arctic Sea ice has e.g. been reduced by 20 per cent, and the summer ice will most likely disappear completely in this century. Also, the polar bear, which is named after the Arctic, has been included on the endangered species list.

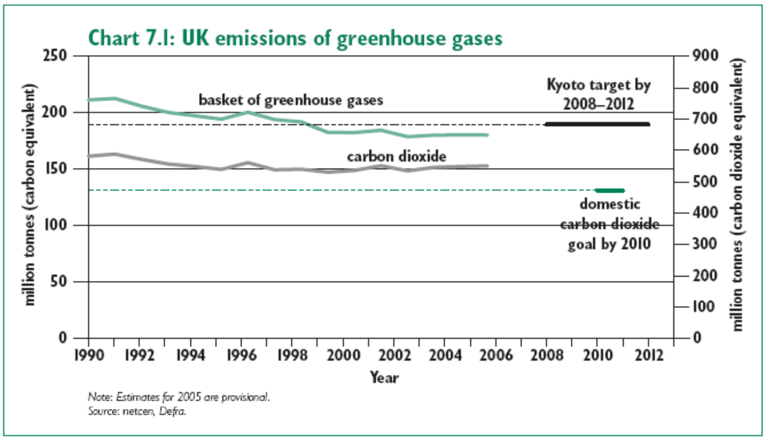
The objective of the EU and Norway is to limit the temperature increase to two degrees, which in turn demands radical emissions reductions. An increase of two degrees on a global scale means that the temperature in the Arctic will rise by 5-7 degrees due to accelerating heating mechanisms. See the figure for changes in global surface temperature.

The Greenland ice contains enormous amounts of water, and with a temperature increase of three degrees, the global sea levels will rise by more than two metres. If the entire ice on Greenland melts, the sea level will rise by seven metres, with extensive and dramatic consequences.

Increased production of renewable energy and energy efficiency improvement can reduce dependency on fossil energy and is an important part of the solution to the challenge. However, internationally, in spite of a massive increase in the production of renewable energy, fossil energy sources will still play an important part in the world's energy supply for years to come. In order to limit the emissions and damage as much as possible, future use of fossil energy on some scale is therefore inseparable from the issue of capture and disposal of CO2.

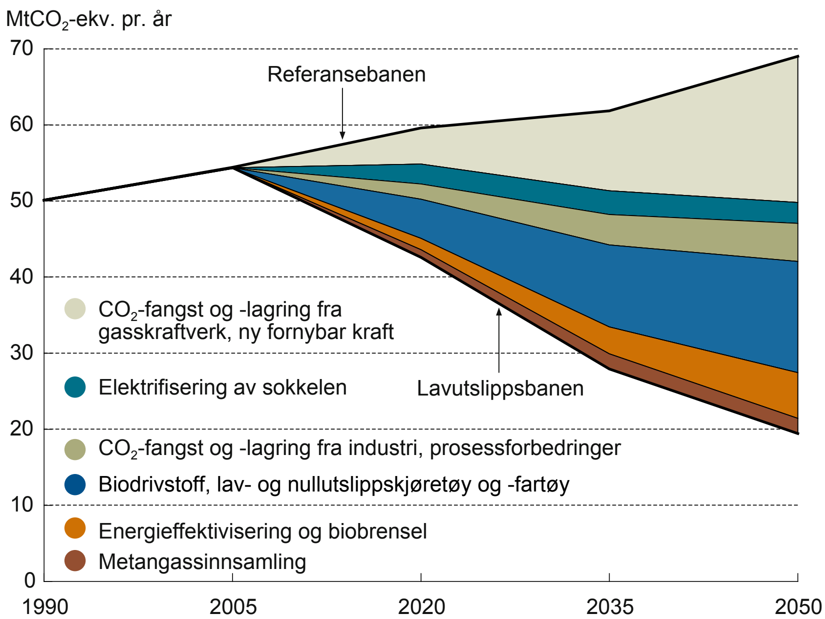
1.2 Climate commitments

The UK accounts for two per cent of the world's global climate emissions and is not on schedule to fulfil its climate commitments. The country is to reduce CO2 emissions by 20 percent and 60 percent compared to 1990-level emissions by 2010 and 2050, respectively.[4] The development which is outlined in this figure shows the discrepancy between objective and actual development in the UK.[5]



In July 2006, British authorities presented an energy analysis where various methods for solving the problems related to a stable energy supply and lowering greenhouse gas emissions were evaluated. CO2 disposal was considered a key measure in this analysis.[6]

Norway is also far from fulfilling its climate commitments. The government-appointed Low Emissions Committee (lavutslippsutvalget) recommended disposal of CO2 as a key instrument to limit short-term emissions and to be able to reduce emissions by two-thirds by 2050. See figure.

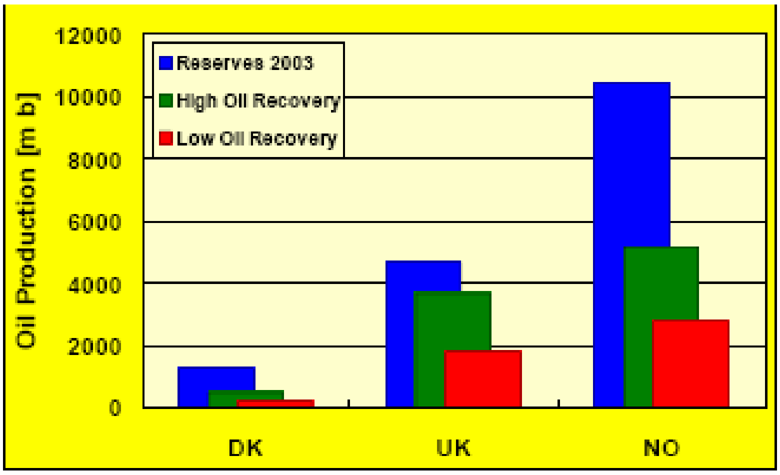


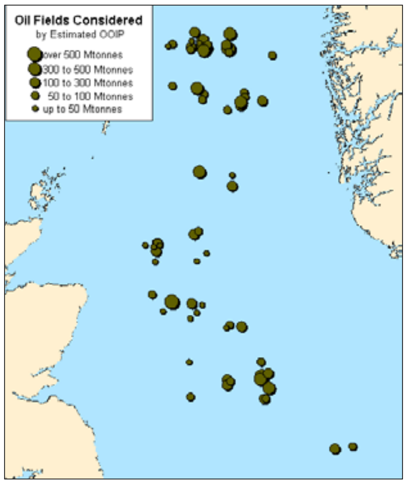
4. The energy review:
5. Ibid
6. The energy review: The Energy Challenge, DTI, 2006

1.3 Storage and use of CO2 in the North Sea

Many different geological formations in the earth's crust can store gases such as CO2. On the Norwegian Shelf alone, formations have been identified which may have the capacity to receive approx. 500 billion tonnes of CO2, more than 10,000 times the annual Norwegian emissions. Disposal would be the main method of storing CO2, but CO2 can to some extent also be used to produce more oil from the petroleum fields in the North Sea.

