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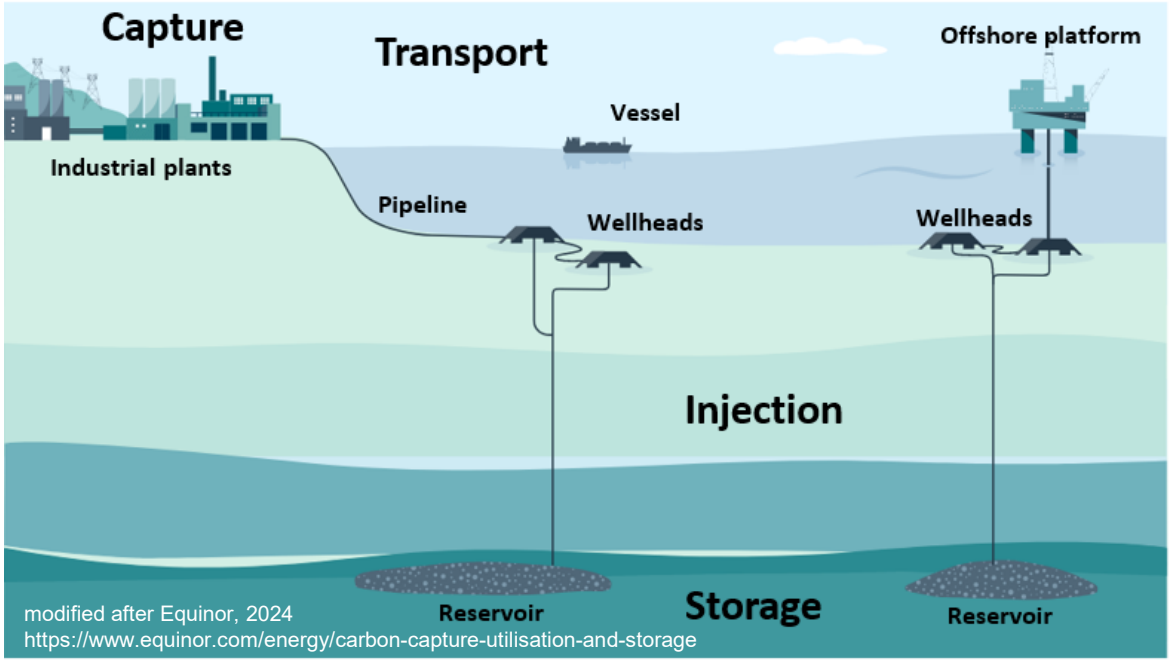
Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

Injection: Risks and challenges

Injection of CO_2 into geological rock formations

Online Expert Workshop 1

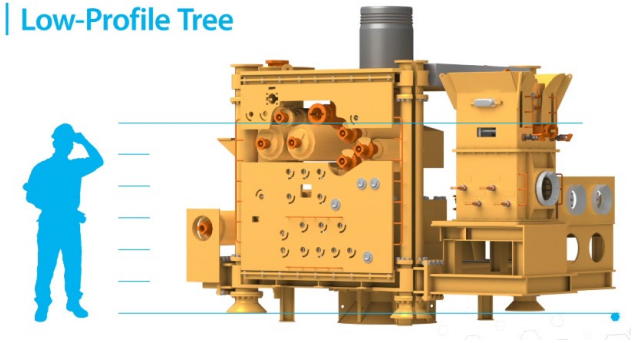


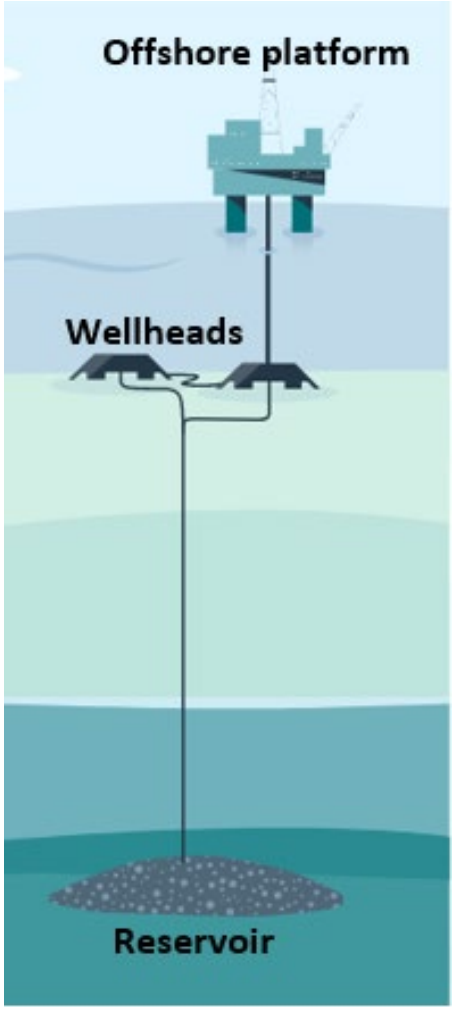
Florian Krob
Öko-Institut e.V.
22/04/2024

1 – Introduction

Technical process description

- Offshore Injection of Carbon Dioxide
  - Into geological rock formations deep underground
  - Via seabed injection wells



