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

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International Workshop on Offshore Geologic CO2 Storage CO2 STORAGE WORKSHOP
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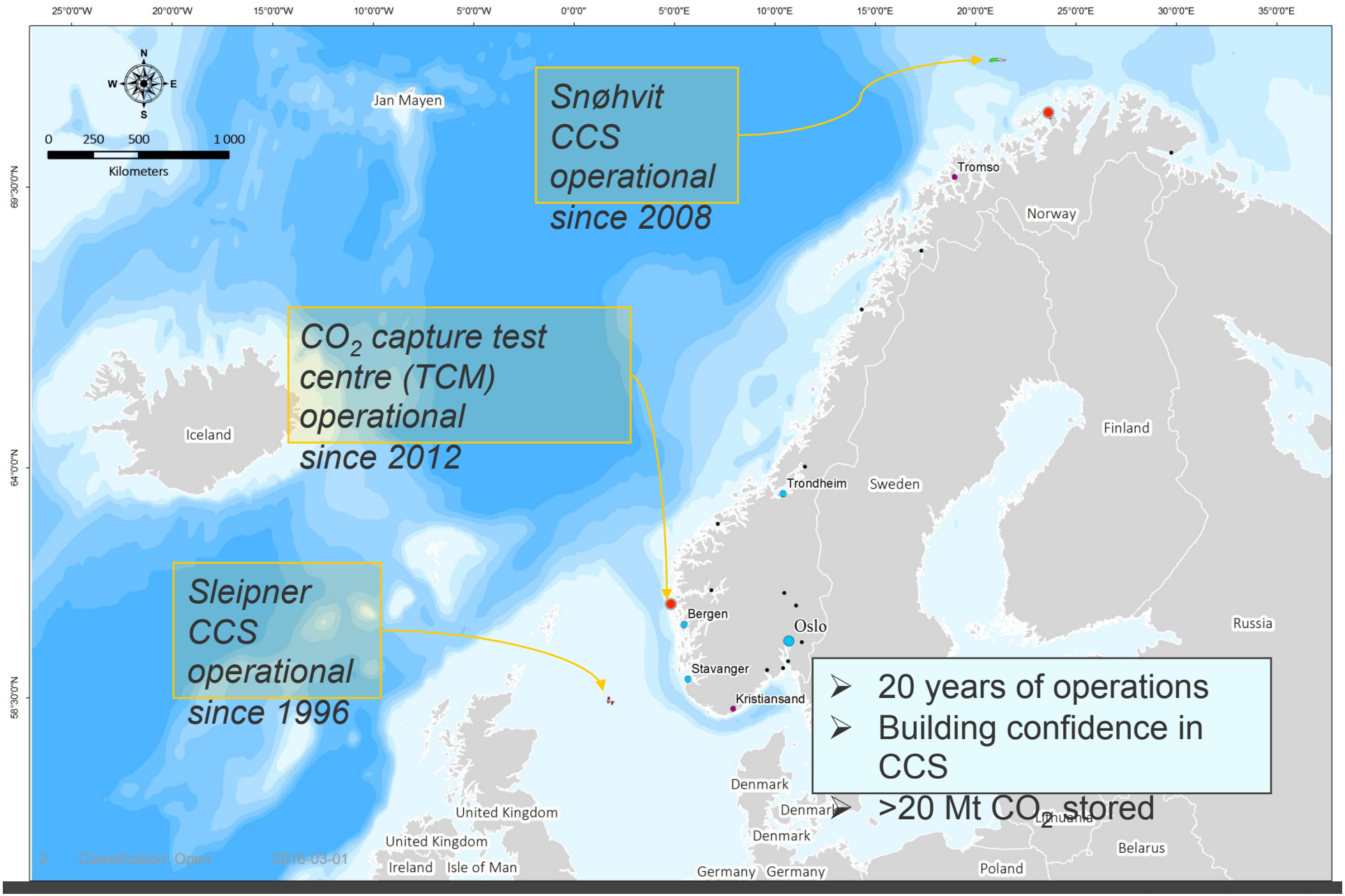
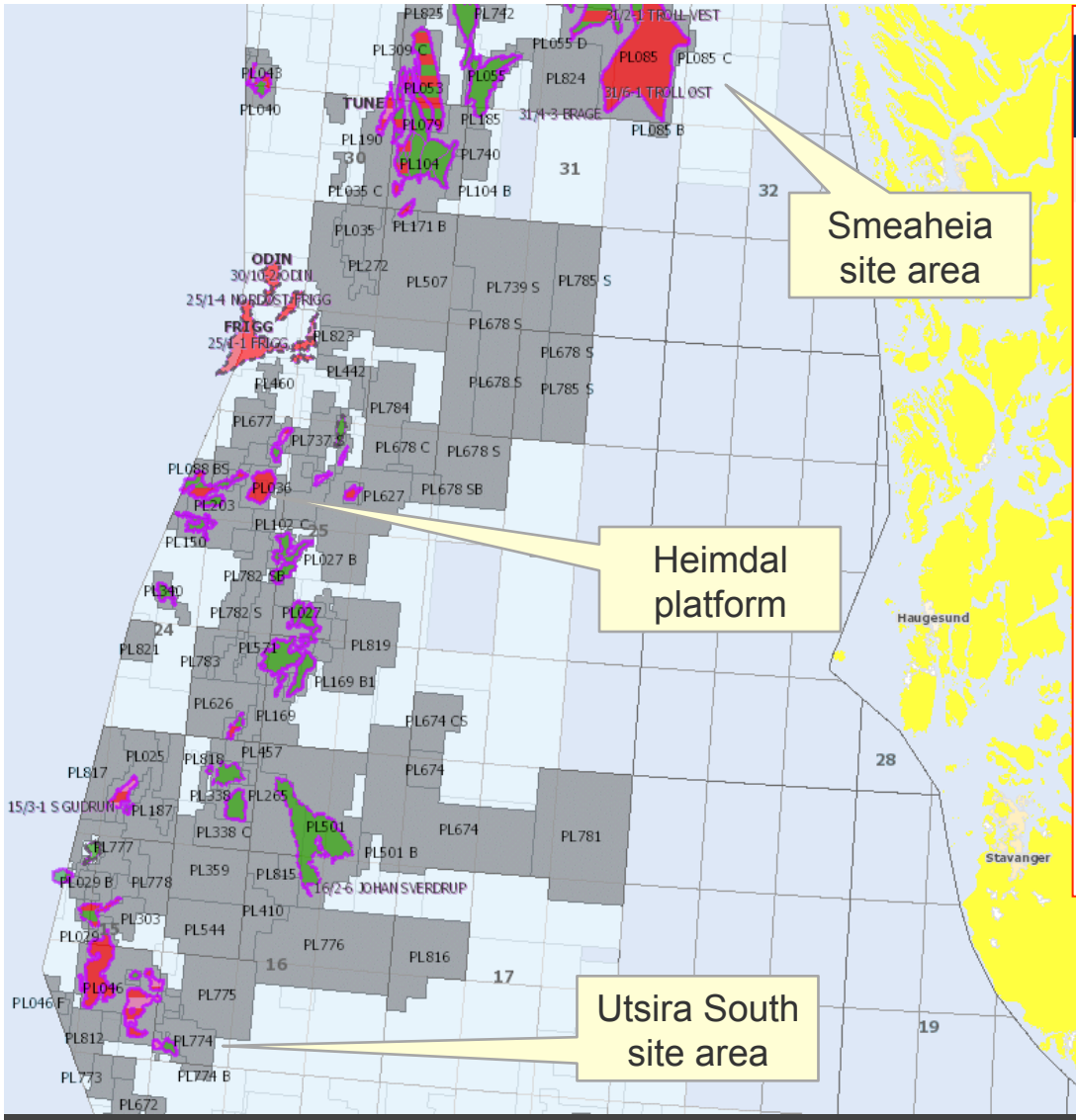
Norway's CCS track record



