DTU

CCS Conference 2023

Denmark as a CCS hub - technologies for upscaling, environmental impact assessments, and monitoring of offshore CO2 storage

Chalk reservoirs for upscaling CO_2 storage

June 6th, 2023, Rungstedgaard

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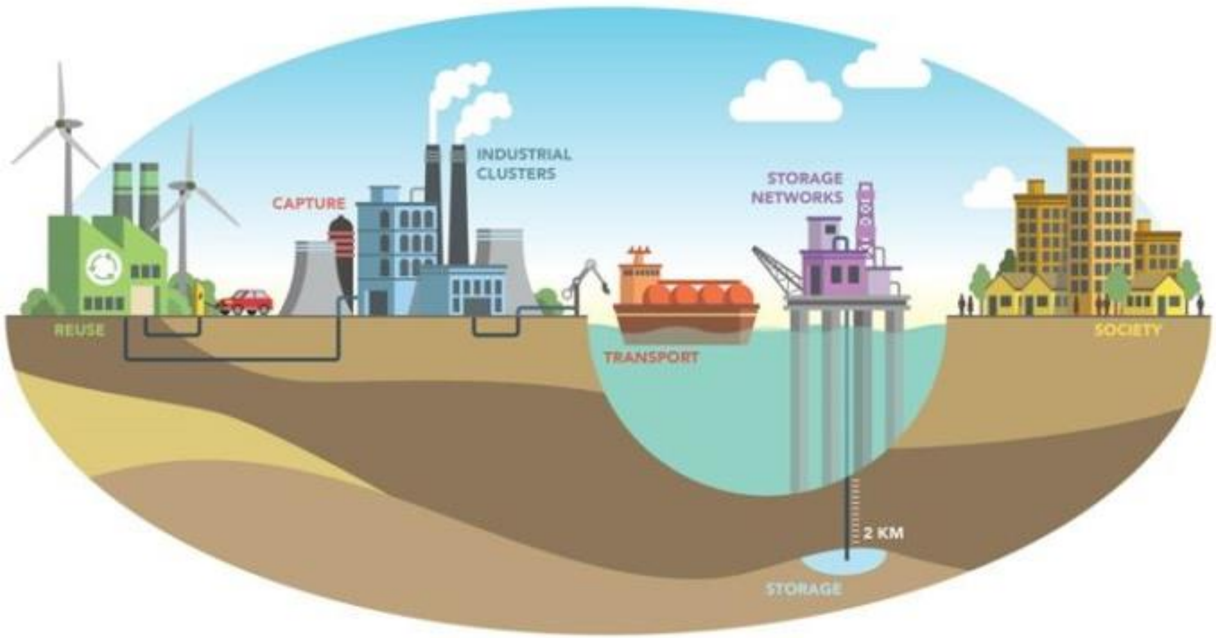
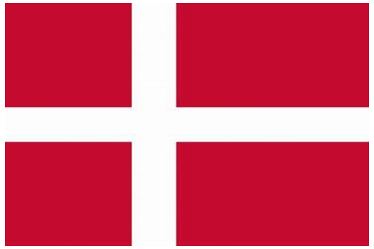
Introduction

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 CO_2 is a key enabler for Denmark to reach its short-term emission reduction goals while CO_2 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.



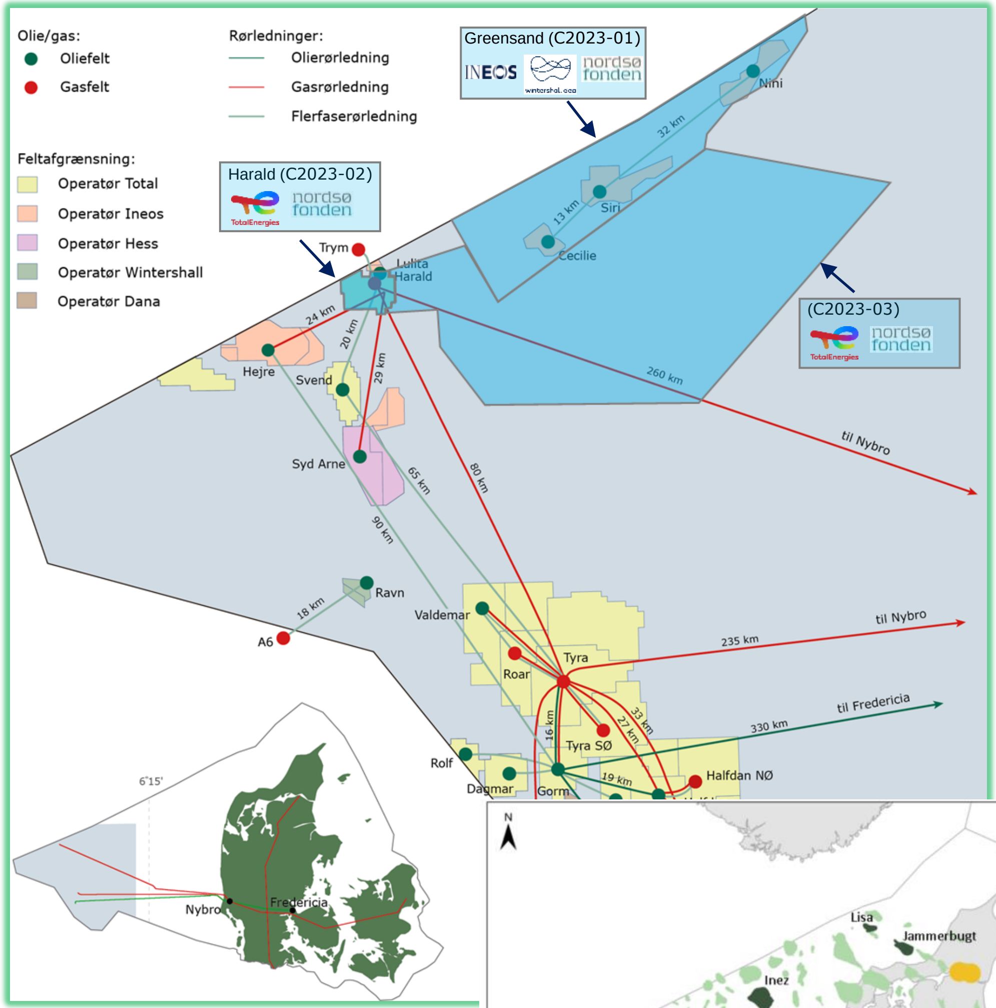
With a significant estimated storage capacity and a central location, Denmark has the potential to become a **European hub for carbon storage.**