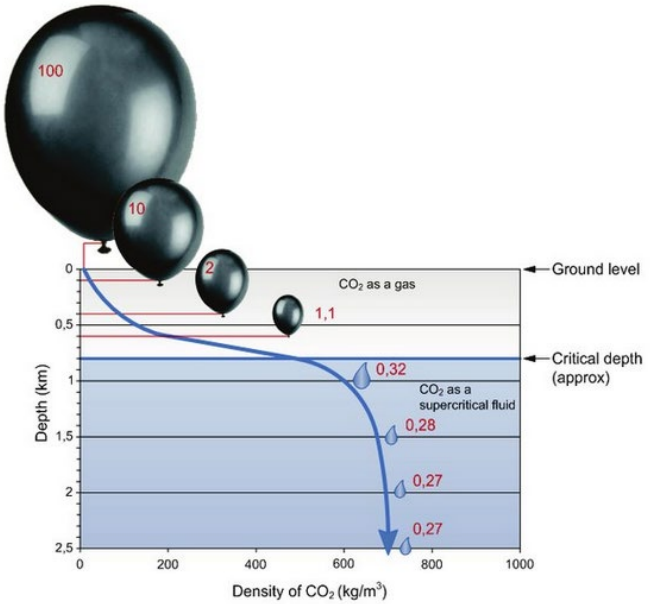


Figures:
Left & Middle: Courtesy of Dril-Quip
Right: modified after Equinor, 2024

1 – Introduction

Technical process description

- Suitable Carbon Dioxide conditions for successful Injection
  - Compressed to liquefied to supercritical state (> 8 Mpa)
  - High purity (>95,5%) without admixtures (< 50 – 100 ppm depending on substance)
- Suitable properties of reservoir rocks
  - High porosity and permeability
  - Pressure of formation water



- Reservoir conditions mainly determine injectivity
- Pressure of CO_2 must exceed the prevailing conditions in the target reservoir

Figure: IEA, 2008

2 – Risks & Challenges

- Lifecyle Risk Profile for Carbon Storage Projects
  - Risk Profile increases and peaks after injection begins
  - After operation Risk Potential decreases significantly
  - After well closure Risk Potential wanes constantly throughout post-operational phase

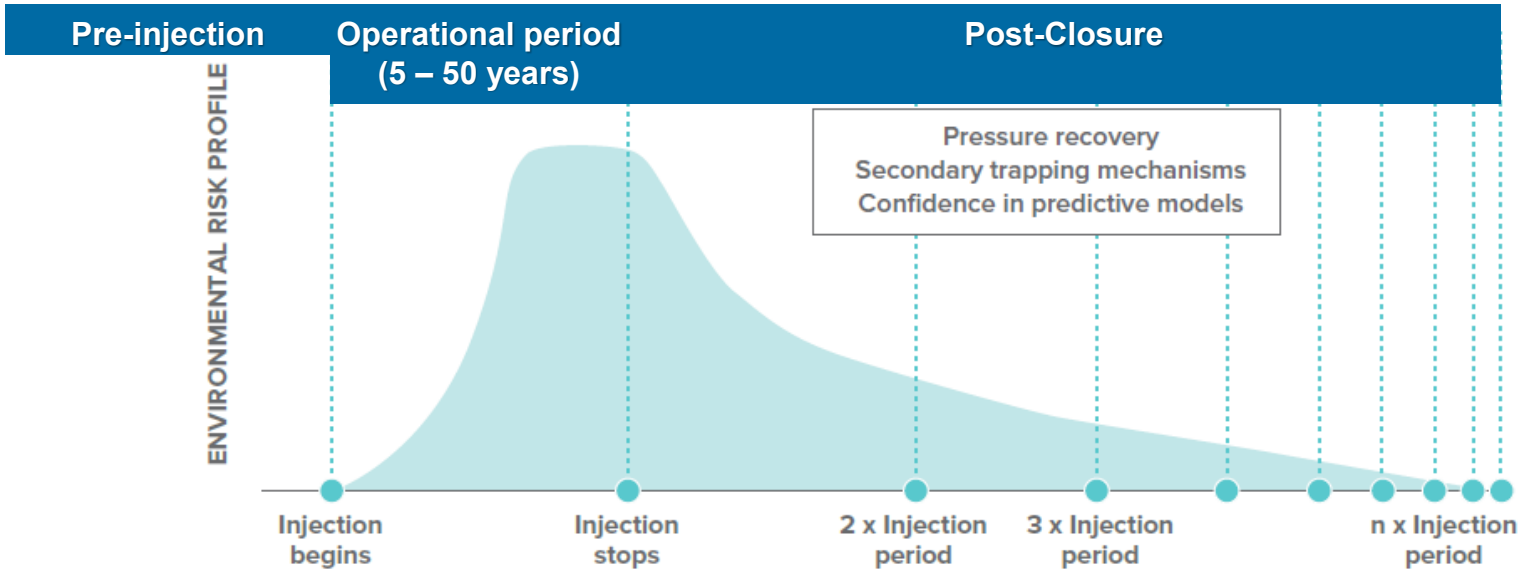


Figure: modified after GCCSI, 2019

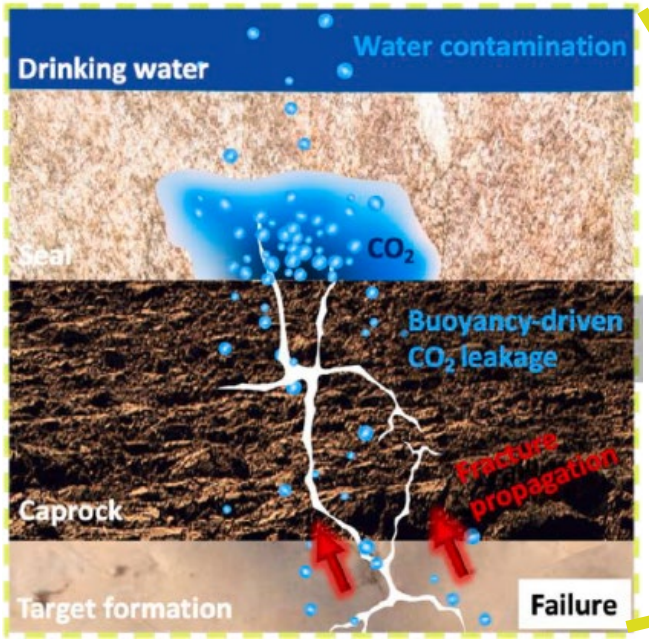
2 – Risks & Challenges

- Risks can materialize in different areas of the geological environment
  - affect the reservoir around injection zone
  - Damage Cap- and Baserocks
  - Far Field effects due to fault reactivation
  - Impacts can even be visible at the Earth's surface

