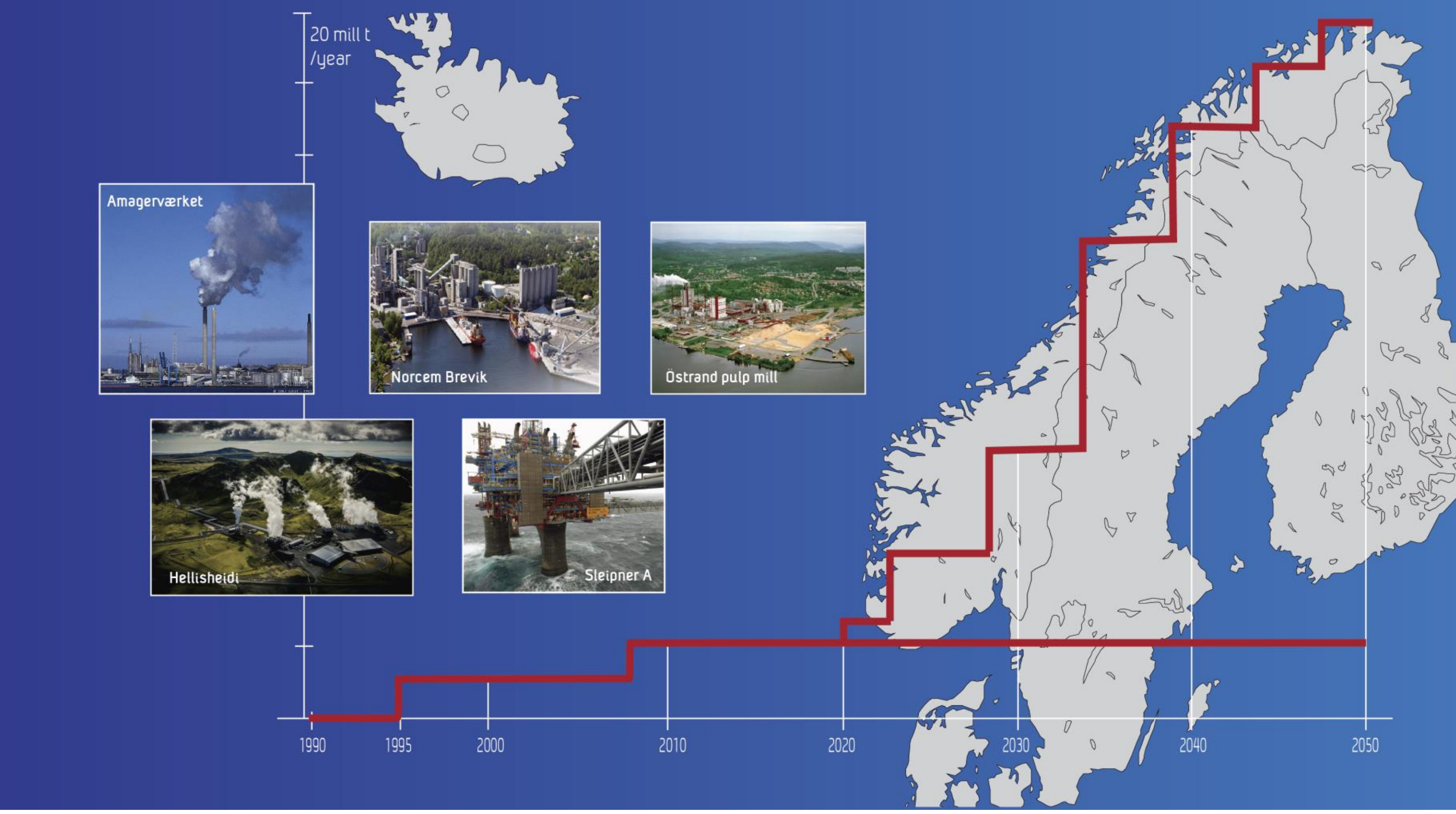


Opportunities for CCS implementation in the Nordic Countries

Marit Jagtøyen Mazzetti

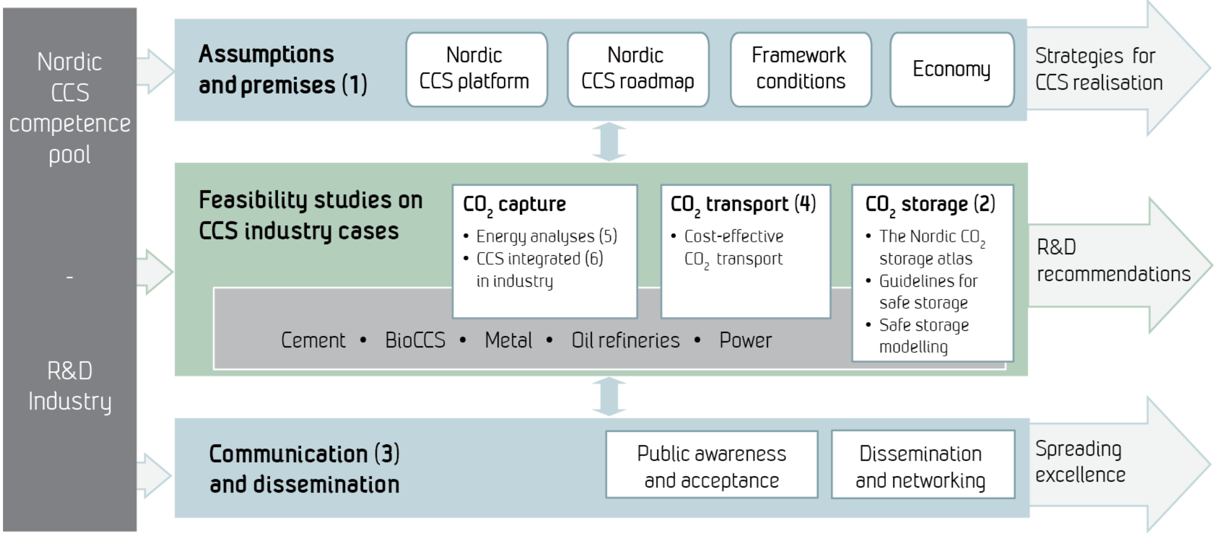
NORDICCS Technical Report D1.4.1201

September 2012

norden
Top-level Research Initiative

nordiccs
Nordic CCS Competence Centre

NORDICCS concept:



Partners:

Contact: Centre Director Nils A. Røkke • + 47 951 56 181 • Nils.A.Rokke@sintef.no
www.sintef.no/NORDICCS

Summary

This paper discusses opportunities for implementing CCS in the Nordic countries and outlines the most likely scenarios for early implementation of CCS and describes the challenges that must be overcome in order to facilitate implementation. The article contains highlights from a seminar arranged by NORDICCS during the Technoport Conference in Trondheim Norway in May 2012.

The seminar was entitled "Barriers and Opportunities for CCS Innovation and implementation", see Acknowledgements.

A complete video recording of the seminar can be found on the NORDICCS web page, link here: http://vimeo.com/42028030

Some of the contents of this deliverable will be part of the NORDICCS roadmap and a following publication on the opportunities and barriers to implementation of CCS in the Nordic countries.

Keywords CCS implementation, Nordic Countries, Technoport

Authors Marit J. Mazzetti, SINTEF Energy Research, Norway, Marit.Mazzetti@sintef.no

Date September 2012

norden

Top-level Research Initiative

About NORDICCS

Nordic CCS Competence Centre, NORDICCS, is a networking platform for increased CCS deployment in the Nordic countries. NORDICCS has 10 research partners and six industry partners, is led by SINTEF Energy Research, and is supported by Nordic Innovation through the Top-level Research Initiative.

The views presented in this report solely represent those of the authors and do not necessarily reflect those of other members in the NORDICCS consortia, NORDEN, The Top Level Research Initiative or Nordic Innovation.

For more information regarding NORDICCS and available reports, please visit http://www.sintef.no/NORDICCS.

