The role of the oil and gas sector in decarbonisation

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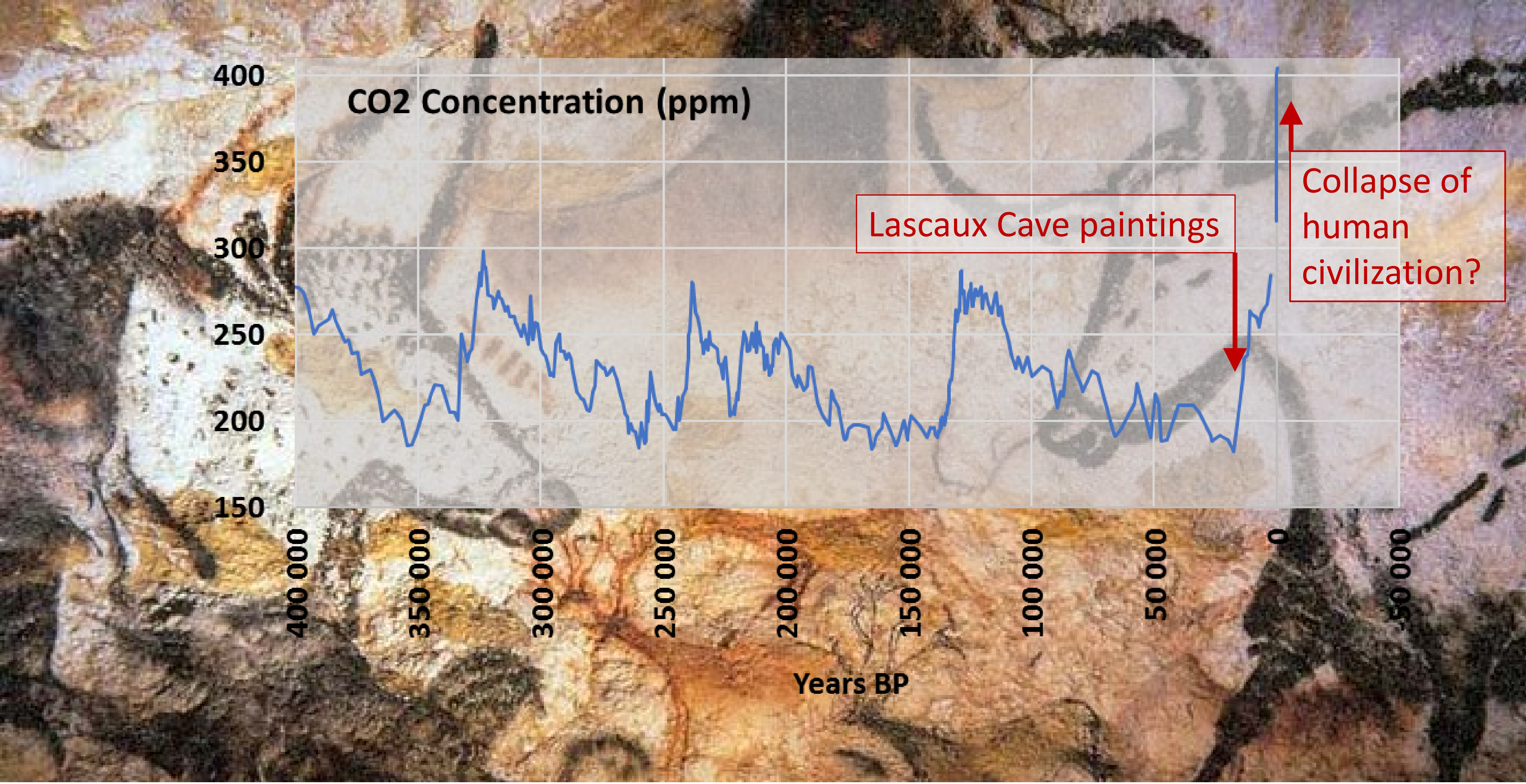
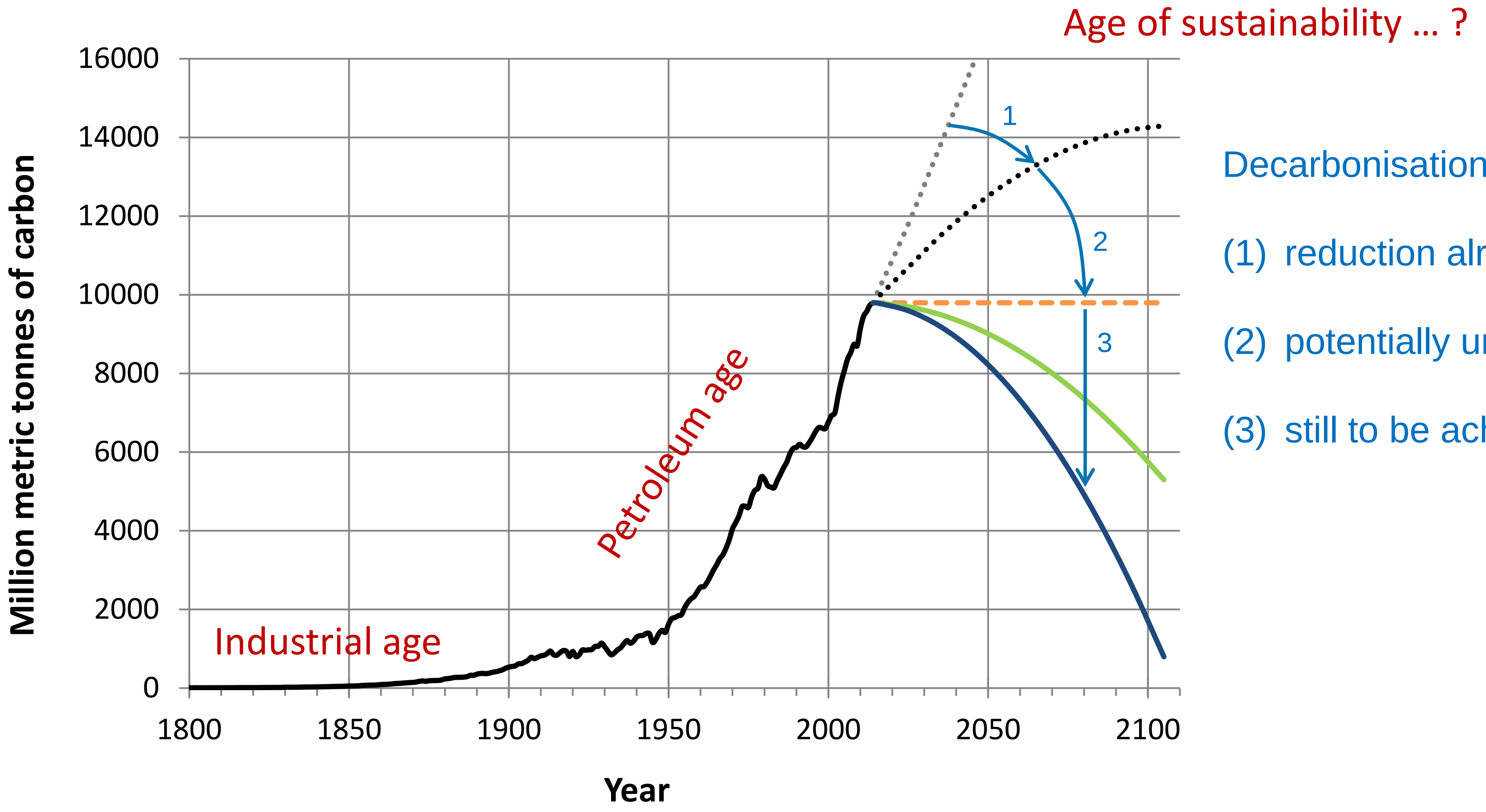
Bryan Lovell Meeting – January 2019
Role of geological science in decarbonisation



Upper Paleolithic depiction of aurochs, horses and deer, Lascaux Caves, Dordogne France

Can human society decarbonise rapidly enough?



