Industrial-scale CCS in Norway: experience gained and application to future projects

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Summary

CO_2 capture and storage has long been recognized as being an important tool for climate change mitigation (IPCC, 2014) and an essential part of the ambition to reach the 2-degree target set by COP21 in Paris. Statoil operates two offshore injection sites where CO_2 is separated from natural gas and injected into siliciclastic saline reservoirs. The Sleipner CCS project started in 1996 and Snøhvit started injecting in 2008. Both sites have provided valuable experience for operating full chain CCS capture and storage projects related to offshore production of natural gas and storage of CO_2 in saline aquifer formations. This experience was utilized when preparing a feasibility study for for the Norwegian State for a full-scale CCS project, where Statoil was responsible for evaluating storage site locations in the Norwegian North Sea (fig 1).

Introduction

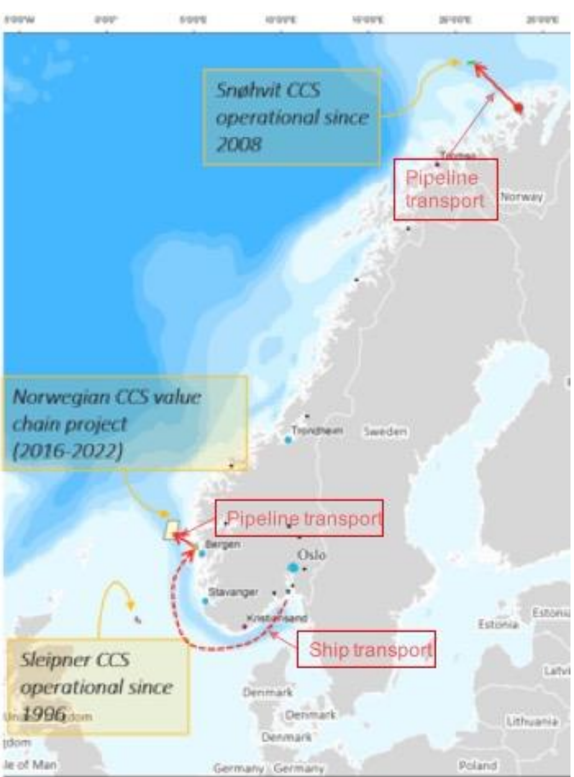

Figure 1: Location of Sleipner, Snøhvit and Norwegian Value Chain Project.

The CCS activity in Norway started after the State had implemented a CO_2 tax, which gave an important incentive to store the CO_2 captured from natural gas/condensate at Sleipner, becoming the world's first industrial scale offshore CCS project in 1996. This trend was followed in 2008 by the Snøhvit LNG and CCS project. Snøhvit is also a natural gas field, but whereas the whole CCS chain at Sleipner is implemented on the Sleipner platform, at Snøhvit the gas is processed onshore and then transported via pipeline with CO_2 injection from a sub-sea template.

Measurement, Monitoring, and Verification (MMV) is an essential and legally required part of each project and important learnings and developments have, over the last 20 years, been shared with the public and scientific communities. The projects have contributed to the understanding of the behaviour of supercritical CO_2 in the subsurface and the monitoring of the CO_2 plumes confirms that safe storage of CO_2 has been achieved (Eiken et al. 2011; Furre et al., 2016).

Key learnings from existing projects (see Ringrose et al, 2017) include improved quantification of the controls on injectivity, improved understanding of flow processes and storage capacity, and approaches for optimization of monitoring programs. The experience gained from these

CCS operations has been very useful for designing future projects, such as the feasibility study for a full CCS project carried out by Statoil on behalf of the Norwegian State in 2016. Three sites were evaluated as part of this investigation: the Utsira formation southeast of the Sleipner field, the Viking Group at Smeaheia area east of the Troll field and the Heimdal Formation at the Heimdal field. The recommendation of the study favored the Smeaheia location due to the good geological reservoir setting, the large available capacity and the scarcity of legacy wells in the area.

Industrial-scale CCS projects

The *Sleipner CCS project* was the first industrial offshore CCS project and it played a pivotal role in developing and demonstrating the numerous technologies related to CCS. The project is an offshore based, amine capture facility processing natural gas from the Sleipner field. It is located 250 km offshore southern Norway. The separated CO_2 is injected into the 800-1000m deep Utsira. So far over 16 Mt CO_2 have been stored at this site. The project continues to provide valuable insights into the value of remote geophysical monitoring methods and their detection capabilities allowing tracking the behaviour of the CO_2 plume (Chadwick et al, 2010; Furre et al, 2016). Geophysical data interpretation contributed to and improved the quantification of CO_2 flow processes in saline, siliciclastic formations (Singh et al 2010; Cavanagh et al., 2016). The regular performance of the Sleipner CCS project over the last 20-years also testifies to the value of careful design and engineering.

