Geological Storage of CO_2

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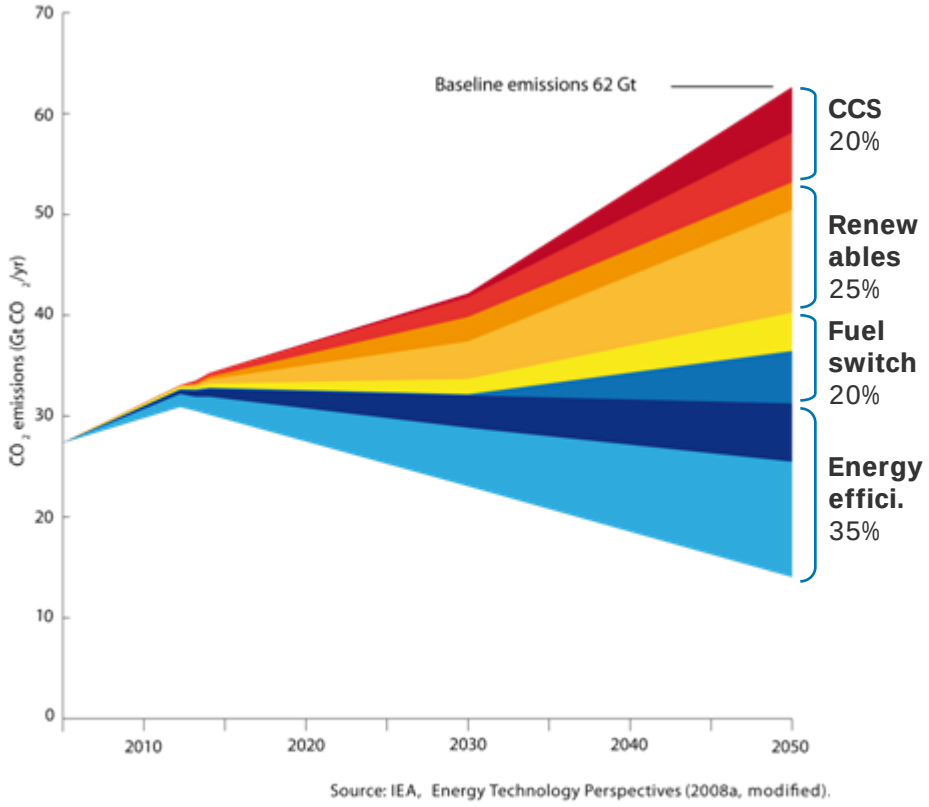
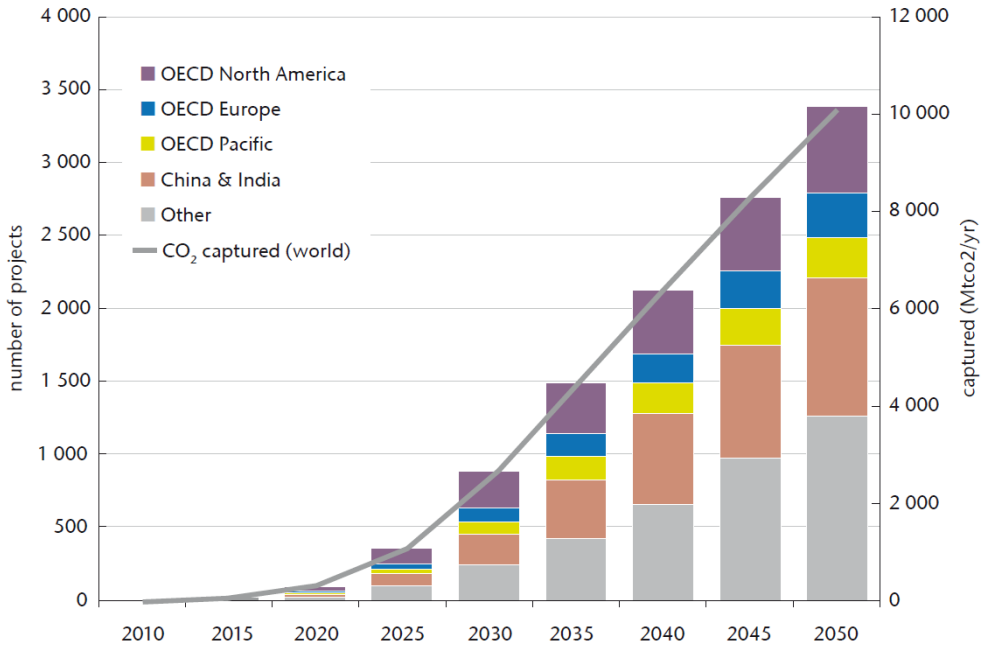
CCS - Essential tool to mitigate climate change

CO_2 emissions and forecast



Source: IEA, Energy Technology Perspectives (2008a, modified).