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 CO_2 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 CO_2 Storage
- Norway also active with international cooperation for widespread deployment of CCS:
  - Especially EU, Southern Africa, China, Persian Gulf and Indonesia

CO_2 storage feasibility study in Norway



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Initiates feasibility study on subsea CO2 storage

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On Monday, the Ministry og Petroleum and Energy signed an agreement with Statoil on a feasibility study regarding CO2 storage on the Norwegian Continental Shelf (NCS). The study will include various development concepts for storing CO2 at three different locations on the NCS. The study is to be completed by 1 June 2016 and is budgeted at about NOK 35 million (USD 4 mill.).

- Statoil is currently evaluating three sites as part of this feasibility study

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Onshore CO_2 capture

Incineration plant at Klemetsrud, Oslo (link)

- CO_2-capture test plant opened January 2016
- First CO_2 capture from a waste-to-energy plant
- Pushing for negative emissions (Bio-CCS)

Yara Ammonia Plant at Porsgrunn

- Already sells food-grade CO_2
- Estimated future emissions ~ 825 kt/y
- 200 kt/y already recovered for use

Heidelberg Norcem at Brevik

- Already reduced CO_2 emissions via energy-efficiency and fuel switching (biofluels)
- High flue gas CO_2 concentration (16-19%)
- Estimated future emissions ~ 760 kt/y