Decarbonisation trajectories:

(1) reduction already achieved

(2) potentially underway

(3) still to be achieved

Ringrose (2017) – Sustainability and Physics

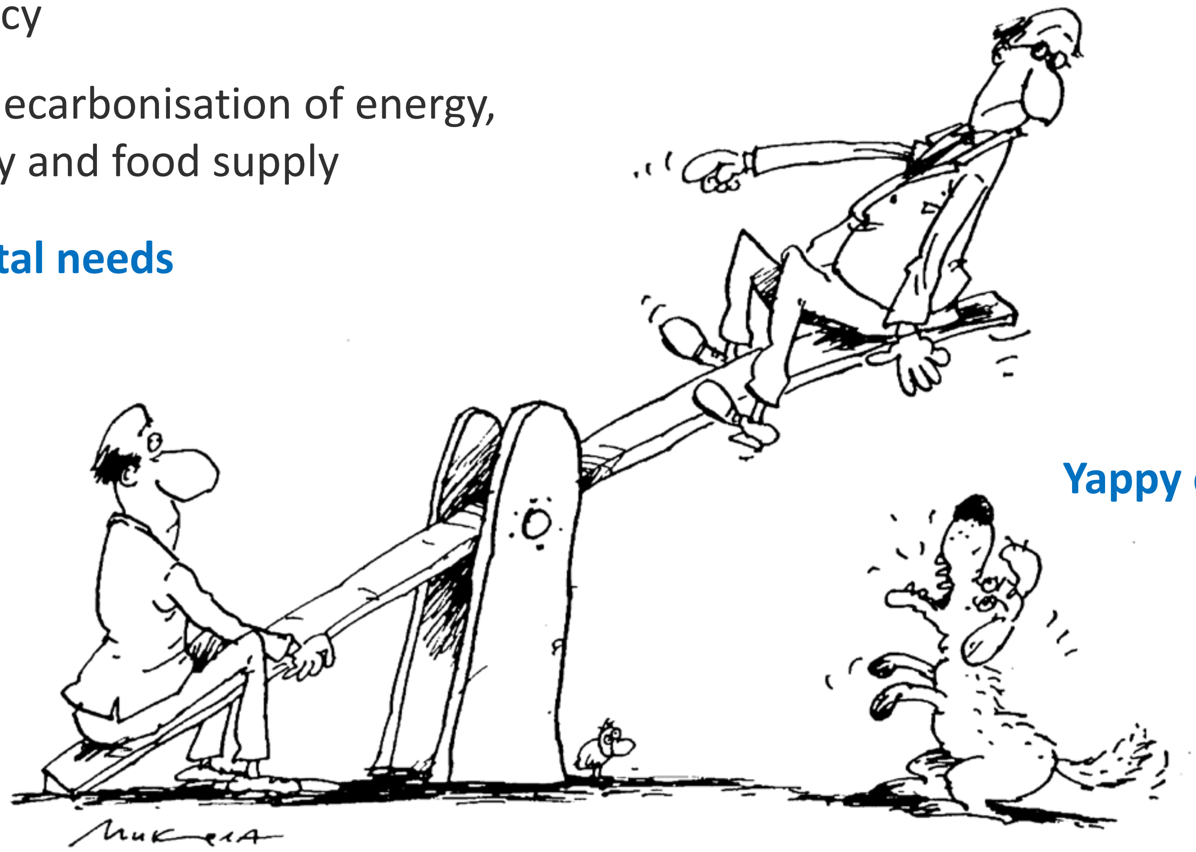
What will the future of energy look like?

Human society needs a massive shift:

- Rapid growth in RE
- Dramatic improvements in energy efficiency
- Rapid decarbonisation of energy, industry and food supply

Societal needs

Industrial challenge



Yappy dog

A modified oil and gas energy sector is most likely to deliver this:

1. Large and long-term investment projects needed
2. CO_2 management and disposal at industrial scales
3. Subsurface resource management skills and tools

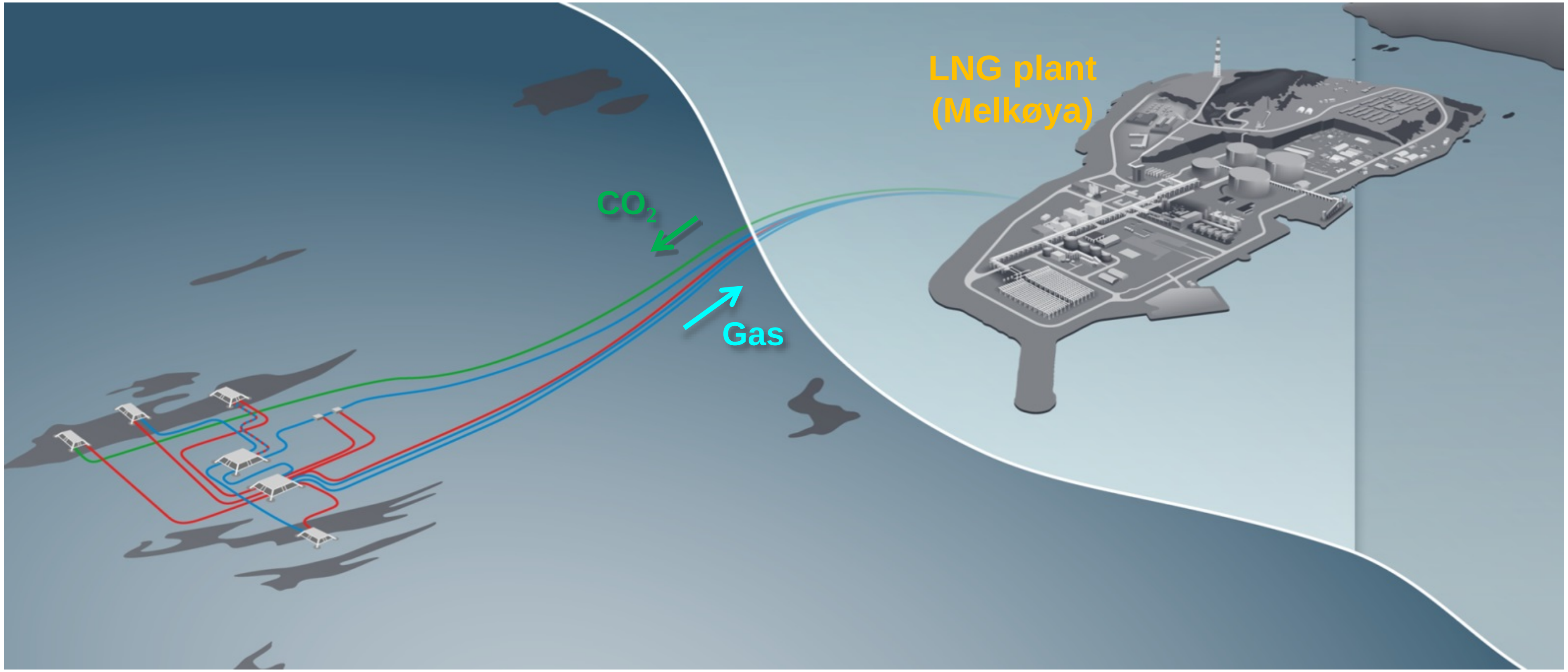
But this will need:

- Public-private partnerships
- Societal and political engagement in the solution

What does large-scale CCS look like?