CCS deployment - predicted



IEA, Energy Technology Perspective

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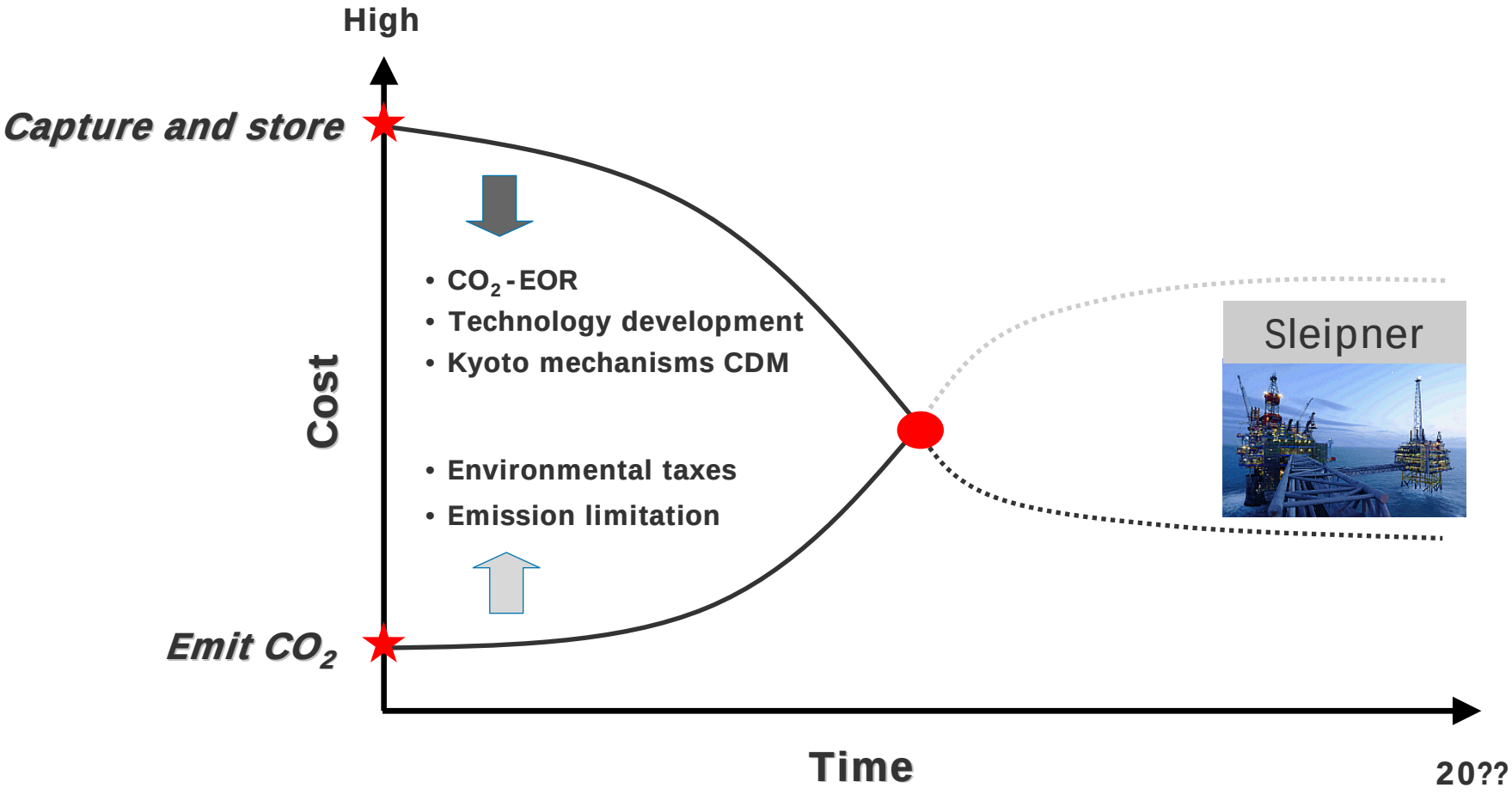
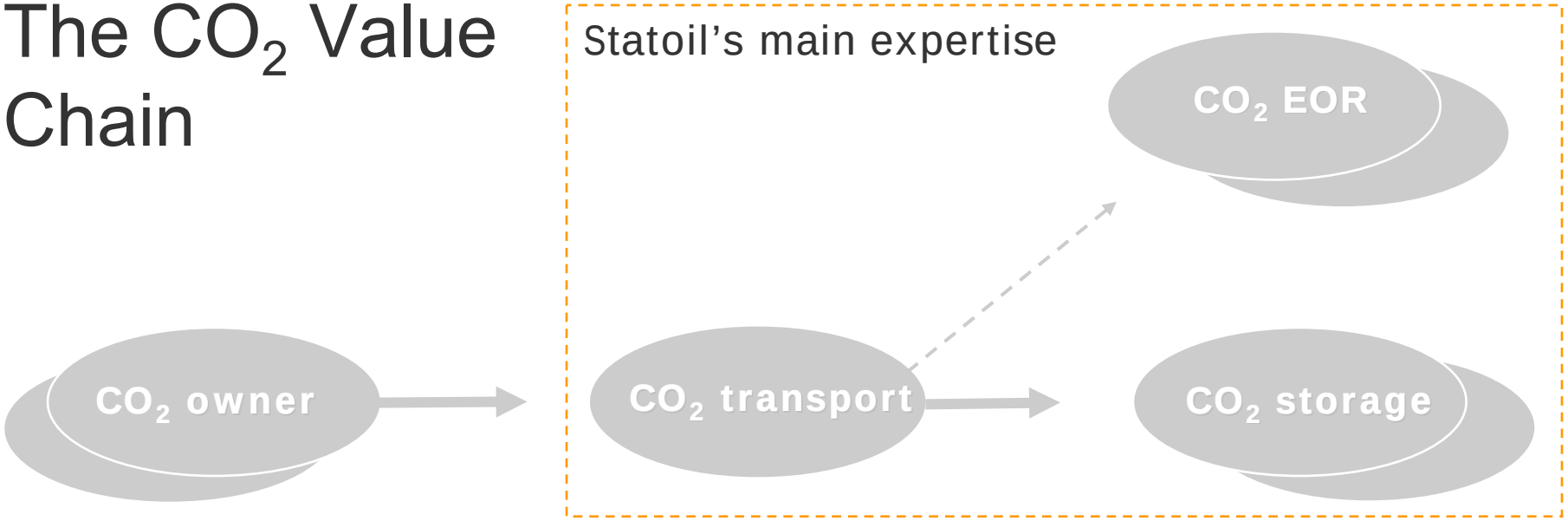
CCS Commercialisation



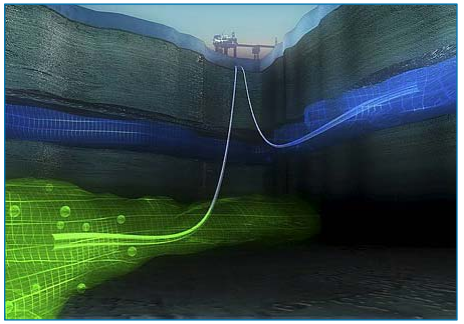
The CO_2 Value Chain



Multiple source but two main clusters;
- Emitter (coal)
- Capture facility

Transport facilities dedicated or dimensioned for additional volumes
- Pipeline
- Vessel

Multiple storage sites possible for large volumes
- Abandoned fields
- Saline formations



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CO_2 storage principles

Capacity

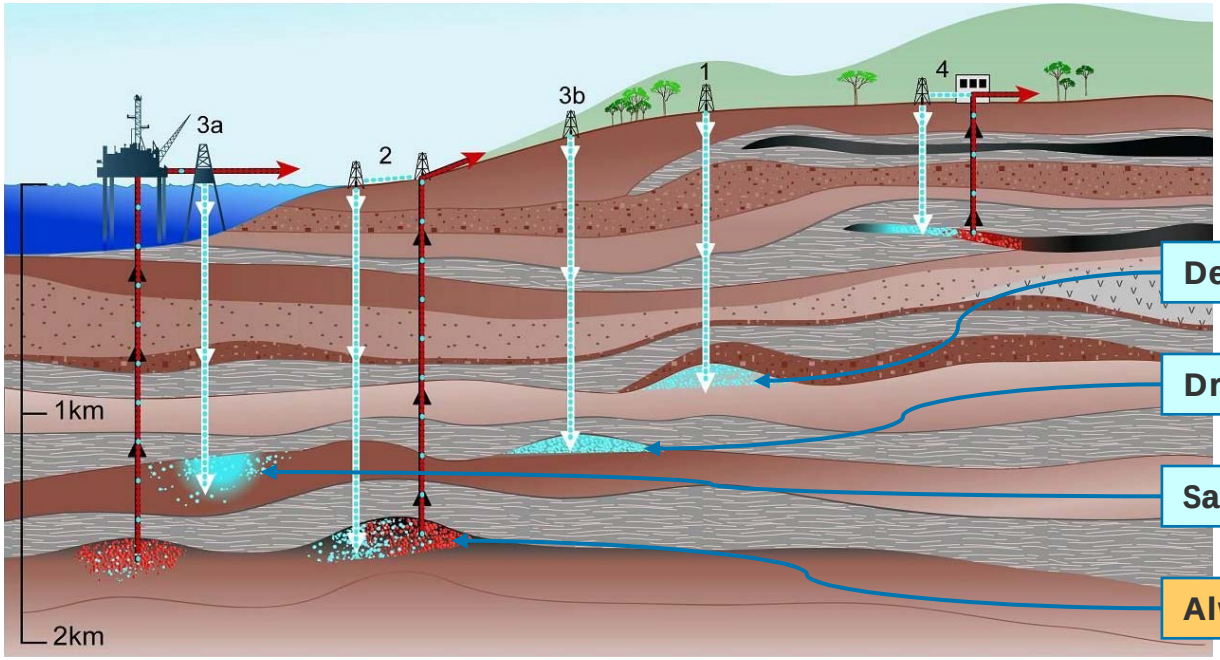
- CO_2 in dense phase
- Large “in-place” pore-volume
- Storage efficiency
- “STOOIP” difficult to calculate