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CO_2 Transport

- 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 Feburary 2016

Study contracts for carbon dioxide transport

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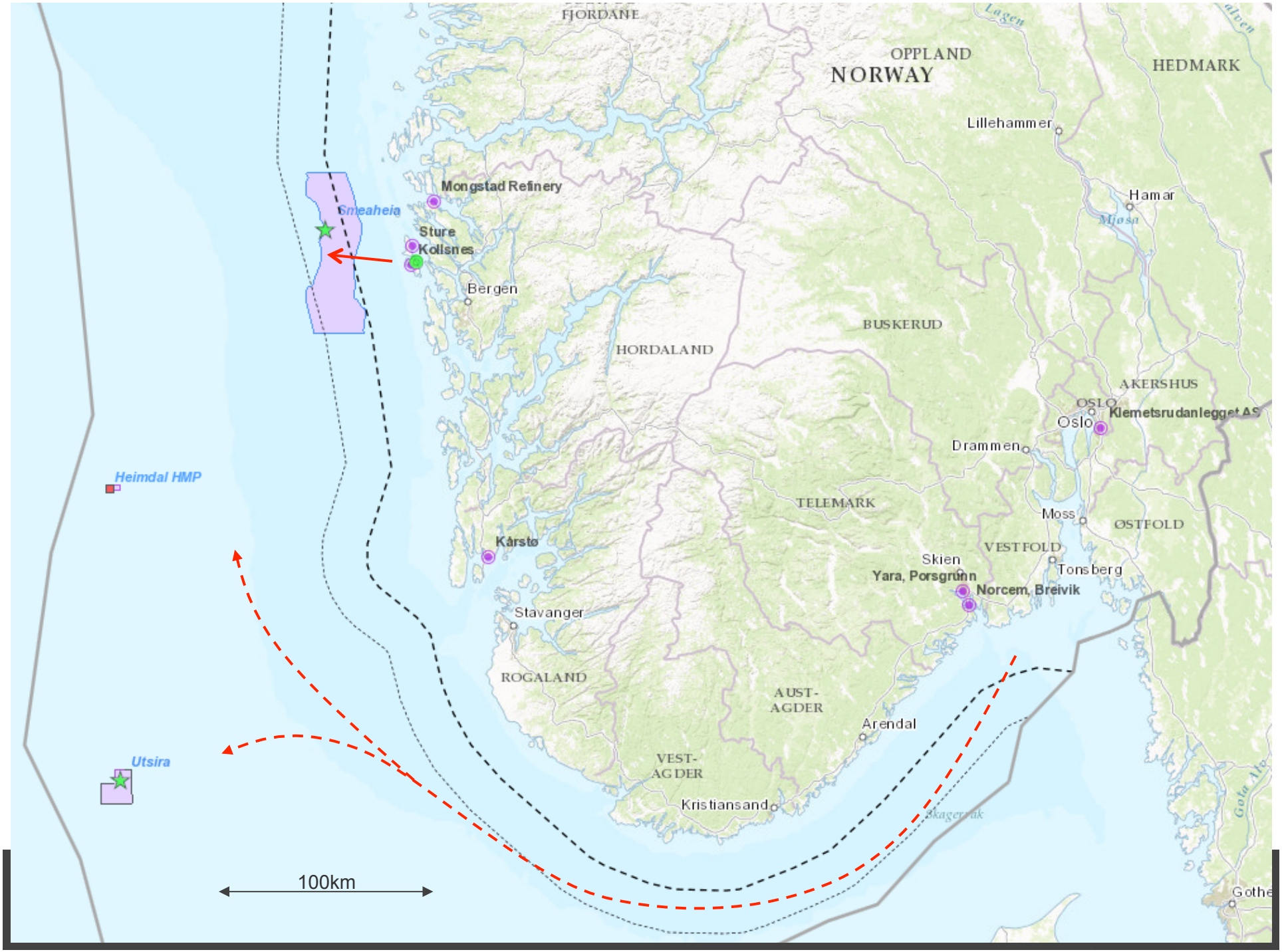
Vessels like Gijon Knutsen might be used for CO2 transport. (Picture: Knutsen OAS).

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.


FJORDANE
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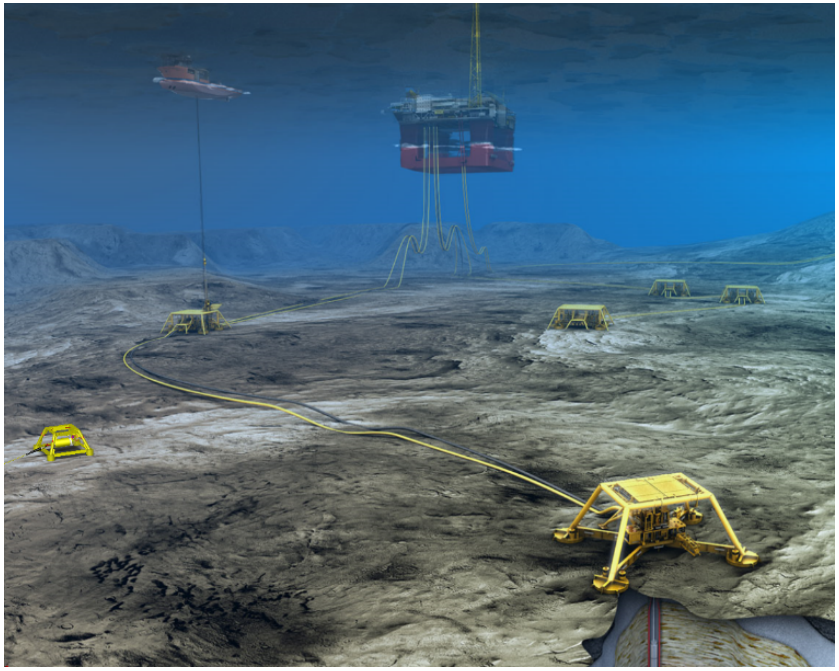
Yara, Porsgrunn
Tonsberg
Norcem, Breivik
Stavanger
ROGALAND
AUST-
AGDER
Arendal
Utsira
VEST-
AGDER
Kristiansand
100km