In the report *Enhanced Oil Recovery using Carbon Dioxide in the European Energy System* (EUR 32895), the additional oil potential for 81 fields in the North Sea was estimated based on their reserves. As we can see from the figure, the Norwegian potential is by far the largest.

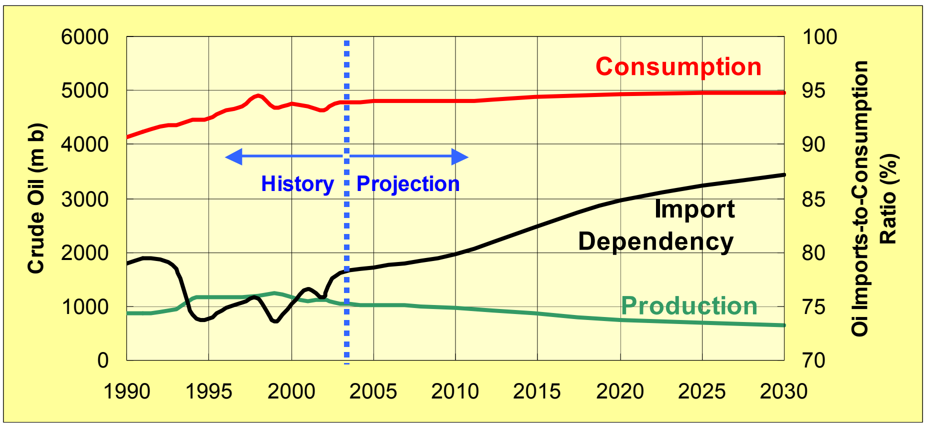




Both in Norway, but in particular for many British fields, there is a growing urgency to get a decision to use CO2 before it is too late.

1.4 Energy security and CO2 disposal

Not only environmental concerns and the potential for increased oil recovery provides the background for increased focus on and discussions of CO2 disposal as something *more* than an alternative to solving climate problems, and to increasing the field-specific recovery potential by oil companies and the authorities. The large international oil companies, unlike the national companies, lack adequate reserves, and the events in recent years regarding instability in the supply of energy to Europe, and an ever increasing energy need in recently developed countries, draw up a new energy situation, partly along old divisions. This is taking place in the context of Europe's increasing dependency upon imports, which one is struggling to find solutions to. Here is an overview from report



EUR 32895 with forecasts showing the consumption in the next 20 years will be relatively stable, production will drop, while European import dependency will increase strongly up to 2030.

Norway is put under pressure to ensure supply of petroleum in the next years, increasing the pressure on the recovery tempo in Norway, and to export to certain countries such as the UK and USA. Uncertainty in the petroleum market as a result of several conflicts and growing demand has led to a rapid increase in the price of oil. The boom now experienced by the petroleum industry, as well as the growing uncertainty as regards import and delivery, cause CO2 storage with potential for increased oil production to be considered as an achievable measure to limit CO2 emissions and improve security of supply to the UK and others.[7] Here, we see the price growth over the last ten years,[8] which has in time resulted in relatively high oil prices. Most experts, who monitor oil price in the medium term, consider it likely that the level of oil prices will not be below 50 dollars for a long period.

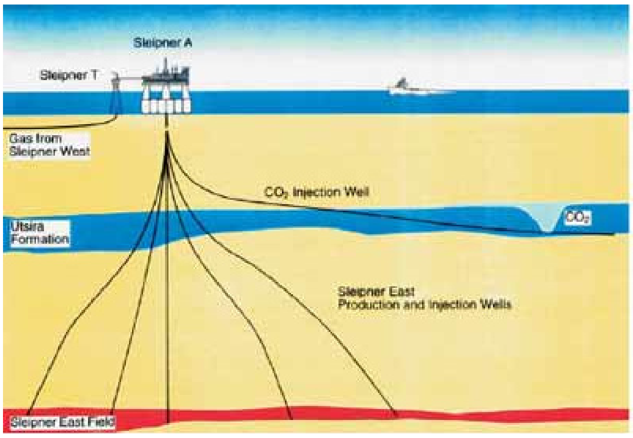
The possibility for capture and storage of CO2 has also paved the way for a coal 'renaissance'. Both the European technology platform and the EU Commission's draft for a new energy policy focus on clean coal power as an important possibility. The EU wants 12 large-scale demonstration plants for capturing and disposing of CO2 by 2015 (independently of fuel - Norwegian projects for clean gas power are also mentioned). Furthermore, there is a desire for all new power plants to have capturing mechanisms from 2020 on.

2. Relevant projects in Norway and the UK

2.1 Norwegian projects

Since 1996, Statoil has stored 1 million tonnes of CO2 **at the Sleipner field** annually in the Utsira formation. So far, this is the only full-scale project for storage of CO2 in the North Sea. At Sleipner CO2 is separated from natural gas. The natural gas recovered from the reservoir contains approx. 9 percent CO2. This does not meet with the delivery terms for the gas, and CO2 must therefore be removed until the content reaches maximum 2.5 per cent. The decision to start the project was taken in 1990 when the introduction of a CO2 tax in Norway was imminent (from 1991). This tax provided important fiscal motivation for Statoil to carry out injection of CO2 rather than releasing separated CO2 in the atmosphere. This shows how measures and requirements directed at the petroleum industry can lead to positive climate adaptation measures in the North Sea. There is a great potential for further CO2 storage in Sleipner, which is only used for storage. This means that Sleipner can receive "excess" CO2 which is not used for increased oil production (EOR).

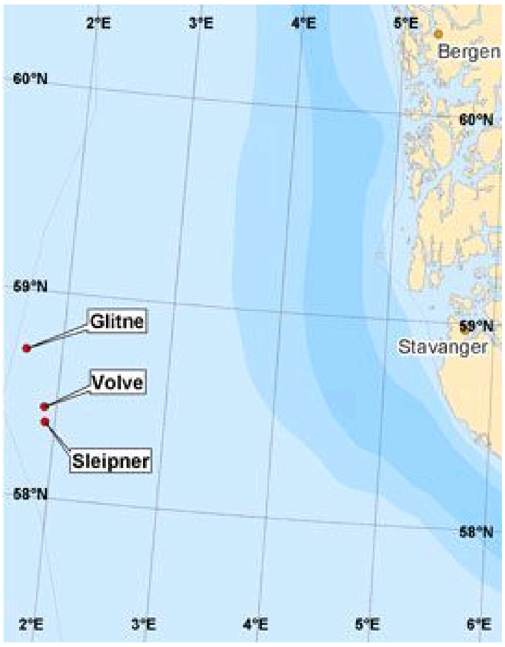
7. House of Commons; Science and Technology Committee: Meeting UK Energy and Climate Needs: The role of Carbon Capture and Storage; 3
8. www.offshore..no



At Kårstø, Naturkraft is building a gas power plant which is scheduled to start production in 2007. The Government has decided that the state will clean the power plant's CO2 emissions, and a capture facility is being planned. According to the Government Declaration, this facility should be ready by 2009, but according to a report from the Norwegian Water Resources and Energy Directorate (NVE), it may take longer before the facility is in operation. In any event, the progress is primarily dependent upon getting a project organisation in place soon.