CCS in Denmark

Currently three CCS licenses have been awarded offshore.

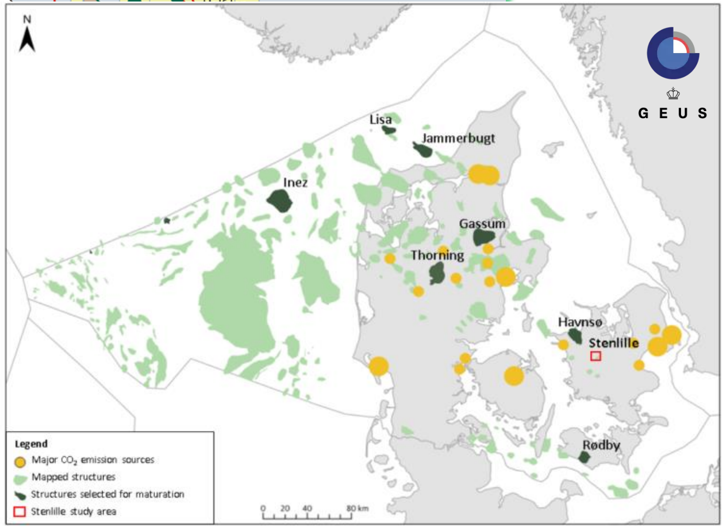
The scale of storage required to achieve significant reductions in emissions is still orders of magnitude larger than currently approved project capacity.

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.