Integrating with offshore storage facilities

- The CO_2 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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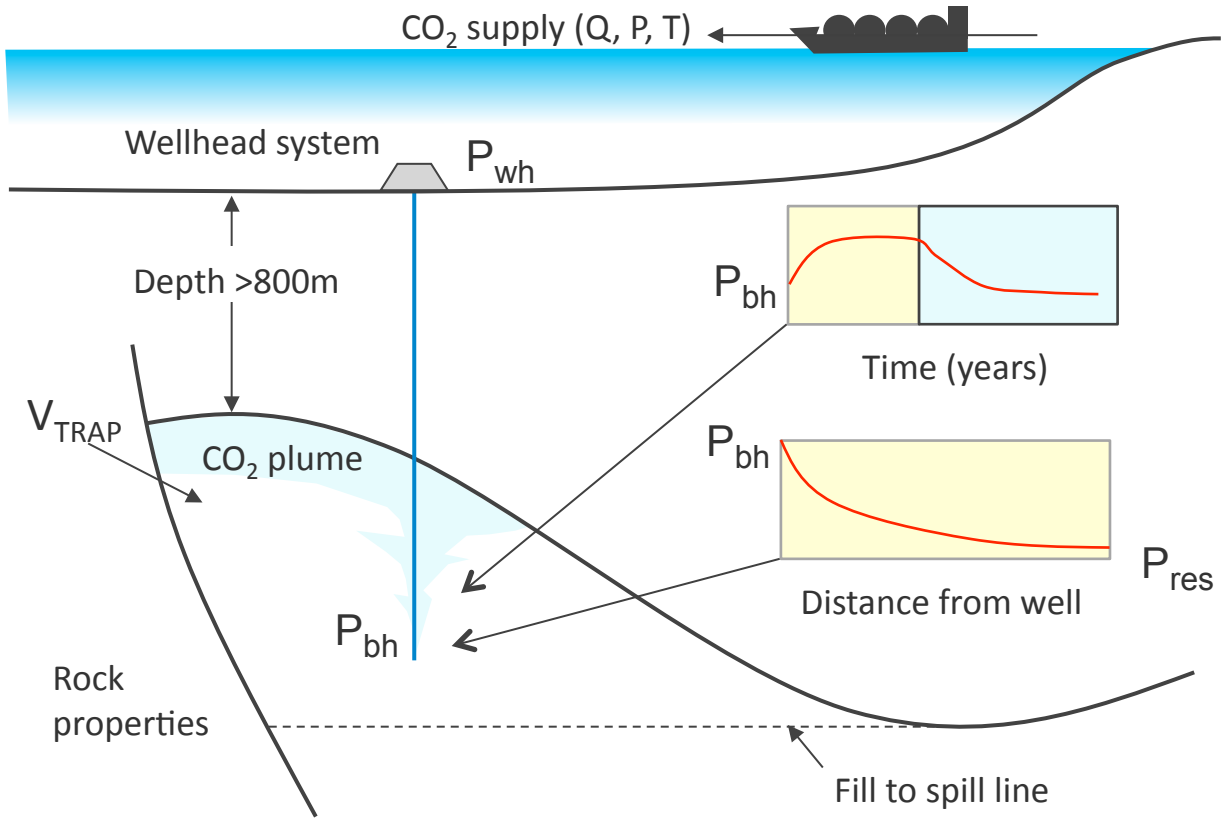
Nuts and bolts: some key questions for the design

- CO_2 supply – rates, pressures, temperatures
- Reservoir depth, water depth
- Storage site capacity
- Well design
- Site performance (plume behaviour)
- Reservoir properties
- Overburden & seal charactersitics
- Risk evaluation
- Monitoring plan
- Regulatory conformance
- Operational optimization



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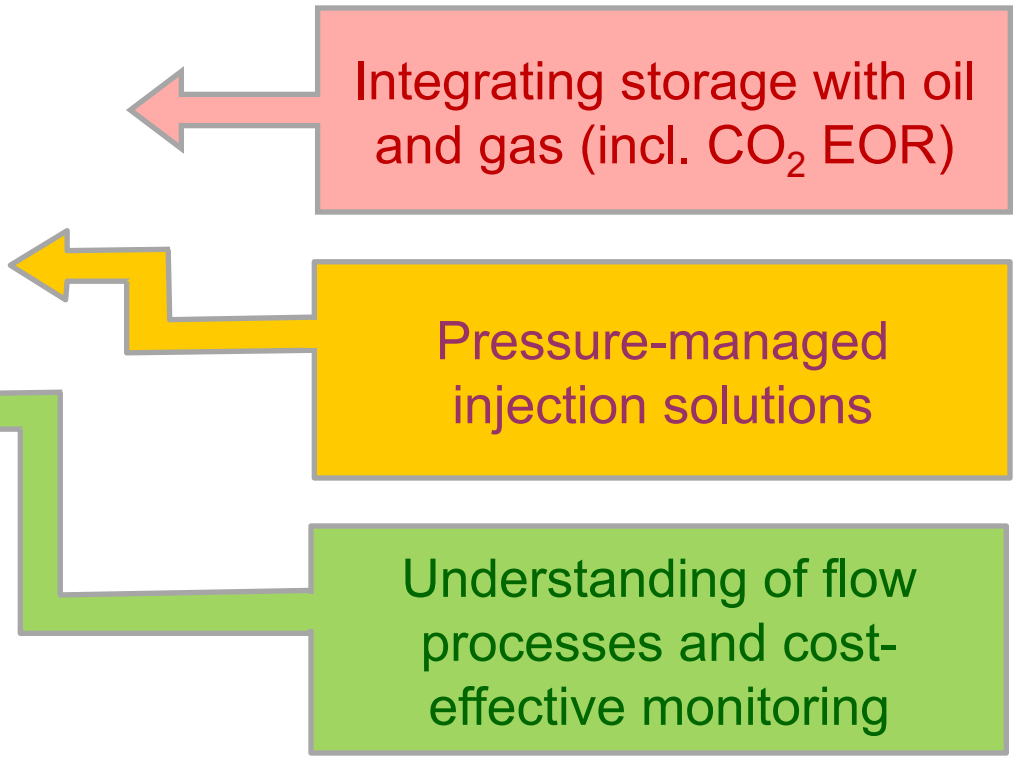
Challenges for large-scale CO_2 storage

How can we develop robust and cost-effective solutions for large-scale CO_2 storage?

