GREENPEACE Briefing

Leakages in the Utsira formation and their consequences for CCS policy

The Sleipner CO_2 project in the North Sea is one of only three large-scale CO_2 storage projects worldwide. The oldest in operation, Sleipner has been injecting about 1 million tonnes of CO_2 into a sub-seabed saline aquifer since 1996. Carbon capture and storage (CCS) proponents point to Sleipner as proof that CO_2 can be stored safely and permanently while heralding the Utsira formation, that it is a part of, as large enough to hold Europe's emissions for years to come. However, recent developments in the North Sea indicate otherwise:

- ***A StatoilHydro-operated project was abandoned in the spring of 2008 after leaked process-water from the Utsira formation revealed an incomplete understanding of the geology of the storage site.***

- ***A study by the Norwegian Petroleum Directorate has reversed previous estimates of CO_2 storage capacity in the Utsira formation from "able to store all European emissions for hundreds of years" to "not very suitable".***

While neither of the above issues received much international attention, they call into question the presumption that Sleipner is flawless and the storage space in Utsira infinite. This briefing provides information on developments related to leakage from Utsira injections and revised storage capacity estimates.

Utsira leakage from Tordis-processed water injection

In May 2008, workers on the Gullfaks platform in the North Sea outside Norway happened to notice oily water at the sea surface near their platform. The produced water[1] originated from the Tordis field and had been injected into the Utsira formation by StatoilHydro. An internal investigation[2] conducted by the company revealed that injection activities had caused cracking in the seabed above the reservoir, thereby allowing a stream of processed water to escape back into the sea.

The project utilised an injection method that created cracks in the reservoir in order to increase permeability. When several unexpected pressure drops occurred in the process, injection was stopped and the cause for the drop investigated. The exact reason for the pressure drops was not ascertained, but each time the injection process was allowed to begin again.

StatoilHydro claims that the technology used has functioned very well. *"The problem is the injection well. […] It's probably located in the wrong place of the formation,"* said Gisle Johansen, a spokesperson for StatoilHydro[3].

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[1] Produced water is oil-polluted water that often comes up with oil extraction. In the past, this had often been released to sea, but now it is often re-injected to avoid pollution.
[2] StatoilHydro internal investigation of the event: «EPN OWE SNO/Tordis: Utslipp av oljeholdig vann og tap av injeksjonsbrønn» (11.08.2008) (Norwegian only so far. Available in full from Greenpeace).
[3] Stavanger Aftenblad: http://aftenbladet.no/energi/olje/article652315.ece (Norwegian news).

Even though the Norwegian Petroleum Directorate requires monitoring and warning systems to discover possible leakages, there was no such system near the location of the leakage, 300 m away from the installation and the monitoring system. As a result, no-one is able to determine how long the leakage had existed before its fortuitous discovery in May 2008. Once the source of the oily water was identified, injection operations ceased. StatoilHydro estimates that 48-175 m^3 of oil leaked from the storage formation.

The leakage from this formation is particularly significant as it was previously believed to be an ideal storage site, completely sealed, and with a seemingly limitless storage capacity for almost anything[4].

StatoilHydro is an experienced operator claiming to know the Utsira formation better than anyone. However, if these so-called experts in the field cannot reliably inject processed water into a single underground formation, how can we assume that gigatonnes of CO_2 from thousands of coal-fired power plants can be safely disposed of in prospective geological reservoirs across the globe?

The Tordis leakage illustrates StatoilHydro's practice of making invalid assumptions and operating a site without proper monitoring. But most importantly, it proves how difficult it is to inject and store anything in underground reservoirs, even in the Utsira formation which is considered to be one of the best studied geological formations on Earth.

Similar problems in other injection projects in Utsira

Today 20-30 projects are in operation involving injection of processed water, sand and liquid refuse into the Utsira formation. In addition to the Tordis leakage, there have been at least two other accidents related to injection projects since 2004 - one at the ExxonMobil operated Ringhorne site and another at the StatoilHydro operated Visund site.

The Ringhorne field started production in 2001, injecting well cuttings, slop and fluids into the Utsira formation. In February 2004, oily water was observed on the sea surface near the platform. The leaked oil was found to be coming from the injection well. Approximately 100-1,000 litres of base oil leaked into the sea[5].

The Visund field started production in 1999, injecting gas, well cuttings, slop and fluids into the Utsira formation. In 2007, there was unexplained activity in the seabed, which was probably related to the injections, in the form of cracking or other damage to the formation[6,7,8]. Other smaller irregularities have also taken place.