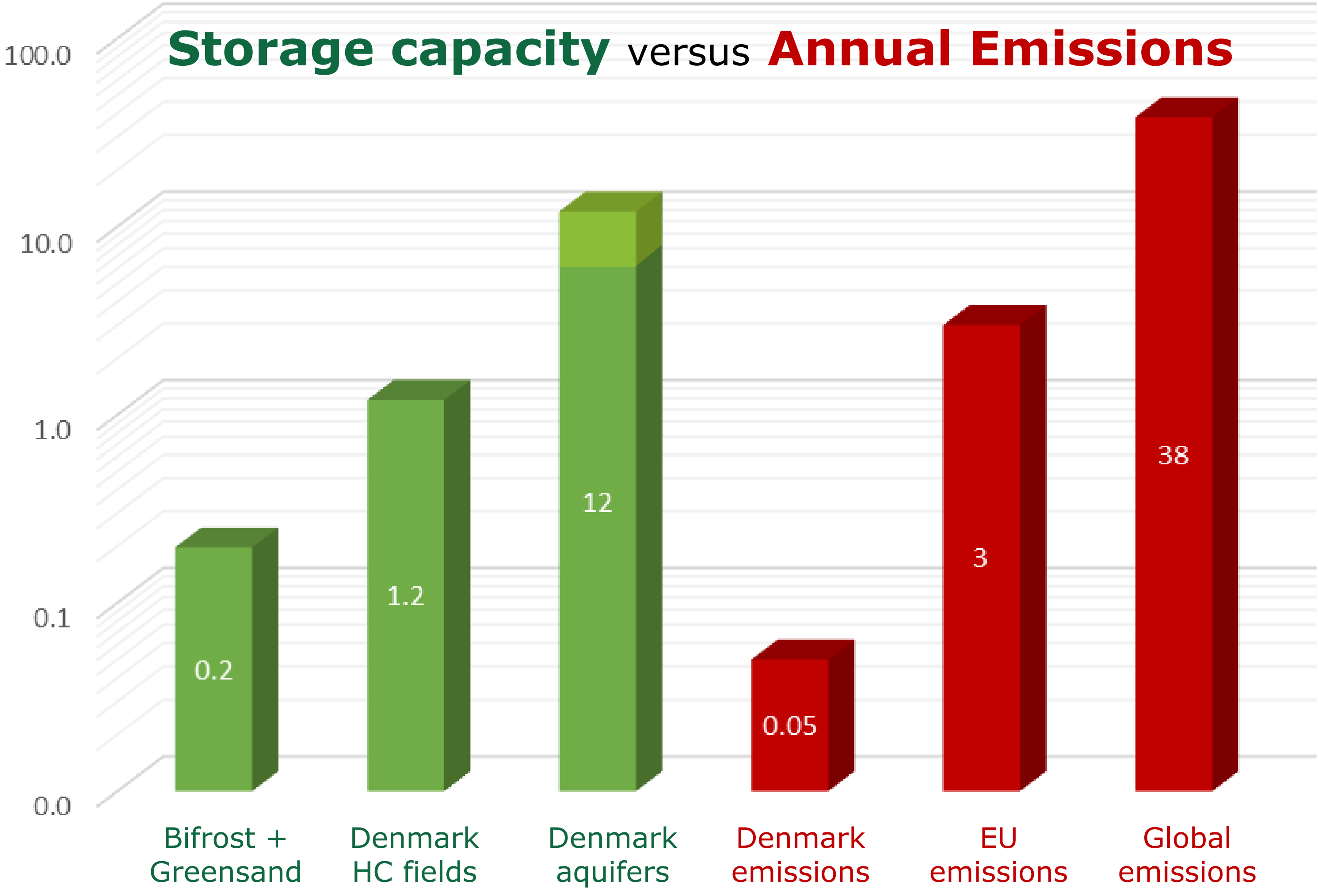


Onshore and near-shore storage opportunities

- 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 in Gt CO_2



Annual Emissions in Gt CO_2/year

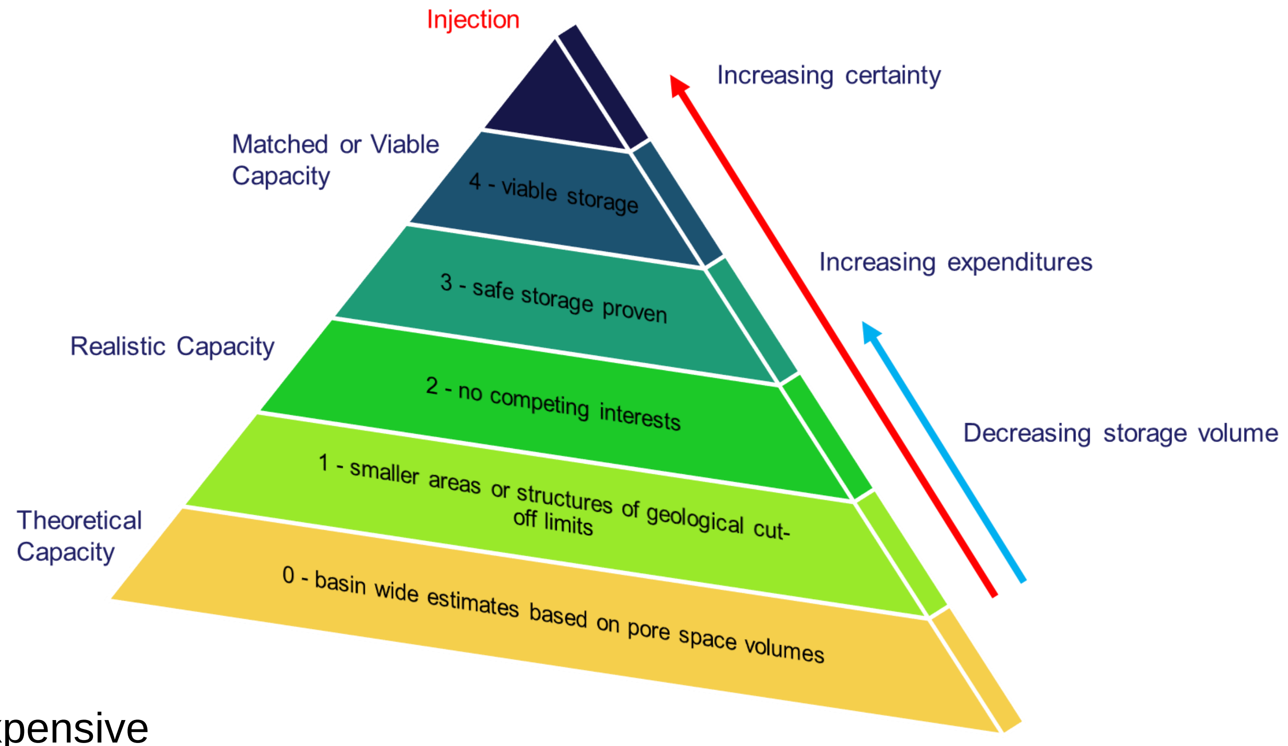
Storage Capacity versus Maturity

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 (injectivity, 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.