Three main barriers:

1. Cost
2. Capacity
3. Confidence



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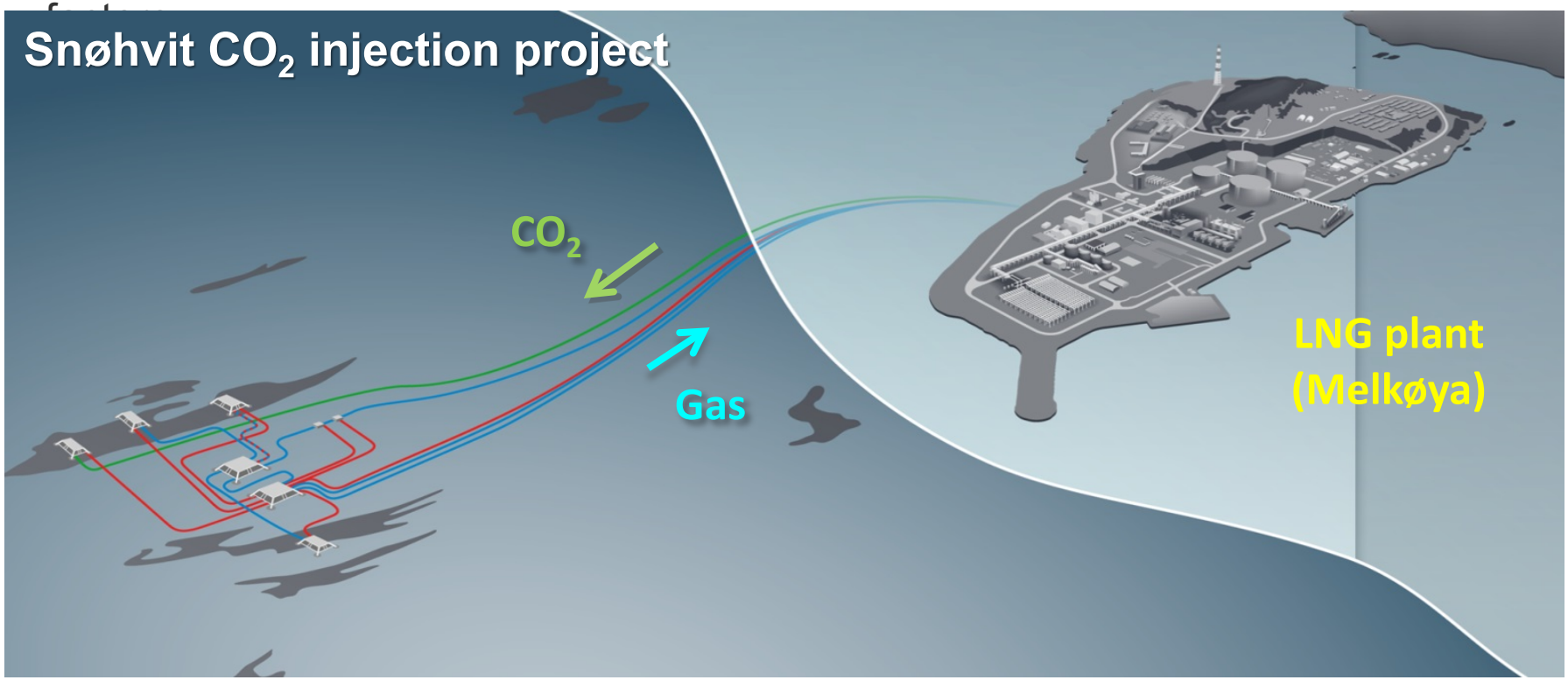
Cost reduction – Storage linked to oil & gas

- 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



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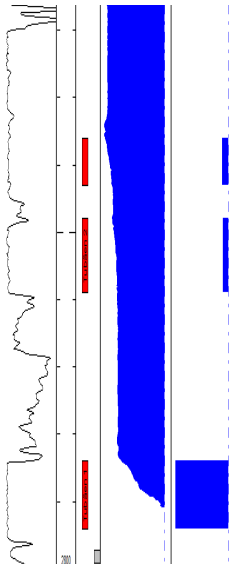
Building Capacity: Pressure-managed injection

