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A technical perspective on the issues around containment between storage complexes and across national boundaries

Gioia Falcone

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Summary



- Reporting of cross-border CCS operations
- International CCS operations
- Migration, Leakage, and the EU Directive on the Geological Storage of CO₂
- Requirements for measurement

Reporting of cross-border CCS operations

- *If CO₂ is injected in one country, Country A, and travels from the storage site and leaks in a different country, Country B, Country A is responsible for reporting the emissions from the geological storage site.*
- *If such leakage is anticipated based on site characterization and modelling, Country A should make an arrangement with Country B to ensure that **appropriate standards for long-term storage and monitoring and/or estimation of emissions** are applied (relevant regulatory bodies may have existing arrangements to address cross-border issues with regard to groundwater protection and/or oil and gas recovery).*
- *If more than one country utilizes a common storage site, the country where the geological storage takes place is responsible for reporting emissions from that site.*
- *If the emissions occur outside of that country, they are still responsible for reporting those emissions as described above.*
- *In the case **where a storage site occurs in more than one country**, the countries concerned should make an arrangement whereby each reports an agreed fraction of the total emissions.*

- 2006 is also the year when the London Protocol established a basis in international environmental law to allow CO₂ storage beneath the seabed when it is safe to do so. The base helps to regulate the injection of CO₂ waste streams into sub-seabed geological formations for permanent isolation.
- Subsequent amendments.

RESOLUTION LP.3(4)

ON THE AMENDMENT TO ARTICLE 6 OF THE LONDON PROTOCOL

(Adopted on 30 October 2009)

NOTING that the transboundary movement of carbon dioxide after injection (migration) is not export for dumping and therefore not prohibited by Article 6; and

2. **INVITES** the Scientific Group under the London Protocol in collaboration with the Scientific Group under the London Convention to consider the need for amendments to the *Specific Guidelines for Assessment of Carbon Dioxide Streams for Disposal into Sub-seabed Geological Formations*, to provide further specific guidance in cases of export of such streams to other countries for disposal and issues related to the management of transboundary movement of carbon dioxide after injection.



