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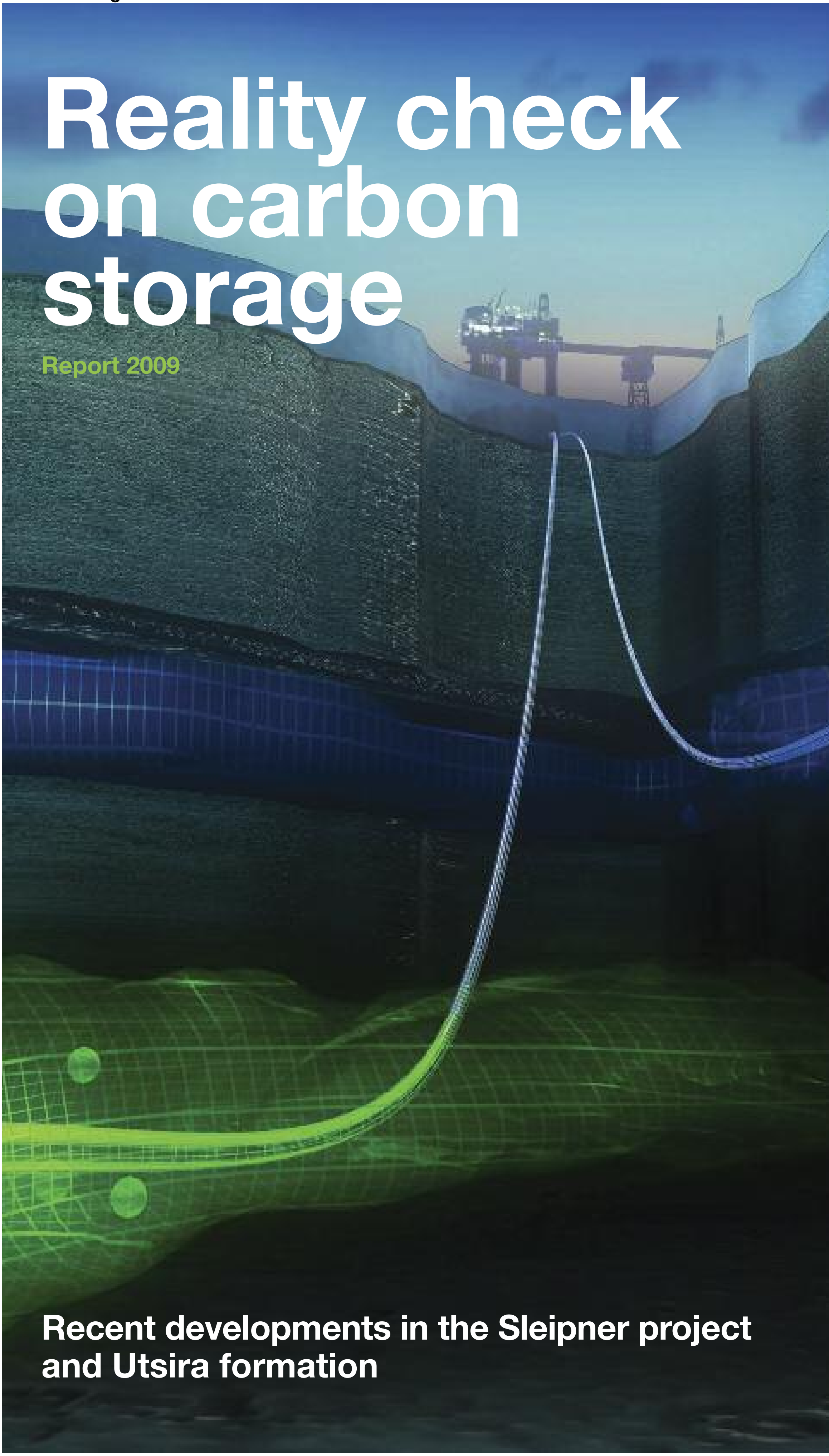

Recent developments in the Sleipner project and Utsira formation

GREENPEACE

Catalysing an energy revolution

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Introduction

Climate change is the greatest environmental threat and humanitarian and economic challenge the world has ever faced. Millions of people are already feeling the impacts of climate change and an estimated 150,000 people die each year from its effects.[1] To avoid the worst impacts of climate change, including widespread drought, flooding and massive population displacement caused by rising sea levels, temperature increases must peak as much below 2ºC (compared to pre-industrial levels) as possible. To do this, the Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report, indicates that global greenhouse gas emissions must peak at the latest by 2015.