Deliverable D 1.4.1201

Opportunities for CCS Implementation in the Nordic Countries

Marit Jagtøyen Mazzetti, SINTEF Energy Research

This paper discusses opportunities for implementing CCS in the Nordic countries and mentions the most likely scenarios for early implementation of CCS and describes the challenges that must be overcome in order to facilitate implementation. The article contains highlights from a seminar arranged by NORDICCS during the Technoport Conference in Trondheim Norway in May 2012. The seminar was entitled "Barriers and Opportunities for CCS Innovation and implementation", see Acknowledgements.

Is CCS part of the World's Energy Solution?

Renewables are sure to be part of the final solution to combat climate change. An important question is if CCS will be part of the solution? It will be more expensive to reach our climate goals if we do not include CCS. The IEA Blue map scenario implies that it will be 70% more expensive to achieve the targets without CCS than with.

Industrial emissions are important and must be addressed in order to go carbon negative. The IEA CCS roadmap states that the path we are currently on must be changed by 2017 if we are to meet the climate goals of keeping the temperature increase to below 2 degrees by 2050. If internationally coordinated action is not implemented by 2017 any new investments thereafter must be zero carbon. The achievement of zero carbon is probably not realistic, and there is only so much CO_2 that can be emitted to the atmosphere. There will therefore be a need to go carbon negative on many projects in the future in order to meet the climate goals, which suggests that CCS will be part of the solution for a long time.

Public acceptance and need for positive demo projects

The public resistance toward CCS is significant in the European countries and part of the Nordic countries as well. In an attempt to elucidate the real risk from the perceived risk, what is the worst case scenario if you have CCS in your back yard? If one looks at the safety issues related to the handling of gas, CO_2 is much safer than natural gas. Methane is stored underground in the US, and natural gas is already used in people's homes for heating and cooking and has public acceptance for in-house use. Handling issues are obviously not the reason for the public resistance towards CCS. The main risk related to CO_2 storage is asphyxiation due to a large scale leakage caused by seismic activity or other catastrophic events. There is some fear that a situation could occur similar to what happened in the Lake Nyos natural volcanic eruption in Cameroon. In that case a CO_2 cloud rose up and then flowed down two valleys and suffocated people in nearby towns and villages(1). However the circumstances are so different from those surrounding deliberate storage of Co2 that there is no danger from deliberate storage. Furthermore one can mitigate against leakages by monitoring the storage site for CO_2 leaks. If a leak should occur it could be easily remedied by gradually draining any potential CO_2 leakage from the storage site or in the worst case pumping the CO2 out of the reservoir again. There are uncertainties involved with the long-term effects of CO_2 storage, but if appropriate methods are used in the development of the storage facility CO_2 storage can overall be considered to be very safe.

In the USA onshore storage is widely accepted by the public. CO_2 is injected into oil wells to enhance oil recovery by about 12%[1], albeit this is primarily seen as a gas and oil operation to obtain higher yields. In the USA 30 million tons of CO_2 are injected into 82 different oil fields every year[2]. 3100 km of pipelines have been built to transport CO_2 from production sites to fields, with a total transport capacity of 50 million tons CO_2 per year. No major accidents have happened.(In Norway Statoil has successfully stored CO_2 removed from natural gas from the Sleipner oil field in the Utsira formation since 1996, and at Snøhvit since 2008 without incidents. 1.2 M Tons CO_2/year has been stored at the In-Salah oil field in Algeria since 2004, and no leakage of CO_2 has been recorded .

The EU Commission has issued a set of regulations and a common framework that covers the security of CO2 storage(4) There is broad acceptance in the scientific community that these regulations are sound and should creat a good framework to provide safe storage. By following these procedures one has the possibility of investigating whether the storage site is ok.

It is believed that some of the negative feelings against the safety of CCS may have been instilled by certain environmentalist- and other interest groups that have created a public fear of CCS in the media. The challenge for the CCS community is to effectively communicate the safety of CO_2 storage to the public.

