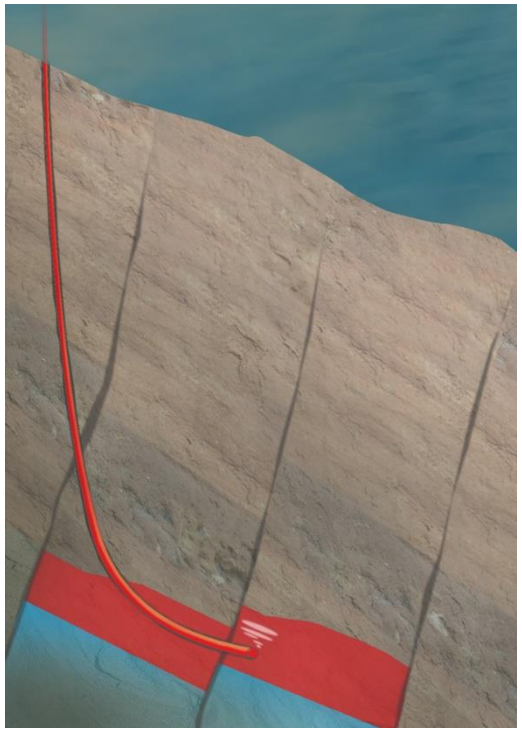
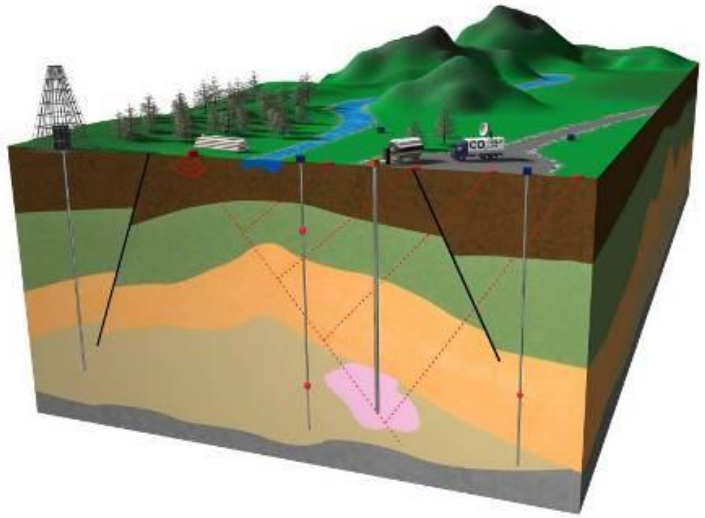
Conformance vs regulation

Discussion, with examples from Norway

Main requirement

- Ensuring there is no significant risk of leakage or damage to health or the environment
- The monitoring of the storage site must be able to demonstrate that this requirement is fulfilled
- The operator must show that the planned monitoring programme (including interpretation methods) is sufficient to achieve this
  - Designed according to identification and analysis of main risks for this particular storage site