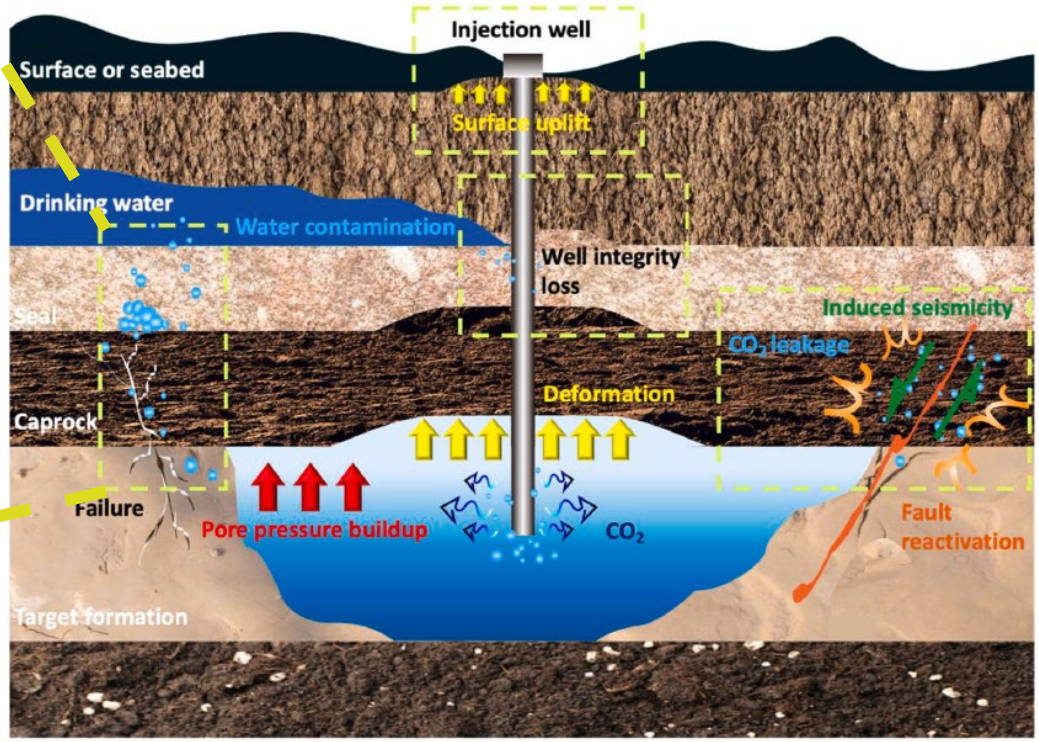
Figure: Vilarrasa, 2016

2 – Risks & Challenges

Risk: Caprock Failure



➔ **Hazards: Rock Fractures and Leakage of CO_2**

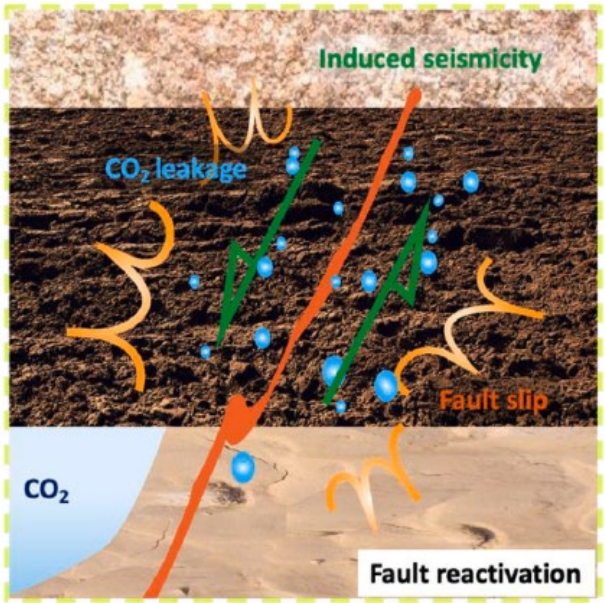


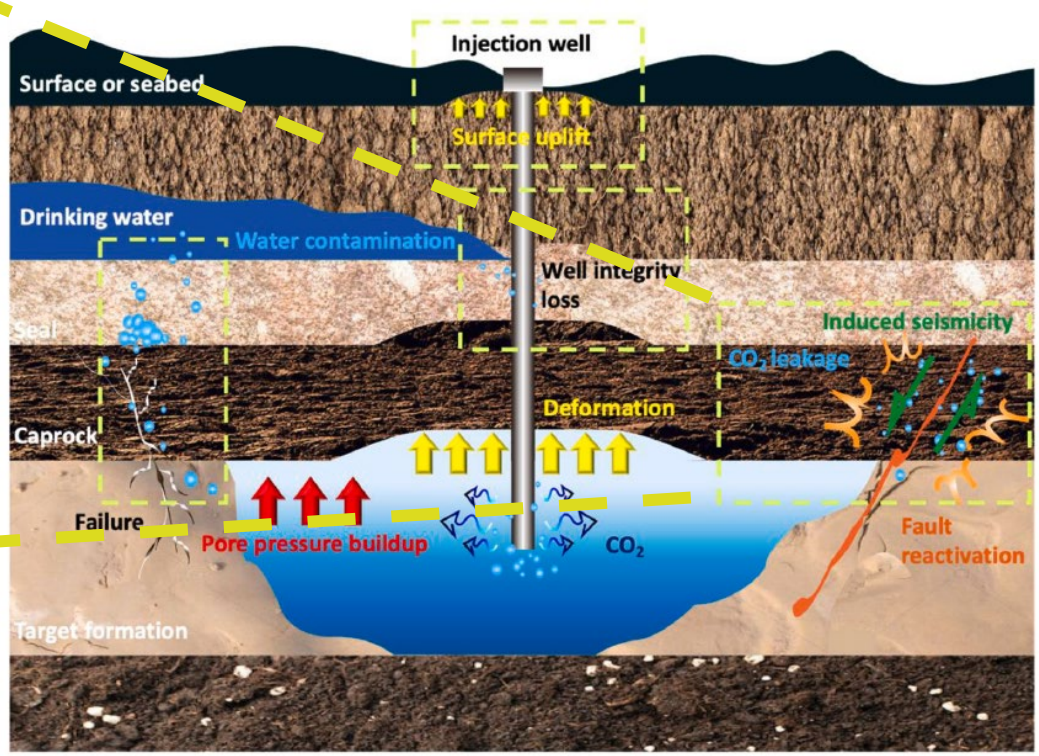
Figures: Song et al., 2023

2 – Risks & Challenges

Risk: Fault Reactivation

➔ **Hazards: Induced Seismicity and Leakage of CO_2**