It will be important to educate people about the facts of CCS storage and the misconceptions that it is not safe. Rapid deployment of several smaller CCS demo projects that give CCS a positive twist in the local communities in the Nordic countries would be effective in this regard.

Financing CCS projects –EOR

A detriment to CCS is the high cost. One example of this is the CCS project at the Mongstad refinery on the west coast of Norway where Statoil has planned a combined heat- and power plant The power plant will provide all the power necessary for the refinery as well as the platforms Troll A and Gjøa, and

the land based gas processing plant at Kollsnes. The plan is for the power plant to have full-scale CCS included. A final decision on the full-scale plant will be made in 2016.
For a full scale operation at Mongstad to be realized, the 25B NOK price tag has to come down. There are several cost and other issues regarding Mongstad, and its fate is not clear at the moment.

The Longyearbyen full scale CCS project is on a relatively smaller scale, emitting about 85 000 tons of CO_2 annually, and could be much easier to implement than Mongstad as it has most of the pre-requisites to succeed.[5] This project has great political support in Norway from among others Nikolai Astrup, from the Conservative party. He envisions that a power plant with full scale CCS could be in operation by as early as 2015, and that the cost of the project is estimated to be in the range of 3 Billion NOK [6]. The main benefit of the Longyearbyen project is that the entire CCS value chain may be realized within a few kilometers from the community of Longyearbyen, which is unique. The coal power plant is positioned right on-top of a geological structure that is perfect for storing the CO_2. The storage project which has been running at this since 2007 has been successful. It has reached the stage where it now can be concluded that CO_2 storage of the capacity needed for capture at the local power plant is very likely possible [7]. This is a very promising case with a reasonable price tag, where the positive benefits of an early CCS success story will outweigh the cost.

An example of another promising CCS project is the Shell-led Quest project in Alberta, Canada. It involves capture and storage of up to 1.2 million tons of CO_2 per year from the Scotford oil-sand Upgrader. The facility at Fort Saskatchewan produces synthetic crude oil from bitumen derived from the Athabasca Oil Sands extraction project. The total cost of the project is estimated at $1.35 billion. Shell also negotiated a two-for-one carbon credit deal with the province, which will help the company balance the higher cost of CCS against the $15 per ton carbon price. The storage is EOR [8].

The CO_2 storage project at the In-Salah oil field in Algeria stores CO_2 from the gas processing from the oil field. The gas contains approximately 5.5% CO_2 at the surface. The CO2 is stored in the Krechba Formation, a depleted gas reservoir located near the gas processing plant. The CO_2 injection costs approximately $6 /ton CO_2at the site. The motivation for this project was to set precedents for regulations and verification of CO_2 storage, and obtain carbon tax credits. Total project cost is estimated to US$2.7 billion[9].

Another example of a successful EOR project is the Weyburn EOR project in Canada which stores approximately 1 MT/yr of CO2 since 2000 and has injected 18 M Tons as of July 2010. The project cost was US$ 80 M and it has extended the life of the Weyburn field by 25 years. Current cost is $20/Ton CO2[10].

Generally CCS projects in the size range of 1- 5 MT/year require CAPEX, i.e. cost of establishing the plant, of 1-5 Billion US$ according to Statoil [11]. The obvious solution to alleviate the cost of a CCS project is to make the project EOR storage. **It may even be a prerequisite for CCS in the future that storage is EOR according to a US study** [12]. And indeed most of the large CCS projects currently in the planning in the US and Canada are EOR projects. EOR should be evaluated as a solution for the Nordic countries as well in order to rapidly implement CCS projects and meet our climate goals.

Changes to the European Carbon Market are Necessary

The current European carbon market is not proving to be effective. The cost of carbon emission is too low, and Norway is not in a position to influence it. It is too inexpensive to emit CO_2 in the EU to incentivize CCS. A potential solution to this is to introduce a carbon quota which will make CCS Mandatory.