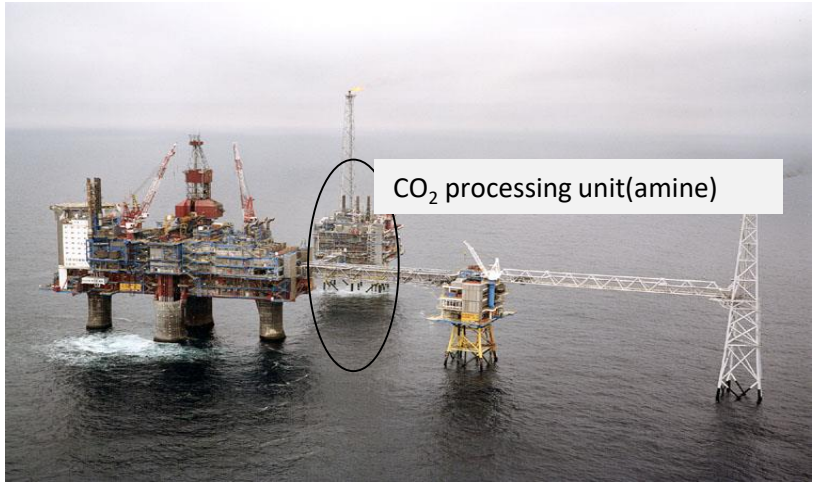


Workshop on Monitoring of CO2 injection,
TNO Feb. 21 2018

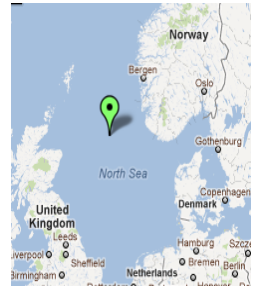
Norwegian offshore experience and regulations

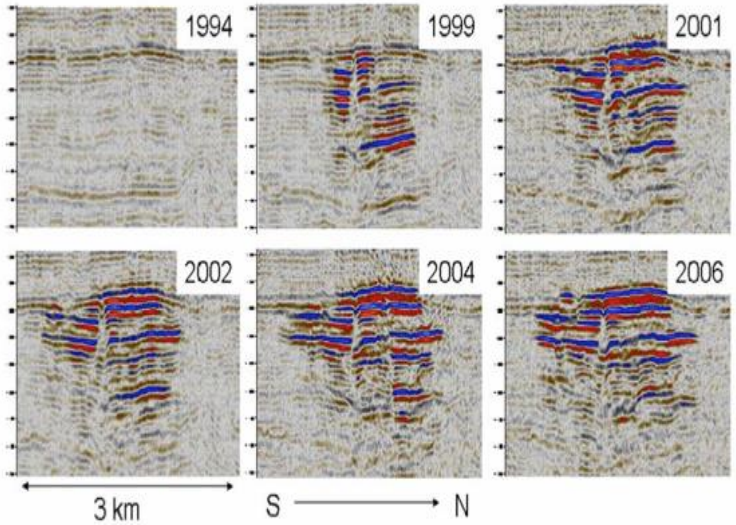
Fridtjof Riis, Eva Halland

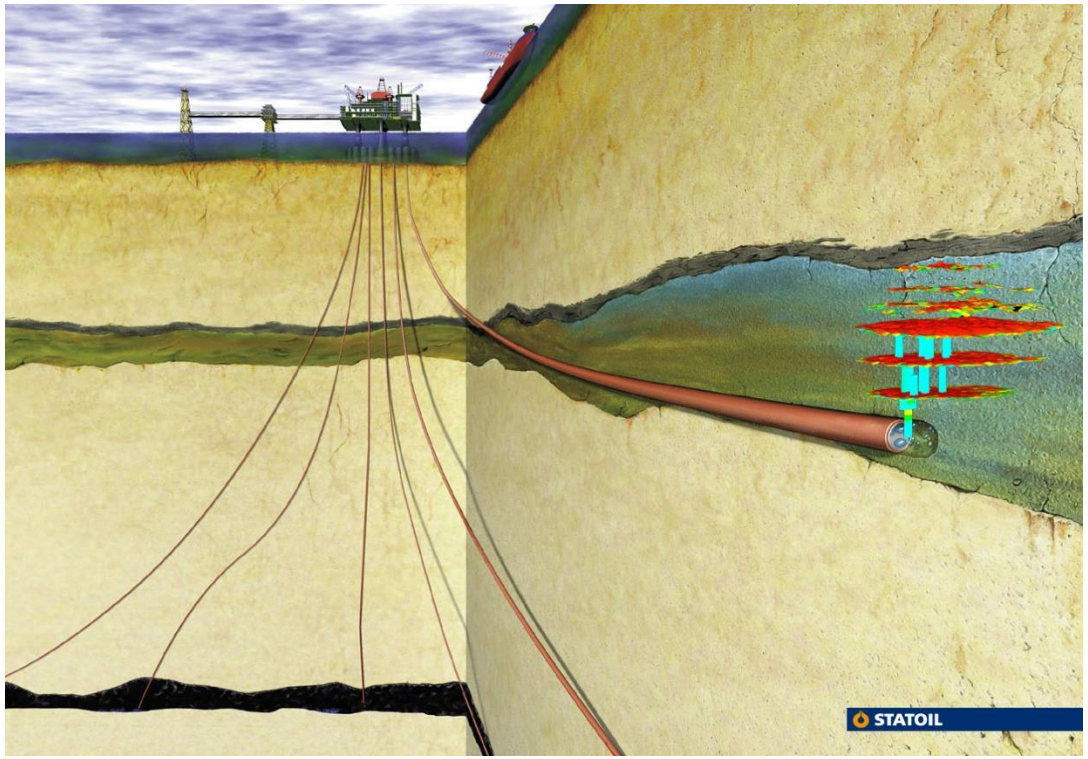
Storage of CO_2 from Sleipner Vest gas Field