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[4] There are more than 20 injection projects in Utsira. See for example Statoil 1998: http://www.statoilhydro.com/no/EnvironmentSociety/Environment/impactassessments/RegionalEIA/Downloads/RKU%20HaltenbankenNorskehavet%20Juni%201998.pdf (Norwegian).

[5] ExxonMobil: Annual report : «Årsrapport SFT 2004 - Balder og Ringhorne.doc /ISk/28/02/05» http://www.olf.no/getfile.php/zKonvertert/www.olf.no/Milj%C3%B8rapporter/Dokumenter/Balder%202004.pdf (Norwegian only).

[6] StatoilHydro internal investigation of the Tordis event: «EPN OWE SNO/Tordis: Utslipp av oljeholdig vann og tap av injeksjonsbrønn» (11.08.2008) (Norwegian only so far. Available in full from Greenpeace).

[7] SFT: Nullutslipp til sjø fra petroleumsvirksomheten: Status og anbefalinger 2003 http://www.sft.no/publikasjoner/vann/1962/ta1962_vedlegg5.pdf (Norwegian).

[8] Norwegian Petroleum Directorate: “Development and operations – northern North Sea”

Utsira and CO_2 storage

The leakages from Tordis, Visund and Ringhorne all occurred in the Utsira formation, the same geological structure where the Sleipner field is located. The CO_2 storage project at Sleipner has been used by the Norwegian government, as well as the EU, IEA and numerous others, as proof that CO_2 can be safely and permanently stored.

For years now, the Utsira formation has been heralded in scientific journals, by industry, NGOs and the media as a geological structure that can store 'endless amounts' of CO_2:

- The storage potential for CO_2 in the Utsira formation has been claimed to be "*practically unlimited*"[9], or "*capable of storing up to 600Gt of CO_2, e.g. all CO_2 emissions from all power stations in Europe for the next 600 years*"[10].

- Another study described the Utsira formation as *"one of the most promising aquifers for CO_2 storage in Europe. It is estimated that the Utsira Formation, below 800 m depth, has a pore volume of 918 km^3, a storage capacity in traps of 847 Mt (megatonnes) CO_2, and that the storage capacity of the entire aquifer is 42 356 Mt CO_2"*[11].

In global assessments of future CO_2 storage capacity, CCS proponents point to saline aquifers[12] like the Sleipner as the structures with the greatest storage potential[13]. However, a recent study conducted by the Norwegian Petroleum Directorate to evaluate possible storage sites for CO_2 from the planned Mongstad and Kårstø CCS gas-fired pilot plants. It concluded that *" […] it remains uncertain whether Utsira is suitable for large-scale storage of Europe's carbon emissions"*[14].

The main reason for this is the depth of the formation, which is too shallow to provide the pressure required to ensure that the CO_2 stays in a fluid phase. The evaluation instead recommends the Johansen formation as a better option. The Johansen formation is said to provide a deep, sealed structure where "carbon storage will almost certainly be possible without leakage to the surface". However, this formation has never been used for injection purposes.

The Sleipner CO_2 injection project

The introduction of a Norwegian CO_2 offshore tax prompted StatoilHydro to begin removing CO_2 from natural gas streams in 1990 and allowed the company to save money and simultaneously conduct research into CO_2 storage. About 12 million tons of

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http://www.npd.no/English/Emner/Geografiske+omraader/Nordsjoen/FeltogFunnNordligeNordsjo.htm.

[9] Statoil 1998:
http://www.statoilhydro.com/no/EnvironmentSociety/Environment/impactassessments/RegionalEIA/Downloads/RKU%20HaltenbankenNorskehavet%20Juni%201998.pdf (Norwegian).

[10] ZEP (2006), or indirectly http://www.risoe.dk/rispubl/reports/ris-r-1608_307-313.pdf.

[11] CO_2 point sources and subsurface storage capacities for CO_2 in aquifers in Norway, http://www.ngu.no/FileArchive/101/2002_010_skjerm.pdf.

[12] Saline formations are sedimentary rocks saturated with formation waters and dissolved salts.

[13] See for example http://www.ieagreen.org.uk/putcback.pdf. The IPCC special report on CCS estimates the total global technical storage potential at 2000 GtCO2 in geological formations.
http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_SummaryforPolicymakers.pdf.