One concern regarding implementing CCS laws in Norway or the Nordic countries that are not implemented in the rest of Europe is that we further undercut the already ineffective European carbon market trading system. In order for laws to be implemented in Norway changes are necessary to the European trading market such as reducing the number of available quotas in the EU to make them more expensive. Otherwise we have no ways of influencing the carbon emitted in the EU afterwards. There are some arguments for letting for example German coal companies buy into Norwegian CCS project. However the down-side to that is that nothing will be done in Germany where the CO_2 emissions are really large and we will have no way of influencing those at a later stage if they buy out by participating in other projects. **Changes to the European Carbon Markets are Necessary for CCS to make a difference to the climate problem.**

Risk distribution necessary

There is great financial risk with large complex projects such as CCS. The overall costs range in the 10-15 BNOK due to requirements for new infrastructure in connection with capture, transport and storage such as pipelines, export terminals for CO_2 and new storage sites. Infrastructure projects are generally difficult, so the risk element is important. The cost of the capture plant could also increase. Who is willing to take such a risk? The governments will not take it. They want the contractors to take it. The risk involves not only the CAPEX, i.e. the cost of establishing the plant, but also the cost of operating for 40 years. What will the disadvantages be of CCS a hundred years from now? Who will take the risk at 40 years? 100 to 500 years out? Like with other infrastructure projects it will be very important to address the risk elements, and this topic is something the Nordic politicians will have to take on immediately to set the table for implementation of CCS.

Environmental Legislation is Essential

Legislation can be a very effective tool in promoting environmental change. An example is two very successful environmental laws that have been implemented in Norway:

1. In 1990 a law was implemented that production flaring is not allowed in oil and gas production
2. A CO_2 tax law was introduced in 1991, this resulted in a more energy efficient oil and gas offshore industry in Norway.

These laws together resulted in the Norwegian oil industry becoming the most energy efficient in the world by 2006, measured in CO_2 released per barrel of oil produced [13]. In the years since 2008 the Middle East has caught up and bypassed us due to an emphasis there of improving their reduction of CO_2release by implementing production processes like the ones on the NCS, such as reduction in flaring. This is an example of how laws are needed if the market will not make CCS happen. On the other hand it is difficult to make CCS mandatory at this stage as better technology is needed, and pilots will be needed to test technology. It should be made mandatory as soon as the technology is ready.

EOR –Promising Opportunity for CCS in Norway and the Nordic countries

The combination of carbon dioxide enhanced oil recovery (CO2-EOR) and permanent CO2 storage in oil reservoirs has a critical near-term solution for reducing green-house gas emissions. It can combine the application of carbon capture from power generation and other industries with CO_2-EOR, which provides beneficial use of CO_2 injection for increasing crude oil production. It will be cheaper than onshore projects as it will finance itself. It can therefore be brought forward quite rapidly. However there needs to be tax payer money involved up front. EOR has been lifted up in the EU and funding will be available from the EU. Norway will have to match that. A closer cooperation with the US and Canada would be beneficial in this area. As discussed previously, CO_2 EOR has been demonstrated to be profitable in commercial scale applications for nearly 30 years in West Texas in the US.

There are great opportunities for Norway to take the lead for facilitating offshore storage and EOR. The storage capacity and experience is present. Large sources of CO_2 exist around the North-sea basin. There is a need to gather the resources and think of the projects in a comprehensive manner. Not one point of emission, but several sources and one point storage, otherwise the cost is too high. The larger the cluster the lower the cost per ton of CO_2 will be. **When conceptualizing EOR for CO_2 storage it is important to look at ONE joint pipeline out to the oil fields.**

Another benefit of EOR offshore is that people will become familiar with the concept of CCS and the resistance will gradually be reduced as people become familiar. There is a need for more successful CO_2 storage projects like Sleipner and Snøhvit to demonstrate that CCS works.