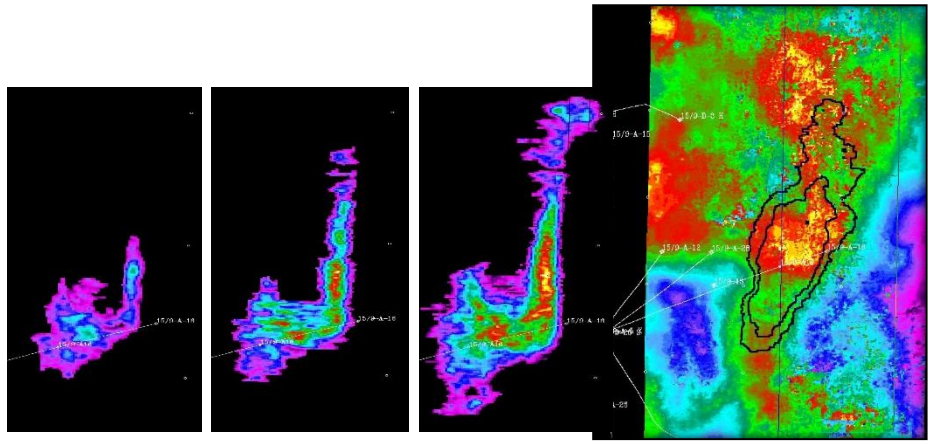


Started in 1996. Separating and injecting nearly 1 mill. tons CO_2 annually. Storing in saline aquifer, Utsira formation, above natural gas reservoir. High injectivity, large capacity. Main risks considered to be geological seal, abandoned wells, plume migration