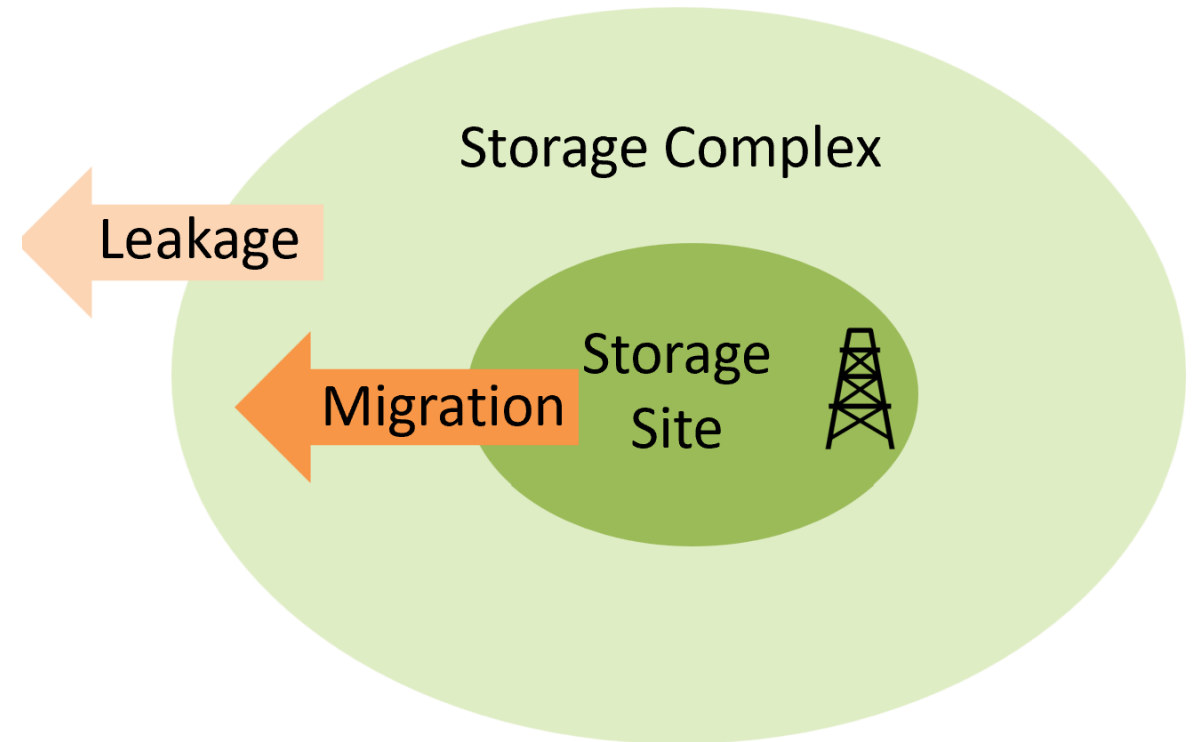
SPE-220031

Migration, Leakage, and the EU Directive on the Geological Storage of Carbon Dioxide

Bob Harrison, Sustainable Ideas Ltd. & Prof. Gioia Falcone, University of Glasgow

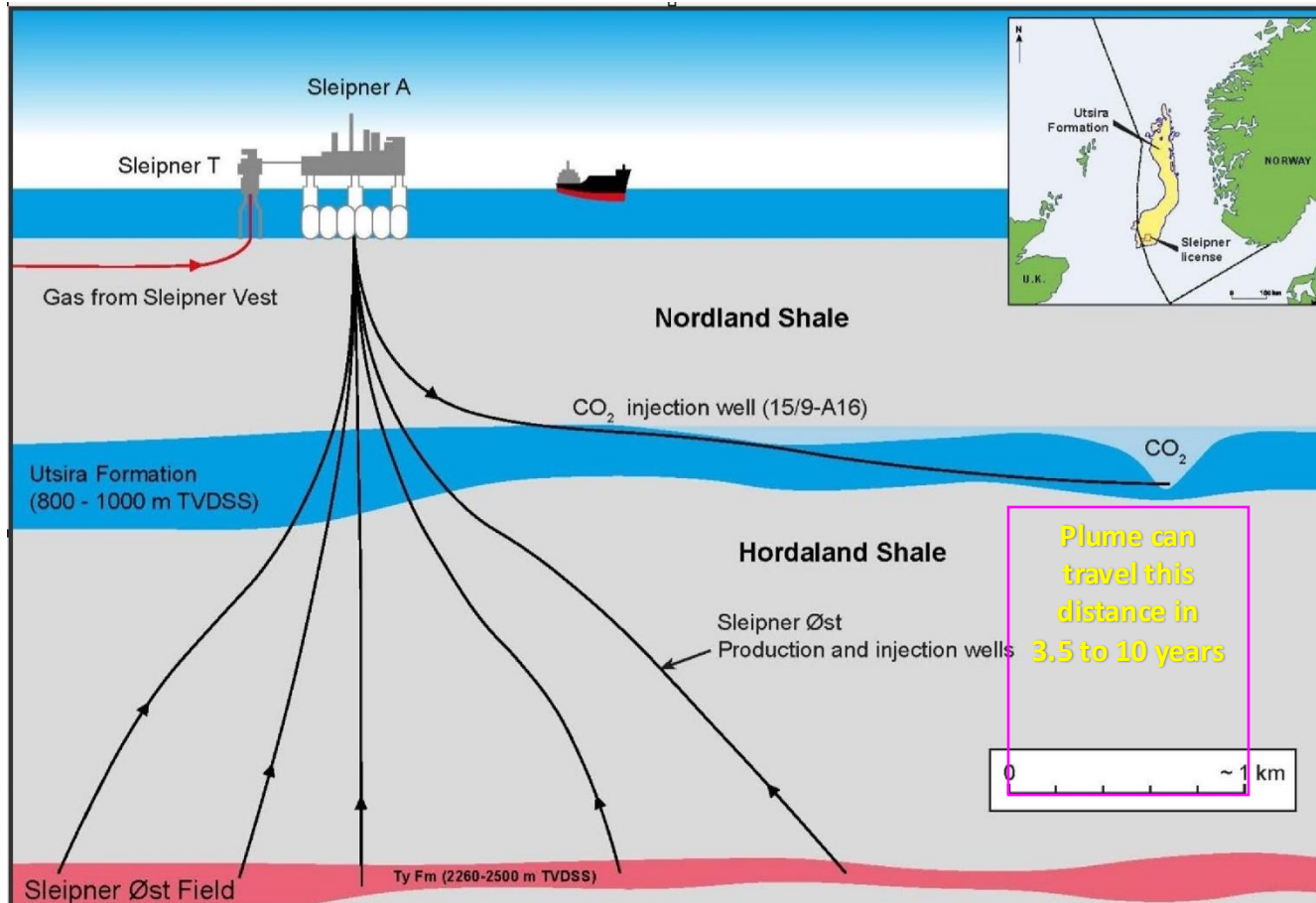
EU Directive on Geological Storage of CO2 (2009/31/EC)