The implementation of CO_2-EOR in Norway has previously been limited by the availability of reliable, affordable supplies of CO_2. An earlier attempt at EOR at the Gullfaks field required 5 million tons/year. This could not be supplied at the time. However, at this time large projects could work if financing is ok. One example of this is the Don Valley power project at Stainforth in the UK, which is one of the leading EU CCS power projects. This EOR project is very promising, and it is due to be opened in 2016 if a decision is made to go ahead. The UK government and the EU are committed to supporting it at this point. It is a 650MW Integrated Gasification Combined Cycle (IGCC) power plant which would capture and store up to 5 million tons per year, or 90% of the emissions that would otherwise be emitted to the atmosphere. 2Co Energy plans to store the CO_2 in North Sea oil fields which provide the most secure and permanent storage for CO_2. CO_2 also helps produce more of the oil than would otherwise be recoverable which can significantly extend the life of the oil field and the associated jobs.

Likewise Norway and the other Nordic countries should spend more effort on EOR. There is currently not enough engagement. Of 70 large CCS projects world-wide, 35 are EOR and none in Norway. **EOR could be promising for a rapid implementation of CCS in Norway. If Norway builds up the infrastructure there are dozens of oil fields that are suitable for EOR on the Norwegian Continental Shelf (NCS). It will be important to get EOR demos up and running. Tax breaks for offshore EOR should be put in place in Norway.**

The most obvious candidate as an EOR CO_2 source in Norway is the Kårstø refinery, which has a gas fired power plant and a natural gas processing plant. It refines natural gas and condensate from the oil fields in the northern part of the North Sea. The terminal and power plant are both significant sources of CO_2. If 80% of the CO_2 is removed from the export gas, approximately 10 million tons of CO_2 could be removed each year. Negotiations with the EU would be needed to obtain credit for the CO_2. The CO_2 could go to the Utsira formation where Statoil currently stores CO_2 from the Sleipner field or to EOR applications in nearby oil fields. CO_2 could also go to Draugen by ship or pipeline. If CO_2 is injected into Draugen one could potentially open up the reservoir again and recover substantial amounts of oil in an EOR application.

Gas Fired Power Plants with CCS in combination with EOR at Utsira. In order to reach the goals set forth in the IEA2050 roadmap, power production must largely be CO_2 free. The most environmentally friendly way of producing power from gas would be to produce the power where the gas comes out of the ground and close to a CO_2 deposit site. Norway has an excellent opportunity at Utsira. A massive gas-fired power plant could be constructed with CCS where the CO_2 is shipped to Utsira for storage or use in EOR at the surrounding oil fields. It is believed that a power plant outfitted with CCS will be more load-flexible and will better accommodate power transients and load variations throughout the day than one without CCS. When CCS is connected, steam is available and the transient response is shorter. **It will be very important in the near term to demonstrate this load-flexibility of gas-fired power plants with CCS.**

Bio CCS is Essential in order to go Carbon Negative

In order to go carbon negative which will be essential for reaching the goals set forth in the IEAs 2050 roadmap, biomass must be an important part of the energy mix. In a long term perspective the world's food supply is not sufficient, meaning that resources that can be used for food production cannot be a source for bioenergy. The source for the bioenergy must therefore be strictly non-food crops. New ways are therefore needed for producing biomass for gasification and combustion to make the energy production process CO_2 negative. In Norway there could be opportunities in algae and seaweed production for bioenergy [14]. In Sweden and Finland the use of biomass for co-firing in coal based power plants is a promising concept as well as methanol and other biofuel production. If the EU trading system included biogenic sources of CO_2, emissions from pulp production could be a target for CCS applications in Finland [15]. **As a first step the EU carbon trading system should be altered to include biogenic sources of CO2.**

Vision for Nordic CCS

So far CCS has not been successfully implemented to a large extent because the projects that have been proposed have been loose/loose situations when it comes to economics, public resistance and value for money, i.e. unacceptable cost of the environmental benefits. **What is needed to make CCS happen are cost effective solutions where politicians, governments, industry and the public all see clear benefits as sustainable technologies.** An example of such an effort is the introduction of the law against gas-flaring in Norway. This was a benefit to all, and a true win/win situation as more money was made in gas production while significant emissions were avoided and contributing significantly towards making Norwegian oil and gas industry the most environmentally friendly in the world up until 2010.