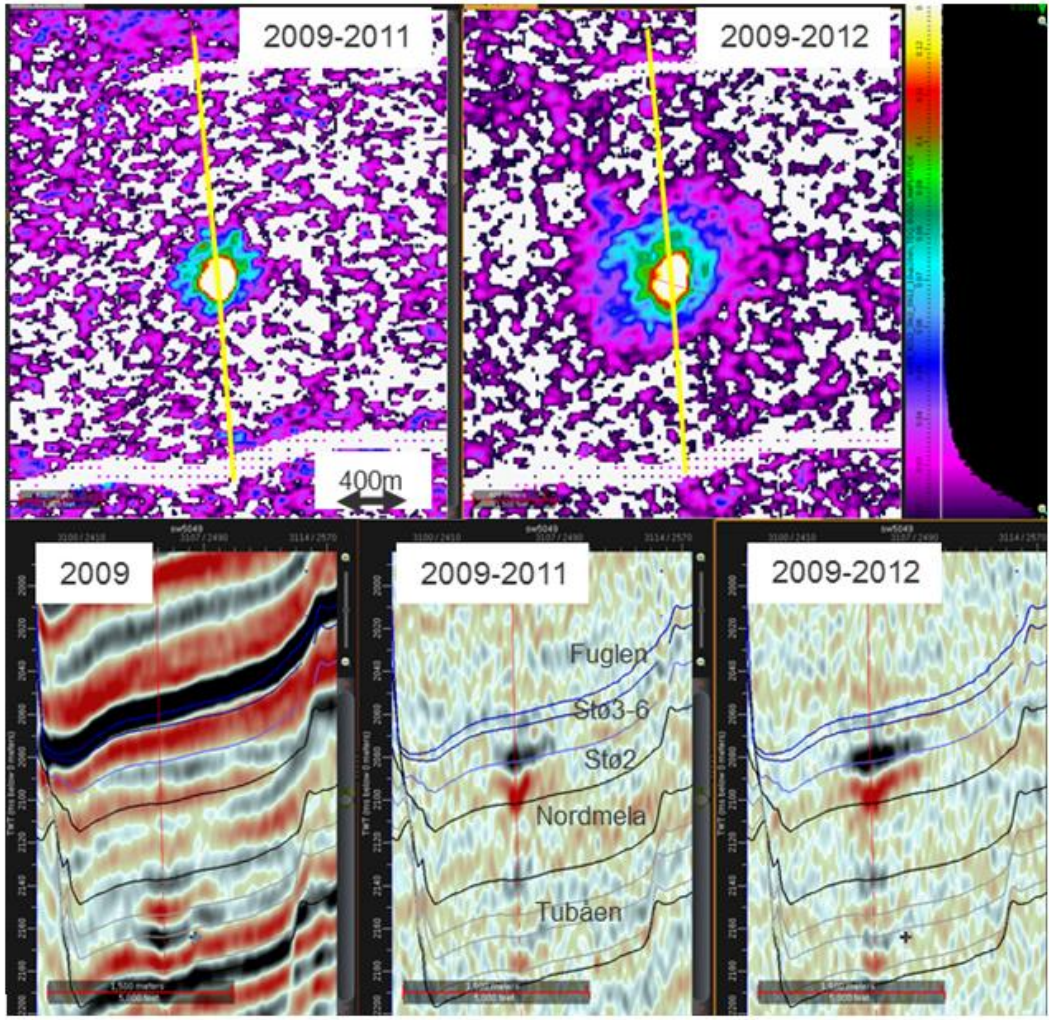






Statoil

Snøhvit: Monitoring and pressure maintenace



4D RMS amplitude map at Top Stø 2 (-10+20ms) for 2009-2011 (left) og 2009-2012 (høyre).

4D seismisk section for 2009 (left), 4D difference 2009-2011 (middle) and 2009-2012 (right).