Storage Capacity Pyramid for saline aquifers



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:

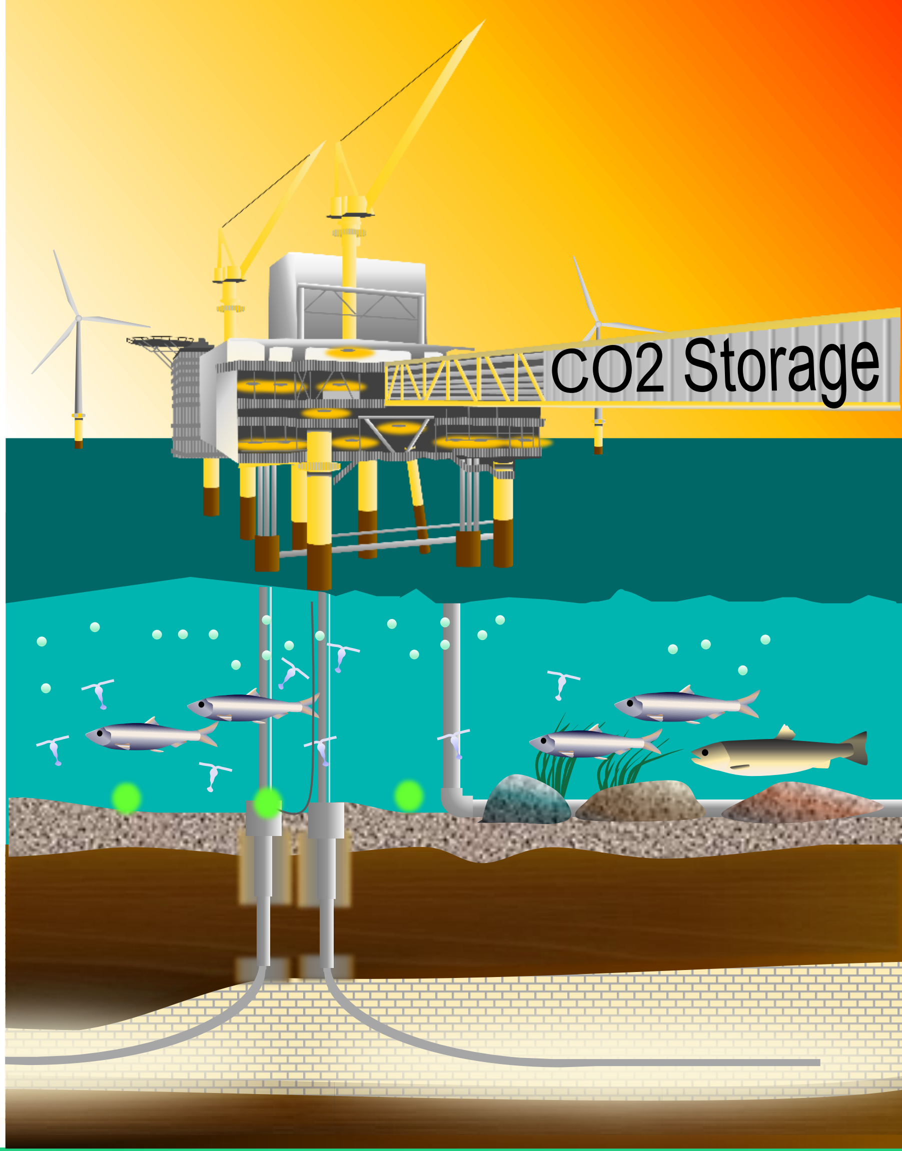
- Large, well described and proven storage capacities
- Containment seals proven over geological time
- Decades of accumulated knowledge/data of subsurface
- Existing subsurface and surface infrastructures
- Lower development cost
- Distance to shore and inhabited areas (DTU management study)

Cons:

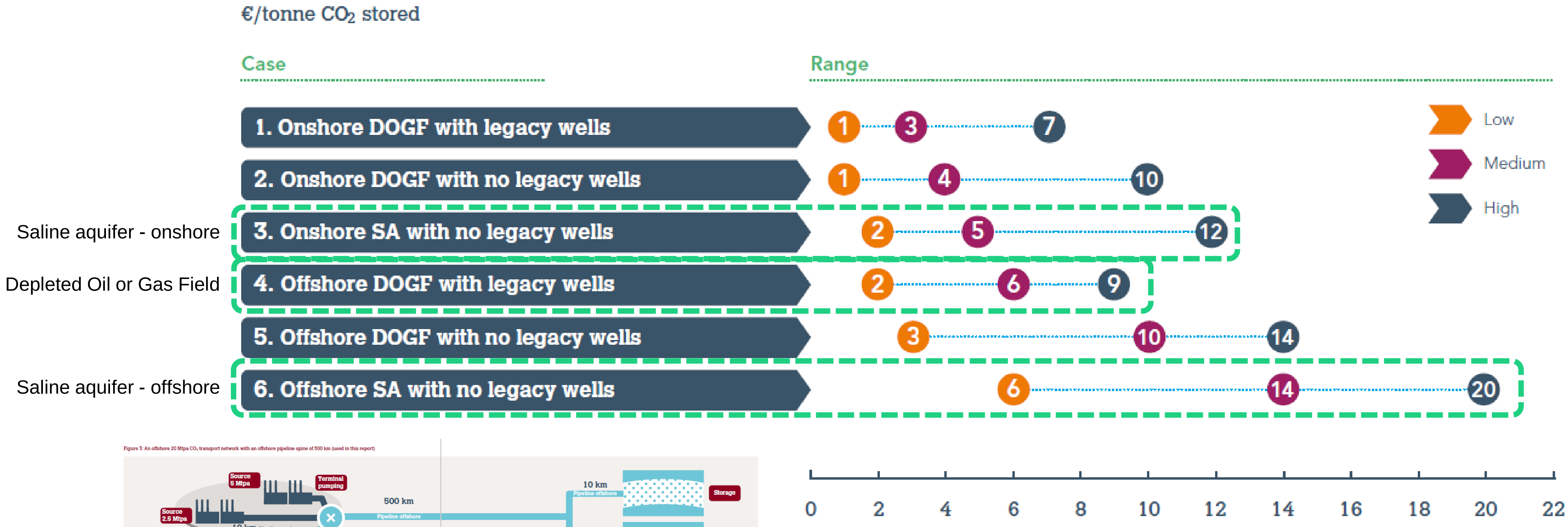
- Legacy wells - are they suitable?
- Distance to shore
- Timing issue on availability

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 CO_2 Storage



Ranges are driven by setting field capacity, well injection rate and liability transfer costs to Low, Medium and High cost scenarios

Source: The Costs of CO_2 Capture, Transport and Storage – Zero Emissions Platform 2011

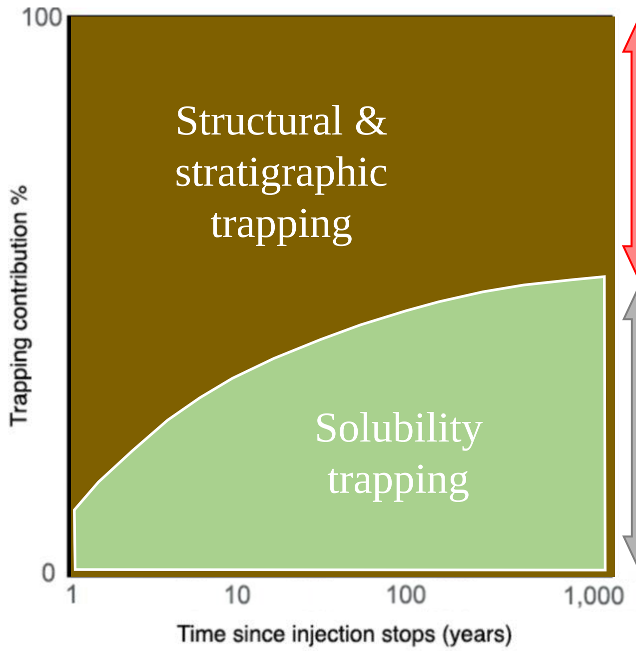
Storage costs make up 10-25% of total CCS costs

Why is chalk important for CCS in Denmark?

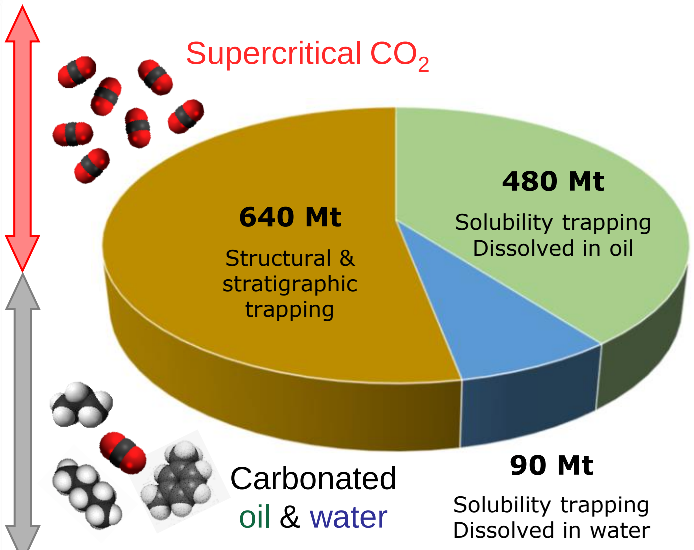
The scale of storage required to achieve significant reductions in emissions is orders of magnitude larger than combined Greensand and Bifrost project capacity of some 200 Mt.