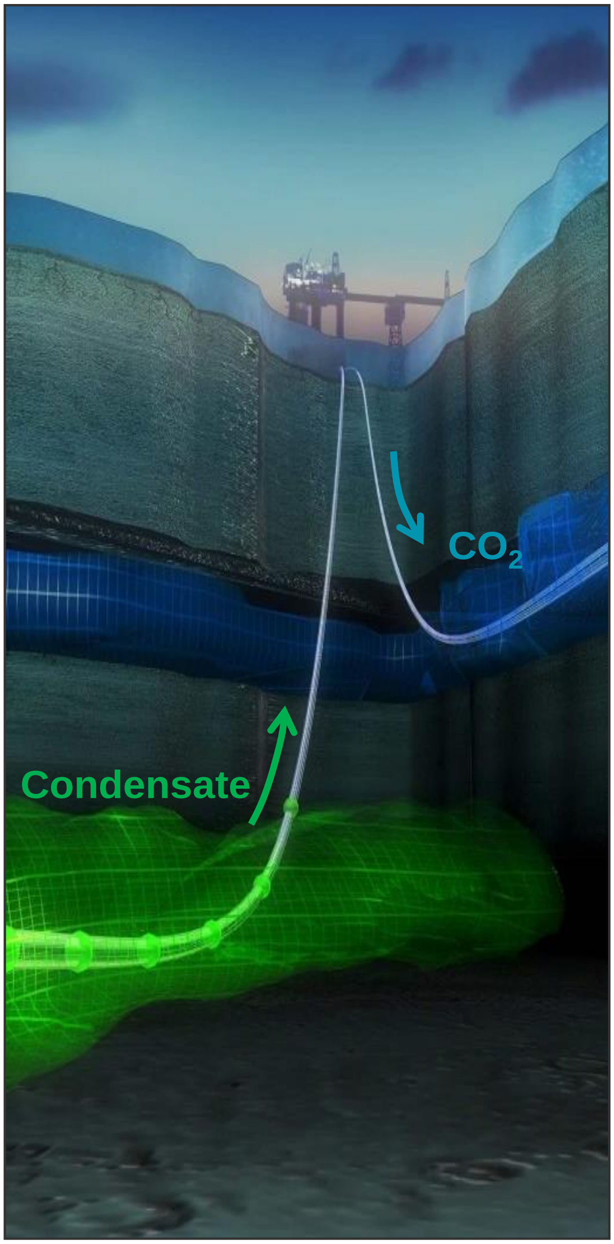

Figure 2: Sleipner project schematic shown an example production well and the dedicated CO_2 injection well.

The *Snøhvit* gas field is located in the Barents Sea and came online in 2008. The gas is stripped from the CO_2 on the onshore gas processing plant and then transported via a 150 km long pipeline to a subsea injection template. By the end of 2016 almost 4 Mt CO_2 have been injected into the subsurface. The first couple of years the CO_2 was injected into the Tubåen Formation, a saline aquifer below the gas bearing Stø Formation. During that time a gradual rise in pressure was observed, mainly due geological barriers which limited the access to the available pore space (Hansen et al., 2013). This led to the decision to perform a well intervention in 2011 leading to a modified injection plan with the CO_2 injected into the aquifer part of the Stø Formation. Injection has continued since then with a stable pressure trend. Crucial to this evaluation was the use of seismic 4D data, downhole gauges and reservoir modelling which allowed optimization of the CO_2 injection plan (Osdal et al. 2014).

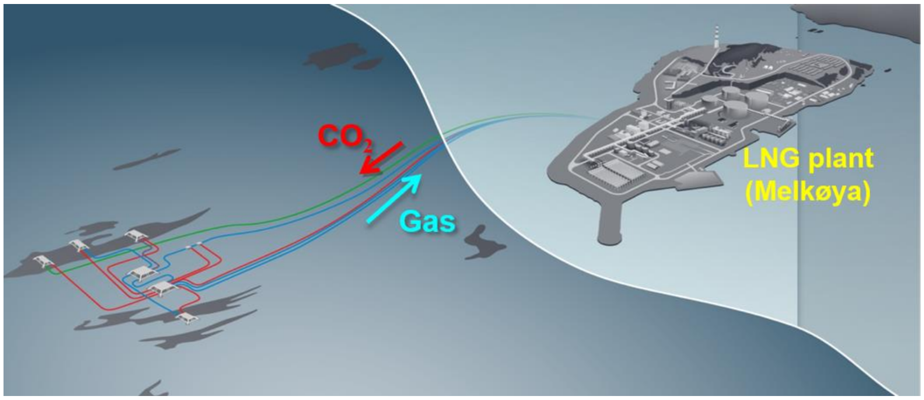

Figure 3: Schematics of the Snøhvit CCS project.

The Norwegain government has an ambition to have a *new full-scale CO2 capture*, *transport and storage project* in place by 2022, linking onshore industrial CO_2 sources to offshore storage. The feasibility study was carried out in 2016 and Statoil was responsible for the storage site evaluation which comprised three potential site candidates (Norwegian Ministry of Petroleum and Energy, 2016). The study was carried out as an industrial feasibility project covering all components from the offloading site through risers, sub-sea facilities and wells to the subsurface reservoirs. The storage site must also comply to the Norwegian and European regulations. The design specification is that the site should be suitable to receive 25 years of injection at 1.3 Mt CO_2 per year. The focus of the study was on injectivity, storage capacity and integrity as well as evaluation of the seal and overburden. The Smeaheia case was recommended as the most favorable location.

The Smeaheia reservoir is located in an unlicensed area east of, and shallower than the Troll field. The main storage reservoirs are the Jurassic Sognefjord, Fensfjord and Krossfjord Formations of the Viking Group at a depth range between 1200 m to 1700 m. The area of interest is charaterized as a large fault block with several structural traps. It is expected that the next stages of the project will further refine and define the storage charactersitics of this site.

Conclusions

The experience gained from Statoil's CCS operations in offshore saline formations is valuable for the scale up of CCS operations world wide. The key learnings from these projects include:

a) Demonstration of successful CO_2 storage operations since 1996;

b) Testing of industrial scale amine-solvent based CO_2 capture technologies at industrial scales;

c) Illustration of how oil and gas sector experience can be applied for realizing large-scale CO_2 storage projects;

d) Demonstration of the value of geophysical imaging and other monitoring data in optimizing CO_2 injection projects and demonstrating regulatory conformance;

e) Practical learnings about actual site capacities and injectivity performance, including improved understanding of CO_2 storage flow processes and trapping mechanisms.

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