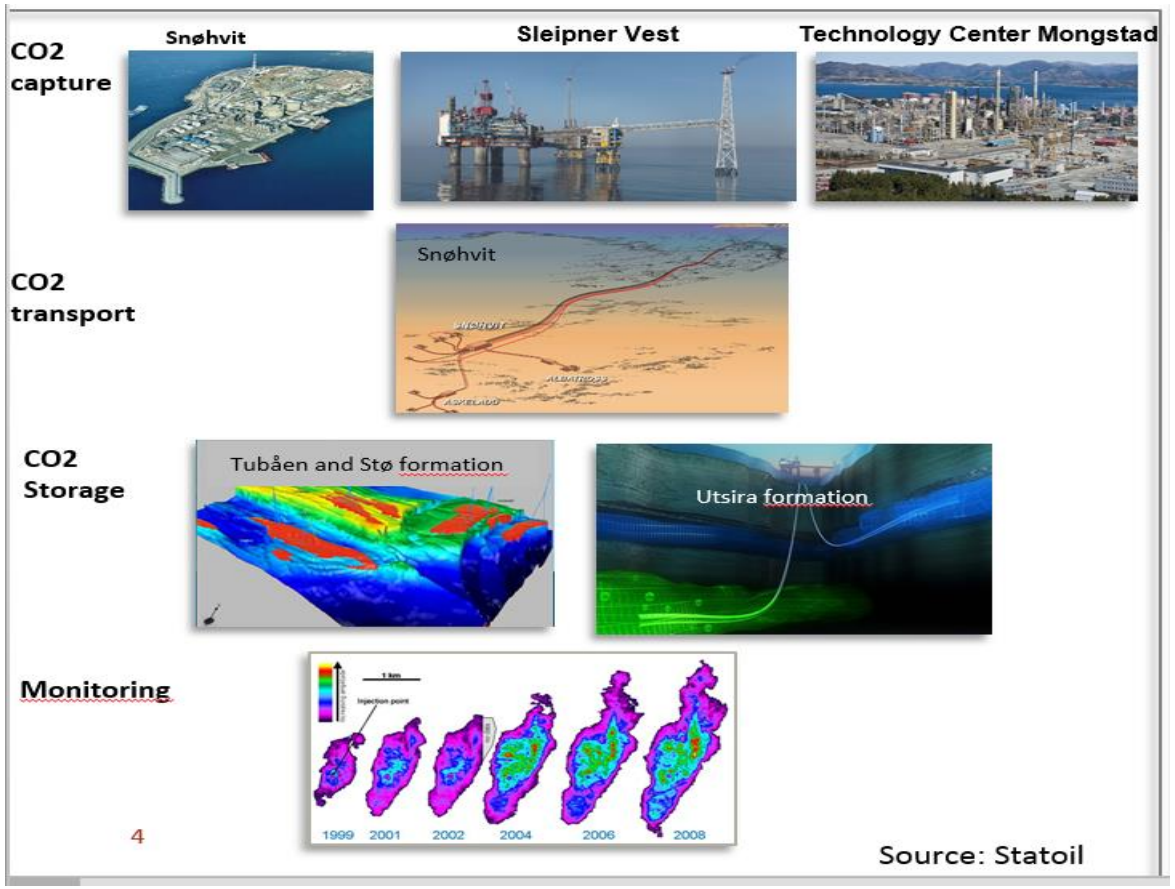
The pressure in the Tubåen formation increased faster then expected and he operator had to do an intervention in the well to prevent that the pressure increase across the established fracture pressure at 390 bar. A new well was later drilled with injection in the Stø Formation

Two aquifers have been tested for injection, Tubåen and Stø Formations.
Main risk Tubåen: Capacity related to connectivity. Injectivity, pressure build-up.
Main risk Stø: Plume migration, interaction with methane gas cap.

Norwegian CCS experience

20 years with offshore CO_2 storage, 16Mt from 1996

CO_2 produced together with methane gas is captured, injected in subsurface reservoirs and permanently stored
Regulated by petroleum legislation



