Statoil’s CCS projects
An Industrial Approach to Climate Change

Building up our knowledge and experience (R&D)


Mongstad Full-scale
Test Centre Mongstad
Snøhvit LNG
In Salah
Sleipner

Application to new challenges (CCS Business)
Statoil’s CO$_2$ Storage Sites

Unique blend of
- Offshore/onshore
- Shallow deep
- Horizontal/vertical wells
Phase Behaviour at Operating Conditions

Down-hole gauges would be nice … … and now we have one at Snøhvit!
CO₂ Injection Performance

16.5 Mt CO₂ stored so far (2010)
Operating the Sleipner CO₂ Project

1. Monitoring Data:
   - Wellhead pressure and flow rate is monitored continuously
   - Gas composition samples are taken intermittently
   - Several Time-lapse (4D) seismic surveys:
   - Several Gravimetric surveys

2. Key Uncertainties:
   - Role of internal Utsira shale layers
   - Reservoir and wellbore modelling
   - Long-term storage capacity
Sleipner CO₂ Project Time-lapse Seismic Data
Sleipner CO₂ seismic monitoring

Top layer

All layers

Injection point

1 km

2008

Increasing amplitude

Time [ms]

0 5 10 15 20 25 30

0 5 10 15 20

mill. tons
Other monitoring at Sleipner


- In-situ CO₂ density: 720 ± 80 kg/m³
- Maximum dissolution rate: 1.8% per year
- Alnes et al. GHGT-10

Seafloor mapping 2006

CSEM survey also done
- no interpretable signal
Sleipner Modelling Insights

• Initial models built from pre-injection seismic:
  ➢ Coarse grid simulations which indicated a circular, dispersed plume.

• 4D monitoring data indicates a northerly extension to the plume propagation.

• IP modeling (Permedia Migration tool) gave closer matches to the seismic, indicating a dominance of gravity/buoyancy forces over viscous forces.

• Adjusted inputs to conventional reservoir simulations in order to capture enhanced gravity segregation and understand physio-chemical processes:
  ➢ Gives better matches to seismic
  ➢ Shows importance of Vertical Equilibrium (VE) assumption
  ➢ Implies dissolution was previously overestimated

• Results presented in SPE Paper 134891, Singh et al, 2010.
  ➢ Now released as a reference model via IEA-GHG
Comparing Sleipner seismic response to model predictions – Layer 9 (SPE 134891)
Sleipner Modelling: Lessons Learned

• Detailed analysis of Sleipner Layer 9 (uppermost) reveals strong gravity segregation and plume thinning
  ➢ IP Migration gives a good match to northern plume extension
  ➢ Use of Vertical (gravity) Equilibrium improves Eclipse simulator match
  ➢ Default simulators have too much dispersion and CO₂ dissolution

• Long-term predictions and capacity estimates need to be based on models verified with short-term monitoring data (5 to 15 years)
• Now focusing on multi-layer model and effects of discontinuous shales
The Snøhvit LNG/CCS Project, Norway

• Snøhvit (Snow White) is an LNG project, in the Barents Sea offshore Norway

• CO₂ is captured onshore and transported in a 153km subsea pipeline to a subsea template.

• The CO₂ is injected at a depth of 2600m into the Tubåen formation (below the gas reservoir).

• Injection of CO₂ started in 2008, and so far 1.0 Mt have been stored.
Snøhvit: Key Statistics

- CO₂ injector line: 153 km
- Seabed depth: 330 m
- One CO₂ injector
- Injected gas is ~99% CO₂
- Injected into Tubåen Fm at 2430-2600m depth
Snøhvit injection well

Depth map of base Tubåen Fm.

Perforated zones
Snøhvit CO₂ monitoring

Modelled CO₂ saturation and pressure increase

Amplitude changes

16 Eiken et al, 2010 (GHGT10)
Snøhvit
Flow Modelling

• Currently working on improved model and history match
• Example shows CO₂ plume distribution at 2030 for different fault seal scenarios

With fault juxtaposition but no seal

With disconnected faults
Conclusions

• At Sleipner and Snøhvit, single wells have successfully injected 0.4-0.9 million tons of CO\textsubscript{2} per year.

• Surface geophysical and well pressure monitor data give rich information on the storage behaviour:
  ➢ Dynamic modelling is better constrained, but still challenging.
  ➢ Indicates strong gravity segregation and minimal dissolution

• The actual plume development has been strongly controlled by geological factors which we learned about during injection.

• High-quality monitor data lowers the detection threshold for any potential leakage:
  ➢ 4D seismic monitoring confirms no leakage into the overburden.

• Detailed site characterization, reservoir monitoring/modelling and well solutions have allowed us to quantify the storage capacity and field performance:
  ➢ Gives a good basis for scoping and optimizing future projects.
References


Thank you