CO₂ Storage in Norway
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Outline

- Norway CCS
- Learnings from Sleipner
- Learnings from Snøhvit
- Plans for the new Norwegian CCS Demonstration project
- Future potential
Norway’s CCS track record

- Sleipner CCS operational since 1996
- Snøhvit CCS operational since 2008
- CO₂ capture test centre (TCM) operational since 2012
- 21 years of operations
- Building confidence in CCS
- >21 Mt CO₂ stored
- New full-scale CCS project operational in 2022

Paasch et al. 2017
Sleipner Overview

Insights from geophysical time-lapse monitoring

Utsira Formation Summary

Net/gross: 0.98
Porosity: 35-40 %
Permeability > 1 D
~ 200 m thick

Kiær et al. 2016
Sleipner monitoring programme

1996: Injection start
2017: 17 Mt
Furre et al. 2017

Seismic
Gravimetry
Marine surveys
Chemical sampling

➢ In 2015 Sleipner CO₂ storage was re-permitted under the new Norwegian CO₂ storage directive (transposed into the Norwegian law with certain modifications from EU Directive). See CSLF Policy Group Report (2017)
Sleipner time-lapse difference

Sleipner time-lapse seismic data, showing amplitude difference between 2010 and 1994 surveys. Bright amplitudes reveal presence of CO₂ complicated by the effects of time-shifts and thin layer effects (Furre et al. 2015).
Sleipner Summary

- **Main learning: CO₂ storage is technically feasible**
  - The World’s first commercial-scale offshore storage project
    - Storage unit: 800-1000 m depth, 200 m thick, high permeability
    - More than 17 Mt CO₂ has been injected since 1996
  - **Challenges:**
    - Role of internal shale layers on plume movement
    - Predicting CO₂ plume flow behaviour
  - **Take-aways:**
    - CO₂ plume can be monitored by seismic and gravimetric methods
    - Significantly improved understanding of CO₂ storage processes
    - Storage re-permitted under new Norwegian CO₂ storage law
Snøhvit Overview

- First onshore capture - offshore storage project (combined with LNG)
  - 150km seabed CO₂ transport pipeline
  - Saline aquifers c. 2.5km deep adjacent to gas field
  - CO₂ stored initially in the Tubåen Fm. and then in the Stø Fm. (2011-)}
Snøhvit and pressure-managed injection

- **Main learning:** Successful well intervention guided by monitoring data
  - Rising pressure due to geological barriers led to well intervention
  - **Integrated use of** geophysical monitoring and down-hole gauges
  - Deployed back-up option in the injector well

**Down-hole data:**
- Downhole flow log
- Downhole pressure data

**Time-lapse seismic** (Amplitude difference)

Hansen et al. 2013; Pawar et al., 2015
Snøhvit Summary

- **Main learning: integrating geophysics and reservoir management**

- **The world’s first offshore CO₂ transport pipeline**
  - Distance: field-to-onshore facility is 150 km
  - Storage unit: 2400-2600 m depth
  - >4 Mt CO₂ has been injected since 2008

- **Challenges:**
  - Reservoir heterogeneity
  - Near-well flow limits

- **Take-aways:**
  - Need for robust design of injection system in heterogeneous reservoirs
  - A good ‘Plan B’ is invaluable when reservoir uncertainties are large
The Norwegian CCS Demonstration project

- Project now in FEED stage
- Statoil, Shell and Total have joined in CO₂ storage partnership project

OSLO
Smeaheia
EGE Energy Recycling plant, Oslo
Yara Ammonia plant, Porsgrunn
Norcem Cement Factory, Brevik
2016 site selection study

Capture sites

Utsira South:
- Miocene/Pliocene Utsira Formation
- Top reservoir depth c. 850m
- Gentle anticline (Seter structure)

Smeaheia:
- Jurassic, Viking Group, Sognefjord sandstones
- Top reservoir Depth c. 1200m
- Fault-bounded closure (Alpha structure)

Heimdal:
- Paleogene Heimdal Formation
- Top reservoir depth c. 2100m
- Anticlinal closure (Heimdal field)

Storage site schematics

Ship transport to storage sites

Pipeline from coast

Smeaheia site area

Utsira South site

Heimdal platform

Ringrose et al., 2017
Development concepts evaluated

1. Direct injection from ship (or from platform for Heimdal)

2. Injection from FSI vessel (Utsira South and Smeaheia)

3. Injection from a land based terminal (Smeaheia only)
The Smeaheia saline aquifer

- Large fault block east of the Troll oil/gas field, structurally higher with similar geology (Jurassic)
- Focus on closed “Alpha” structure
- 200 m thick Sognefjord sandstones
- Wells issue:
  - Plugged exploration wells
- Upper bound CO₂ capacity ~ 100 Mt (for Alpha)
- Injection solution:
  - c.50km pipeline from land-based offloading terminal

Prospect: Alpha
Reservoir properties:
N/G: 50-85%
Permeability: 420-1300 mD
Porosity: 30%
Plans for monitoring system design

Issues:

**Containment**
- Focus on overburden, well path, geological conduits

**Conformance**
- Plume extent and spill point
- Potentially over a large area

Likely solutions:
- Limited number of marine seismic surveys (covering large areas)
- Permanent seabed monitoring (around injection point)
- Downhole options (fibre-based?)
- Flexibility plans to accommodate changes (trigger surveys)
- Optimised to keep costs down
Norwegian CO₂ Storage: Future potential

- Reduces risk and threshold
- Enables additional CO₂ storage

- Allows stepwise development of CCS from more hubs

- Basis for development of CO₂ value chains for:
  - CO₂ EOR
  - Natural gas to hydrogen.

Distances to Kollsnes:
Norway 600 km;
Teesside 750 km;
Rotterdam 900 km

Possible catalyst for roll-out of CCS in Europe?
References