Full-scale carbon capture, transport and storage (CCS) in Norway

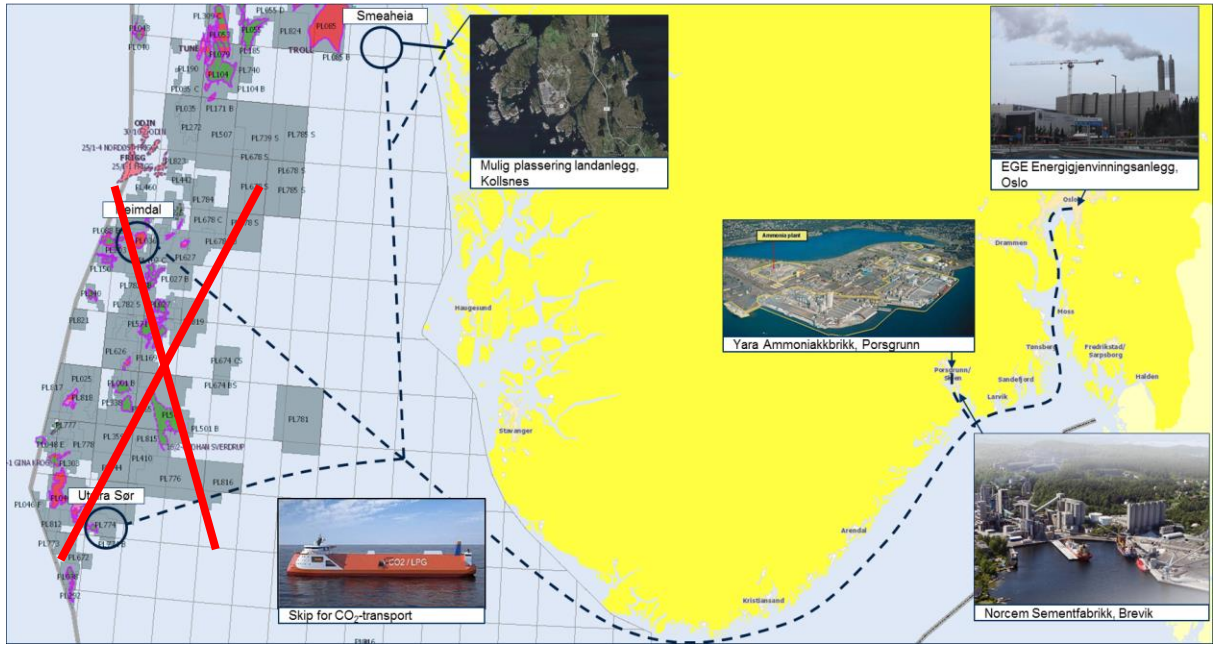


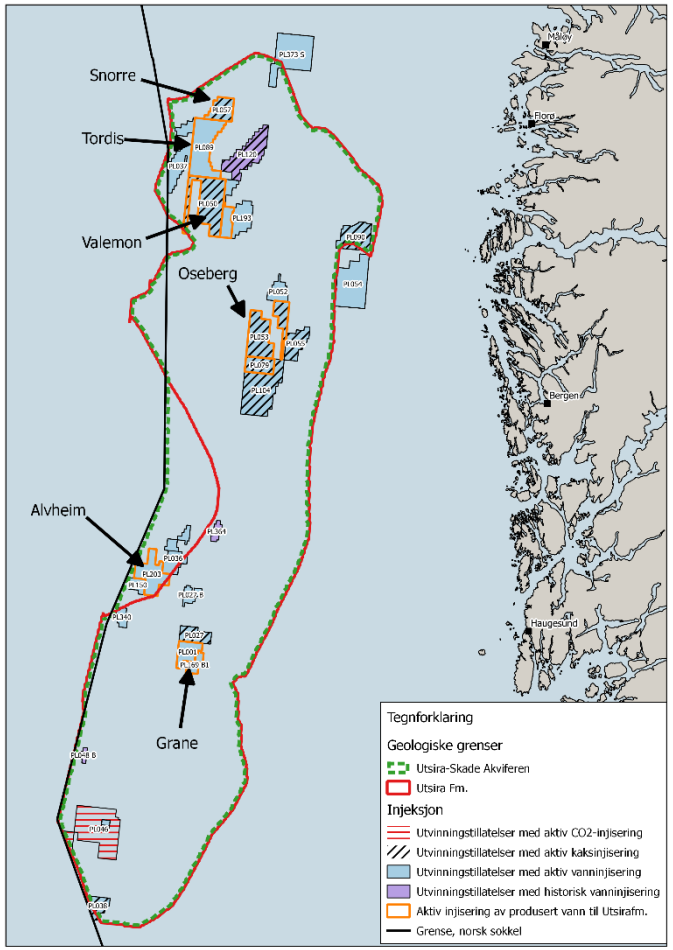
Figure from feasibility study 2016

CO_2 to be captured in 3 locations in East Norway,
Shipped to Kollsnes, West Norway,
Piped to storage location east of the Troll field
The CO_2 storage regulation will be applied
Plan: full-scale CCS chain in Norway by 2022