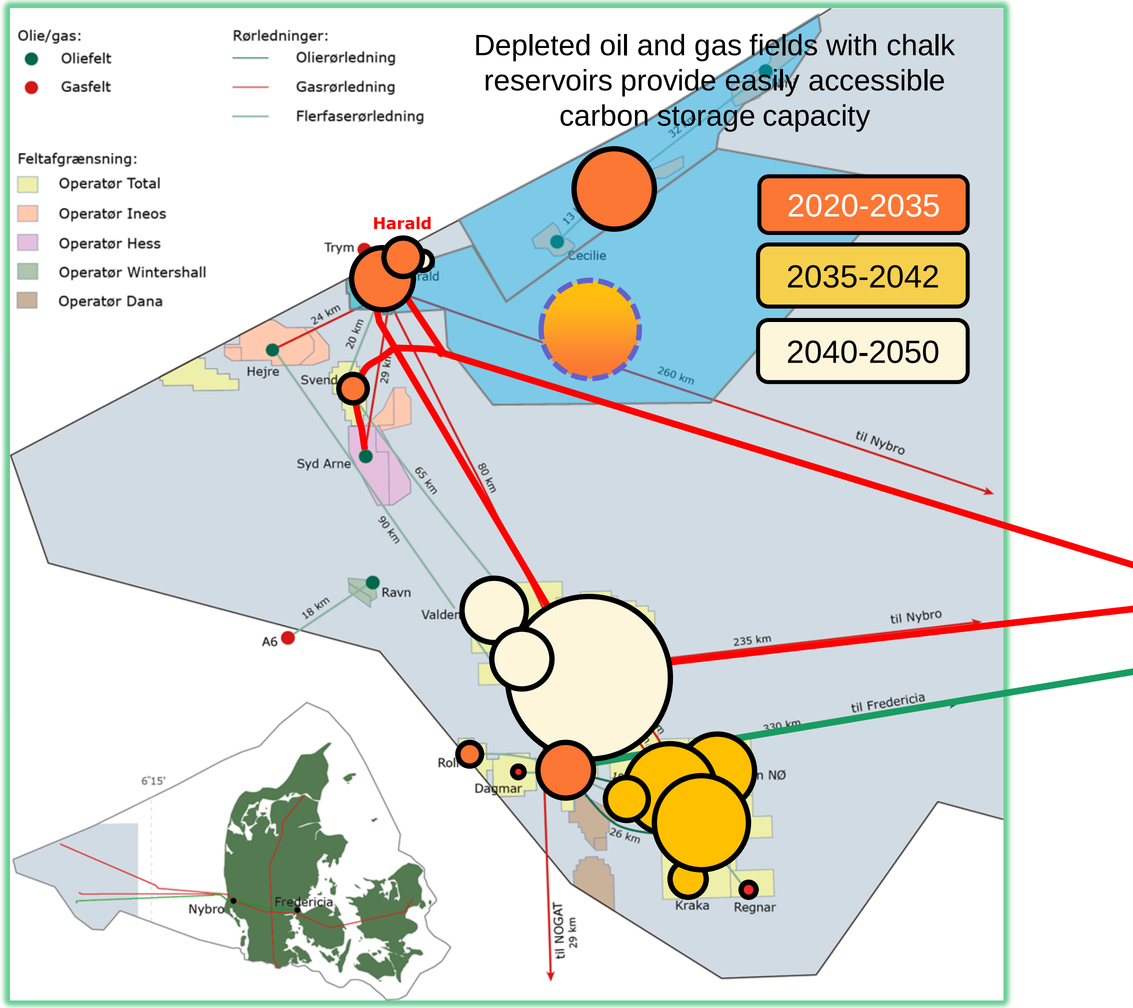
Option 2: Storage of CO_2 in depleted oil/gas fields

