Chalk reservoirs for upscaling CO₂ storage

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Hans Horikx, Advisor Reservoir Engineering, DTU Offshore
Birgitte D Larsen, Advisor Geoscience, DTU Offshore
Introduction

CCS is a prioritized technology for reducing emissions fast enough to meet the national Danish climate targets and the goals of the Paris Agreement, and there is consensus that CCS will play a key role in the transition to a carbon neutral future.

Subsurface storage of CO₂ is a key enabler for Denmark to reach its short-term emission reduction goals while CO₂ utilization technologies are being matured.

Upscaling capacity is key to developing the right long-term solutions for Denmark. With the majority of Danish oil and gas fields being in chalk reservoirs, the reuse of these depleted chalk fields has the potential to significantly increase the scale of CCS in Denmark.

With a significant estimated storage capacity and a central location, Denmark has the potential to become a European hub for carbon storage.
Currently three CCS licenses have been awarded offshore.

The scale of storage required to achieve significant reductions in emissions is still orders of magnitude larger than currently approved project capacity.

What options do we have?

**Offshore storage opportunities**

- Near-term potential for Denmark in depleted fields Bifrost Project & Greensand Project.
- Long-term potential in the depleted oil and gas fields (many of these are chalk fields) and saline aquifers.

**Onshore and near-shore storage opportunities**

- Huge potential in saline aquifers: Gassum, Skagerrak and Bunter sandstone formations.
- Structures like Stenlille, Havnsø, Rødby, Gassum, Thorning Inez, Lisa as well as structures up in Jammerbugten.
Storage requirements exceed current project capacities

**Storage capacity versus Annual Emissions**

**Storage capacity in Gt CO₂**

- Bifrost + Greensand: 0.2 Gt CO₂
- Denmark HC fields: 1.2 Gt CO₂
- Denmark aquifers: 12 Gt CO₂

**Annual Emissions in Gt CO₂/year**

- Denmark emissions: 0.05 Gt CO₂/year
- EU emissions: 3 Gt CO₂/year
- Global emissions: 38 Gt CO₂/year
Storage Capacity versus Maturity

In order to move theoretical storage capacity (basin wide estimates) to actual storage capacity - subsurface knowledge/data is needed, and investments need to be made to develop the storage sites.

- 3D seismic data acquisition
- Appraisal wells
  - drilling & coring
  - data acquisition
- Well testing (injunctivity, reservoir dynamics)
- Reservoir modelling
  - reservoir lateral connectivity
  - compartmentalization
  - faulting
  - reservoir dynamics
- Seal evaluation, geomechanical modelling
- Development cost
  - development wells
  - pipelines
  - facilities

This makes CO$_2$ storage in offshore aquifers more expensive than storage in already developed offshore oil and gas fields.
Why CO\(_2\) storage in existing oil and gas fields?

Depleted reservoirs and existing infrastructure in oil and gas fields represent an opportunity for accelerated implementation of CO\(_2\) storage. Reusing offshore installations will help ensure projects are further scalable, while being energy efficient and minimizing CO\(_2\) emissions.

Pros:
- Large, well described and proven storage capacities
- Containment seals proven over geological time
- Decades of accumulated knowledge/data of subsurface
- Existing subsurface and surface infrastructures
- Lower development cost
- Distance to shore and inhabited areas (DTU management study)

Cons:
- Legacy wells - are they suitable?
- Distance to shore
- Timing issue on availability

We need to consider if the added benefits of re-using existing oil and gas fields outweigh the added complexity (re-using legacy wells etc.). We need to understand how re-using oil and gas fields can improve cost efficiency and we need to look more at public acceptance.
Cost of CO₂ Storage

€/tonne CO₂ stored

Case | Range
--- | ---
1. Onshore DOGF with legacy wells | 1 - 3 - 7
2. Onshore DOGF with no legacy wells | 1 - 4 - 10
3. Onshore SA with no legacy wells | 2 - 5 - 12
4. Offshore DOGF with legacy wells | 2 - 5 - 9
5. Offshore DOGF with no legacy wells | 3 - 6 - 14
6. Offshore SA with no legacy wells | 6 - 10 - 20

Storage costs make up 10-25% of total CCS costs


Ranges are driven by setting field capacity, well injection rate and liability transfer costs to Low, Medium and High cost scenarios
Why is chalk important for CCS in Denmark?