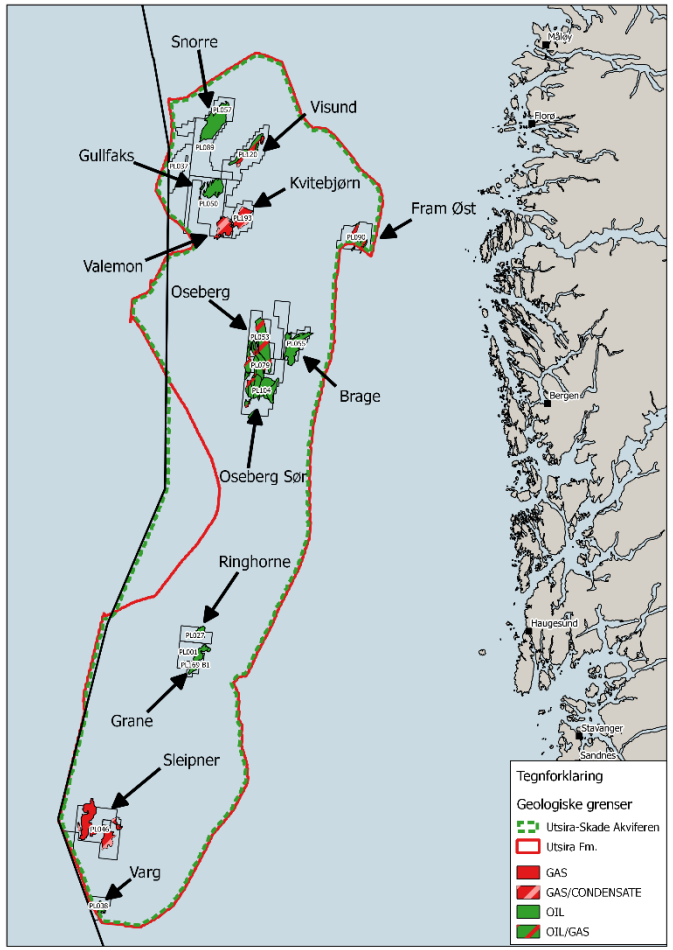
Storage in aquifer: Main risk: Mapping, capacity
Risk of pressure depletion – CO_2 in gas phase

Utsira Formation is used for produced water and cuttings injection

Injection of produced water to Utsirafm.



Injection of cuttings (mainly below Utsirafm.)



Until 2010 there were some events of fracturing to the surface from cuttings injection, and one event with leakage of produced water (pockmark 40 m in diameter formed at Tordis in 2008 caused by over-injection of produced water). Since then, the industry has improved their procedures related to pressure monitoring and training of staff. Experience is that continuous pressure monitoring and interpretation is necessary and effective. And that geological seals tend to heal themselves when pressure is reduced.

Break-through of water in Tordis was recognized by pressure drop in the injection well. Indicated by oil slick at the surface. Water volume estimated to 50-175 m3. When water injection stopped, the water discharge gradually stopped

CCS Regulation in the EU ("CCS Directive")

Ensuring there is no significant risk of leakage or damage to health or the environment

Norway: CCS legislation process

- The Norwegian CCS legislation is based on the EU "CCS Directive" and the existing Norwegian Petroleum legislation

  Ministry of Petroleum and Energy (new regulations)

  Ministry of Environment (amendment to Pollution Control regulations)

Risk acceptance criteria are based on the EU "CCS directive" and the London Protocol

http://www.npd.no/en/Regulations/Regulations/Regulations-relating-to-exploitation-of-subsea-reservoirs-on-the-continental-shelf-for-storage-of-CO-and-relating-to-transportation-of-CO-on-the-continental-shelf/

§5.1. Prudent storage of CO_2

Storage of CO_2 , closure of the storage locality and post-closure operation shall take place in accordance with prudent technical and sound economic principles and in such a manner that leakage from transport of CO_2 and from the CO2 storage locality is avoided as far as possible. The licensee shall carry out continuous evaluation of technical solutions and take the necessary measures in order to achieve this.

CO2 storage regulation: main steps from mapping to CO2 injection

Reconnaissance permit
Geophysical mapping, sea floor studies, shallow drilling.
Define area/block for the exploration phase.