Injectivity

- Reservoir quality (permeability)
- Geochemical reactions
- Injection strategy (no of wells)
- Handle pressure increase

Containment

- Seal capability (lateral extent, geomechanics, etc.)
- Trapping mechanisms
  - geometry (structural)
  - residual trapping
  - geochemical trapping



Depleted oil and gas reservoirs

Dry structures - “static” storage

Saline formation - “dynamic” storage

Always CO_2 for EOR as an option!

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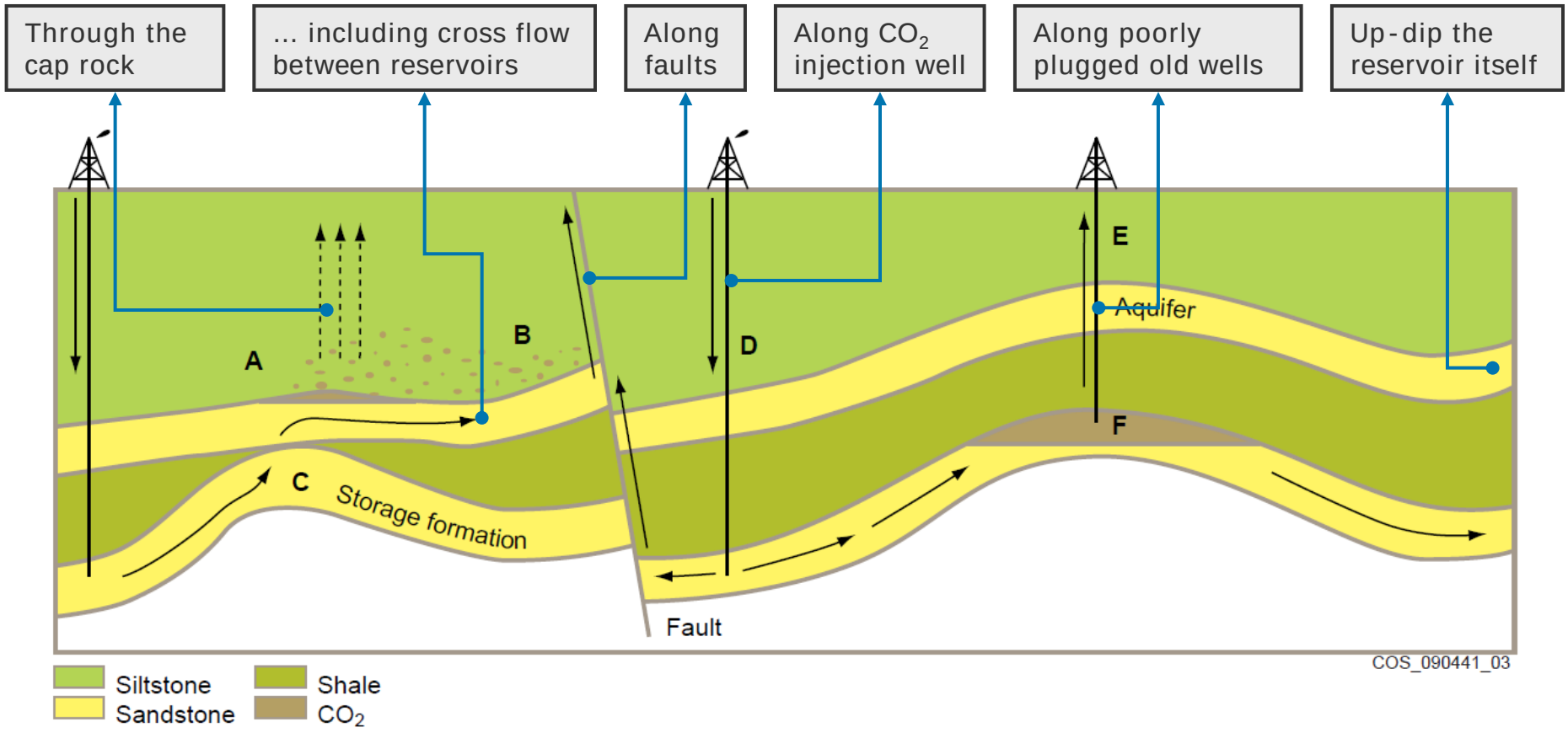
Permanence –potential leakage routes



Site specific - Each storage needs individual attention

Handle pressure increase, produce water?

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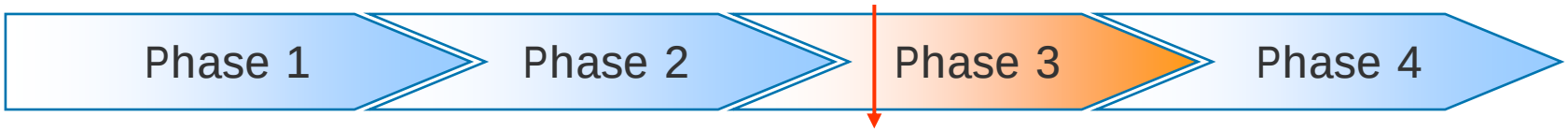
COSMaP - Ambition and overall outline

CO_2 Storage Mapping Programme (COSMaP)

Map and mature suitable reservoirs for storage of CO_2 (own or others) for development and operation by Statoil where this creates a *business opportunity*



Phase 1	Phase 2	Phase 3	Phase 4
• Planning/ manning	• Screening	• Characterisation	• Feasibility
• Methodology review	• Desktop studies	• Uncertainty study	• Development solution
• Risk management	• Prioritisation	• License application	• Expected value
• Database construction	• Establish a portfolio	• Exploration drilling	• Customer review

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Key Measures – Storage Site Selection

Site selection is addressing a variety of measures from screening to feasibility

Screening

Location (versus source)

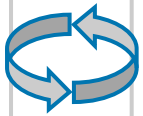
Timing

Data availability

Permit to explore?

Regional mapping

Prioritised portfolio



Characterisation

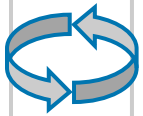
CO_2 - characteristics

Injectivity

Containment

Geological modelling

Capacity – 1st estimate
(estimation methodology)



Feasibility

Dynamic modelling

Well integrity

Geo-mechanics

Geo-chemistry

Pilot/demonstration?

Capacity – 2nd estim.