- Published in 2009, the Directive provides a legal framework for safe geo-sequestration.
- Covers all CO2 storage in geological formations within the EU for the lifetime of the sites.
- Outlines requirements that a geological formation is only selected as a storage site if, under the conditions of use, there is neither significant risk of leakage, nor risk to the environment or to public health.
- **Directives** set goals that EU countries must achieve, individual countries devise their own laws on how to reach these goals
- **Regulations** are binding and must be applied in their entirety across the EU.

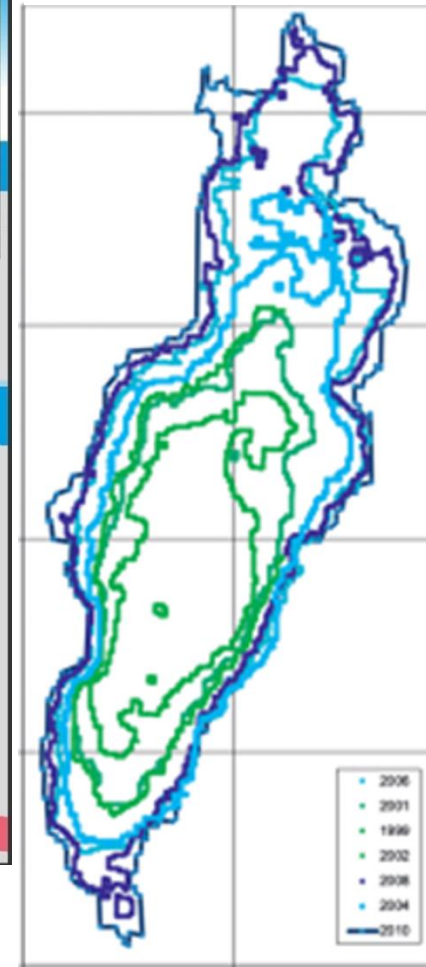


An escape of CO2 from a storage site is not a leak, it's a migration of CO2 into the surrounding storage complex