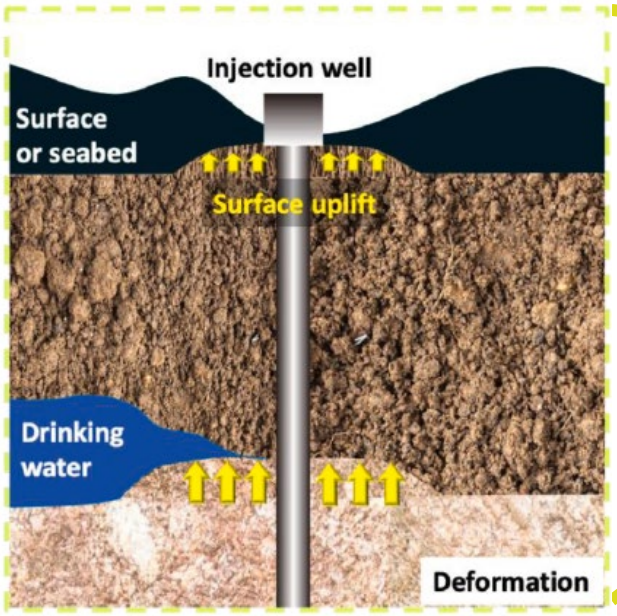


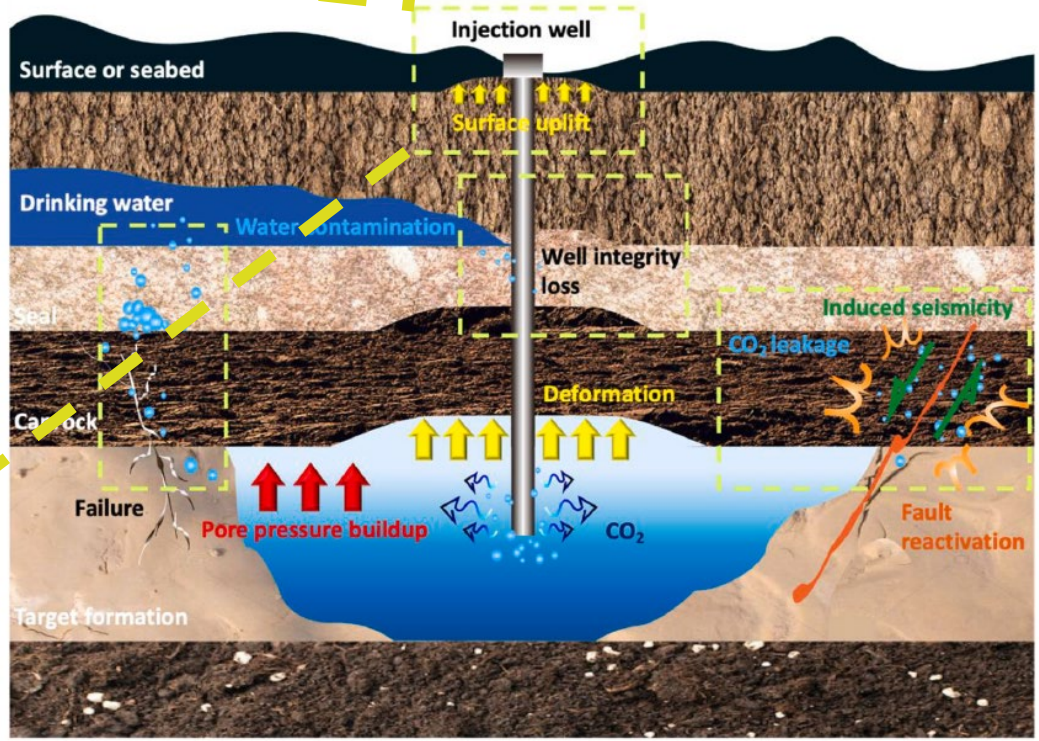
Figures: Song et al., 2023

2 – Risks & Challenges

Risk: Deformation

➔ Hazards: Surface Uplift and Ground Movement

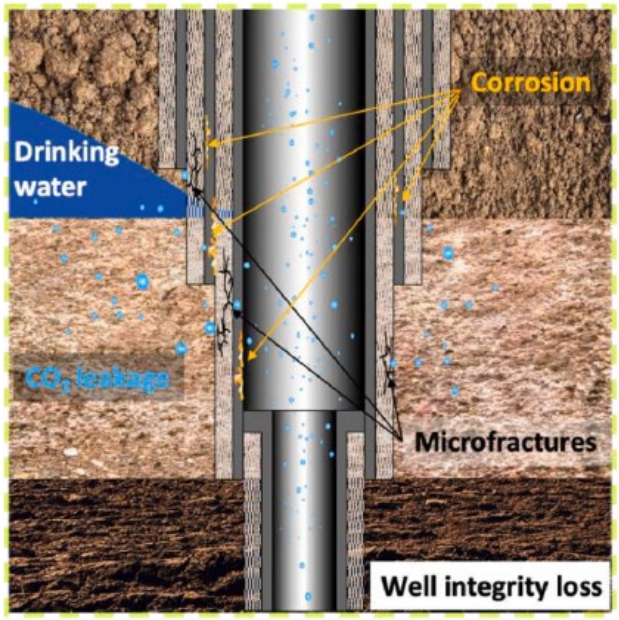




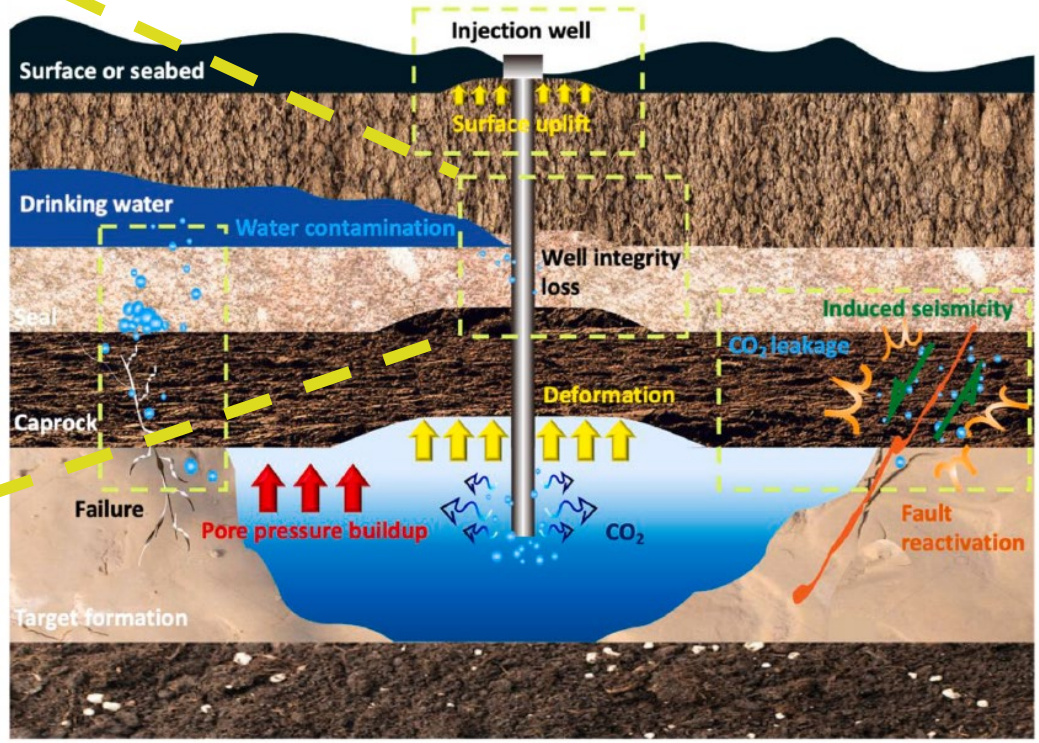
Figures: Song et al., 2023

2 – Risks & Challenges

Risk: Well Integrity Loss



➔ Hazards: Leakage of CO_2 and Microfractures



Figures: Song et al., 2023

2 – Risks & Challenges

Main Challenges

- Pre-Injection Site Characterisation
  - Site Performance characterisation (e.g., reservoir properties & conditions, and capacity)
  - Pressure Management (e.g., determination of reservoir fracture pressure and injectivity)
- Injection
  - Monitor and Intervene
  - Pressure Management (e.g., Blowouts, and Overpressurisation)