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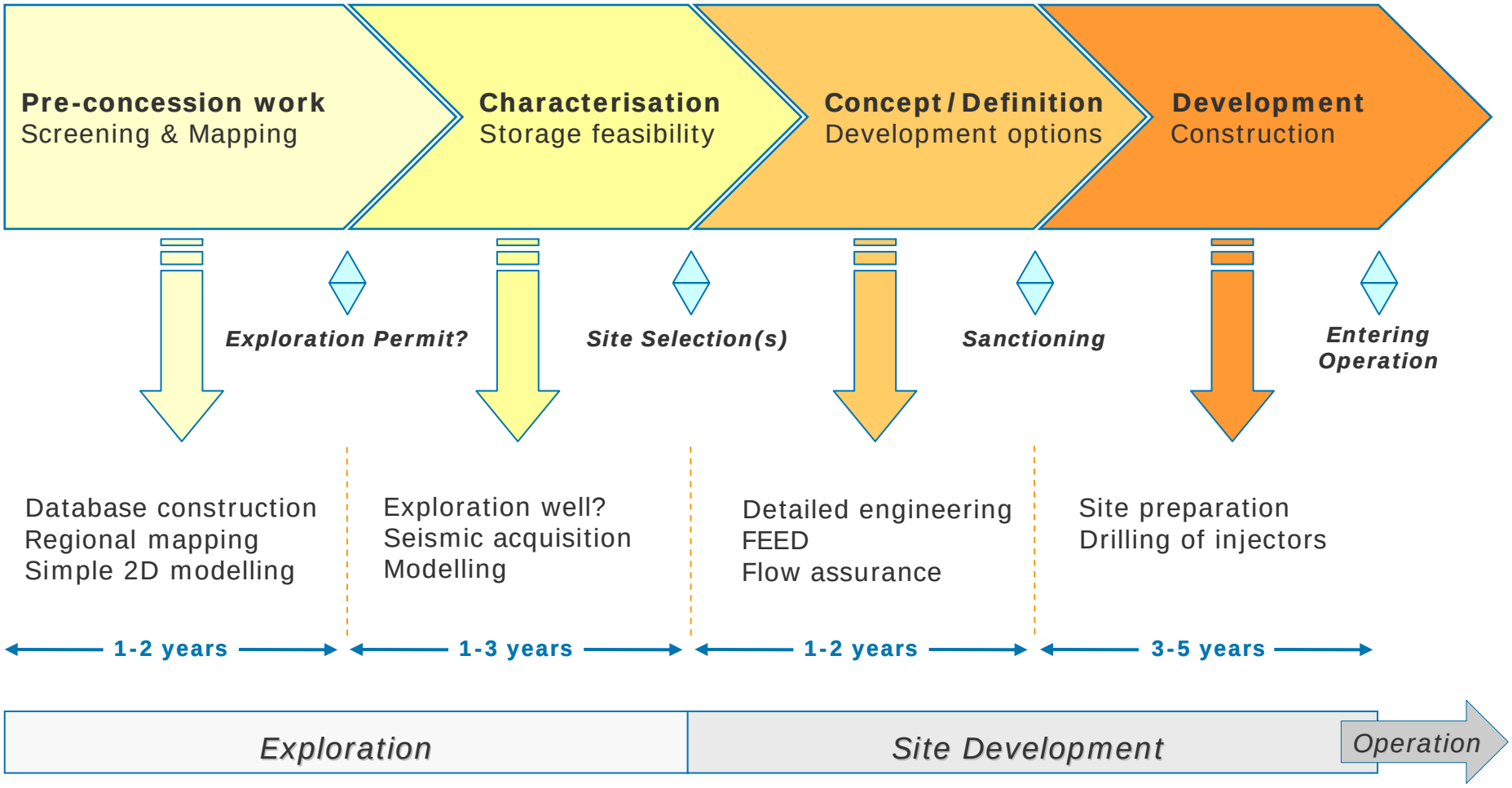
Generic time-line from screening to operation



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COSMaP Findings – Screening

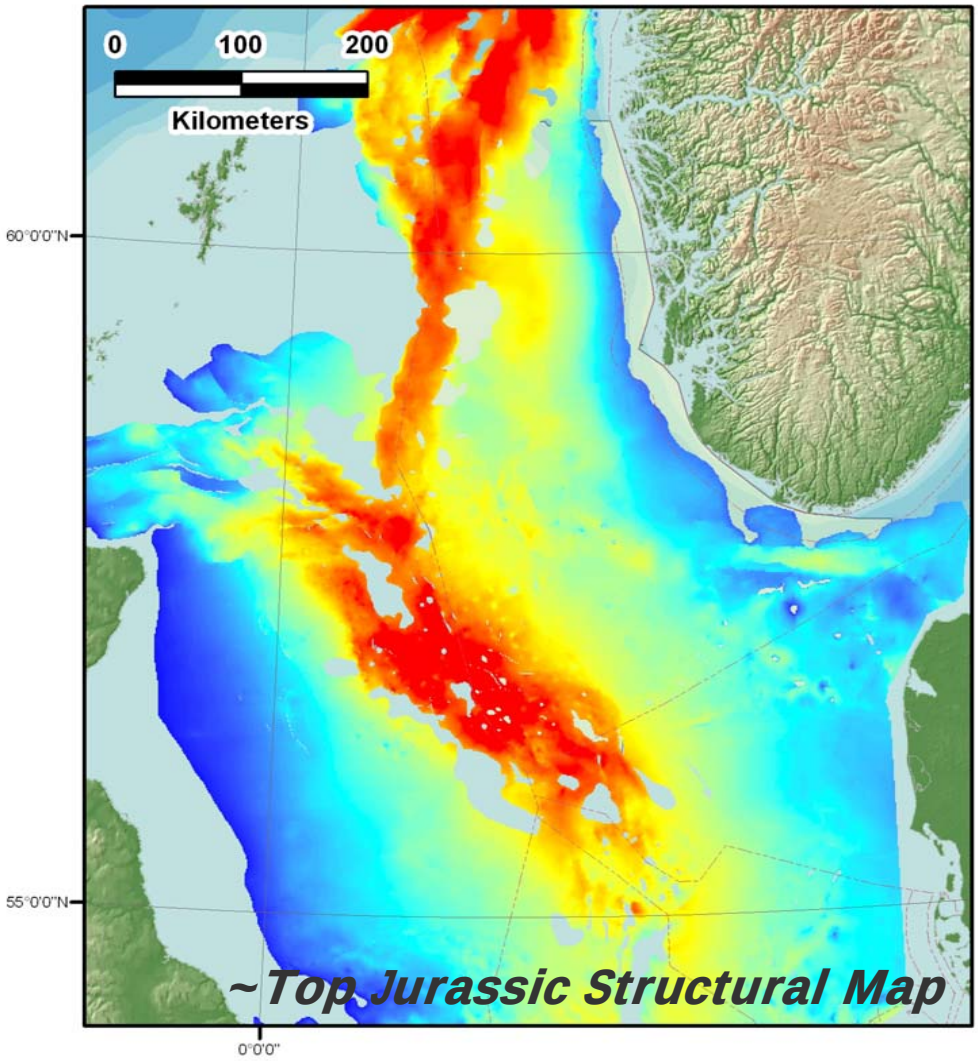
A total of 23 reservoir-seal pairs (saline formations) and 83 fields, have been evaluated