> "Sleipner is a location well suited to storing CO2 from Naturkraft's facility at Kårstø until definite opportunities for using CO2 for increased recovery have been established," stated Statoil CEO Helge Lund in December 2005. "Such a solution may represent the first step in the construction of a larger CO2 chain and perhaps a definite industrial cooperation of CO2 between the UK and Norway."[9]

Volve. The CEO also stated that the company wants to use CO2 for EOR-purposes at the Volve field, located near the Sleipner field in the North Sea. "If the authorities contribute the necessary infrastructure, Volve can become the first offshore field in the world where CO2 is used for increased oil recovery. This can be the first step towards a comprehensive CO2 value chain, where the oil industry and the authorities work together to handle the climate challenges," Lund stated.[10]



According to plan, Volve will start production in the spring of 2007. Presently, the plan is to inject 1 million tonnes of CO2 - the same amount that will be captured from the gas power plant at Kårstø. CO2 injection in Volve is estimated to be able to increase oil production from the field by about 6.3 million barrels, but getting started soon is very critical.

In June 2006 five other fields in addition to Volve were assessed by Gassco, in cooperation with Petoro and Gassnova, as being the most relevant for use of CO2 for increased oil production now; Draugen, Gullfaks, Oseberg East, Brage and Gyda.

9. From Statoil's web pages: http://www.statoil.com/statoilcom/SVG00990.nsf/UNID/41256A3A0055DD32C12570F8004F33E9?OpenDocument&kat=nyhet
10. Ibid

As for Draugen, Shell and Statoil announced a joint project for construction and capture of 2.1 million tonnes of CO2 from a 860 MW gas power plant at Tjeldbergodden as early as March 8th 2006, with the CO2 being used in this field and then later at Heidrun in the Norwegian Sea. Operation is scheduled to start in 2011/12. The realisation of the project depends on the framework conditions being clarified in 2007. As this project plans to integrate capture and use of CO2, it will not be dealt with further in this memo.

Gullfaks is the field among those mentioned above which has been studied most intensively and which has been seen as the most promising candidate. Gullfaks is also the field which will need the most CO2, an estimated 5 million tonnes or more. The use of CO2 will be very profitable in socio-economic terms, but Statoil believes other alternatives are more commercially attractive and is considering shelving the project. Statoil believes the ball is now in the authorities' court.

Production from the Snøhvit field will start in 2007 and Statoil will dispose of approx. 0.75 million tonnes of CO2 from the LNG facility. However, the plan does not call for purification of the emissions from the gas power plant at the facility, but a potential subsequent Snøhvit train II will probably be prepared for this. As Snøhvit has an available disposal solution which will be put to use soon, this will not be dealt with further in this memo.

Statoil will build a gas-based power and heat plant **at the Mongstad** refinery, generating 280 MW of electricity and 350 MW of heat. In order to issue a license for this, the Government required that a pilot facility be built by 2010 with a capacity of 100,000 tonnes of CO2 annually, and that a full-scale capture facility be in place by 2014. The authorities were to contribute to the financing of this.

2.2 British CO2 disposal projects

On the British side, several projects have progressed far in the planning phase. For the best known project - BP's hydrogen power plant project tied in with the Miller field- a possible investment decision is expected in early 2007. It also seems as if General Electric will take part in the project in time, as the company has signed a letter of intent to cooperate in 10-15 large CO2 storage projects in different parts of the world over the next ten years.

The other promising project, which has also progressed far in the engineering phase, is Progressive Energy's and Centrica/British Gas' Teeside project. Here, the construction of a new coal power plant where CO2 will be captured and bro transported to oil fields is being planned. The project partners are also discussing the potential for further efforts in new CO2 disposal projects.

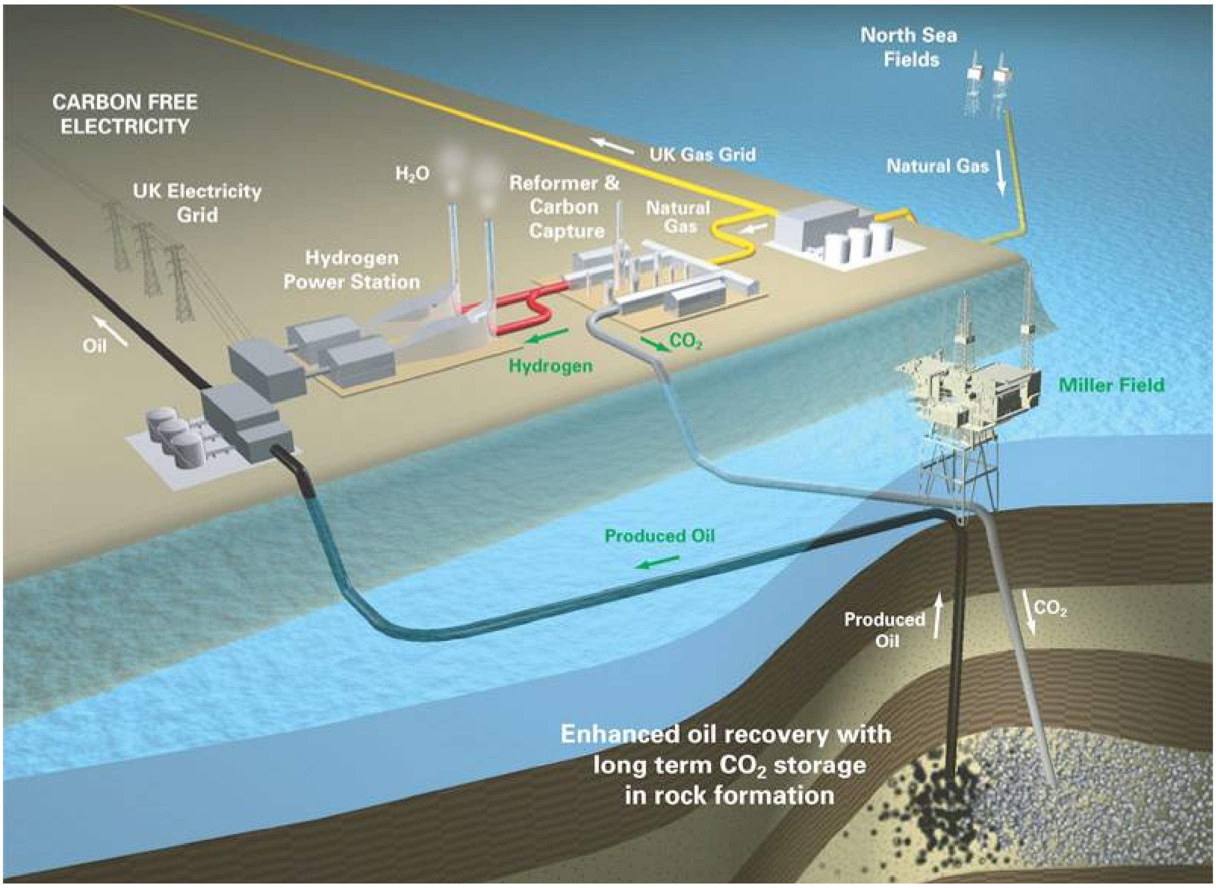
Mutual for the two projects is that they are considered to be large-scale demonstration plants, which British authorities now plan to support. The companies consider the projects to have a large chance of being successful. Both companies are also building new power stations using hydrogen and coal, respectively, to generate electricity, which is also most likely the case for the four other projects which are being planned. See the overview of British projects below.