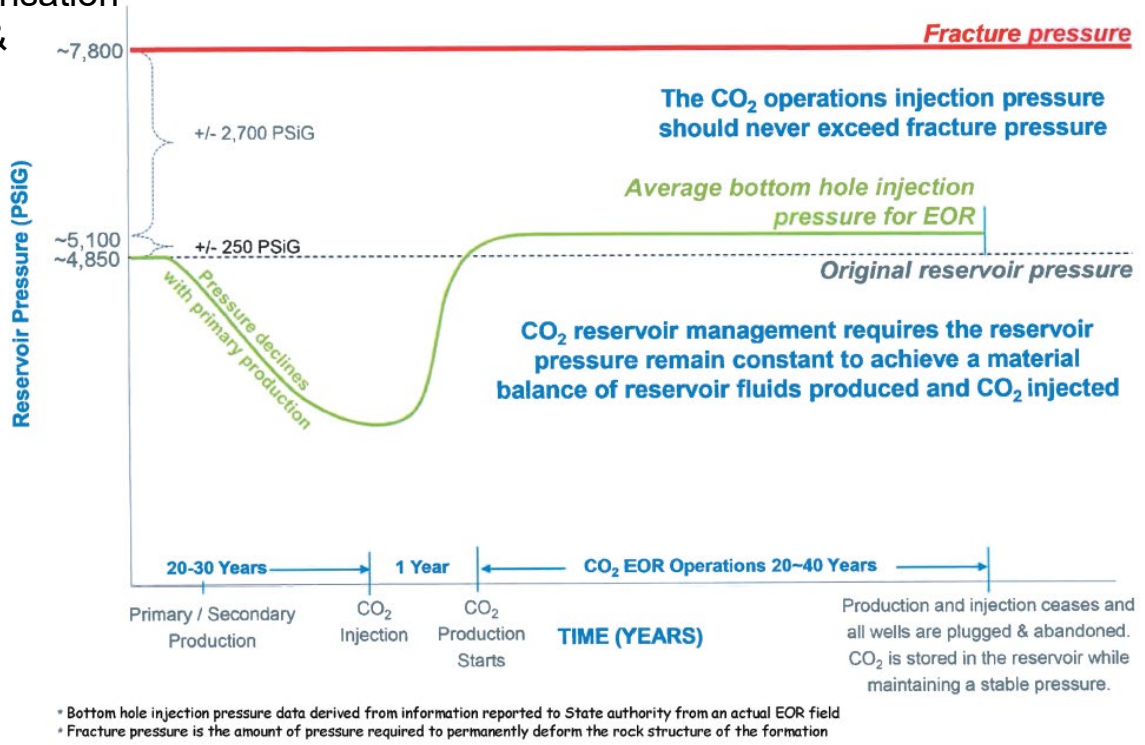
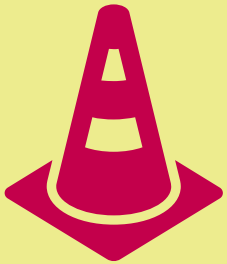


Figure: Marston, 2023

Take Away Messages

- Not a zero-risk technology **but** a comparatively low-risk technology overall
- **Decades of experiences** with CO_2 injection wells were being made
- **Challenges** can be addressed through efficient pre-injection site characterisation, monitoring, and remediation
- Examples have shown that **interventions minimize risks efficiently**

- As with any technology, **various risks & challenges exist**
- Every storage site has its own unique geology and technical set up: **Risk factors must be avoided or mitigated**
- No characterisation methods is fool proof: **Unforeseen storage behaviour should be expected at all time**
- Comprehensive **monitoring and remediation** is imperative to track deviations
- **Which are technical limitations!?** Safe, industrial ramp-up to achieve climate goals might be the biggest challenge



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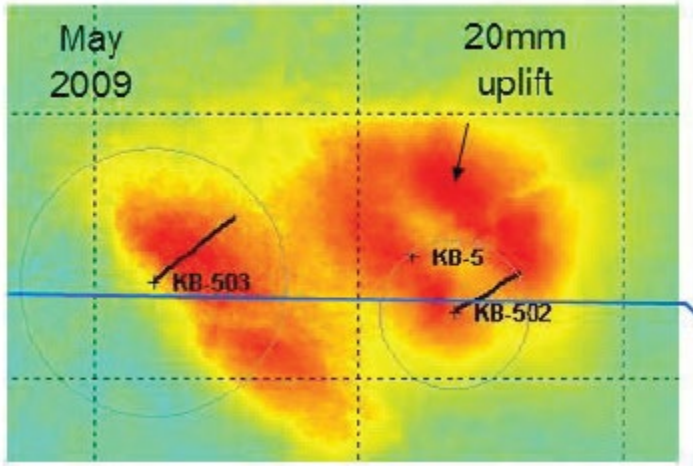
Thank you for your attention!

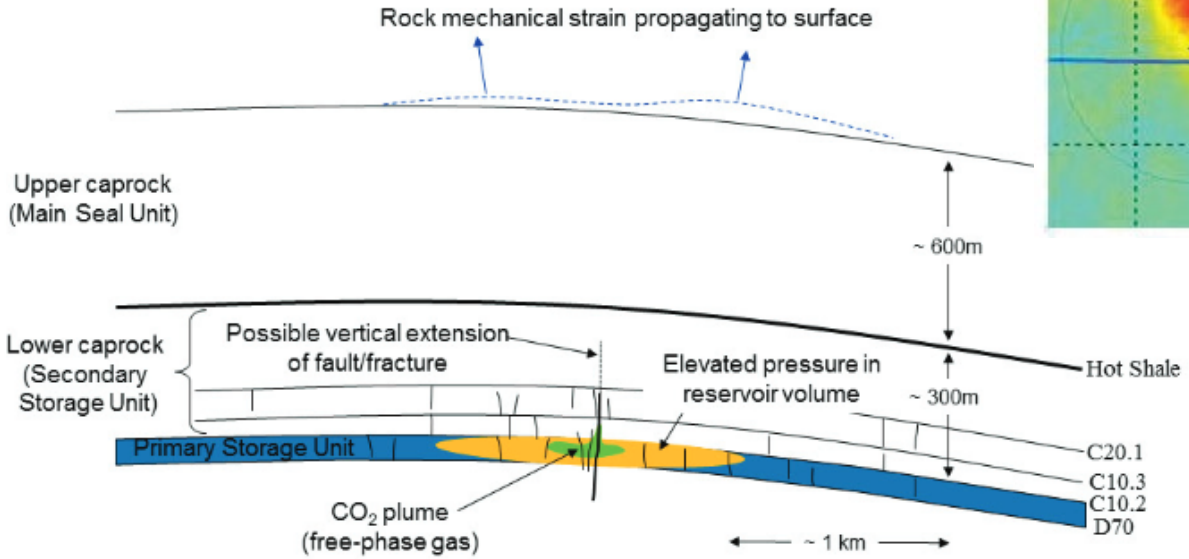
Do you have any questions?