Exploration permit. Granted by King in Council. Apply to Ministry of Petroleum :
Geophysical mapping, drilling, reservoir studies.
Define area and reservoir level(s) for the injection phase, estimate storage capacity and seal properties

Exploitation permit Granted by King in Council. Apply to Ministry of Petroleum, copy NPD, Ministry of Labour and PSA :
More detailed studies leading to development plan. Delimitation of area needed for injection and plume development.

Impact assessment
Assessment of environmental impact of alternative technical solutions, and how monitoring of environment can be performed. Interaction with all relevant authorities and organisations. Results to be integrated with development plan.
Assess how environmental monitoring in the area can be carried out

Plan of development of subsurface reservoir for CO2 injection and storage. Submitted to Ministry of Petroleum together with Impact Assessment. Copies to NPD, Ministry of Labour, PSA, Ministry of Environment

CO2 storage regulation: Monitoring.

Consent for injection and storage of CO2, following development plan. Granted by Ministry of Petroleum and Ministry of Labour / NPD and PSA.

Applications for consent for injection and storage of CO_2 shall contain:

- The storage location's and storage complex' area and delineation, as well as information about the subsea geological reservoir, including the hydraulic unit for which the consent for injection and storage shall apply,
- The injection operation, the volume of CO_2 that can be injected, limit values for reservoir pressure and limit values for injection rates and pressure,
- Volumes and limit values for pressure build-up,
- The operator's monitoring plan, cf. Appendix II to these Regulations,
- Measurement of CO_2 injection rates,
- Plans for any corrective measures,
- Plan for shutdown and post-operation.

The operator shall monitor the injection facilities and the storage complex, including the dispersion of CO_2 in order to:
a) Compare the actual and modelled behaviour of the CO_2 and the formation water in the storage location,
b) Identify significant irregularities,
c) Follow the migration of CO_2,
d) Detect leaks of CO_2 from the storage complex,
e) Update the assessment of the storage complex' safety and integrity over the short and long term, including whether the stored CO_2 will remain safely stored.

Following shutdown of a storage location pursuant to Section 5-7(1)(a) or(b), all obligations concerning monitoring and corrective measures pursuant to these Regulations shall be transferred to the State, represented by the Ministry of Petroleum and Energy or the entity it authorises, either on its own initiative or upon application from the operator, given that the following conditions have been fulfilled:

Criteria for establishing and updating the monitoring plan in Section 5-4 and post-operation plan in Section 5-7

a) The parameters to be monitored,

b) The monitoring techniques that will be used and a substantiation for the chosen monitoring techniques,

c) Monitoring locations and a substantiation for the chosen sampling locations,

d) Sampling frequency and a substantiation thereof,

The parameters to be monitored shall be chosen such that they can satisfy the objective of the monitoring. The plan shall nevertheless always include continuous or periodic monitoring of the following factors:

e) Diffuse emissions of CO_2 near the injection facility,

f) CO_2 volume flow near the injection wellheads,

g) CO_2 pressure and temperature near the injection wellheads (in order to determine mass flow),

h) Chemical analysis of the injection flow,

Appendix II in regulations.

i) Reservoir temperature and pressure (to determine the CO_2 phases' behaviour and condition), The choice of monitoring techniques shall be based on the best practice available at the time of design. The following alternatives shall be considered and used, if possible:

j) Technologies that can detect the presence, location and migration route of CO_2 in the subsurface and on the surface,

k) Technologies that can provide information about the development of pressure and volume and area/vertical saturation of the CO_2 cloud (plume) in order to improve numerical 3D simulations related to 3D geological models of the storage formation established pursuant to these Regulations' Section 1-10 and Appendix I,

l) Technologies that can cover a broad area in order to obtain information about previously undiscovered potential leakage routes across the area dimensions of the entire storage complex and above, in the event of significant irregularities or migration of CO_2 out of the storage complex.