Snøhvit case study

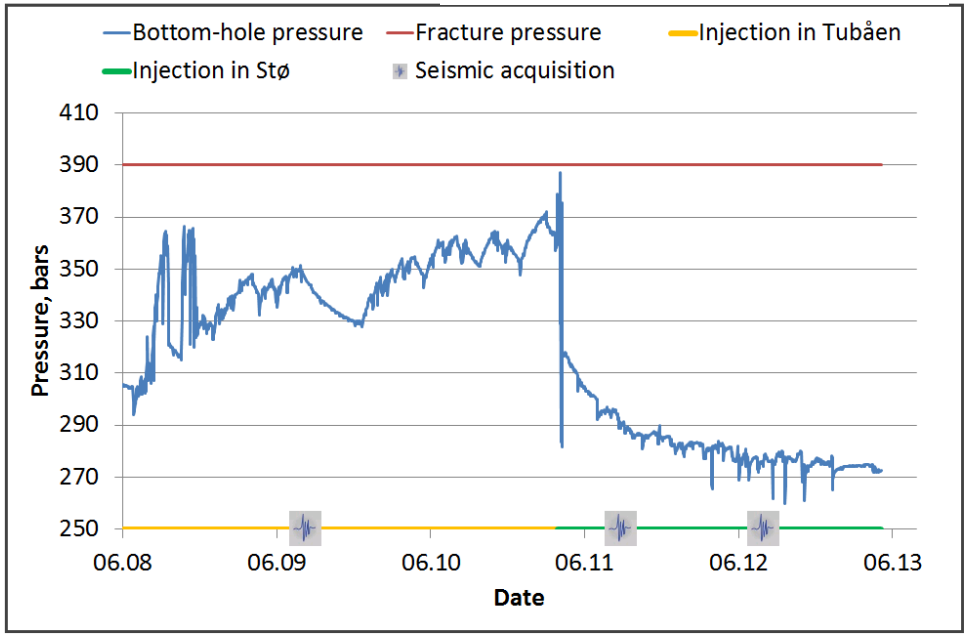
Well intervention guided by:

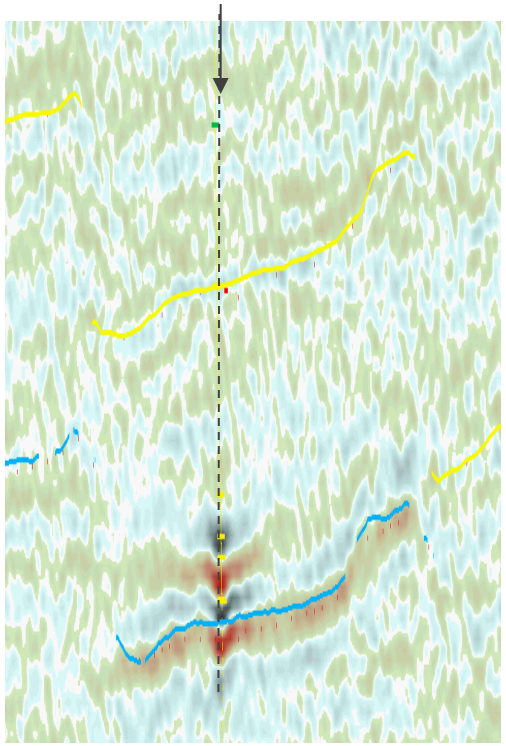
- Time-lapse seismic
- Downhole P/T gauges and flow logging

Down-hole data:
P, T, Q



Down-hole pressure data





Time-lapse seismic
(Amplitude difference)

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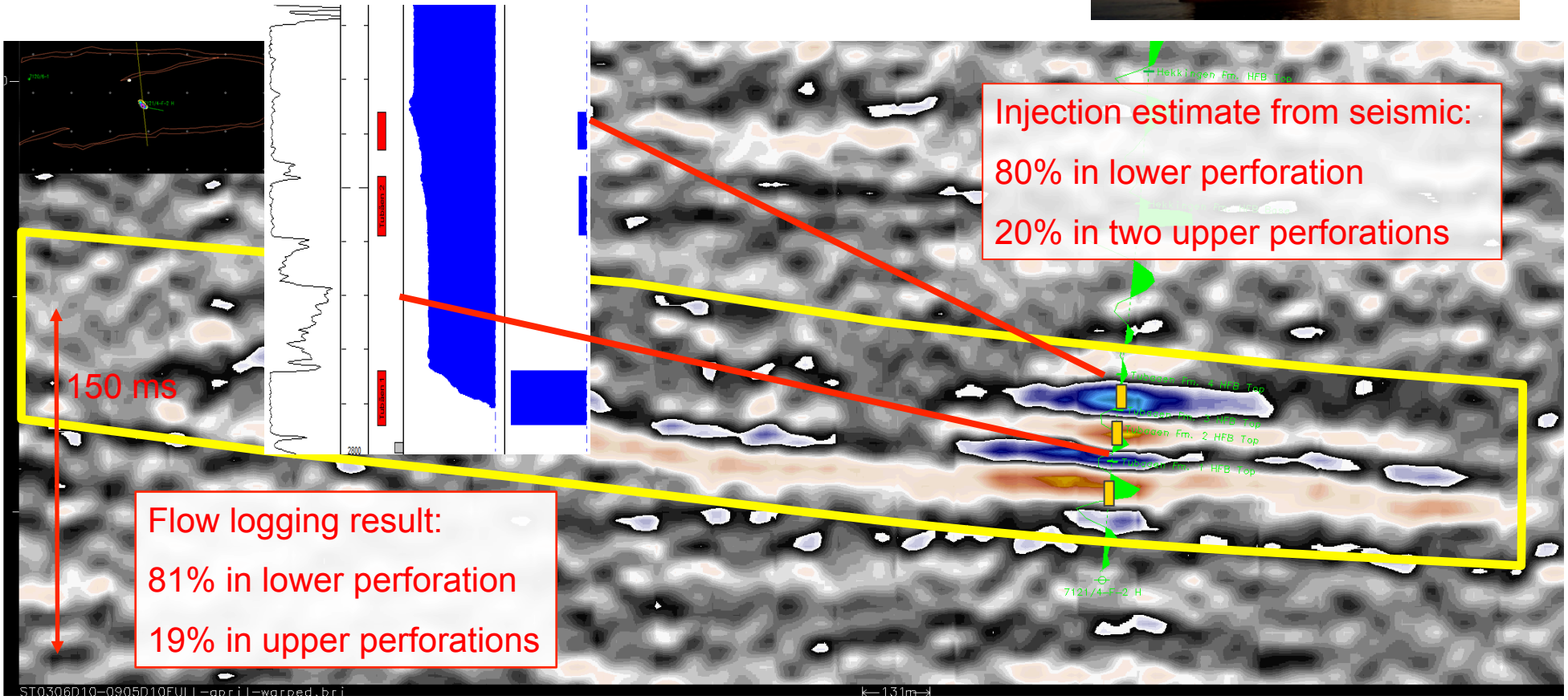
Monitoring CO_2 injection (Tubåe