Saline Formations

- Good quality opportunities widespread throughout the AOI
- Most viable opportunities found in the Jurassic and Tertiary
- No capacity estimations performed, but gross rock volumes suggest potentials

Abandoned Fields

- Highest potential will be assessed if further evaluation is prioritised



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Storage fundamentals and next phase

Two main CO_2-storages categories

- Part of a development; storage close to installations (abandoned field, small saline formation)
- Storage stand-alone; storage in best available geological formation (large saline formation)

Preferred reservoir characteristics

- Widespread, homogeneous sandstone-bodies with adequate qualities at favoured depth
- Well defined and high-quality cap-rock

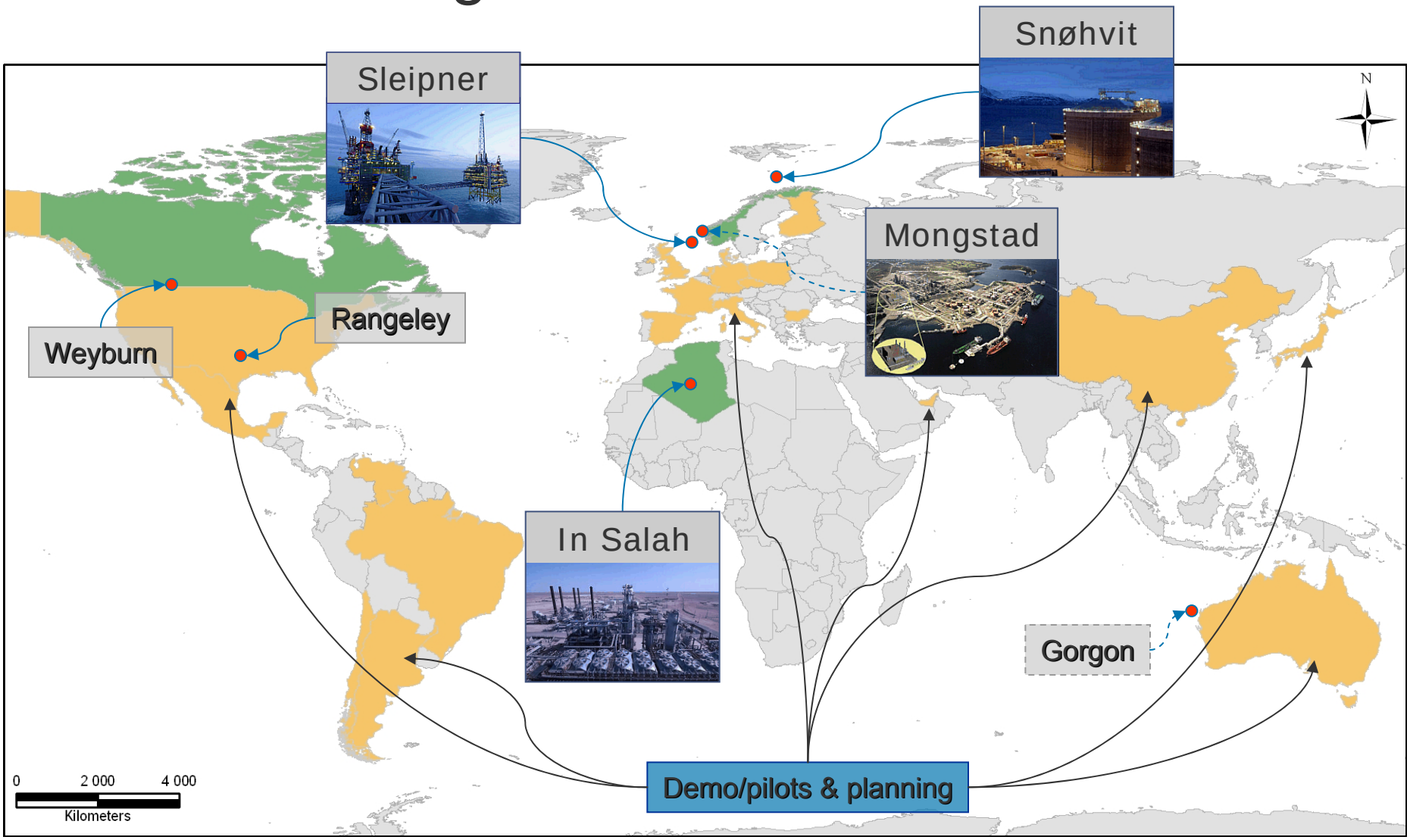
Storage safety

- Utilize operating experience and R&D initiatives
- Select best suitable site will allow sound and secure storage

Next phase

- Characterise and “prospect evaluate” high ranked opportunities
- Prepare technical basis for a storage exploration license application to authorities
- Further assess risks and uncertainties using experience from own operations
- Follow designated studies on sealing capacity (CO2Seal)

Full scale storage sites of the world



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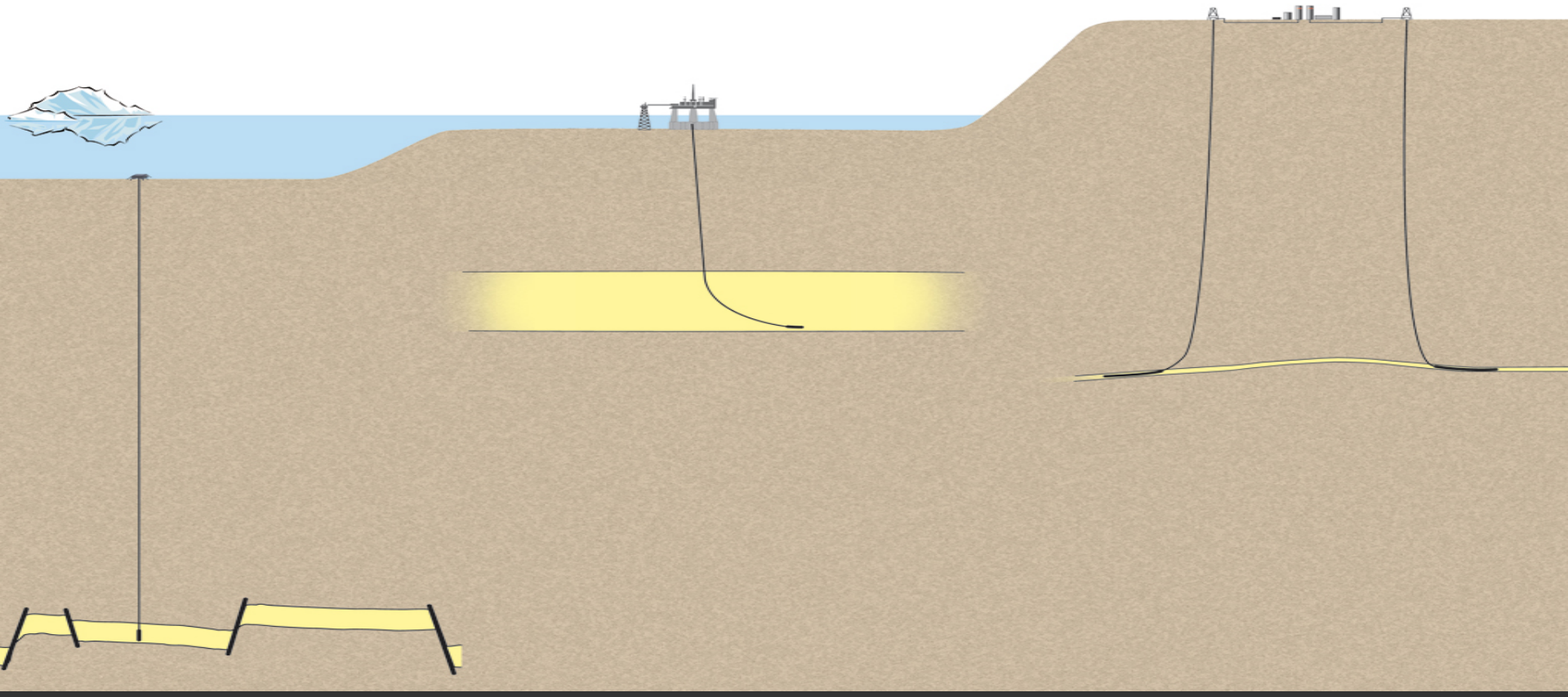
Storage site settings