Snøhvit Project: First onshore capture - offshore storage project

- 150km seabed CO_2 transport pipeline from LNG plant
- Saline aquifers c. 2.5km deep adjacent to gas field
- CO_2 stored initially in the Tubåen Fm. (2008-2011) and then in the Stø Fm. (2011-)



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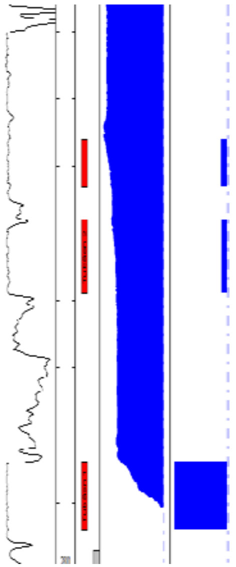
Monitoring the subsurface at Snøhvit

➢ Successful well intervention guided by monitoring data

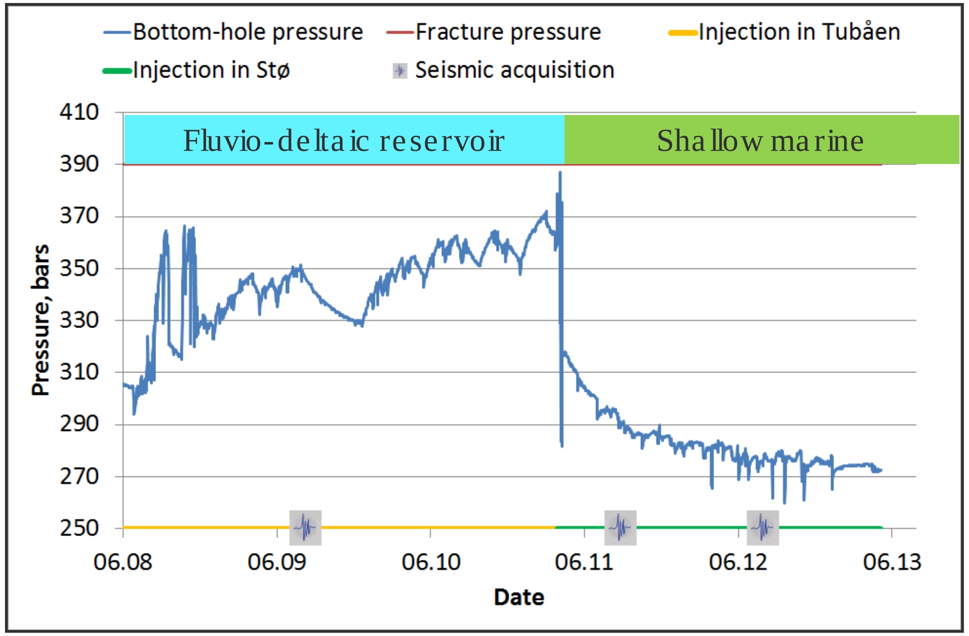
- Rising pressure due to geological barriers led to **well intervention**
- **Integrated use of** geophysical monitoring and down-hole gauges
- Deployed back-up option in the injector well