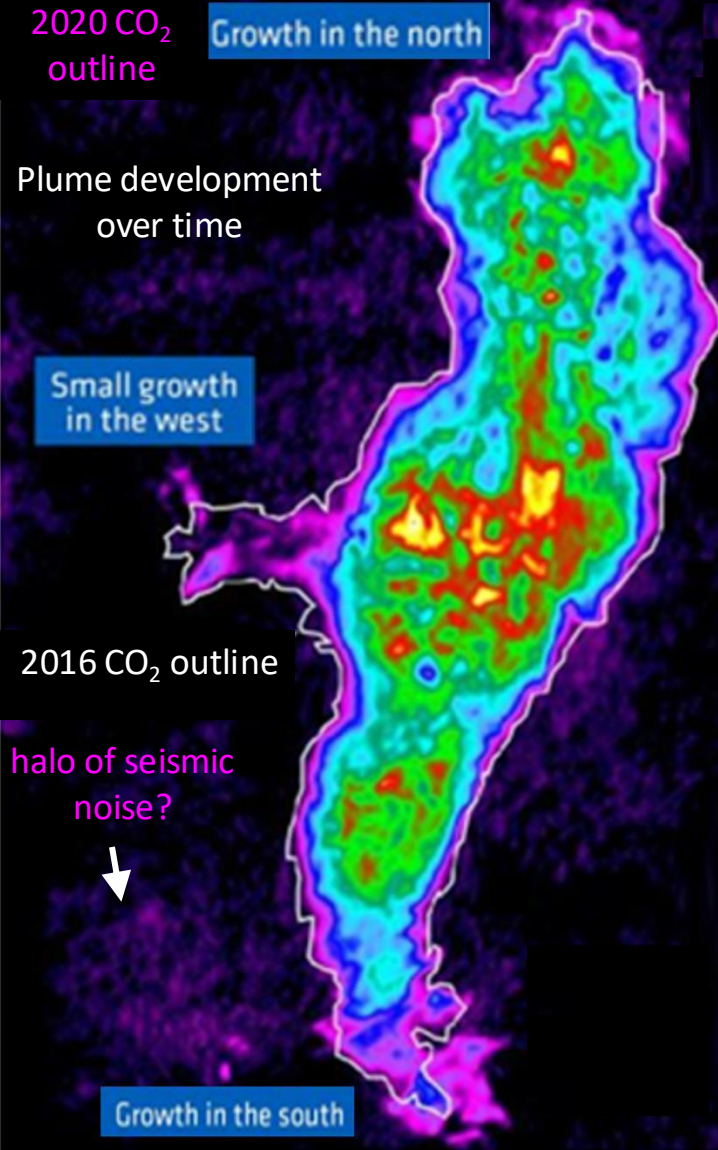
Case Study - Sleipner CCS project (Norwegian North Sea)