Snøhvit (Barents Sea)

Sleipner (North Sea)

In Salah (Algeria)



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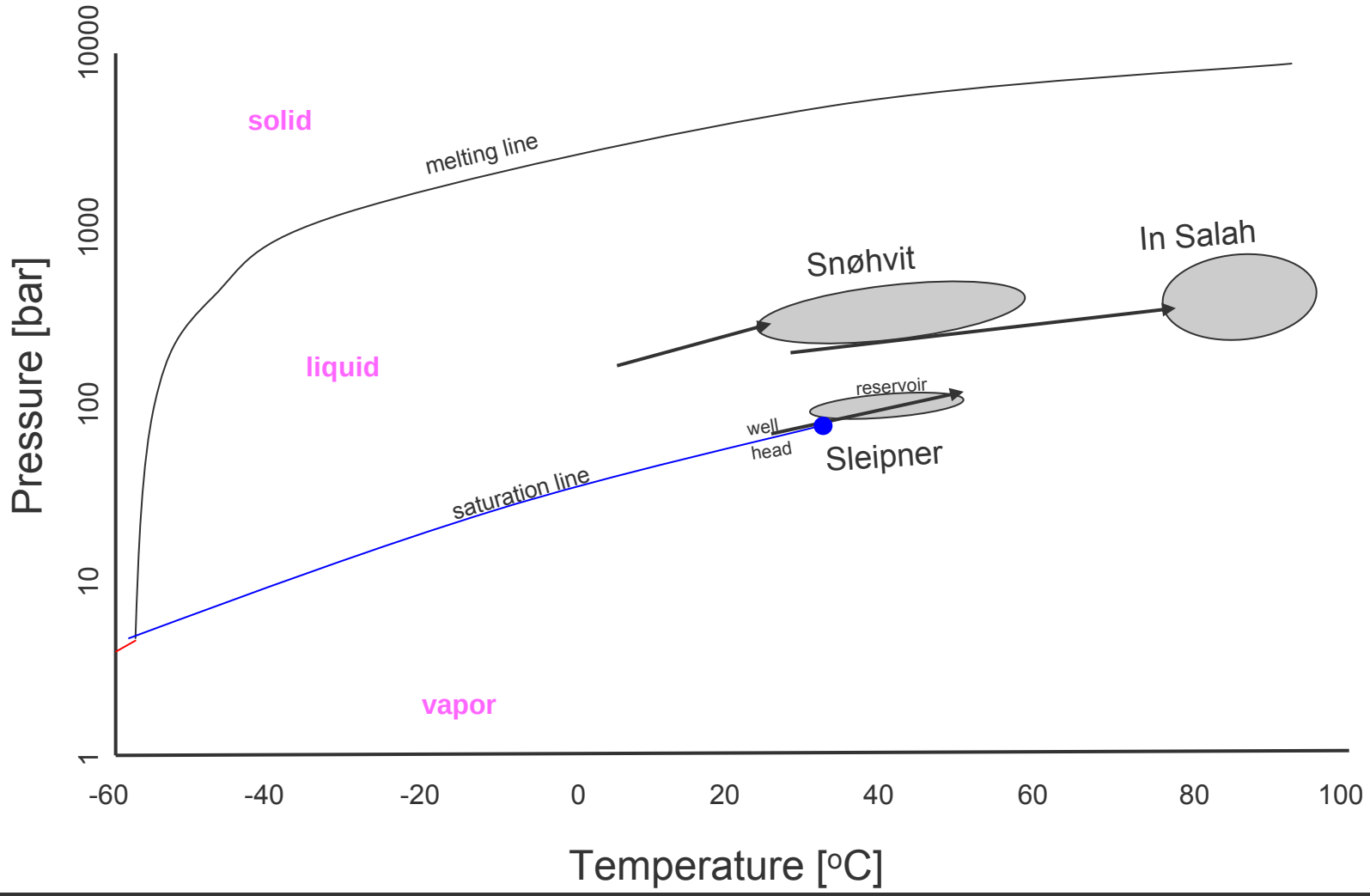
Injection conditions – pressure/temperature