Carbon capture and storage (CCS) has emerged as a potential solution to the climate crisis. However, a wide range of issues regarding the safety, efficacy and permanency of CO_2 storage remain unresolved. By examining the world's longest running CO_2 storage project - the Sleipner project, and the Utsira formation on which it is located - this briefing highlights some of the major challenges and uncertainties facing CCS.

Sleipner has been heralded by the European Union, International Energy Agency, and numerous others as proof that CO_2 can be safely and permanently stored. However, what this briefing shows is that it may not be possible to accurately map and interpret geological structures for the purpose of ensuring safe, permanent CO_2 storage. Furthermore, Utsira formation storage estimates, which the Sleipner field is a part of, have recently been revised downwards and non-CO_2 leakages have also occurred in some projects. In these instances, this briefing reveals how storage estimates, monitoring efforts and technology choices were improperly made and how geological understanding and expertise were either insufficient or absent.

All of this should give pause to governments as they assess their response to climate change. CCS remains largely unproven and will not be ready before 2020 – the key timeframe in which global greenhouse gas emissions must peak then begin to fall. In the meantime, the urgency to respond to climate change in an effective manner grows with every passing day.

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The Sleipner CO_2 Injection Project

The Sleipner CO_2 project in the North Sea is one of only four large-scale CO_2 storage projects worldwide. The project is run by StatoilHydro, which operates the Sleipner field on behalf of a group of industrial partners, producing natural gas for a range of customers.[2]

The introduction of a Norwegian CO_2 offshore tax prompted StatoilHydro to begin stripping CO_2 from natural gas streams in 1990, allowing the company to save money, and simultaneously conduct research into CO_2 storage. To date, these activities have pumped more than 11 million tonnes of CO_2 into the Utsira formation.[3]

According to StatoilHydro, the Utsira reservoir is continuously monitored using seismology, and comprehensive models have been developed for calculating how the CO_2 moves once underground.[4] The company maintains that there have been no major CO_2 leaks from the Sleipner project.

Yet several scientists correctly point out that it is not possible to be this definitive. Peter Haugan, the leader of the Institute of Geophysics at the University of Bergen, stated that: *"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."*[5] While StatoilHydro acknowledges this, it nevertheless argues that the above ceiling structures are safe enough to prevent leakage into the external environment and there is, therefore, no just cause for concern.[6]

Unpredicted movements of CO_2 in the formation, however, show that perhaps there *is* cause for concern. When the Sleipner project commenced 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 100 metres per year.[7] So far, this unpredicted movement has not been satisfactorily explained by any reservoir geologist. What it does indicate is that the mudstones (rocks) present in the Utsira formation may not serve as the barrier to the vertical CO_2 movement as originally expected. Additionally, it might also mean that the geological characteristics of the formation have been altered by the injected CO_2.[8]

The above demonstrates that currently it may not be possible to accurately map and interpret geological structures, like the Utsira formation, for the purpose of ensuring safe CO_2 storage.[9] This point is vitally important as avoiding leaks, which could undermine potential climactic benefits of geological storage,[10] depend on the ability to predict how and where CO_2 will be stored in a formation over the lifetime of a project.[11] Recent scientific findings further underscore the need for sites to be secure and potentially monitored for longer periods of time since much of the CO_2 will not be permanently trapped.[12] But, regardless of site security, no project can guarantee permanent storage. Even though unidentified leakages may be unlikely to occur in well-characterised, managed and monitored sites,[13] permanent storage cannot be guaranteed since tectonic activity and natural leakage over long timeframes are impossible to predict.[14]

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Recent developments in the Sleipner project and Utsira formation - continued