1, 2009/10: Centrica & Progressive Energy. Coal power, 800 MW: Teeside
2, 2010: BP and Scottish and Southern Energy. Gas and hydrogen. Peterhead, Scotland
3, 2010: Powerful PLC. Coal, 900 MW. Hatfield Colliery
4, 2011: E.ON. Coal, possibly also petcoke, 450 MW Killingsholm, Lincolnshire Coast
5, 2011: Scottish and Southern Energy. Coal, 5000 MW, Ferribridge.

6, 2016: RWE. Coal, 1000 MW. Tilbury

The British Department of Trade and Industry has not been able to state which oil fields are being considered as possible disposal sites, but both the fields along the Norwegian border and the southern North Sea have been confirmed to have great potential for CO2 storage. Several of the fields are entering the tail phase of their production life, which means that one cannot wait too long before making a decision on whether to shut down a field or keep it going by injecting CO2.

The Peterhead project, which is the name of joint effort between BP and its project partner Scottish & Southern, is operated by BP. The costs have been estimated at NOK 7 billion. With a conservative oil price development estimate, BP estimates that the CO2 will extend the lifespan of the Miller field by 15 to 20 years, during which another 50-60 million barrels of oil can be produced. The hydrogen power plant which receives gas from Miller will produce 475 MW of electricity in Peterhead and 1.8 million tonnes of CO2 which will be sent annually to the Miller field for permanent storage. The field lies 40 kilometres from the Sleipner field.



The Teeside project is the first UK project to combine integrated CO2 capturing with disposal from coal power plants and has progressed far into the planning phase. Centrica/British Gas' 800 MW coal power plant is planning to start production in 2009/2010. The process is really quite similar to the one used in the Peterhead project. The power plant is also supposed to be able to run on gas, and the CO2 emissions will be transported to the North Sea where they will be used to increase oil production where they are stored. The CO2 potential is calculated to be 5 million tonnes per year.[11]

11. Sources: press release 8 Nov. 2006 and email correspondence

3. Possible emission sources in Norway, Scotland and England

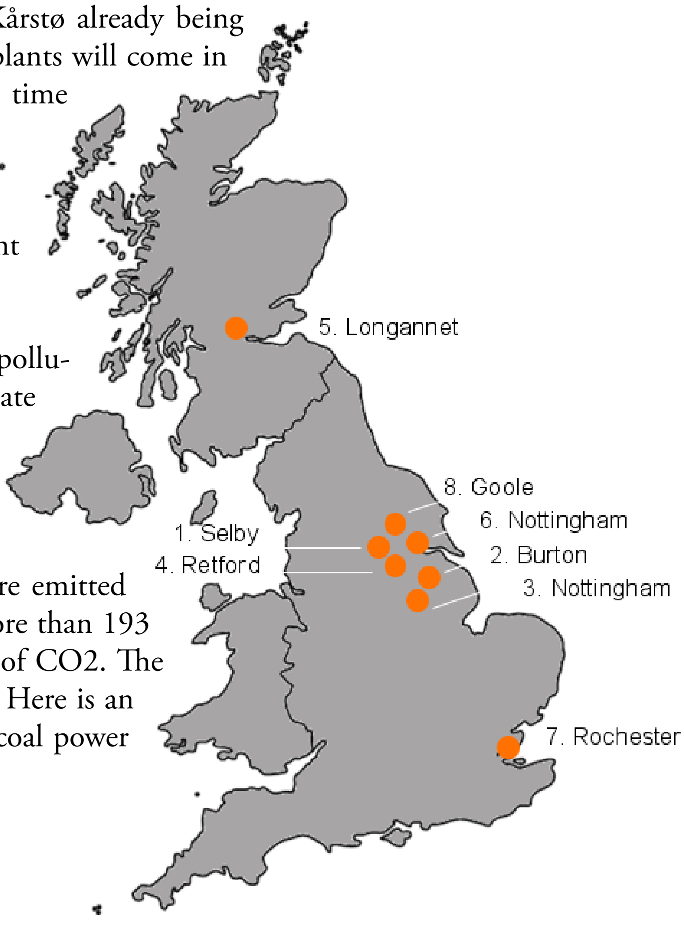
Both on the Norwegian and the British side, CO2 disposal as a climate measure and use of CO2 for increased oil production require significant point sources of CO2. The fields that can utilise CO2 will have different needs for CO2 at different times, while the recovery rate and the reservoir characteristics will vary and may be hard to predict accurately. There are also significant scale advantages in transporting larger amounts of CO2. Access to relatively large point emissions on land and an adequate infrastructure are therefore prerequisites to achieve this.

In Norway, the total CO2 emissions were 43.3 million tonnes in 2005, with the oil and gas industry contributing 27 per cent. The stationary emissions on the mainland contributed approx. 12.3 million tonnes in 2004. Here is an overview of the largest emission sources in 2005:

1. Statoil, the Mongstad refinery - Hordaland County, 1 504 000 tonnes
2. Gassco, gas terminal, Kårstø - Rogaland County, 1 112 000 tonnes
3. Norcem, cement, Grenland - Telemark County, 742 000 tonnes
4. Yara Porsgrunn, fertiliser, Porsgrunn - Telemark County, 594 000 tonnes
5. Hydro Aluminium, Sunndalsøra - Møre og Romsdal County, 586 000 tonnes
6. Hydro Aluminium, Karmøy - Rogaland County, 497 000 tonnes
7. Norcetyl, petrochemical, Grenland - Telemark County, 425 000 tonnes
8. Norcem, cement, Kjøpsvik - Nordland County, 403 000 tonnes
9. Hydro Aluminium, Årdal - Sogn og Fjordane County, 393 000 tonnes
10. Tjeldbergodden methanol factory, Aure - Møre og Romsdal County, 357 000 tonnes
11. Esso, the Slagen refinery, Tønsberg - Vestfold, 330 000 tonnes
12. Elkem Aluminium, Mosjøen - Nordland, 306 000 tonnes