The scale of storage required to achieve significant reductions in emissions is orders of magnitude larger than combined Greensand and Bifrost project capacity of some 200 Mt.

Option 2: Storage of CO₂ in depleted oil/gas fields

Aging variation in storage form and contribution rate

CO₂ status

- 640 Mt: Structural & stratigraphic trapping
- 480 Mt: Solubility trapping (Dissolved in oil)
- 90 Mt: Solubility trapping (Dissolved in water)

Depleted oil and gas fields with chalk reservoirs provide easily accessible carbon storage capacity:

- 2020-2035
- 2035-2042
- 2040-2050
Chalk for CO₂ storage - what are the concerns?

Myths on chalk:
- Chalk compacts and/or collapses in the presence of CO₂
- Chalk formation dissolves in the presence of CO₂
- Permeability of chalk formations is low, reducing injection rates
- Infrastructure of chalk field developments is not suitable for dealing with CO₂ storage
Research addressing concerns of CO₂ storage in chalk

**CO₂ storage programme**
- Research funded and coordinated by DTU Offshore
- Water flooded field scenario
- Partners: DTU, GEUS, GEO

**Bifrost**
- Development project funded by EUDP, DTU Offshore lead WP’s
- Depleted gas field scenario
- Partners: DUC, Ørsted, DTU Management & DTU Offshore

**Inno-CCUS**
- Research funded by Danish state, DTU Offshore research contributors
- No specific scenario
- DTU Offshore has researchers in two projects

Timeline:
- **Q1 2022**
- **Q2 2022**
- **Q3 2022**
- **Q4 2022**
- **Q1 2023**
- **Q2 2023**
- **Q3 2023**
- **Q4 2023**
- **Q1 2024**
- **Q2 2024**
Geomechanics tests to address rock strength concerns

Aim is to investigate the mechanical strength and compaction of reservoir rock related to CO$_2$ injection for different operational scenarios

- Including rock deformation tests in different stress regimes
- Including rock dissolution experiments

Effect of CO$_2$ injection on chalk properties

CO$_2$ storage in Chalk

Depleted Gas Field
Depleted Oil Field
Waterflooded Oil Field

Continuous CO$_2$ injection
Blow down of gas cap prior to CO$_2$ injection
Intermittent injection of CO$_2$ - due to shut-downs

Continuous CO$_2$ flood Elastic regime
(150 bar effective stress)
Continuous CO$_2$ flood Elastic/Plastic regime
(380 bar effective stress)

3xWAG CO$_2$ flood Elastic regime
(150 bar effective stress)

Extreme case
3xWAG flood Elastic/Plastic regime
(380 bar effective stress)
Experiments to address CO₂ dynamics concerns

Investigation of CO₂ interactions with other fluids and rock, impacting storage rates and capacity

- Covering all relevant fluid phases: liquid CO₂, supercritical CO₂, brine, oil
- Reservoir modelling of hydro dynamics, geomechanics and geochemistry

No geomechanics or CO₂ dynamic showstoppers for CO₂ storage in chalk, based on lab experiments and reservoir modelling
Conclusion and further work

Chalk suitable for CO₂ storage - No showstoppers were identified

Re-use of existing O&G fields enables early implementation of CO₂ storage in Denmark to meet 2030 goals, and the chalk fields have an important role to play

Storage capacity of existing Oil and Gas fields can be up-scaled at comparatively low cost, thanks to existing infrastructure (wells, platforms, pipelines)

Developed oil and gas fields have already acquired subsurface information for the storage sites and therefore no significant costs related to additional data gathering/evaluation are expected

Containment of stored CO₂ in existing fields is proven and safe

Future Work - Investigate the effects of higher porosity samples, impurities in the CO₂ stream, the presence of residual oil and integration of lab experiments in dynamic modelling
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Thank You