> ➢ Demonstrates value of flexible well design

Down-hole data:
Downhole flow log

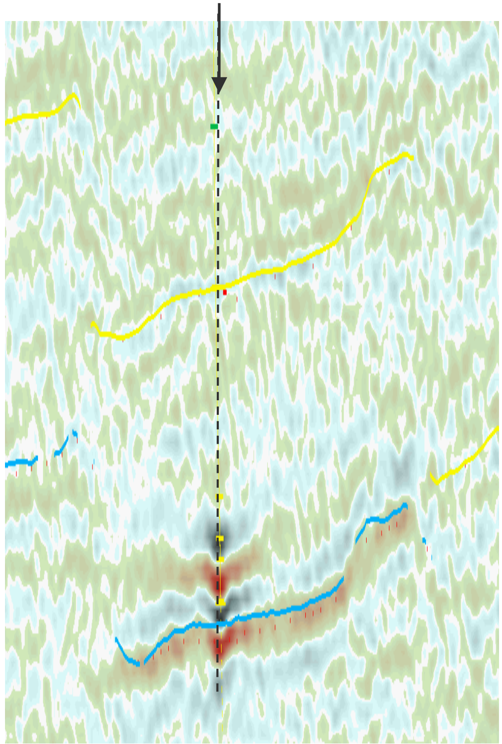


Down-hole pressure data



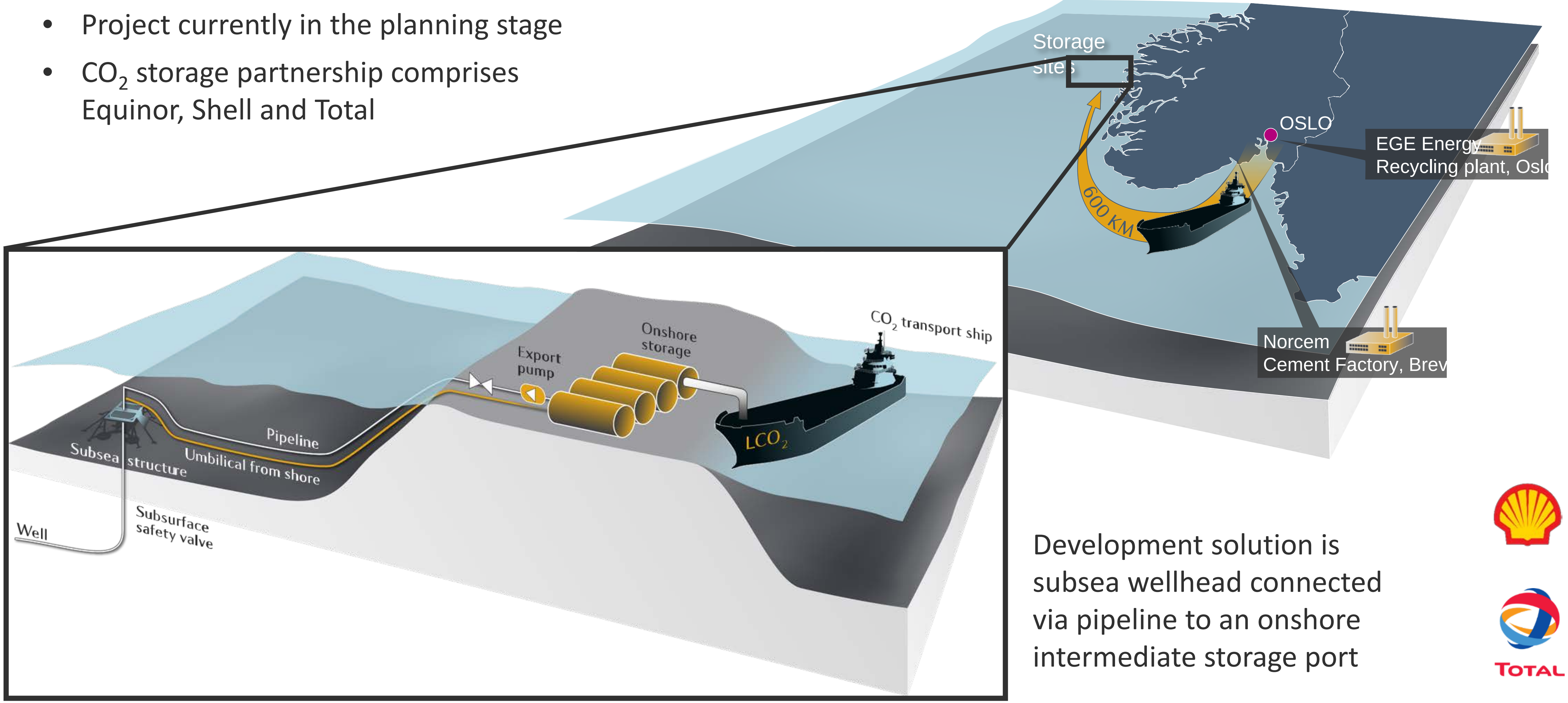
Hansen et al. 2013; Pawar et al., 2015

Time-lapse seismic
(Amplitude difference)



The Norwegian CCS Demonstration project

- Project currently in the planning stage
- CO_2 storage partnership comprises Equinor, Shell and Total



Development solution is subsea wellhead connected via pipeline to an onshore intermediate storage port

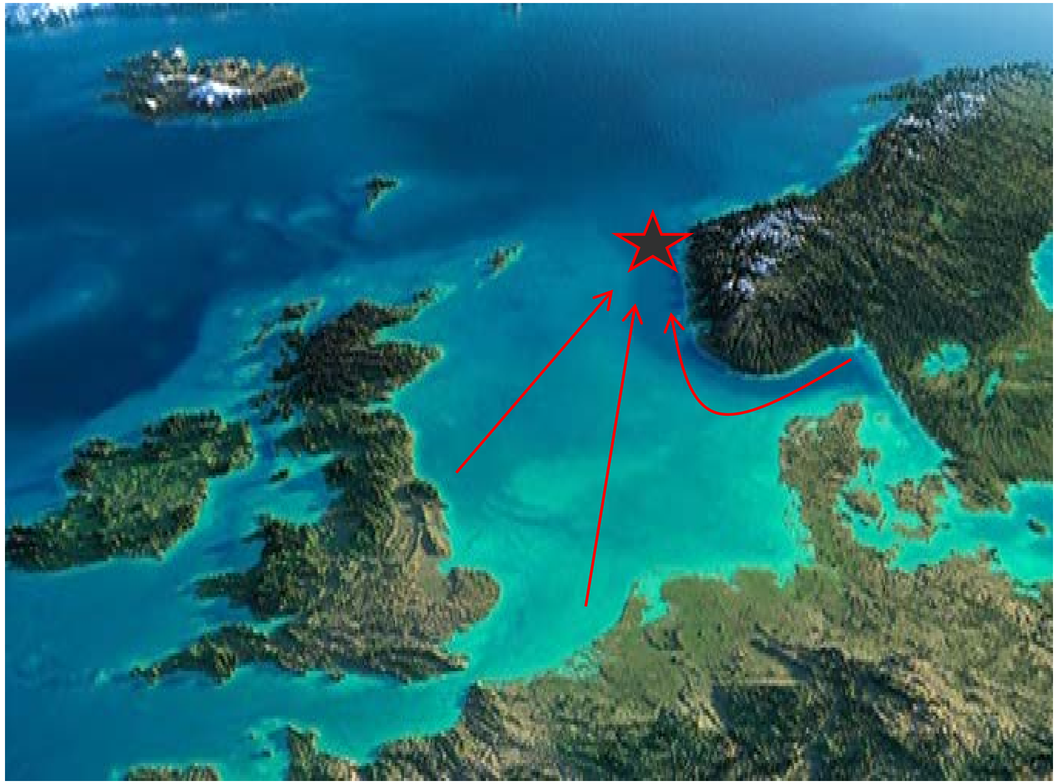
Norwegian CO_2 Storage: Future potential

equinor

- Reduces risk and threshold for others
- Enables additional CO_2 storage

- Allows stepwise development of CCS from more regional hubs

- Basis for emerging CO_2 value chains:
  - Natural gas to hydrogen
  - CO2 EOR



- Norway CO_2 storage hub: Possible catalyst for roll-out of CCS in Europe?

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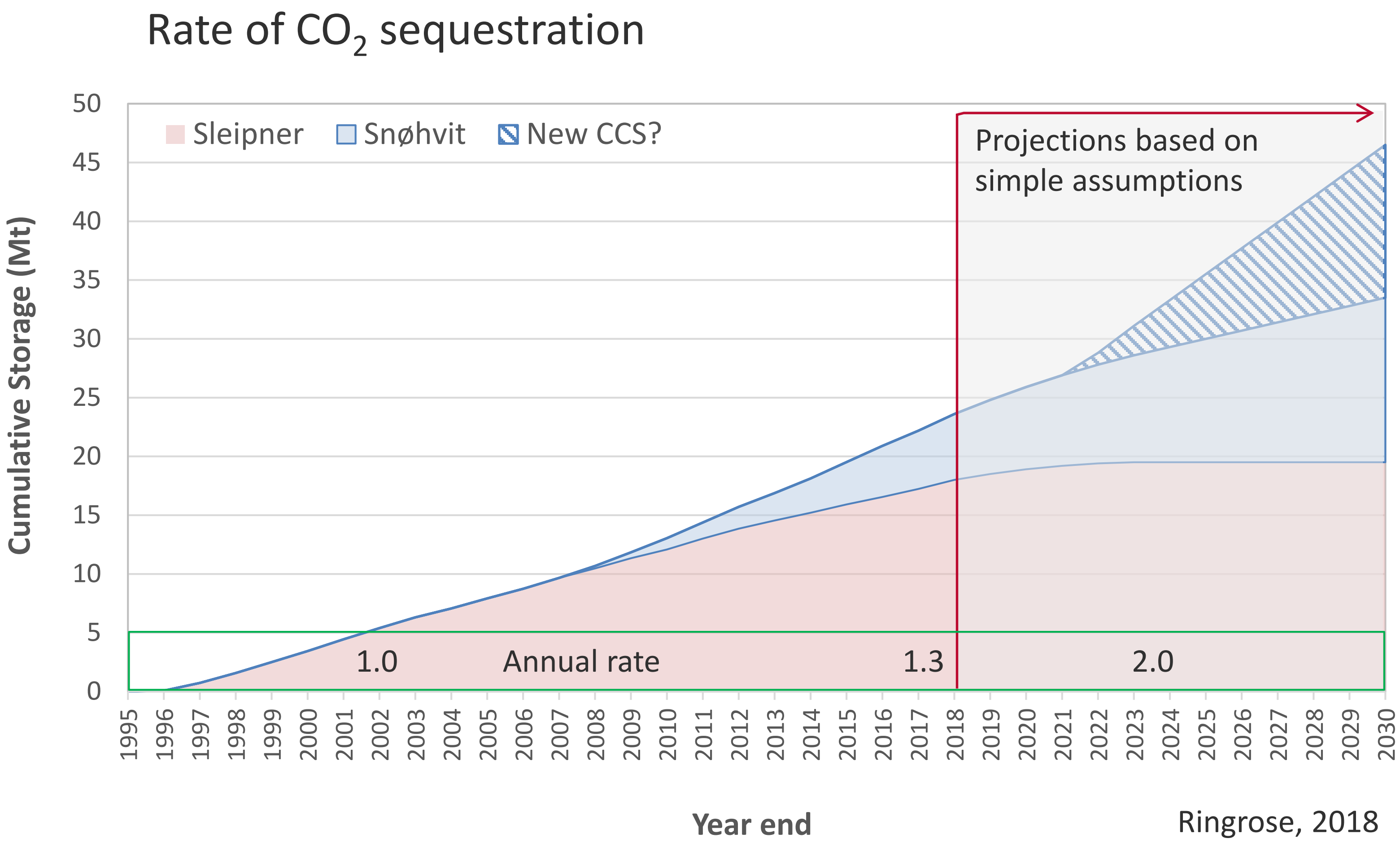
Norway CO_2 storage in numbers