2006 - 2010 CO₂ outline



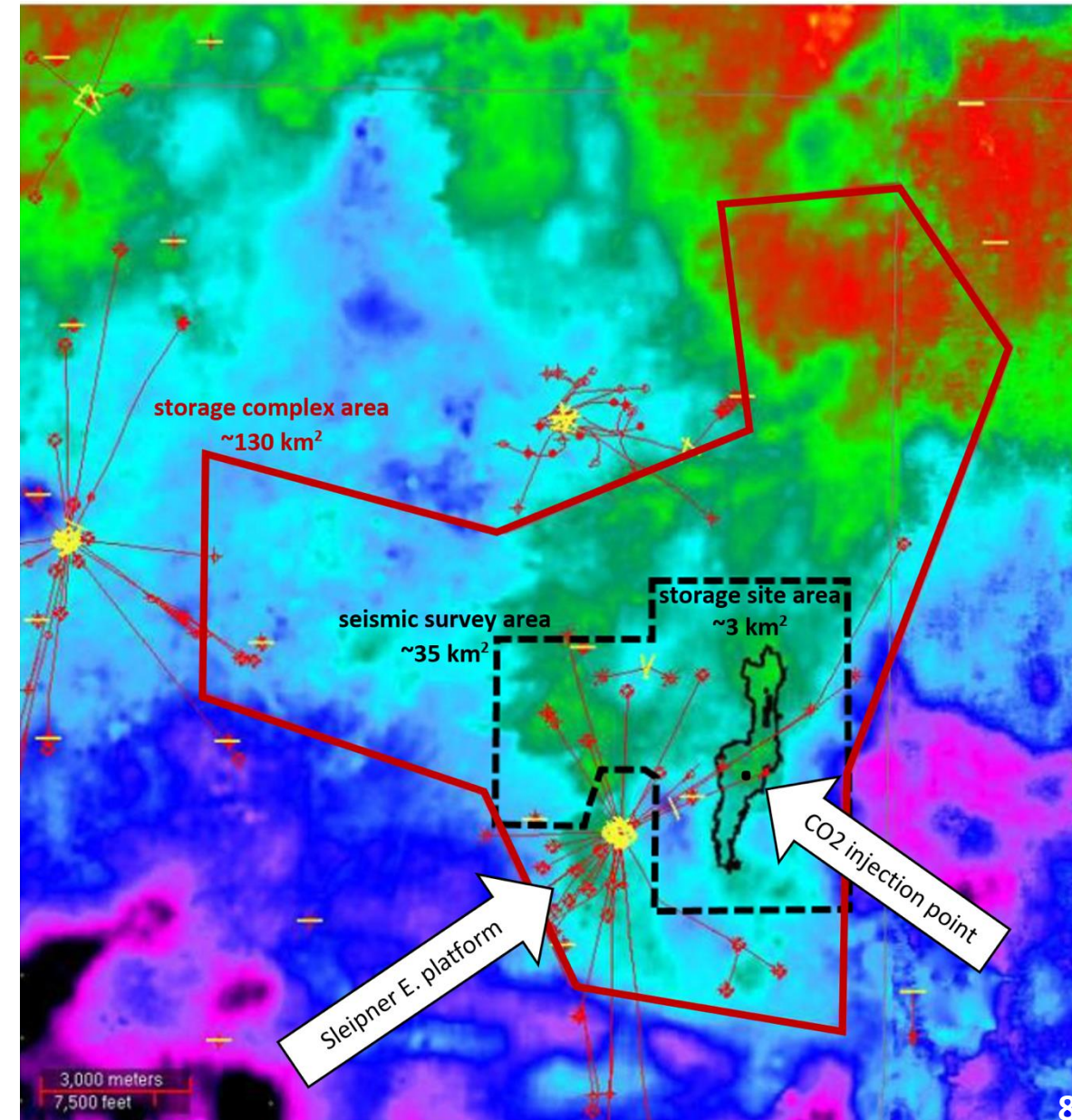
Plume can travel this distance in 3.5 to 10 years



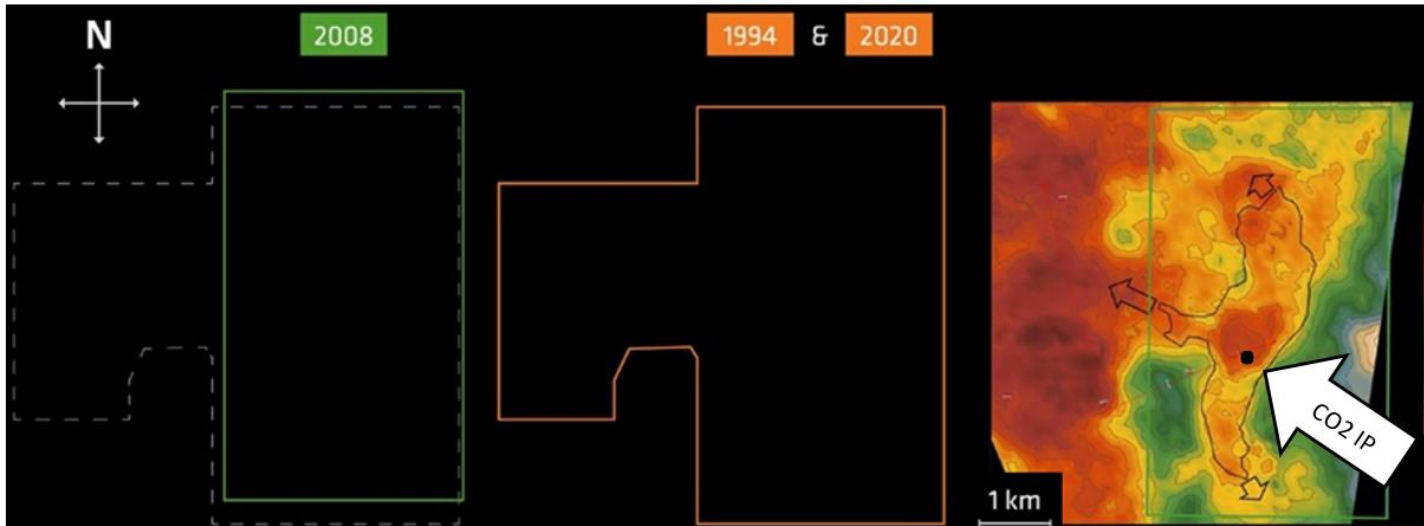
Average plume speed assumed to be 100 m per year originally. 2020 survey analysis suggests plume speed may now be 3x faster.