Aging variation in storage form and contribution rate



CO_2 status

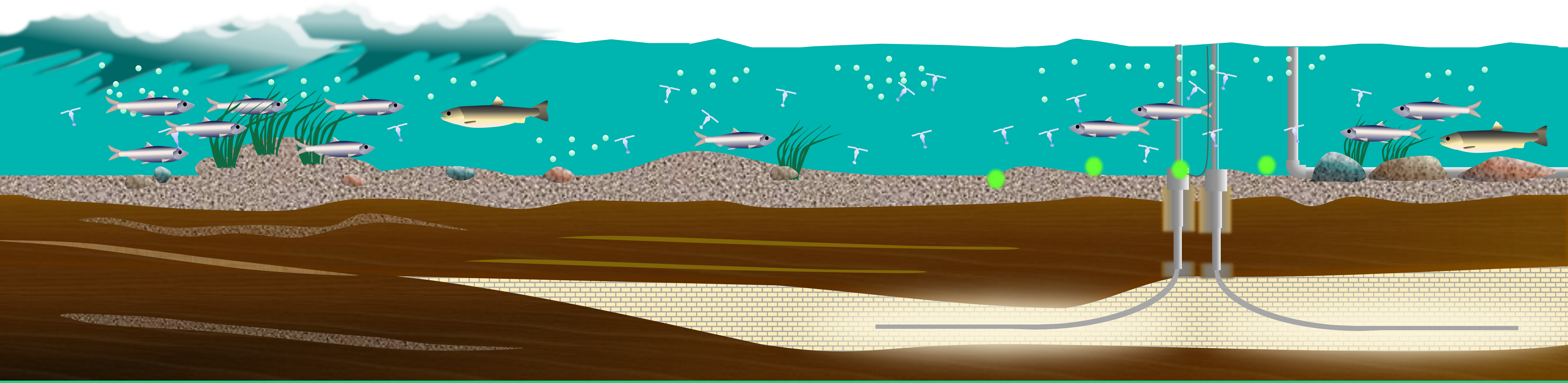




Chalk for CO_2 storage - what are the concerns?

Myths on chalk:

- Chalk compacts and/or collapses in the presence of CO_2
- Chalk formation dissolves in the presence of CO_2
- Permeability of chalk formations is low, reducing injection rates
- Infrastructure of chalk field developments is not suitable for dealing with CO_2 storage



DTU

Research addressing concerns of CO_2 storage in chalk

CO_2 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

Kicked off research

Kick off research

Research end

Research end

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*

CO_2 storage in Chalk

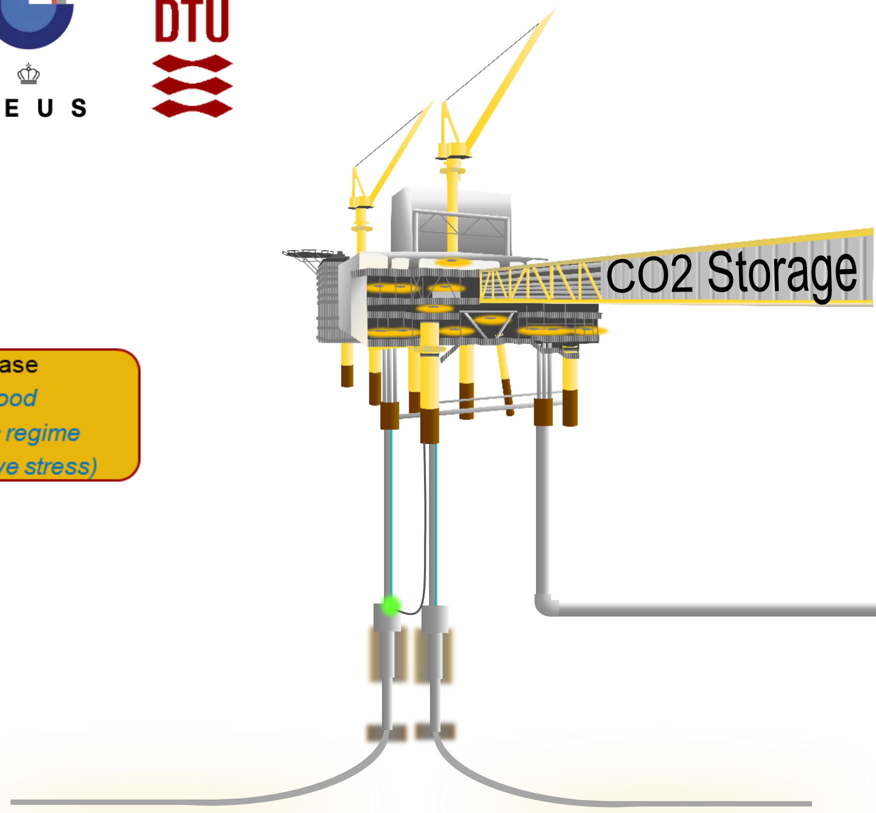
- Depleted Gas Field**
- Depleted Oil Field
- Waterflooded Oil Field

Effect of CO_2 injection on chalk properties

Water flooded 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	*Continuous CO_2 flood*	*3xWAG CO_2 flood*
Elastic regime	*Elastic/Plastic regime*	*Elastic regime*
(150 bar effective stress)	*(380 bar effective stress)*	*(150 bar effective stress)*