Ringrose, 2018

How much is 1Mt of CO_2?

- Annual emissions from 330,000 cars (assuming 200g/km)
- 5 million passenger air kilometres
- 100 million tonnes/km of maritime shipping
- One tenth of Norwegian road traffic emissions in 2014

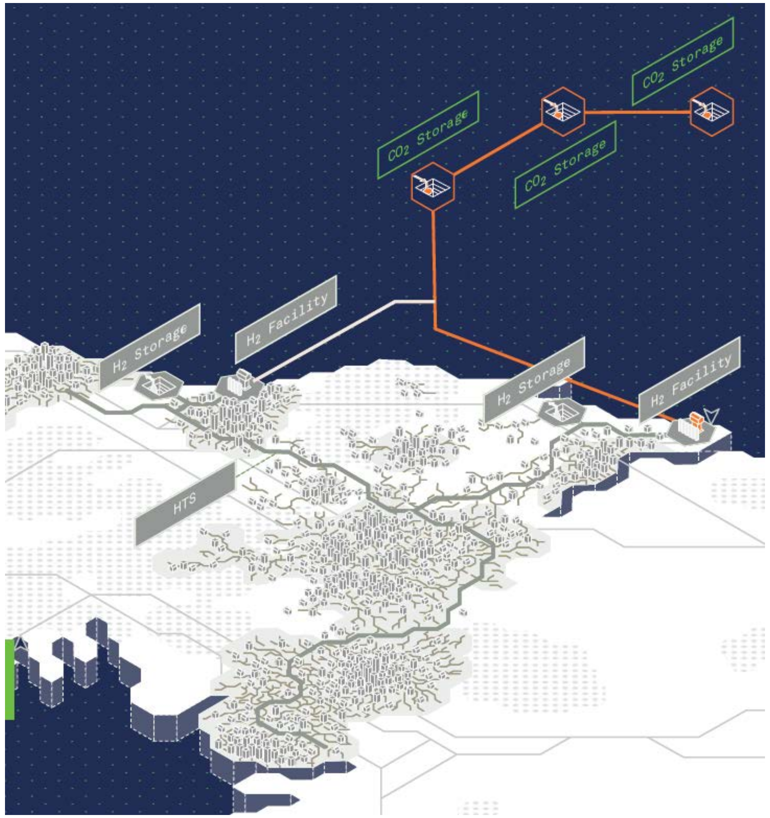
Annual rate of gas injection in all Equinor-operated oilfields (NCS)

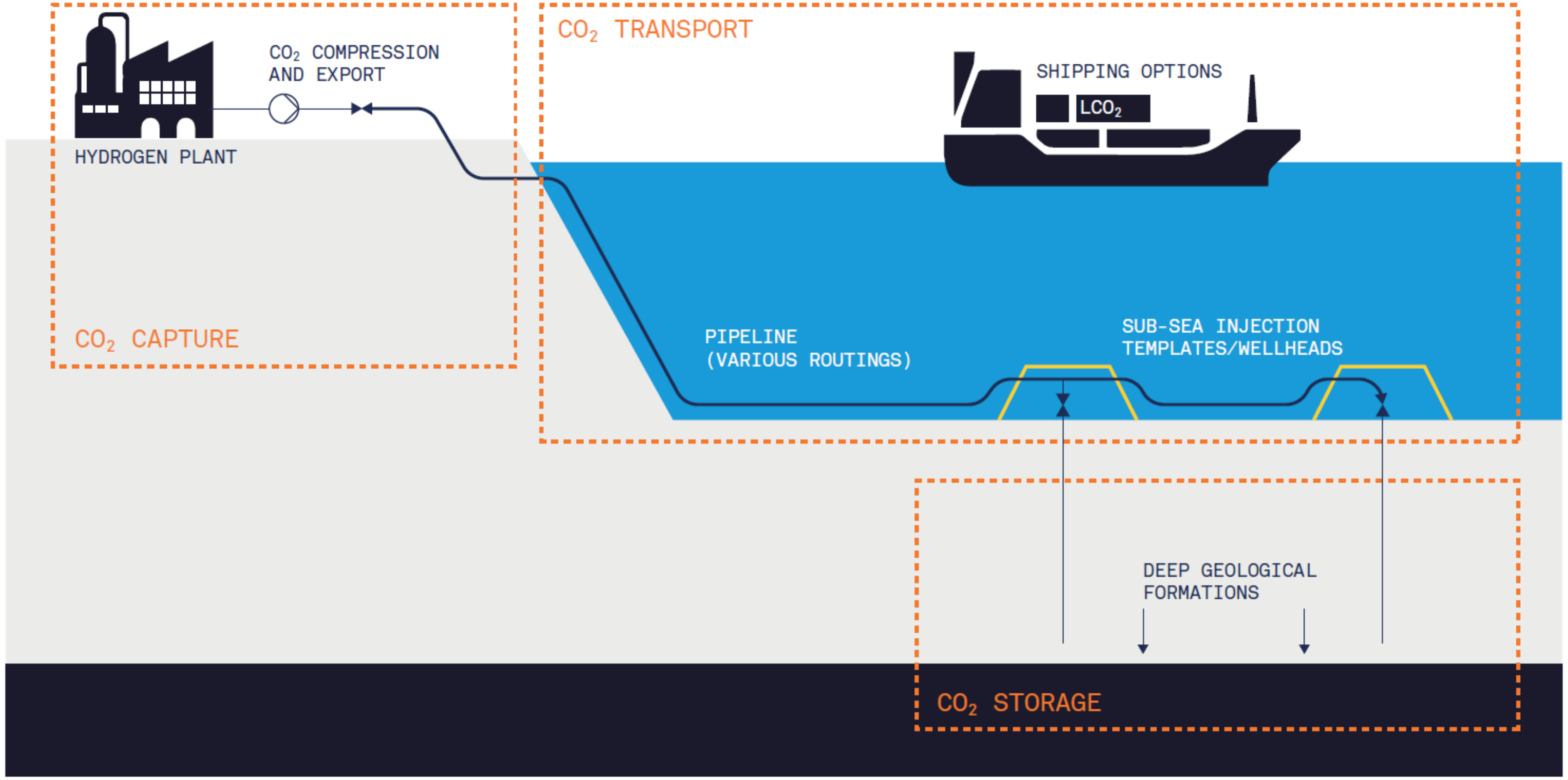
- ~35 Gsm^3/year (methane)
- Which is equivalent to 64.8Mt CO_2