Geological storage estimates and the Utsira formation

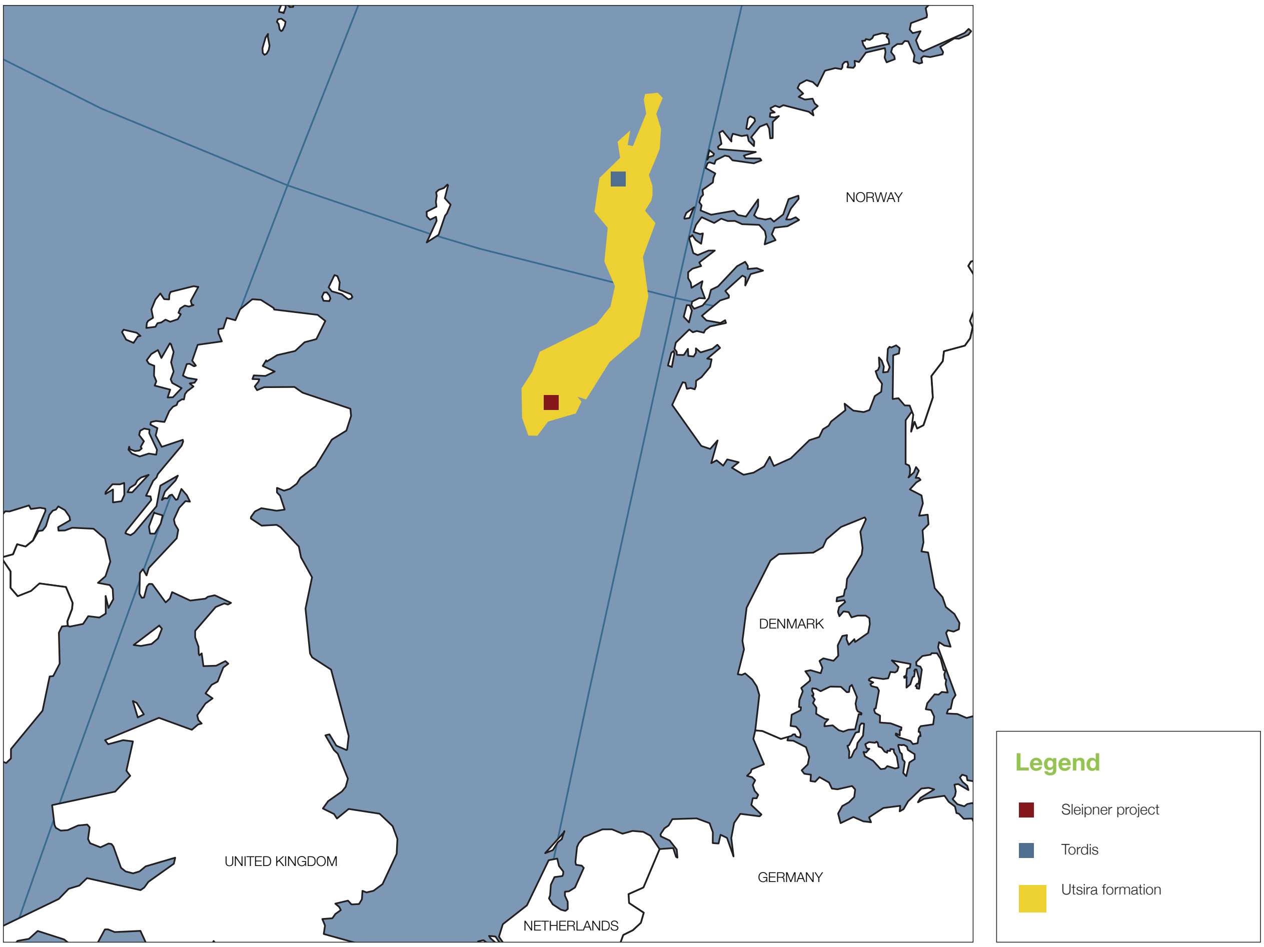
Global assessments of CO_2 storage capacity indicate that saline aquifers[15], such as at Utsira, are the formations with the greatest storage potential.[16] However, most storage estimates are overly optimistic and frequently based on methodologies that are insufficiently robust.[17]

It is important to realise that the CO_2 storage estimates cited in the literature are at times purely indicative. As noted by Ansolabehere et al. (2007), *"most efforts to quantify capacity either regionally or globally are based on vastly simplifying assumptions about the overall rock volume in a sedimentary basin or set of basins…they lack information about local injectivity, total pore volumes at a given depth, concentration of resources, risk elements, or economic characteristics."*[18] For example, the vast majority of these estimates quantify storage capacity assuming that 100% of pore space is available to store CO_2, when in fact that is never the case.[19]

Storage estimates for the Utsira formation are illustrative of the above. For years, it has been heralded as a geological structure that can store endless amounts of CO_2.[20] Indeed, the storage potential for CO_2 in the Utsira formation has been characterised as *"practically unlimited"*[21], and *"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"*.[22] Others have described the Utsira formation as *"one of the most promising aquifers for CO_2 storage in Europe"*.[23]

However, a recent study conducted for the Norwegian Petroleum Directorate concluded that *"it remains uncertain whether Utsira is suitable for large-scale storage of Europe's carbon emissions"*.[24] The primary 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. As a result, the Directorate has downgraded the storage capacity for Utsira from *"able to store all European emissions for hundreds of years"* to *"not very suitable"*. It is currently unclear how this revision will impact the effort by Norway to encourage the transport and storage of CO_2 from other countries into the North Sea.

Figure 1.1 Location of the Sleipner project and Utsira formation



The Tordis incident

The difficulty of injecting and storing anything in underground reservoirs is illustrated by the Tordis incident. The brief treatment here of this case provides some key lessons for those contemplating CCS as a solution to climate change.