The most exiting CCS opportunities for the Nordic region over the next few years are to establish a few successful EOR project demos utilizing CO_2 from different sources including industry. **There are dozens of oil fields on the NCS that are excellent candidates for EOR and could support CO_2 storage for at least Norway and possibly parts of Sweden. Denmark has promising fields for EOR as well.**

Another focus area should be a demo project involving biomass in order to prove the potential of going carbon negative involving either biomass co-firing in a coal power plant or biogas co-firing in a gas power plant with CCS. In order to reach the goals for 2050, **innovative bio energy project demos are needed in the near future and should become a priority.**

The full-scale CCS project at the coal fired power plant Longyearbyen, Svalbard should also be a priority. **The Longyearbyen CCS project has the promise of becoming one of the early success stories that are needed in order to make CCS happen on a larger scale.**

Along with the CCS concept development it will be important for the politicians to develop a more effective carbon pricing system as well as consider new laws and support for CCS infrastructure to speed up the implementation of CCS.

Acknowledgements:

The article contains highlights from a seminar arranged by NORDICCS during the Technoport Conference in Trondheim Norway in May 2012. The seminar was entitled "Barriers and Opportunities for CCS innovation and implementation". Six leading CCS expert panelists took part in the discussions at the seminar: Frederik Hauge, Bellona, Nicolai Astrup, The Conservative Party, Philip Ringrose, STATOIL, Nils Røkke, SINTEF, Oscar Frederik Graff, Aker Solutions, Rune Volla, Research Council of Norway and Michael Koch, Alstom. Moderator was Sverre Aam, SINTEF Energy Research. This article contains some of the main points from the discussions, although it must be emphasized that some of the views are not necessarily supported by all of the participants.

References:

1) Freund, P and Kaarstad, O., "Keeping the lights on", Fossil Fuels in the Century of Climate Change, Universitetsforlaget, 2007

2)Report from Zero on EOR: http://www.zero.no/ccs/storage/co2-in-enhanced-oil-recovery/

3)IPCC, 2005: IPCC Special Report on Carbon Dioxide Capture and Storage, edited by Mertz et al., published by Intergovernmental panel on climate change: https://docs.google.com/file/d/0B1gFp6Ioo3akWFVURndxRU5xU1E/edit?pli=1

4) http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0114:0135:EN:PDF

5) Svalbardposten: http://co2-ccs.unis.no/Pdf/booklet_web.pdf and

http://co2-ccs.unis.no/newsletters/PoliticalSupport.News.uke-07-2012.pdf

6) Dagens Næringsliv (the NorwegianNewspaper) Interview with Nikolai Astrup,Norwegian Member of Parliament, Conservative Party , Jan 17, 2012

http://co2-ccs.unis.no/Pdf/17.01.2012.DN-Kullkraft-p%C3%A5-Svalbard%281-3%29.pdf

7) Gunnar Sand, Nils Røkke, Svalbardposten nr. 50 21 desember 2011: http://co2-ccs.unis.no/Pdf/21.12.2011.Gryteferdig-milj%C3%B8prosjekt.pdf

8) Financial times, September 5, 2012

9) http://www.insalahco2.com/

10) http://sequestration.mit.edu/tools/projects/weyburn.html

11) P. Ringrose, STATOIL, presentation during Technoport seminar

12) US EOR Document

13) The Norwegian Oil and Gas Industry's Environmental Report 2011, by OLF (Oljeindustriens Landsforening, "Association of Norwegian oil and gas industry")

14) Renevable bio energy magazine, May 5th, 2012: http://www.renewableenergymagazine.com/article/offshore-wind-farms--seaweed--biofuel

15) "Biomass with CO2 Capture and Storage (Bio-CCS) - the way forward for Europe", by the IEA

http://www.iea-coal.org.uk/site/2010/publications-section/newsletter-information/current-newsletter/biomass-with-co2-capture-and-storage-bio-ccs---the-way-forward-for-europe?