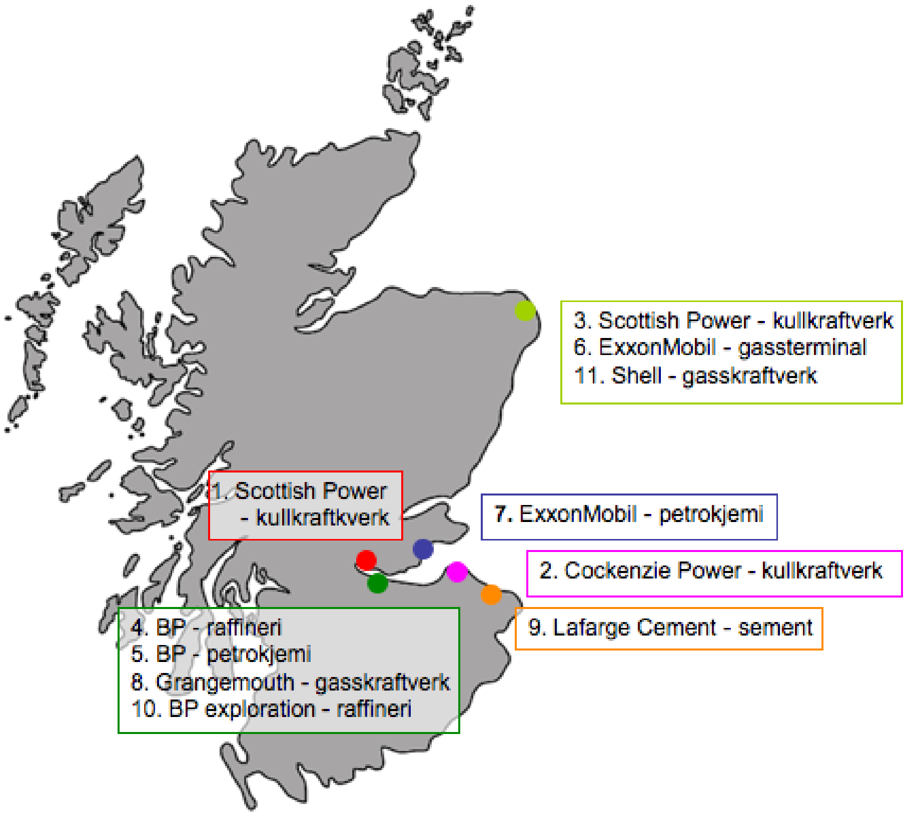
It is worth noting that in addition to Mongstad and Kårstø already being the two largest emission sources in Norway, gas power plants will come in addition there. These will, as previously mentioned, in time become subject to capturing requirements, which will require CO2 infrastructure. This creates increased opportunities for capturing existing emissions in addition. The third area with a relatively large density of significant emission sources is Grenland.

In the UK, coal power plants are the largest source of pollution. Most of the coal power plants were built in the late 1960s and the early 1970s and it can be expected that several CO2 disposal projects in the near future will entail use of technology for capturing in already existing facilities, or that they are built anew with full-scale capture. Of the 265.5 million tonnes of CO2 which are emitted by stationery sources, the energy industry contribute more than 193 million tonnes, and refineries almost 23 million tonnes of CO2. The third largest source is emissions from metal production. Here is an overview of the largest emissions sources, which are all coal power plants:



1. AES Drax Power, coal power, Selby, approx. 20.5 million tonnes of CO_2
2. EDF (West Burton Power St.) coal power, Retford, approx 9.2 million tonnes of CO_2
3. EON, coal power plant, Nottingham, approx 9.2 million tonnes of CO_2
4. EDF (Cottam Power St.), coal power, Retford, approx 8.9 million tonnes of CO_2
5. Scottish Power, coal power, Longannet, Scotland, approx 8.5* million tonnes of CO_2
6. Keadby Generation, coal power, Knottingley, approx 8 million tonnes of CO_2
7. EON UK PLC, coal power, Rochester, approx 7.8 million tonnes of CO_2
8. British Energy PLC, coal power, approx 7.3 million tonnes of CO_2

In excess of 60 million tonnes of CO_2 are emitted from stationary sources in Scotland. The oil and gas industry dominate the emissions, together with fossil fuel power plants, and many of them are geographically concentrated, as can be seen here in the map over the ten largest emission sources.



1. Scottish Power, coal power, Longannet, 8.8 million tonnes of CO_2
2. Cockenzie Power, coal power, Prestonpans-East Lothian, 2.8 million tonnes of CO_2
3. Scottish Power, coal power, Peterhead-East Lothian, 2.6 million tonnes of CO_2
4. BP, oil refinery, Grangemouth, 2.4 million tonnes of CO_2
5. BP, petrochemical, Grangemouth, approx. 1.3 million tonnes of CO_2
6. ExxonMobil, gas terminal, approx. 881 000 tonnes of CO_2
7. ExxonMobil, petrochemical, approx. 719 000 tonnes of CO_2
8. Grangemouth CHP, gas power plant, approx. 708 000 tonnes of CO_2
9 Lafarge Cement, approx, approx. 639 000 tonnes of CO_2
10. BP Exploration, refinery?, approx. 421 000 tonnes of CO_2
11. Shell, gas power plant, Peterhead, approx. 345 000 tonnes of CO_2

4. Government initiatives and cooperation

In the UK, as in Norway, the authorities are very concerned with the CO2 storage problematic and have started facilitating solutions. In February, the British parliamentary committee on science and technology published a report which shows that there are good opportunities for achieving a commitment to CO2 handling in the UK. The report says the UK, and especially Scotland, is in a particularly good position to exploit CO2 handling technology, as one has large CO2 emission sources close to geological formations which are well suited for long-term storage. "CO2 handling can be a real opportunity to take the leading role as regards climate while building long-term growth, diversity and innovation in the British energy sector," says the British report. The parliamentary committee, lead by Liberal MP Phil Willis, believes that the UK has a good chance of taking a lead in the development of CO2-handling technology. The export opportunities are also emphasised. "If the UK is serious about making an impact on India and China (in a positive direction as regards CO2 emissions, our note), the most useful thing it could do would be to get full scale demonstrations of several different types of CO2 handling technology up and running domestically as soon as possible. This would prove the viability of the technologies and give UK companies comparative advantage in terms of experience and know how. In the absence of such demonstrations, the idea of major export opportunities for UK companies is unrealistic". One possible main competitor is also mentioned in the committee's report. That competitor is Norway.

4.1 Government-level Norwegian-British cooperation

In 2006, Norwegian and British authorities looked at how a framework for common regulations and principles for regulation of transport and disposal in the North Sea can be organised. This work is scheduled for presentation in early 2007. The next phase in the work entails the two countries, in common, looking into what sort of infrastructure is needed to transport and store CO2 in the North Sea. The UK is also heading a UK-China project under which the building of a large-scale coal power plant with CO2 capturing is taking place. The results from both of these projects will be presented in July 2007 at the latest.

On December 6, 2006, British Chancellor Gordon Brown, the counterpart to the Norwegian Minister of Finance, presented the preliminary report to the 2007 budget. During the presentation, Brown emphasised the cooperation between Norway and the UK as sensible, as one can learn from Norwegian authorities' approach to subsidy schemes and investments, but not least as they believe a bilateral agreement with Norway will be an important step towards a development which aims to utilise CO2 disposal in all the countries around the North Sea. This applies not only to technical development, but also to the establishment of permits and a regulatory framework, where there are clear advantages of a common approach in both Norway and the UK. Both Norway and the UK are engaged in relevant work under the EU climate change program, which will present its report later this year, states the British report.[12]

5. A comprehensive step-by-step development

The purpose of creating a common Norwegian-British infrastructure is primarily to:

- Making available sufficient disposal solutions for greater emission sources.
- Making available sufficient amounts of CO2 for increased oil production for various fields.

12. Ibid

- Making sufficient buffer capacity available in the system.
- Making possible singular projects, which are difficult to make real on their own.
- Exploiting scale advantages, thus reducing transport and disposal costs.