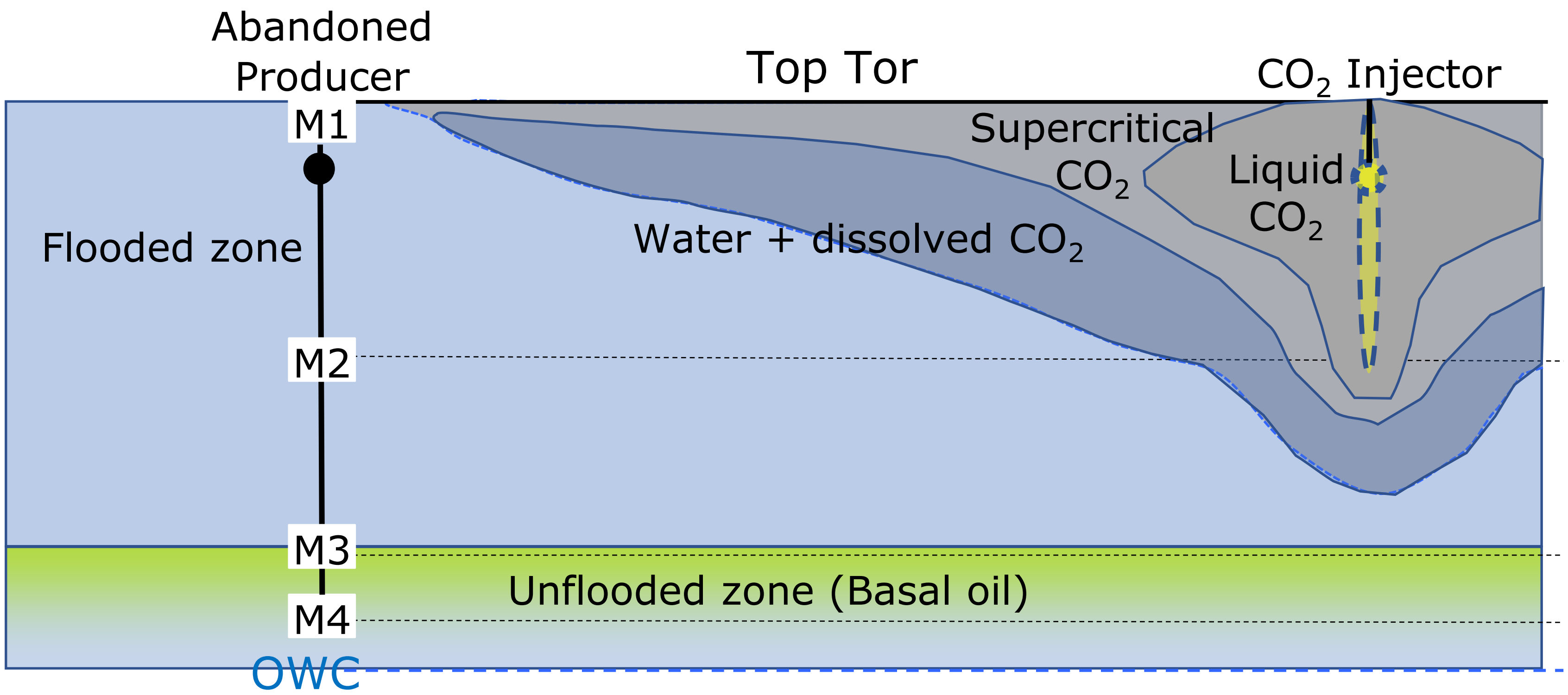
Extreme case
3xWAG flood
Elastic/Plastic regime
(380 bar effective stress)

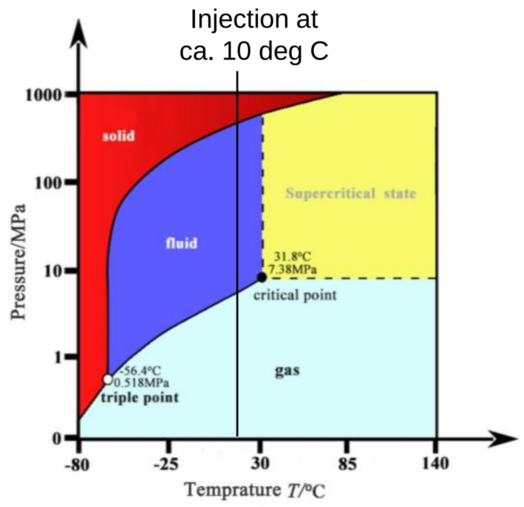


Experiments to address CO_2 dynamics concerns

Investigation of CO_2 interactions with other fluids and rock, impacting storage rates and capacity

- *Covering all relevant fluid phases: liquid CO_2, supercritical CO_2, brine, oil*
- *Reservoir modelling of hydro dynamics, geomechanics and geochemistry*





No geomechanics or CO_2 dynamic showstoppers for CO_2 storage in chalk, based on lab experiments and reservoir modelling

Conclusion and further work

Chalk suitable for CO_2 storage - **No showstoppers** were identified

Re-use of existing O&G fields enables early implementation of CO_2 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 CO_2 in existing fields is proven and **safe**

Future Work - Investigate the effects of higher porosity samples, impurities in the CO_2 stream, the presence of residual oil and integration of lab experiments in dynamic modelling

DTU Offshore - A key Player in the Energy Transition

Thank You