Sleipner storage structure / site / complex

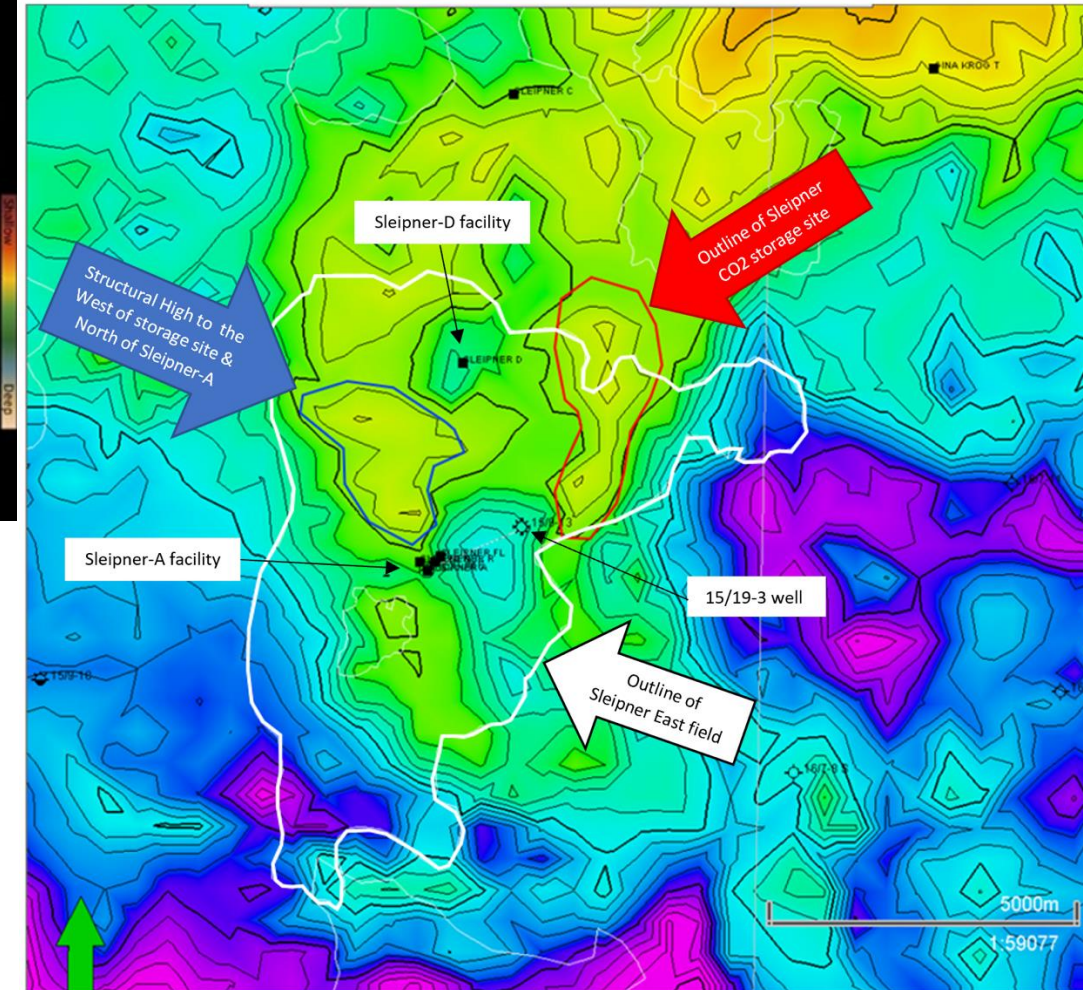
- Background map is Top structure of Utsira Sandstone in TWT.
- **Green** denotes highs; **Blue** denotes lows.
- **Red** polygon outlines Storage Complex area.
- **D-a-s-h-e-d Black** polygon outlines 2020 seismic survey area.
- **Black** outlines the CO2 plume.
- Storage Complex area is over 40x bigger than the Site area and 4x bigger than the current Survey Grid area.
- The Operator and Regulator uses the terms site & complex interchangeably.