3 – Examples

In Salah, Algeria

- Onshore CCS-Project, Operation: 2004 – 2011
- Materialised Risk: Overpressurisation, Caprock Failure, and Deformation
- Effect: Surface Uplift (20 – 25 mm)

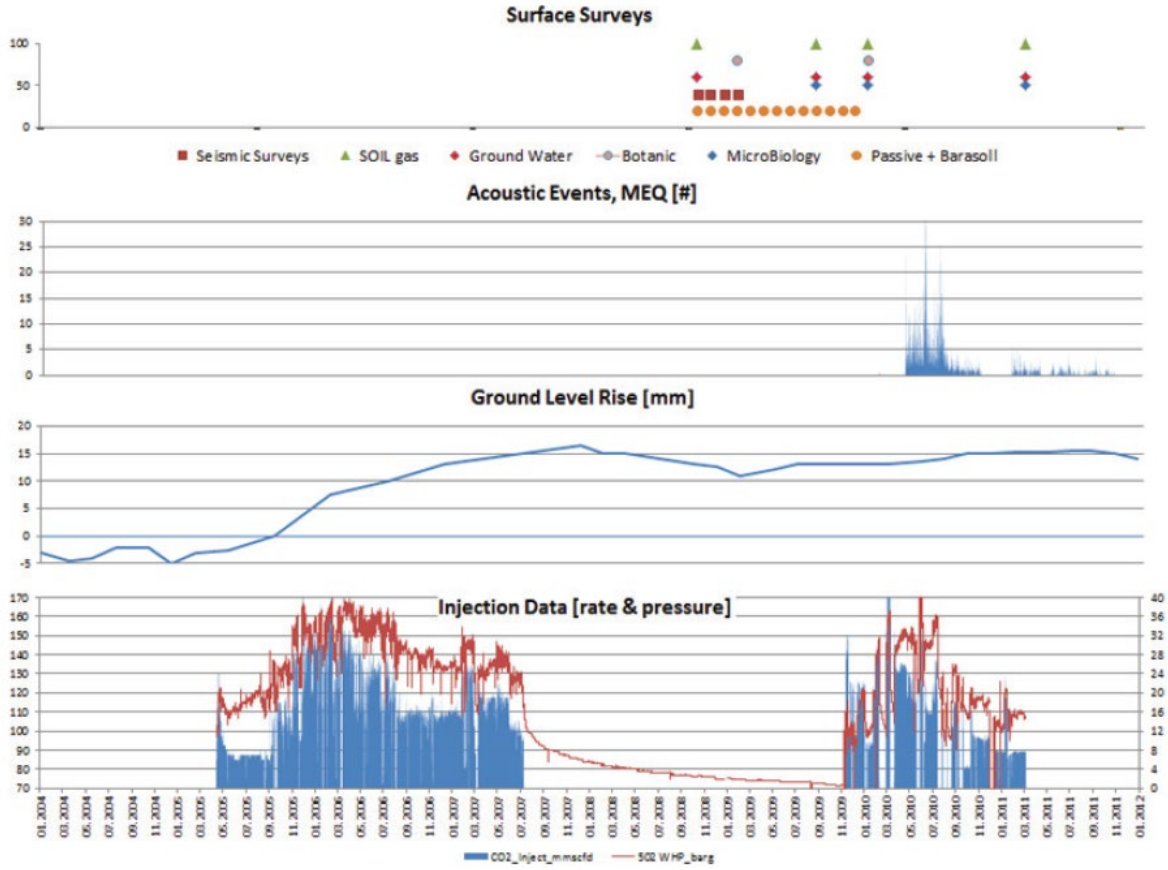




Figures: Ringrose et al., 2013a

3 – Examples

In Salah, Algeria



Consequences:

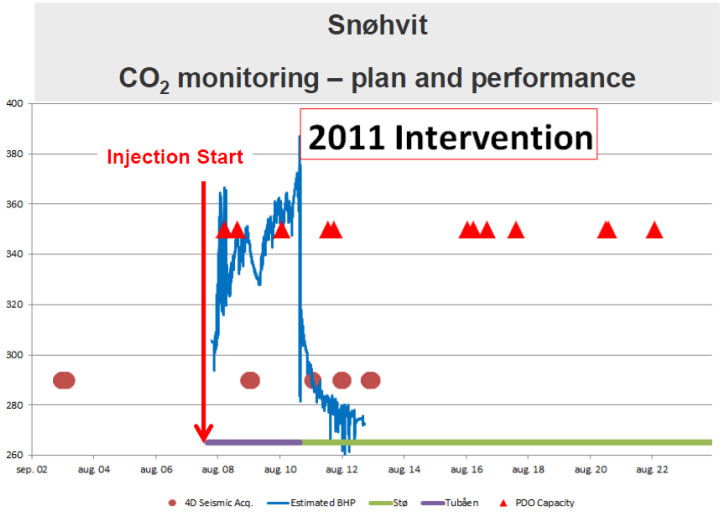
- Wells were eventually shut down permanently to avoid further hazards
- CO_2 may have leaked outside the target reservoir
- No proof that leaked CO_2 reached the Earth's surface