Of the total investment costs in capture and disposal of CO2, transport and injection costs normally make up one third.[13] However, there are significant scale advantages. As a rule, the transport capacity can be tripled without having to increase the investment cost by more than one third, and the increase in operating costs will be modest.

However, it will be difficult to pre-invest in transport capacity without knowing in advance if there will be a need for the capacity, i.e. if there will be more CO2 capture, where and when. However, in this memo, our basis is taken from the most likely activities in CO2 capture and storage on the Norwegian and British sides and is founded on projects which have either been adopted or announced, or which are good candidates.

Our basis is that large-scale CO2-capture will be necessary in any case and that it is therefore desirable that this takes place in as good a manner as possible. In such a context it is important to consider the projects together so that the infrastructure gets in place and suboptimal solutions are avoided.

One challenge in using CO2 for increased oil production is that while one has to expect to invest in capture and transport infrastructure for a given amount of CO2, some of the CO2 which is injected into the field will in time come up again with the petroleum flow and be recycled. This means that the import need in many cases will decrease over time, something which entails that the "CO2 surplus" must be placed somewhere.

It is therefore desirable to have an infrastructure which also includes pure storage solutions. If not, another user must be directly available, but including pure disposal solutions makes the system more robust and flexible. Paradoxically, access to sufficient amounts of CO2 for the largest increased oil production projects has been a challenge in Norway.

Phase 1

The first step towards a joint Norwegian-British infrastructure will be exploiting the short distance between the Sleipner and Miller fields, where the first CO2 storage projects in Norway and the UK, respectively, are taking place.

As mentioned, BP is planning to capture 1.8 million tonnes of CO2 annually from a power plant in Scotland, which is planned used to increase oil production from the Miller field.[14] BP expects to operate the field an additional 15 to 20 years due to the increased oil production resulting from injected CO2.

40 kilometres from Miller is the Sleipner field. Since 1996, Statoil has disposed of 1 million tonnes of CO2 annually in the Utsira formation, which has almost unlimited storage capacity.[15] Sleipner is also the most relevant reception point for disposing of CO2 from the gas power plant under con-

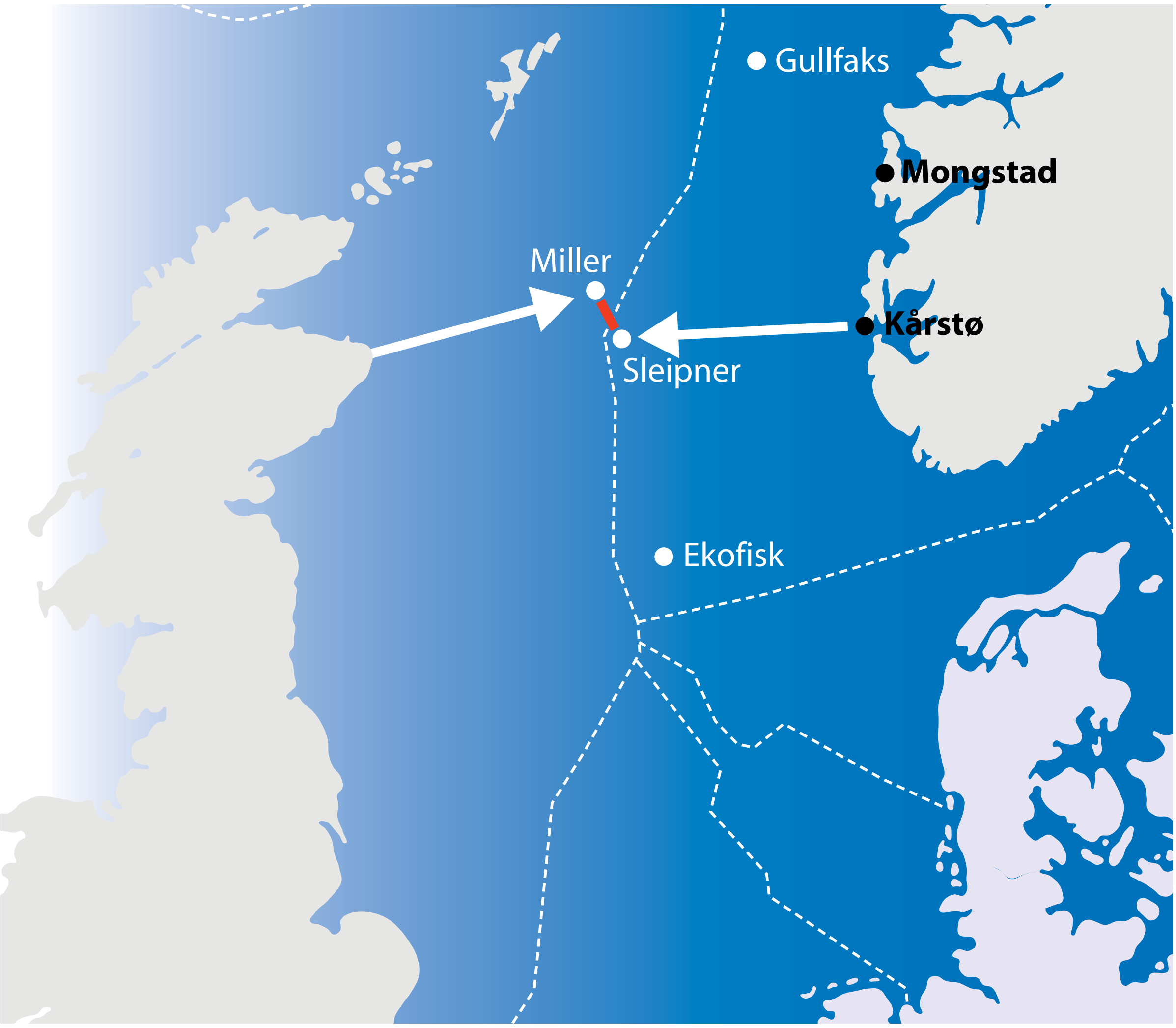
13. Depending on the size of the facilities, transporting distance, etc.
14. The power plant will transform gas into hydrogen and CO2
15. The storage capacity under the aquifer under 800 meters depth is estimated at a total of 42 billion tonnes of CO2.

struction at Kårstø and where Norwegian authorities, as mentioned, have decided that a capturing facility must be built.

Not far from Sleipner lies the Volve field, which is scheduled to come on stream in 2007. Statoil has considered the opportunities for using CO2 for increased oil production at Volve, but this is only relevant for a few years, and getting CO2 to such a project is urgent.

By laying down a pipeline between Sleipner and Miller, Norway and the UK could become connected, and thereby create a unique and necessary hub for further capture, use and storage of CO2. ZERO has discussed this with BP and Statoil, and they are positive to the idea.