H21 North of England Project (Transport and Storage part)

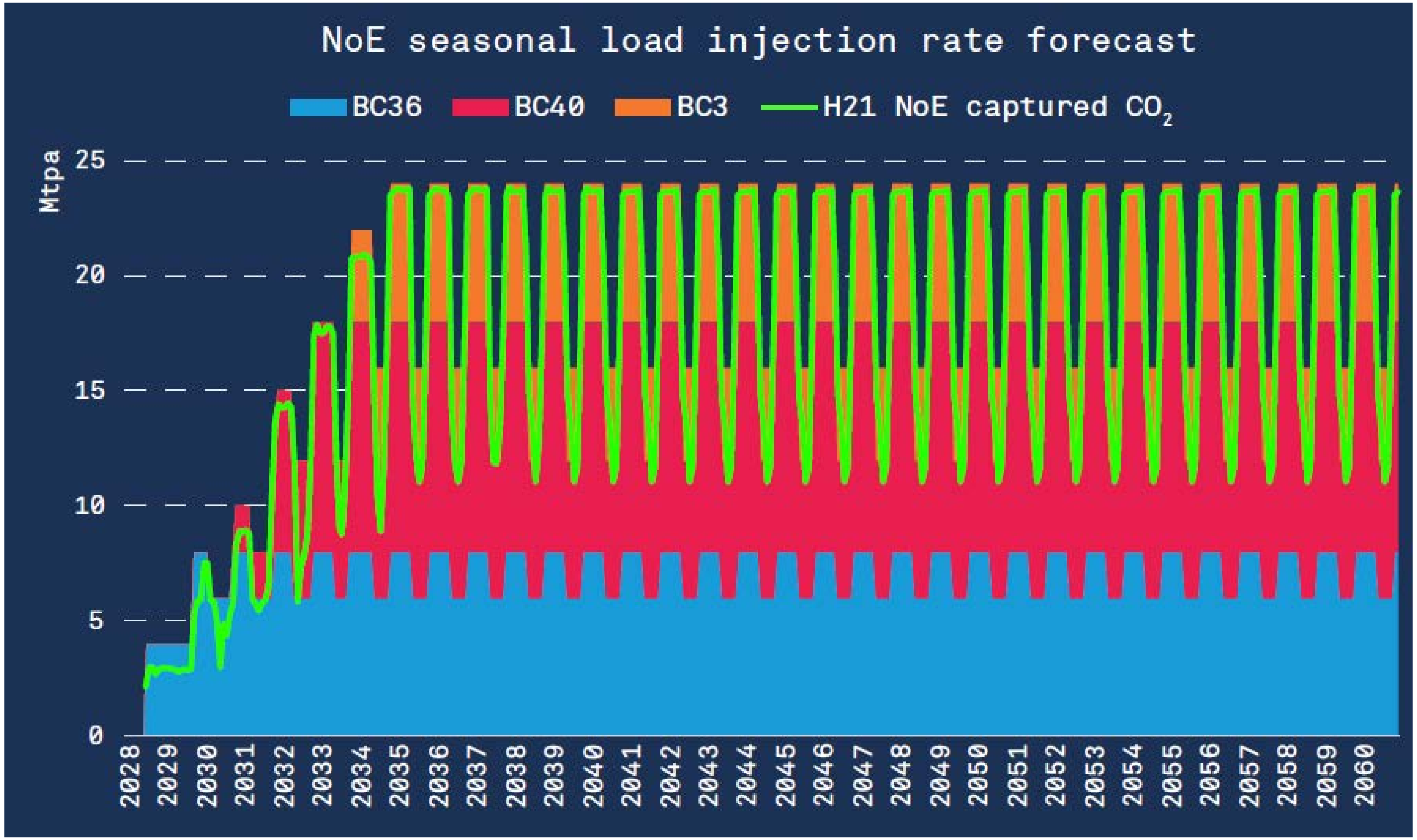
Engineering concept study for a 17-20 Mtpa storage scheme for H21 (UK storage option):

- Assessed 3 Triassic Bunter sandstone structures in UK Southern North Sea
- Solution involves 12 sub-sea wells drilled from 4 templates
- Baseload and seasonal fluctuations assessed





Model scenario for H21 UK storage scheme with ramp-up and seasonal load



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The Pressure Management story

Remember those early “oil gusher wells” (e.g. California oil rush)