Figures: Ringrose et al. (2013)

3 – Examples

Snøvhit, Norway

- Offshore CCS-Project, Operation: since 2008
- Materialised Risk: Unexpected subsurface storage behaviour
- Effect: Geological formation unable to accept predicted amounts of injection



Consequences:

- Fast unexpected rise of CO_2 injection site pressure
- Immediate emergency well intervention
- Target Formation (Tubåen Fm) turned out to be significantly less porous
- Wells were plugged and abandoned

Figure: Ringrose et al, 2013b

3 – Examples

Snøvhit, Norway

Consequences:

- Switched to shallower formation (Stø Fm) on the same well bore
- Stø formation turned out to provide significantly less storage capacities and obtain other risks
- By now, Equinor switched to a third storage site (future Snøvhit)
- Besides explosion of financial costs for remediation measures and intervention, no further effects are known so far

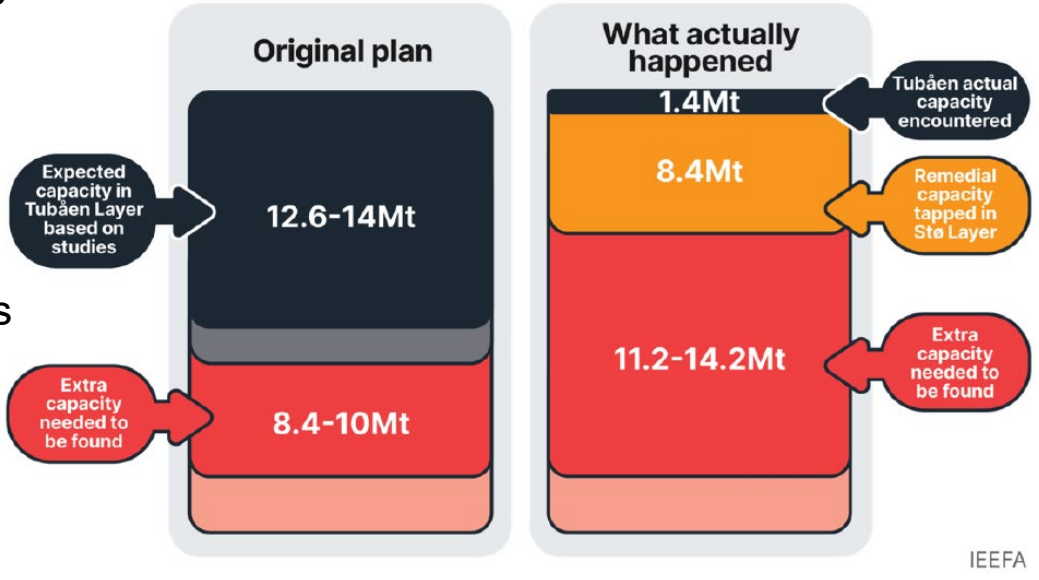
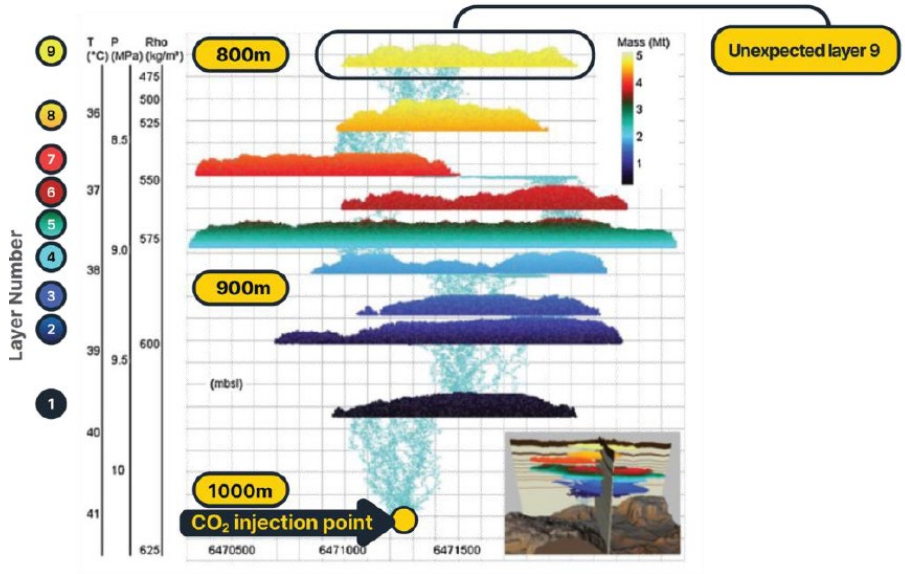


Figure: IEEFA, 2023

3 – Examples

Sleipner, Norway

- Offshore CCS-Project, Operation: since 1996
- Materialised Risk: Unexpected subsurface storage behaviour
- Effect: Fast migration of CO_2 into unexpected areas



Consequences:

- Deviation from plan
- CO_2 migrated to shallower previously unidentified layer 9 (220 m in 3 years)
- Comprehensive 3D seismic surveys followed since
- To date, Layer 9 contained further migration of CO_2

Figure: IEEFA, 2023

Backup Slide. Industrial Ramp-up

EU Carbon Management Strategie, 2024

- Net Zero Act proposed at least 50 Mt CO_2/a until 2030
- EU CMS proposes

  ~230 Mt CO_2/a by 2040

  ~2%0 Mt CO_2/a by 2050