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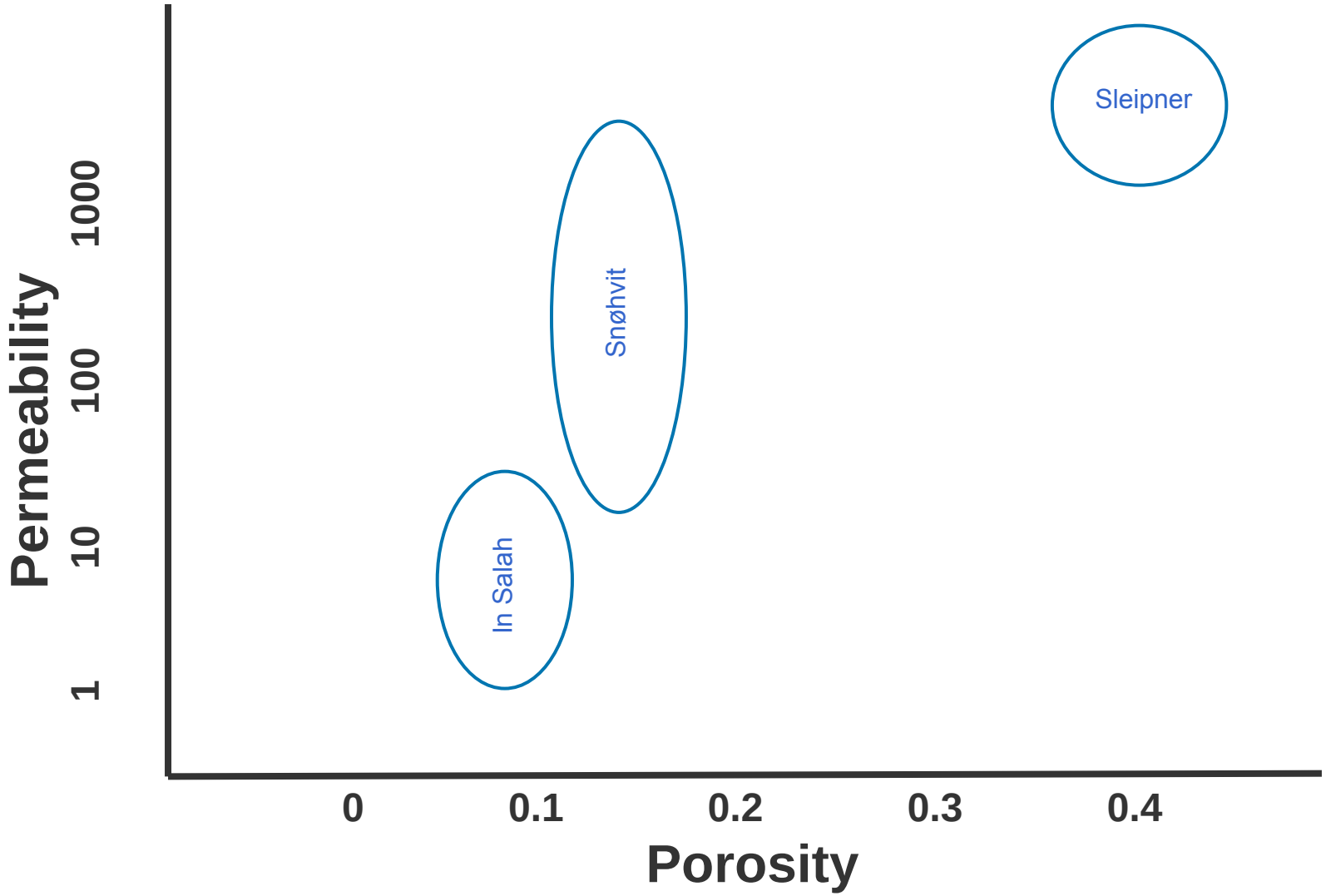
Injection conditions – porosity/permeability



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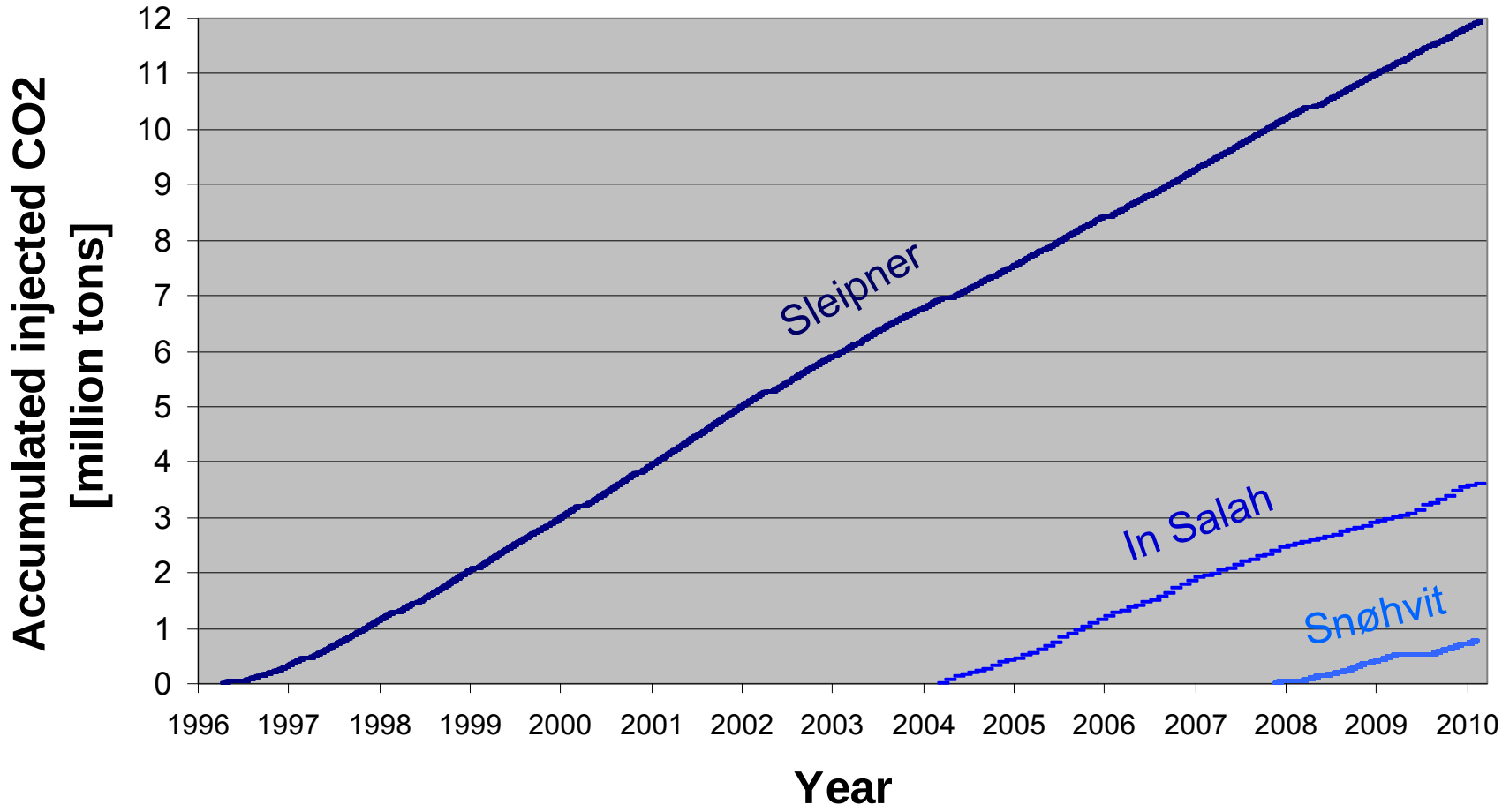
Injected CO_2 volumes



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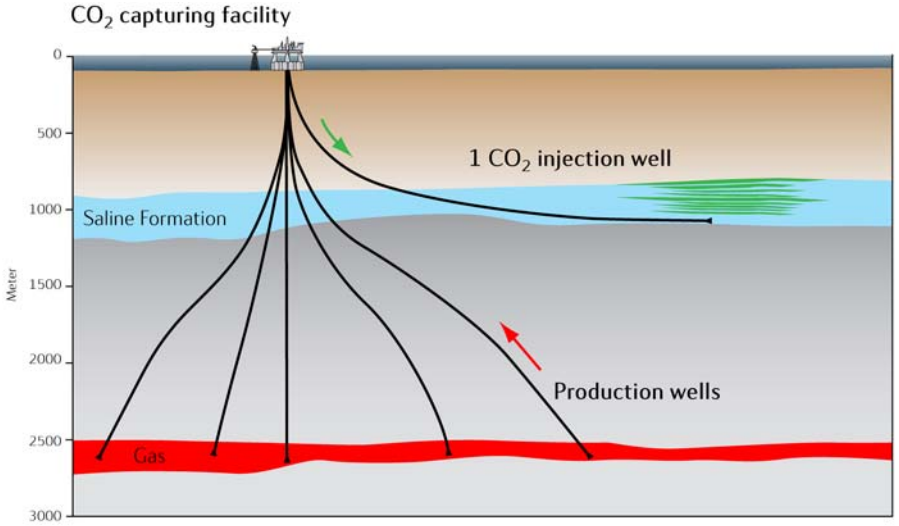
Sleipner (Utsira Formation) – Norway