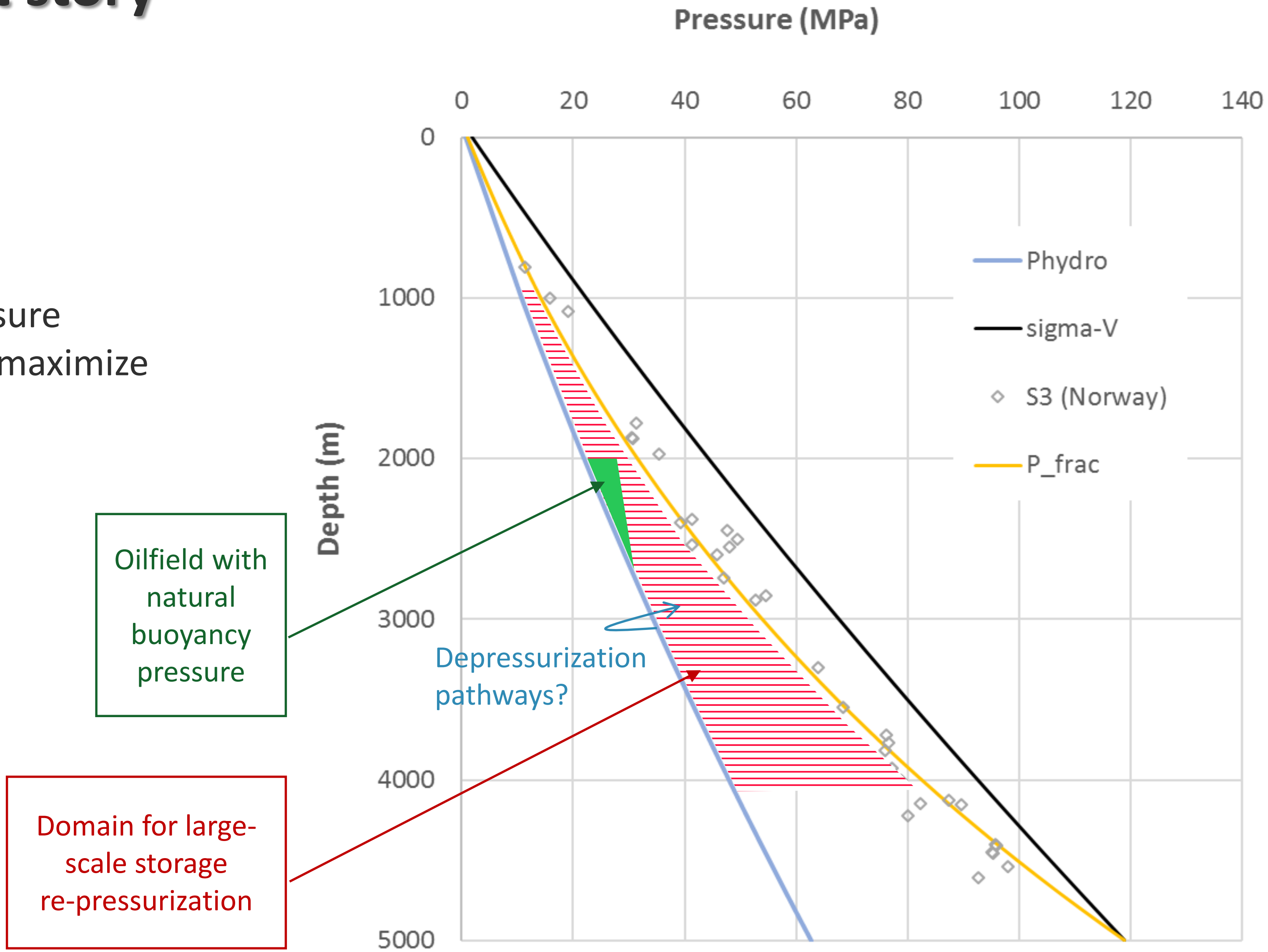
- Natural pressure depletion

Since then the oil industry has used pressure management and water/gas injection to maximize recovery

- Secondary and Tertiary recovery

Large-scale CO_2 storage will also require pressure management

- Re-pressurization technology

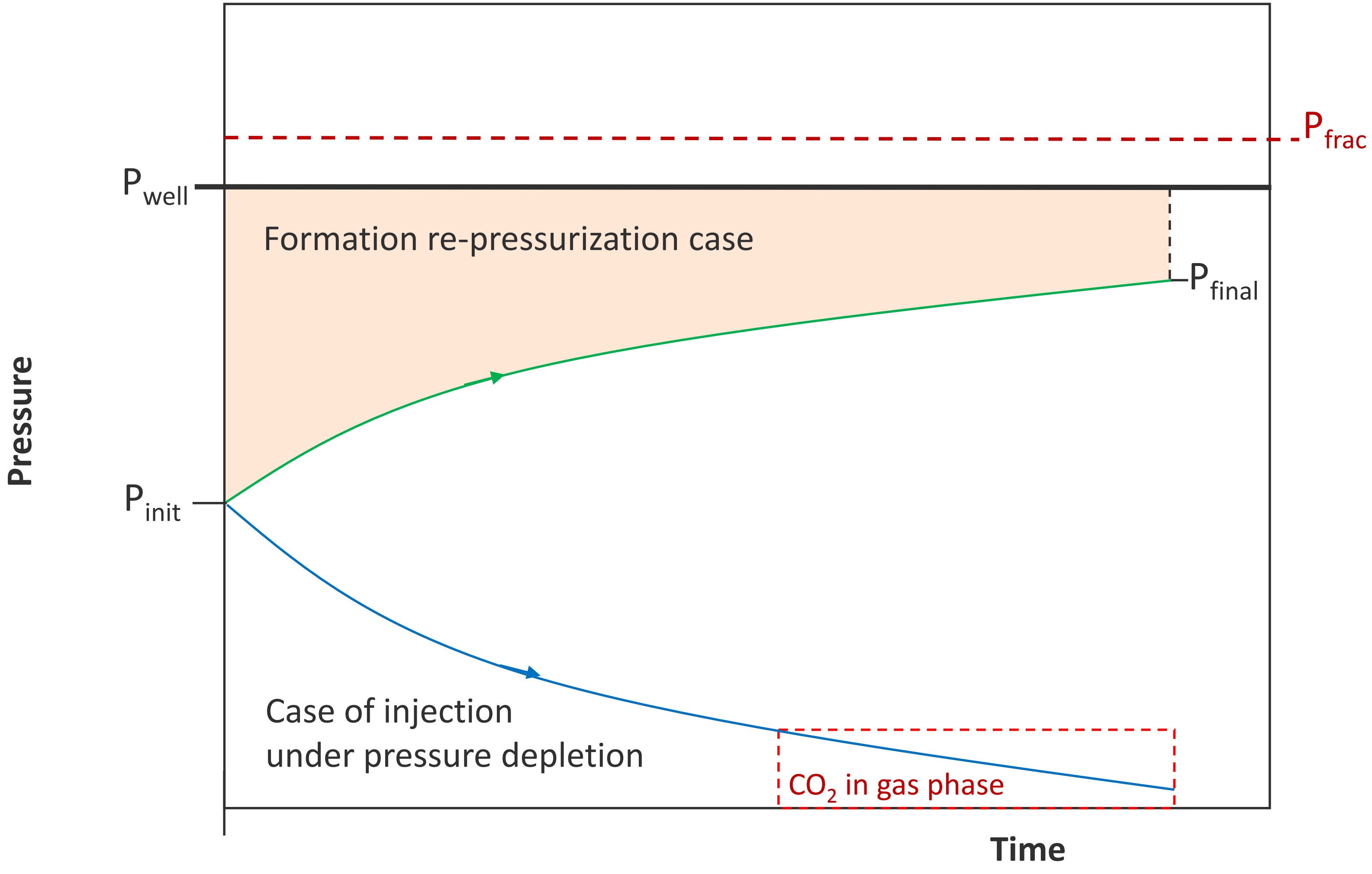


Ringrose & Meckel (work in progress); minimum stress data from Bolaas and Hermanrud (2003)

Pressure management for contrasting injection projects

Keys factors we need to understand or control:

- Injection pressure, P_{well}
- Fracture pressure, P_{frac}
- Acceptable injection pressure limits
- Plume expansion (site conformance)
- Phase behavior
- Geological uncertainties