Seismic survey grid size changes & Secondary Containment



- Original survey grid area was halved, then re-instated (possibly due to observed CO2 westward migration)
- Equinor and NOD are confident that the injected CO2 will be contained in the Utsira Sandstone aquifer forever.
- Earlier concerns over migrating CO2 contacting Sleipner East gas wells are dismissed.



Issues surrounding Migrating Plumes, Surveys and Grids

1. Does migrating CO₂ within the storage complex have the same likelihood of containment as CO₂ in the original storage site?
2. Aquifers are rarely cored or tested, therefore spatial property maps have inherent uncertainty, so is it more likely that mobile CO₂ plumes will migrate to places that the models did not predict?
3. If a CO₂ plume migrates to an area with less seismic coverage, where data are older and poorer quality, is accuracy of the time-lapse modelling impaired? (Earlier seismic acquisition was designed to explore deeper hydrocarbon plays, not for shallower saline aquifers, so not optimized for CCS applications).
4. Lower limit of response by a seismic survey is a CO₂ saturation of 20-30% in the aquifer, so is there an undetected region of brine + CO₂ beyond the picked edge of a plume?
5. How has the risk of CO₂ migrating back to Sleipner gas wells reduced from 50% in 2007 to zero today?

Conclusions & Recommendations

1. EU Directive 2009/31/EC is vague on defining a storage complex but allows adjustment of the monitoring grid for changing perceptions of plume size and distribution.
2. Operators and Regulators collaborate closely and so have aligned views on CO2 containment risk.
3. Yet, Operators are reluctant to release pilot data and studies. Regulators should strive to get as much data as possible into the public domain as soon as possible. We must get up the CCS Learning Curve as quickly as we can.
4. With so little operational experience in the sector, and very few aquifer appraisal wells and pilots, the perceived confidence in the likelihood of lateral containment in open saline aquifers is surprising.
5. Far more targeted aquifer appraisal wells and pilots are needed to fill knowledge gaps in aquifer characterization.
6. The Directive could include criteria for seismic surveys, such as mandatory spatial coverage vs. well density, permitted noise-to-signal levels, allowable age of baseline seismic, and obligatory distance between plume & legacy wells.

Requirements for measurements

CARBON DIOXIDE (CO₂) CAPTURED AND STORED

Indicators	Boundary	Unit	2023	2022	2021	2020	2019	2018	2017	2016
CO ₂ emissions captured and stored per year	Operational control	million tonnes	0.8	0.5	0,3(b)	0,9(b)	1,2(b)	1,3(b)	1,2(b)	1.4
Accumulated CO ₂ emissions captured and stored	Operational control	million tonnes	27.1	26.3	25.8	25.6	24.6	23.4	22.2	20.9

(b) Due to a flawed flow transmitter at Equinor's CO₂ injection facilities at Sleipner, the figures for CO₂ injected were over-reported in the period 2017-2021. The transmitter was replaced in March 2021, and the figures have been updated accordingly.

Guidance for Measurement of Carbon Dioxide for Carbon Storage Permit Applications

Norway's Equinor Admits It "Over-Reported" Amount of Carbon Captured At Flagship Project for Years

DeSmog review of company data shows North Sea's leading oil and gas producer downgraded estimates for CO₂ stored at Sleipner gas field by almost a third.