INFLOW LOG



Hansen et al., 2013

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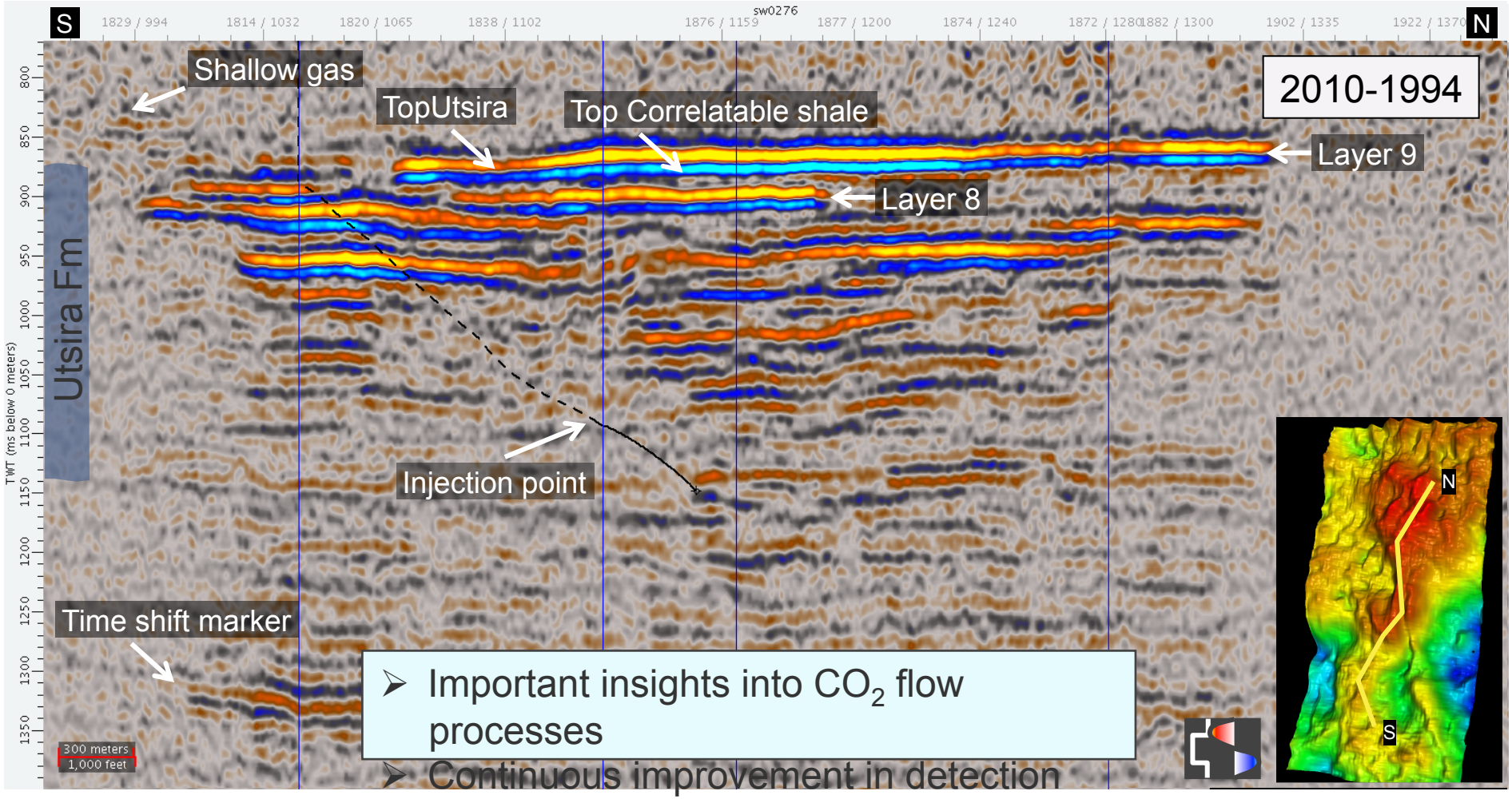
Building Confidence: Using first-mover projects

Sleipner monitoring dataset



- Important insights into CO_2 flow processes
- Continuous improvement in detection levels