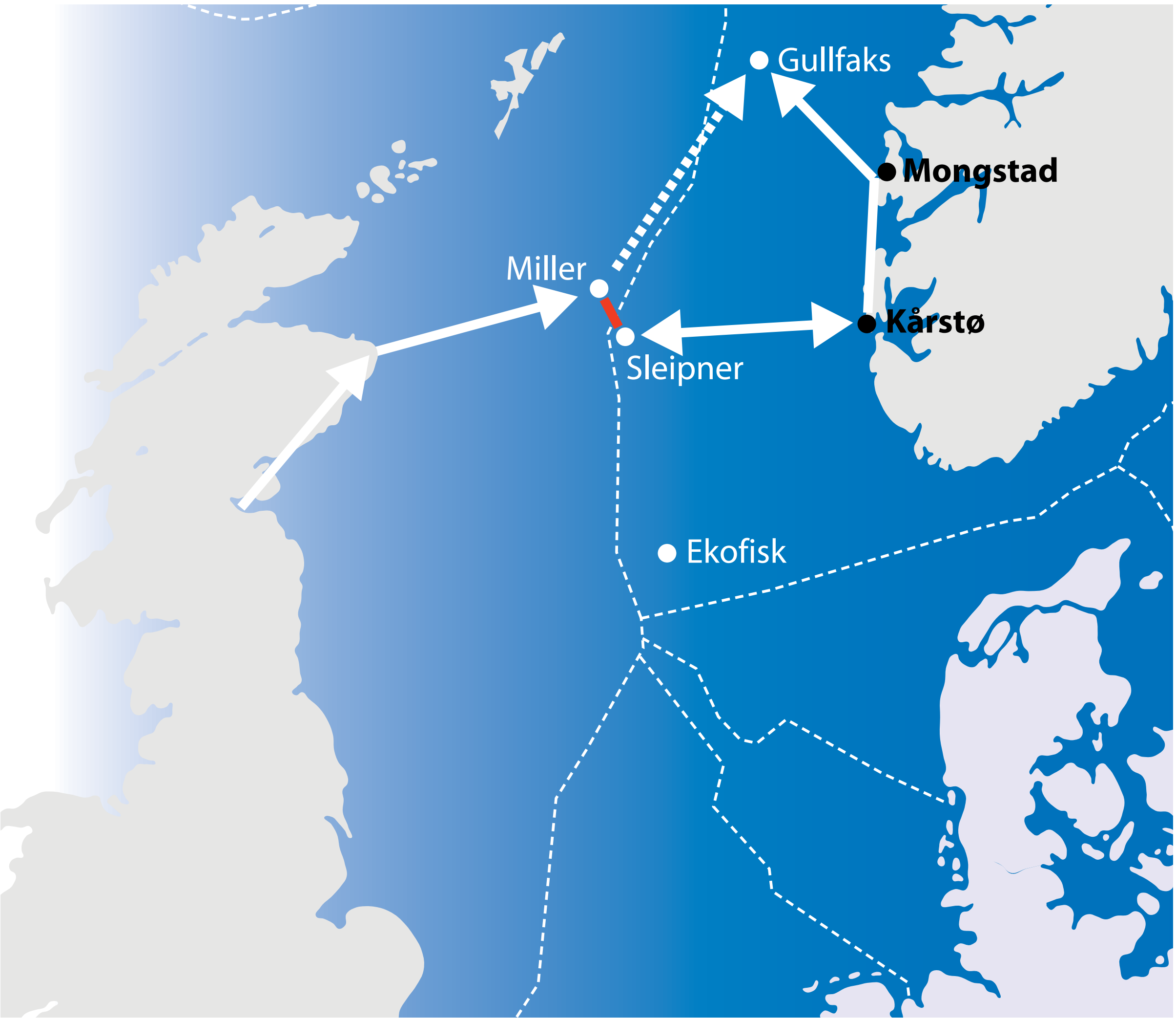
In the figure below, the pipeline between Miller and Sleipner is shown in red, as well as the pipeline from Peterhead in Scotland to Miller and the pipeline from Kårstø to Sleipner.



Phase 2

In the next phase, one can include the largest pollution sources along the west coast of Norway, and not least those in Scotland, where several coal power plants and oil-related activities can be found. This also means that CO2 will be available for several increased oil production projects, as for instance at the Gullfaks field. Sufficient amounts of CO2 can be acquired in Norway and Scotland and either transported on from the Sleipner hub or gathered at Kårstø and transported on from there. The transport from Kårstø can go through Mongstad, where Statoil will build a gas power plant which must have capture facilities in place by 2014, and which can therefore supplement the supply from that time on. If it proves impossible to achieve a decision on use of CO2 on Gullfaks, Mongstad will still have a need for a transport and disposal solution which can then go to Kårstø and on to a hub in the Sleipner system.

The figure below shows how one can collect more CO2 from the closest sources in Scotland, see also map of these sources in Scotland in Chapter 3, and transport it via sources at Kårstø and Mongstad to Gullfaks. The dotted line shows the alternative where one can transport everything to the Sleipner hub and then on to Gullfaks.