[14] Carbon containment in the spotlight:
http://www.npd.no/English/Aktuelt/Nyheter/2007.10.29+Store+muligheter+for+lagring+av+CO2.htm.

CO_2 have been separated from natural gas and injected back into the formation since 1996.[15]

As far as StatoilHydro and the Norwegian government have reported, there have been no major leaks from the Sleipner injection. However, several scientists claim that the current technological limitations make this impossible to guarantee. "*It's not possible to prove that all injected CO_2 is still there. There's no way of measuring the amount of CO_2 in the formation with sufficient accuracy using seismic mapping,"* said Peter Haugan, the leader of the Institute of Geophysics at the University of Bergen[16].

What's more, unpredicted movement of injected CO_2 has been observed in the reservoir and so far has not been satisfactorily explained by any reservoir geologist.

When the Sleipner project began in 1996, CO_2 was expected to rise gradually through the layers of the formation once it was injected underground. However, seismic imaging has shown that the CO_2 is instead flowing almost immediately to the top of the formation - moving up by more than a hundred meters per year.

As described in a recent article, this demonstrates that the mudstones present in the formation were not serving as a barrier to the vertical CO_2 movement, as scientists had originally expected. Additionally, it indicates that the geological characteristics of the formation may have been altered by the injected CO_2[17]. A more disturbing possibility is that much less CO_2 is being stored in the formation than estimated, meaning that CO_2 is leaking at an unknown rate[18,19]. While this is currently speculative, leakage rates at any level are of interest. Even very low annual leakage rates, as low as 0.1 percent, could undermine potential climatic benefits of geological storage on a time scale of a few centuries[20]. As mentioned, it is currently not possible to detect CO_2 leakages in these small volumes. While StatoilHydro acknowledges this, they argue that the above ceiling structures are nevertheless safe enough to prevent leakage into the external environment.

However, the relevant issue for decision-makers is that the current scientific ability to accurately map and interpret geological structures, such as the Utsira formation, for the purpose of ensuring safe, permanent CO_2 storage, may not be possible.

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[15] See StatoilHydros description at http://www.statoilhydro.com/en/TechnologyInnovation/ProtectingTheEnvironment/CarbonCaptureAndStorage/Pages/CarbonDioxideInjectionSleipnerVest.aspx.

[16] Newspaper article in Norwegian: "No guarantee against CO2-leakage" (22.10.2008) http://www.aftenbladet.no/energi/olje/933702/Ingen_garanti_mot_CO2-lekkasjer.html.

[17] CO_2 Flow in the Utsira Formation: Inferences made from 4D seismic analyses of the Sleipner area: http://aapg.confex.com/aapg/2007int/techprogram/A113135.htm.

[18] Modelling carbon dioxide accumulation at Sleipner: Implications for underground carbon storage, M. Bickle et al, Earth and Planetary Science Letters 255 (2007) 164–176, Editor: C.P. Jaupart.

[19] Effects of CO_2 capture and storage on ocean, Haugan, P. M., Geophysical Institute, University of Bergen, Bergen Marine Research Cluster in Monaco, October 2008.

[20] "Metrics to assess the mitigation of global warming by carbon capture and storage in the ocean and in geological reservoirs," Haugan, P. M., Joos, F., Geophysical research letters, vol. 31, L18202, doi:10.1029/2004GL020295, 2004.

Summary

Greenpeace believes that the Utsira events regarding unpredicted leakages, unpredicted CO_2 movements inside the geological formation and dramatically reduced storage estimates, underline how each field, each injection rate and each storage location is unique and would require detailed characterisation, management and monitoring. The occurrences described above show that CCS is neither a simple process nor a one-size-fits-all solution to CO2 pollution. It should give pause to policymakers as they deliberate what role, if any, CCS should play in mitigating climate change emissions.

In general, Greenpeace does not support CCS given the substantial risks and uncertainties surrounding the effectiveness, safety, energy penalties, liability and environmental impacts of the technology. Alternative energy strategies, namely ones based on renewable energy and energy efficiency, are already available to deliver emission reductions. These technologies do not carry similar risks to those posed by CCS, nor do they leave open the possibility of transferring the burden of today's climate pollution to future generations. In light of all of the above, we urge the EU and other governments to reconsider attempts to encourage CCS and, instead, to redouble their efforts to fully support the development of truly sustainable energy solutions.

For more information:

You can find the Greenpeace report on CCS "False Hope: Why carbon capture and storage won't save the climate" (May 2008) on www.greenpeace.org/ccs.

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