Assessing options for offshore transport and storage and onshore capture in Norway

Philip Ringrose
Statoil ASA & NTNU, Norway

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Norway’s CCS track record

- Sleipner CCS operational since 1996
- Snøhvit CCS operational since 2008
- CO₂ capture test centre (TCM) operational since 2012

- 20 years of operations
- Building confidence in CCS
- >20 Mt CO₂ stored
Current Norway CCS strategy

• The Solberg Government maintains the ambition to realize at least one full-scale CCS demonstration facility by 2020.

• The state enterprise Gassnova is focused on technology solutions to ensure CCS can be implemented and become an effective climate measure.

• In May 2015, Gassnova delivered its pre-feasibility study on potential full-scale CCS projects in Norway to the Ministry of Petroleum and Energy:
  − Recommended continuing feasibility studies of CO₂ capture at the Norcem Cement plant and Yara Amonia facilities.
  − Also recommended continuing studies on Waste-to-Energy at Klemetsrud, Oslo

• In January 2016 the government initiated a feasibility study on subsea CO₂ Storage

• Norway also active with international cooperation for widespread deployment of CCS:
  − Especially EU, Southern Africa, China, Persian Gulf and Indonesia
Statoil is currently evaluating three sites as part of this feasibility study.
Onshore CO₂ capture

Incineration plant at Klemetsrud, Oslo (link)
- CO₂-capture test plant opened January 2016
- First CO₂ capture from a waste-to-energy plant
- Pushing for negative emissions (Bio-CCS)

Yara Ammonia Plant at Porsgrunn
- Already sells food-grade CO₂
- Estimated future emissions ~ 825 kt/y
- 200 kt/y already recovered for use

Heidelberg Norcem at Brevik
- Already reduced CO₂ emissions via energy-efficiency and fuel switching (biofuels)
- High flue gas CO₂ concentration (16-19%)
- Estimated future emissions ~ 760 kt/y
Norwegian transport entity Gassco has the task of maturing transport options for the full-scale CCS project.

Main focus is on shipping solutions:

- But a pipeline option from onshore intermediate storage is also being evaluated.

Ship transport study contract announced in February 2016.

Gassco has commissioned Knutsen OAS Shipping and Larvik Shipping to study transport of CO2 by ship in connection with the Norwegian government's full-scale project for managing this greenhouse gas.

In cooperation with Gassnova, Gassco has earlier studied CO2 handling chains.

"The transport study will help to ensure that the government’s ambition of realising at least one full-scale CO2 facility by 2020 can be met," says Gassco CEO Frode Leversund.
Integrating with offshore storage facilities

• The CO₂ storage feasibility project is evaluating a range of options
  ➢ Platform-based
  ➢ Subsea-template based
  ➢ Floating storage and injection

• Reference design scope is for a 1Mt/yr project with 25-year lifetime

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Nuts and bolts: some key questions for the design

- CO₂ supply – rates, pressures, temperatures
- Reservoir depth, water depth
- Storage site capacity
- Well design
- Site performance (plume behaviour)
- Reservoir properties
- Overburden & seal characteristics
- Risk evaluation
- Monitoring plan
- Regulatory conformance
- Operational optimization
Challenges for large-scale CO₂ storage

How can we develop robust and cost-effective solutions for large-scale CO₂ storage?

Three main barriers:

1. Cost
2. Capacity
3. Confidence

- Integrating storage with oil and gas (incl. CO₂ EOR)
- Pressure-managed injection solutions
- Understanding of flow processes and cost-effective monitoring
Cost reduction – Storage linked to oil & gas

• Most CCS projects developed so far are linked to oil and gas field developments
• The oil and gas sector has mature technologies that are needed to operate CO$_2$ storage
• CO2 EOR and use of oil and gas infrastructure gives important cost-reduction factors

Snøhvit CO$_2$ injection project

CO$_2$ injection point

Gas flow

LNG plant (Melkøya)
Building Capacity: Pressure-managed injection

Snøhvit case study
Well intervention guided by:
• Time-lapse seismic
• Downhole P/T gauges and flow logging

Down-hole data:
P, T, Q

Down-hole pressure data

Time-lapse seismic
(Amplitude difference)
Monitoring CO₂ injection (Tubåen)

Injection estimate from seismic:
- 80% in lower perforation
- 20% in two upper perforations

Flow logging result:
- 81% in lower perforation
- 19% in upper perforations

Hansen et al., 2013
Building Confidence: Using first-mover projects

Sleipner monitoring dataset

- Important insights into CO₂ flow processes
- Continuous improvement in detection levels
Insights from Sleipner

- Steady improvements in CO₂ plume detection from seismic data:
  - Saturation, pressure
  - Plume extent
- Significant improvements in understanding CO₂ flow dynamics:
  - Gravity segregation
  - Dissolution rate

High-resolution Layer-9 model (2008)
Cavanagh (2013)
Key drivers for offshore CO₂ storage

- Norway has strong track record in CO₂ storage operations
  - 20 Mt CO₂ safely stored underground
- Importance of the learning curve
  - Oil and gas sector has the experience needed for realizing large-scale CO₂ storage projects
  - Value of geophysical imaging and monitoring data
  - Practical learnings about capacity and injectivity
  - Improved understanding of CO₂ storage processes
  - Building confidence in models and forecasts
- Norway ambition to realize at least one full-scale CCS demonstration facility by 2020 is underway