Gt-scale injection under pressure depletion

Examples from Nazarian et al. (2019), GHGT-14 Conference

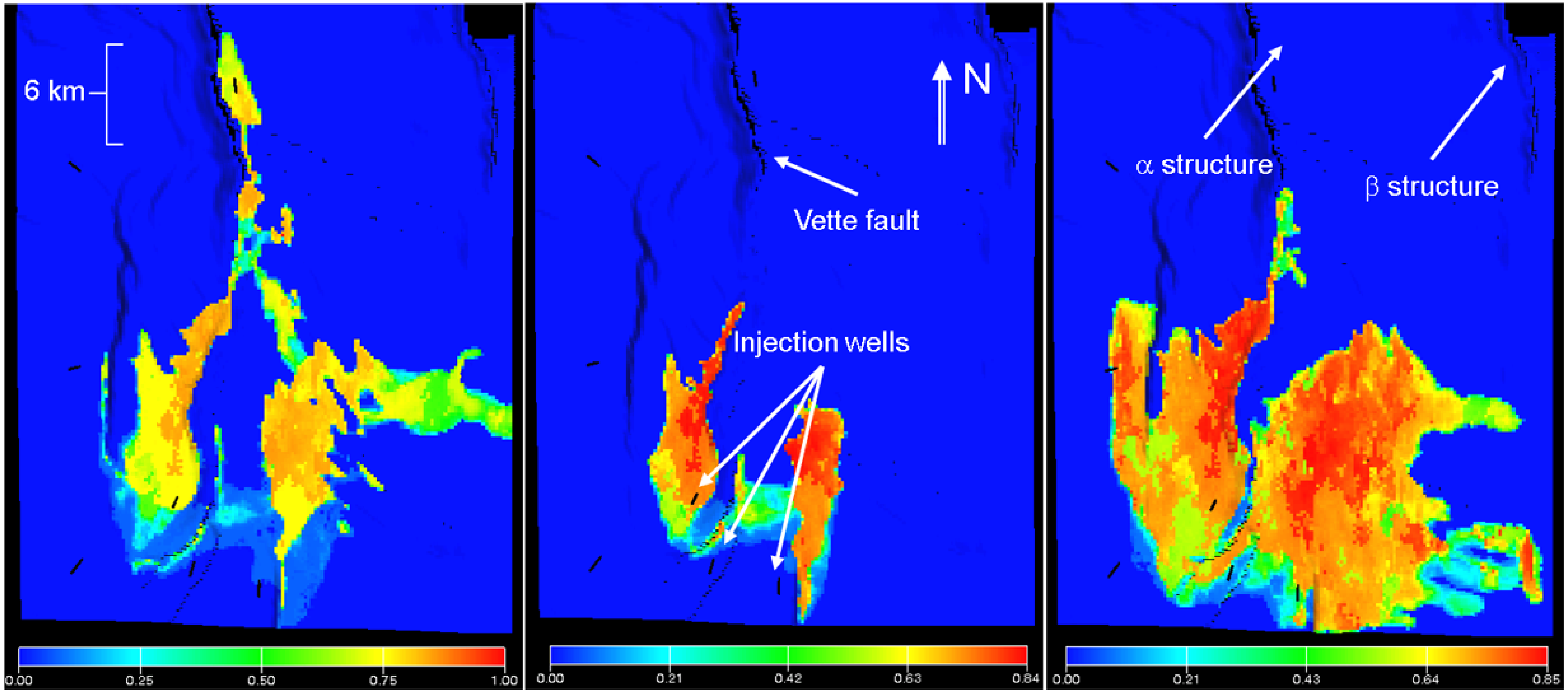


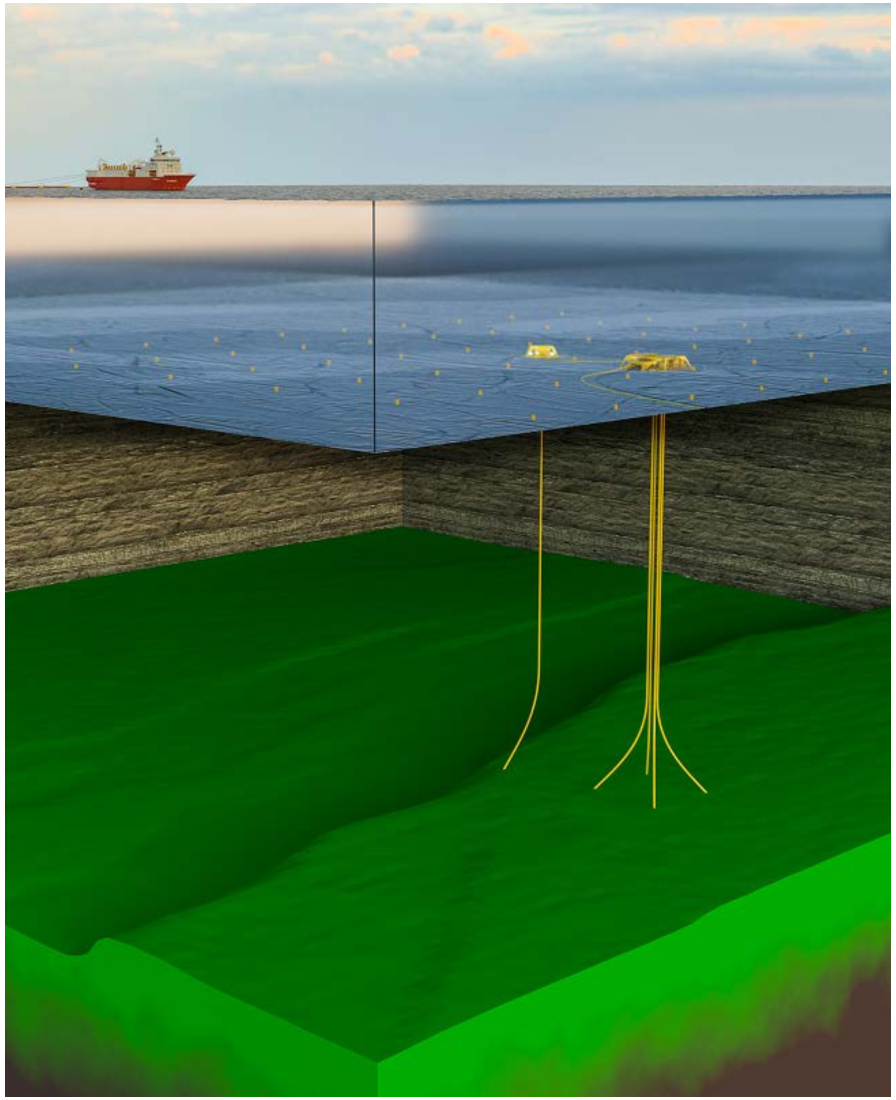
Figure 3. Left. Top view of CO_2 plume 650 years after injection of more than 600 Mt in a continuously depleted Smeaheia. Middle. 600 Mt CO_2 injected in a non-depleted Smeaheia. Right. 3 Gt CO_2 injected under continuous depletion. CO_2 plume is almost stabilized 650 years after the injection.

Building confidence using advanced monitoring solutions

Summary from Ringrose et al. (2019), GHGT-14 Conference

Advanced cost-effective monitoring is key to storage confidence:

- Blend of marine-streamer seismic acquisition, supplemented by sparse seabed-node system
- Use of fibre-optic downhole monitoring wherever possible
- Environmental monitoring - optimised/targeted
- Use advanced data analysis methods (go digital)



Value proposition – Norway offshore reference case:

Lifetime cost of monitoring programme:

~42 Million Euro (M€) or ~2€/tonne

Cost vs. benefit

Key storage project cost items:

1. Offshore injection well ~50-100M€
2. Major well intervention programme ~10M€

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Conclusions

1. Urgent need for rapid decarbonisation of energy, industry and food supply
2. A modified oil and gas industry has the skills/tools/dimensions needed
3. CO_2 storage in saline aquifers has huge potential:
   - 1 Sleipner injector well = Emissions of 100 million tonnes/km of maritime shipping
4. Large-scale CCS will need basin-scale pressure management approach
   - Need to consider basin/formation pressure limits
   - Could utilize 'depletion space' from oilfield history
5. Although CCS is a 'large ticket' item… the societal value is undeniable
   - Cost of avoided emissions per €/$/£ is excellent value for money
   - Ready to move forward in support of the H21 Hydrogen project

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