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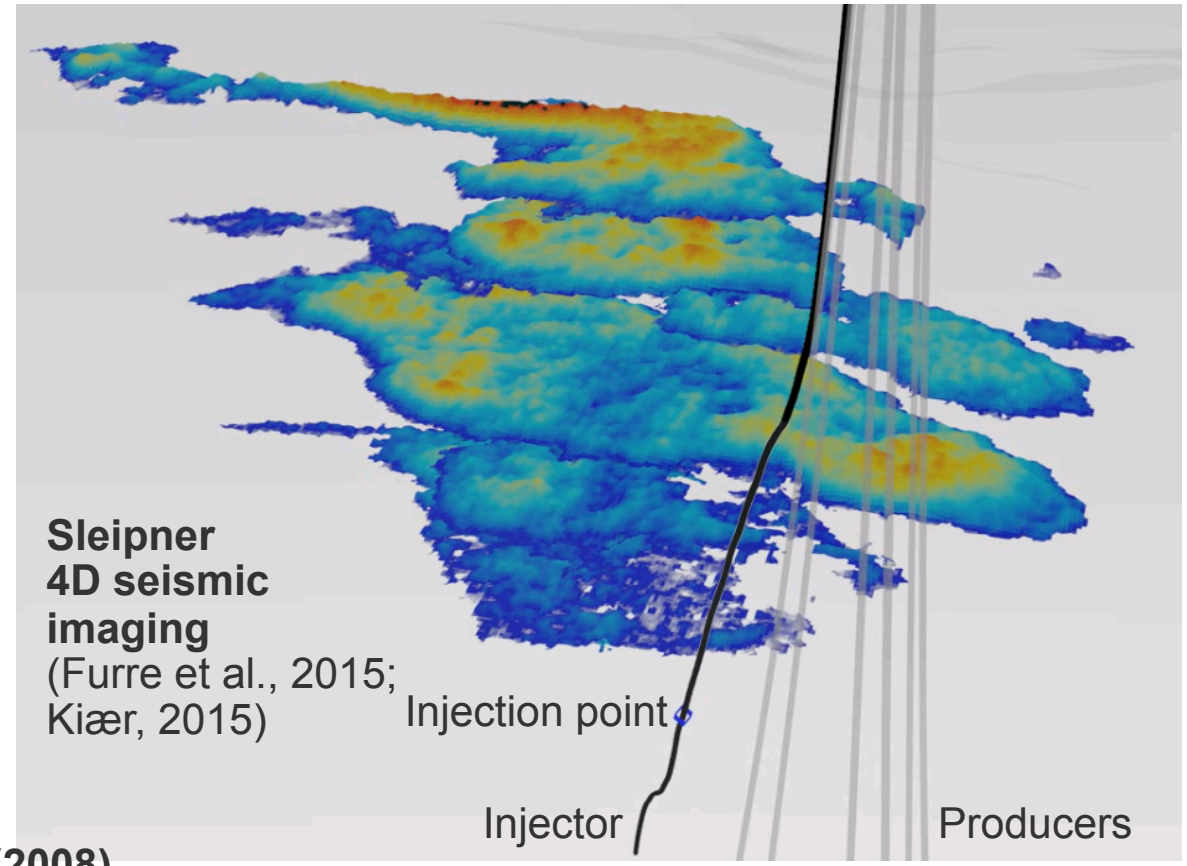
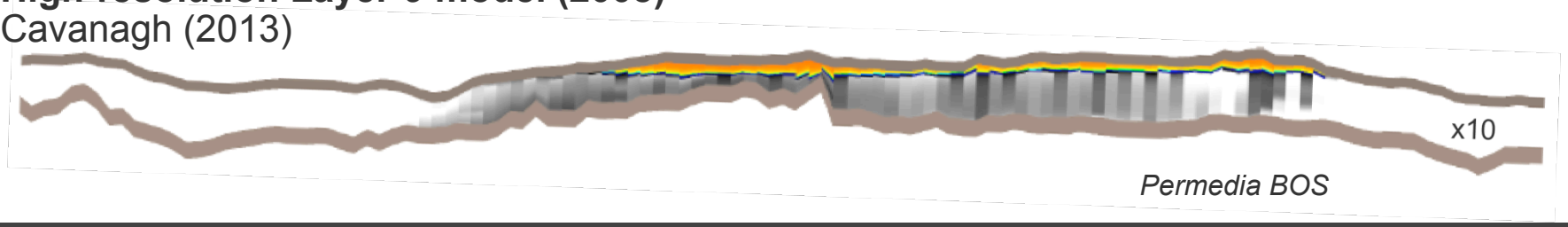
Insights from Sleipner

- Steady improvements in CO_2 plume detection from seismic data:
  - Saturation, pressure
  - Plume extent
- Significant improvements in understanding CO_2 flow dynamics:
  - Gravity segregation
  - Dissolution rate



Sleipner 4D seismic imaging
(Furre et al., 2015; Kiær, 2015)

High-resolution Layer-9 model (2008)
Cavanagh (2013)



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Key drivers for offshore CO_2 storage

- Norway has strong track record in CO_2 storage operations
  - 20 Mt CO_2 safely stored underground
- Importance of the learning curve
  - Oil and gas sector has the experience needed for realizing large-scale CO_2 storage projects
  - Value of geophysical imaging and monitoring data
  - Practical learnings about capacity and injectivity
  - Improved understanding of CO_2 storage processes
  - Building confidence in models and forecasts
- Norway ambition to realize at least one full-scale CCS demonstration facility by 2020 is underway