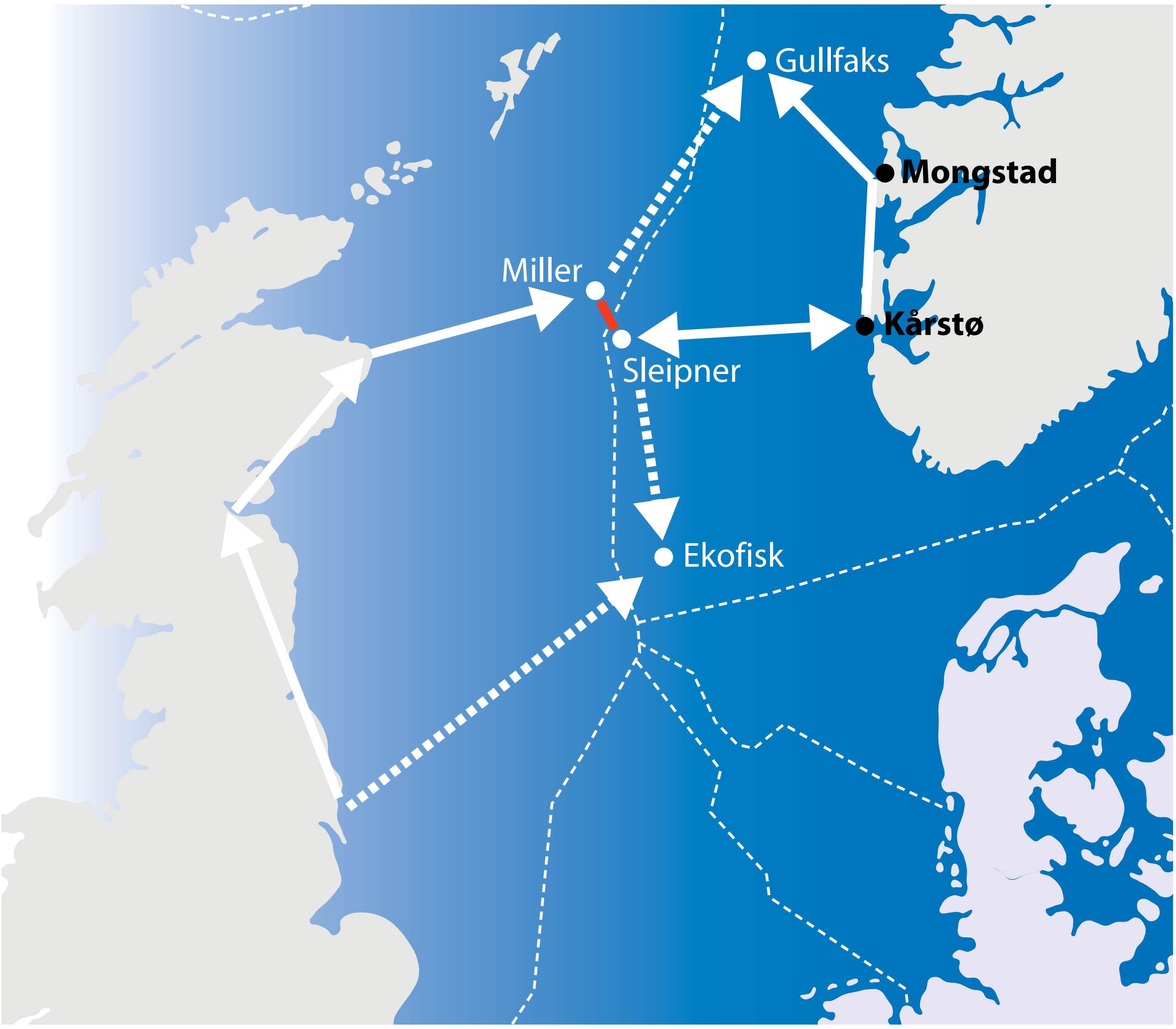


Phase 3

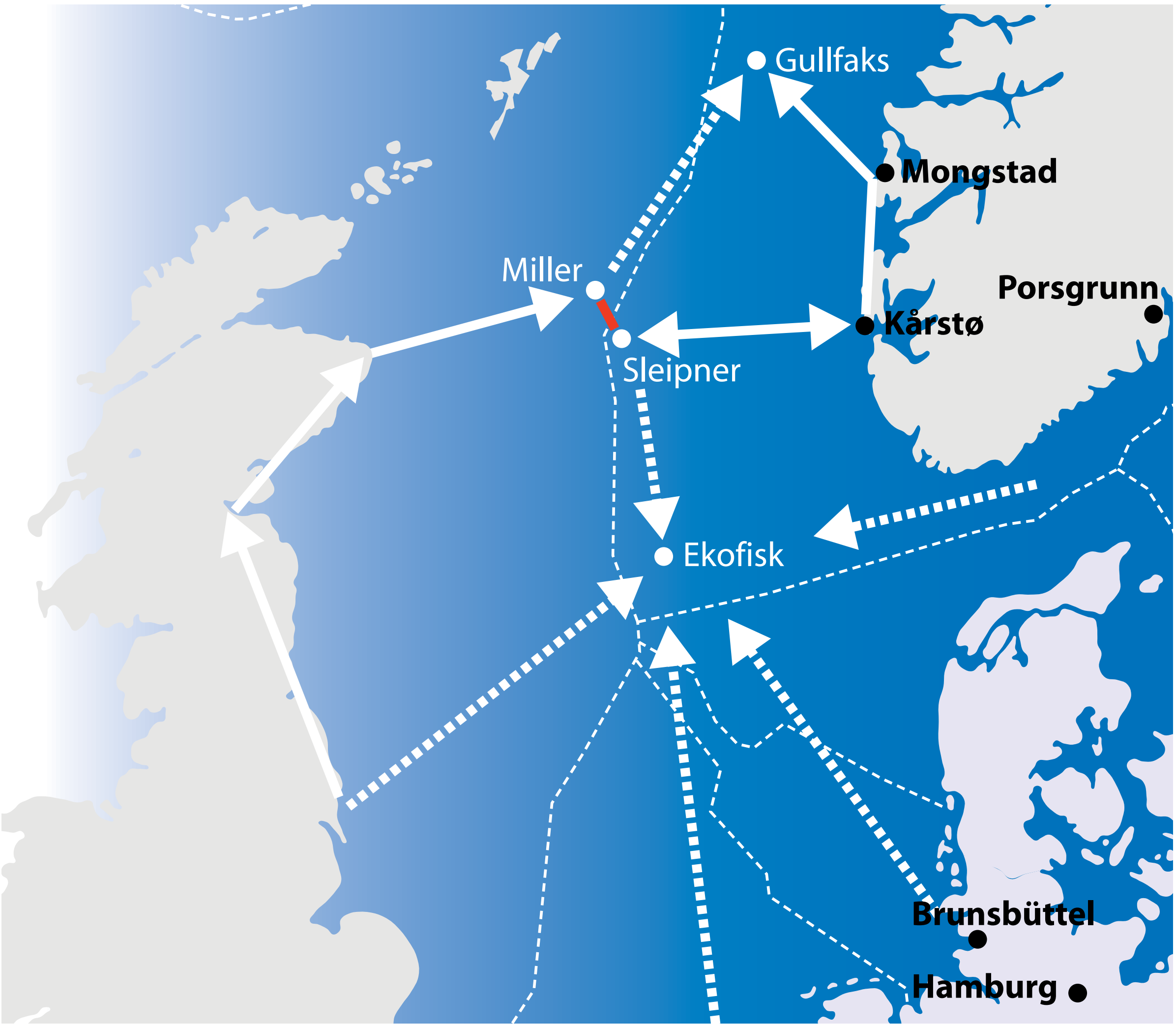
A third phase entails tying the large emission sources in northern England into the CO2 infrastructure, mainly coal power plants, and any new large-scale power plants in Norway. In this period, it will also be more relevant to use CO2 in several of the fields in the southern North Sea, for some this is the case now.

The figure below illustrates the development. To see possible sources in England where the CO2 is collected, see map in Chapter 3. From England, it is of course also possible to transport CO2 directly to fields in the south North Sea from both the British and the Norwegian side (here drawn into the Ekofisk area).

Also, it must be mentioned that it will naturally be possible to connect other possible sources in Norway, Denmark and in continental Europe, without discussing this further here. The figure below shows this through the dotted lines.



During all this, the competence from Sleipner and the enormous disposal capacity in the Utsira formation will be the crucial key, as it, in addition to representing a desirable buffer capacity in the system, can guarantee that there is room to store all CO2.



The road ahead

In this memo, we do not assume that a decision to use CO2 for increased oil production on the Norwegian Shelf is necessary to realise the infrastructure, but we assume that this will become increasingly attractive - also to our neighbours. Large-scale capture and disposal of CO2 must in any event be carried out for climate reasons.

This memo is merely a brief idea outline of some of the existing opportunities. There are many factors which must come together before this can be realised, primarily framework conditions, courage and will. ZERO will continue to work to ensure that the necessary infrastructure can be realised.

In the NVE report on the capturing at Kårstø, one assumed a higher design pressure and a larger pipeline diameter than is necessary to transport and inject the CO2 into the Utsira formation. NVE also considers it desirable to pre-invest more than strictly necessary to retain the opportunity to include future CO2 flows from Kårstø and to expand the pipeline to fields for increased oil production in the future. Compared to the capacity needed for what is described in this memo, it must be increased somewhat. This will entail a very limited cost compared to the gain, and is one example of the many issues that ZERO will pursue in the time ahead.

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