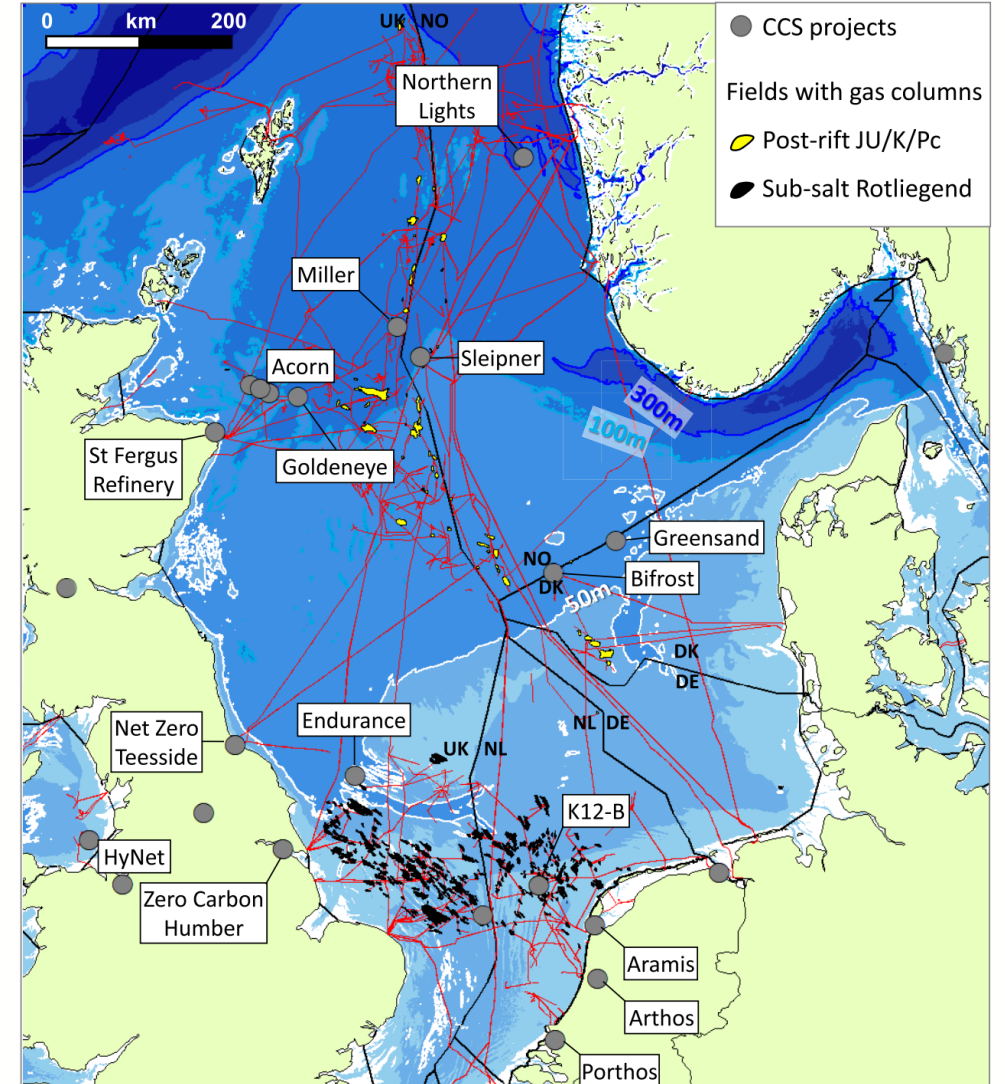
By **Edward Donnelly** on Oct 28, 2024 @ 02:01 PDT

8 min read

It can get crowded out there....

- Need to:
 - monitor quantity and quality of CO₂ streams, included imported ones
 - develop reliable post-injection (*in perpetuity*) monitoring strategies
 - develop allocation best practices

- Useful in view of potential litigation cases...





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Thank you!

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