On 14 May 2008, produced water originating from the Tordis field was being injected into the Utsira formation by StatoilHydro in order to increase gas recovery. Workers on the Gullfaks platform noticed oily water at the sea surface near their platform. On 30 May, the source of the oily water was found to be a leaking crater on the seabed floor. Injection was shut down shortly thereafter and the leak eventually stopped. The exact amount of the leaked material is unknown; however, the company estimates that anywhere between 48 and 175 m^3 of oil escaped the storage formation.[25]

Even though the Norwegian Petroleum Directorate requires monitoring and warning systems to discover leakages such as these, there was no system near the location of the leakage, 300 m away from the installation and the monitoring system. As a result, an indication that something was wrong happened only after oily water was observed at the sea surface. It is not certain when the leak first began.[26]

The cause of the leak was later determined to be due to an over-pressurisation of the geological formation. This caused the propagation of fractures to the seabed and the release of oily water into the sea[27] However, inadequate site characterisation, poor project management and incomplete monitoring were ultimately to blame.[28] Statoil's own internal investigation showed that assumptions made about the injection capacity of Tordis were incorrect and the company neglected to include any geologists on its project team. As a result, the injection process was based on insufficient geological understanding and weak modelling analyses.[29] Further, there were no specific requirements for geological competence in such projects; possible consequences of jointing to the ocean floor were not adequately assessed; and equipment for inspection and detection of emissions to the ocean floor was incomplete and only partially accessible.[30]

CCS proponents have claimed that this is an isolated incident.[31] Nevertheless, other injection projects in the Utsira formation have had similar problems.[32] In addition to the Tordis leakage, there have been at least two other leakage accidents since 2004 - one at the ExxonMobil operated Ringhorne site and another at the StatoilHydro operated Visund site.[33]

While the Tordis and Sleipner fields are located in the Utsira formation, it is important to note that this briefing is not suggesting that leakages in one part of the Utsira formation mean that leakages will inevitably occur in other parts. Sleipner and Tordis are located 300 km away from each other, and geological maps confirm that while Sleipner is located in a very thick and central part of Utsira, Tordis (and other places where leakage from oil-water injection has occurred) are located in far thinner and more marginal locations of the Utsira structure.

What the Tordis incident does illustrate are the consequence of making invalid assumptions and operating a site without proper monitoring. For example, the project utilised an injection method that created cracks in the reservoir in order to increase permeability. However, the technology used to monitor the site could not differentiate between intended and unintended cracks.[34] This case also 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.

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Recent developments in the Sleipner project and Utsira formation - continued

Conclusion

Commercial viability notwithstanding, the challenges facing CCS are many. The occurrences described above show that underground storage operations are not simple processes, nor do they offer a one-size-fits-all solution to climate change. The Utsira events regarding leakages, unpredicted CO_2 movements inside the geological formation and dramatically-reduced storage estimates, underscore how each field, each injection rate and each storage location is unique and requires detailed characterisation, management and monitoring.

All too often key points such as these are glossed over in the public policy arenas contemplating CCS. Decision-makers would do well to keep them in mind as they deliberate what role, if any, CCS should play in mitigating climate change emissions.

Together with the German Aerospace laboratories, the European Renewables association and a dozen scientists from around the globe, Greenpeace produced the Energy [R]evolution. The scenario shows how CO_2 pollution can be reduced sharply through the use of renewables and energy efficiency to power our society.
Scenario available at: www.energyblueprint.info


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1 Patz, J., et al., 2005. “Impact of regional climate change on human health.” Nature 438: 310-317.

2 Licensees for the Sleipner West field are Statoil (operator) with 49.50% (this includes 32.37% as the government's direct financial interest), Esso Norge with 32.24%, Norsk Hydro with 8.85%, TotalFinaElf Exploration Norge with 9.41%. See: www.co2captureandstorage.info/project_specific.php?project_id=26

3 See StatoilHydro’s description at: www.statoilhydro.com/en/TechnologyInnovation/NewEnergy/Co2Management/Pages/SleipnerVest.aspx

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16 See for example: www.ieagreen.org.uk/putcback.pdf

The IPCC special report on CCS estimates the total global technical storage potential at 2000 $GtCO_2$ in geological formations. http://arch.rivm.nl/env/int/ipcc/pages_media/SRCCS-final/SRCCS_SummaryforPolicymakers.pdf

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34 The company employed various methods to monitor the CO_2 in the Sleipner formation, such as seismic monitoring (use of fixed measuring tools) and pH/CO_2 buoyancy, see page measurements, and sidescan sonar, seabed monitoring for pockets and brines of CO_2.

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Greenpeace is an independent global campaigning organisation that acts to change attitudes and behaviour, to protect and conserve the environment and to promote peace.

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