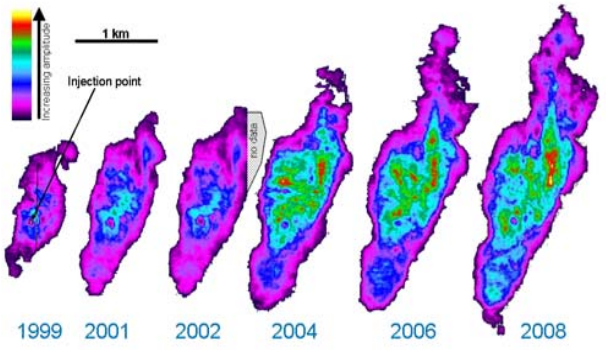
Statoil (58% & operator), ExxonMobil (32%) and Total (9%)

Storage Concept

- CO_2 captured from NG stream at Sleipner field (9% CO_2)
- Started in 1996 (amine capture offshore)
- Injected gas ~98% CO_2
- Wellhead pressure stable at 64-65 bar
- CAPEX ~770 MNOK (1996)
- ~12 MT injected (1996-2010)



Gained experiences



4D seismic CO_2 plume in map view

- Development of monitoring techniques, including time-lapse (4D) monitoring (figure above)
- CO_2 injection into a good quality reservoir
- 100% offshore operation
- “Research laboratory” to prove CCS

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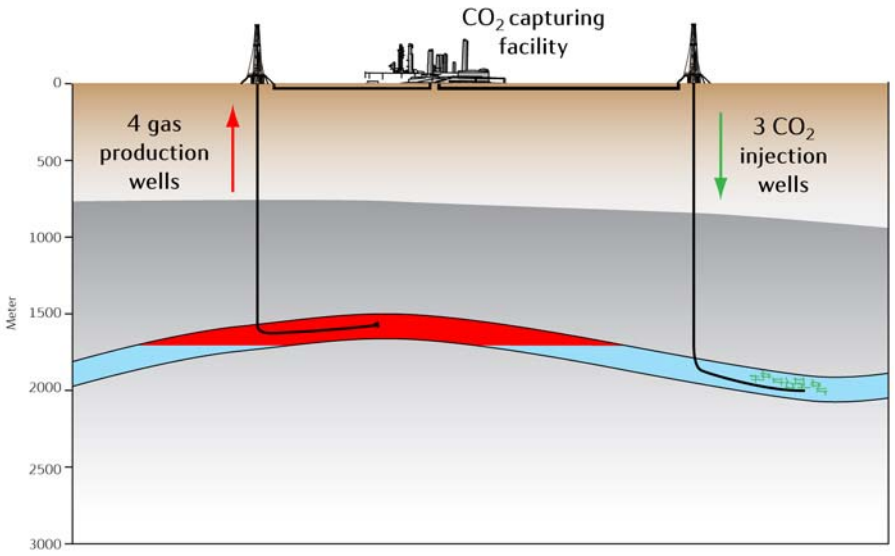
In Salah (Krechba field) – Algeria

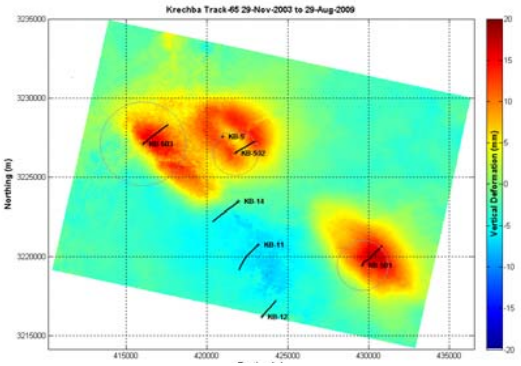
Joint Venture (Statoil, Sonatrach and BP)

Storage Concept

- CO_2 from fields (5-10% CO_2) in the *In Salah* Natural Gas development
- Started in 2004 (amine capture)
- Long-reach wells (up to 1800m horizontal sections)
- Initial pressure : 180 bars
- ~3 MT injected (2004-2010)
- CAPEX ~ US$100 million (2004)



Gained experiences



Satellite monitoring for pressure

- Investigation of a number of monitoring techniques
  - Satellite InSAR surveys
  - Time-lapse seismic
  - Wellhead measurements
  - Observation wells
  - Surface measurements
- CO_2 injection into a fractured low permeability reservoir
- Onshore operation in the Sahara

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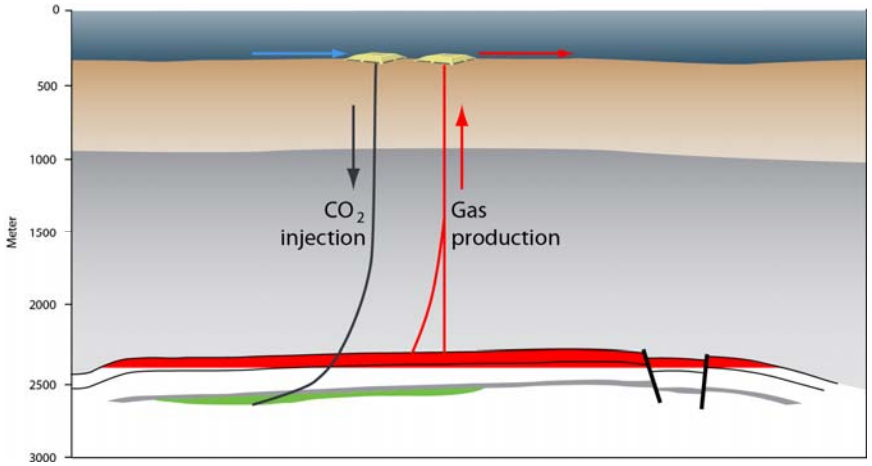
Snøhvit (Tubåen Formation) – Norway

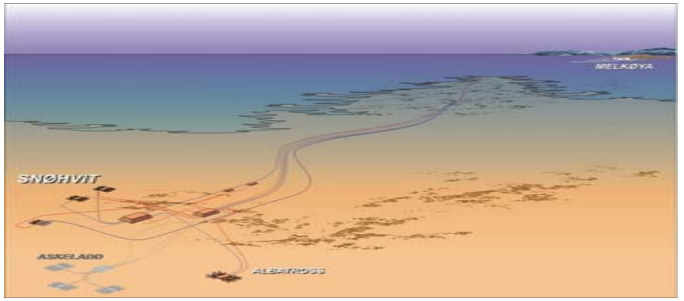
Statoil (34% & operator), Petoro (30%), Total (18%), GDF Suez (12%), Hess (3%) and RWE Dea (3%)

Storage Concept

- CO_2 from the Snøhvit field (5 - 8% CO_2) LNG development
- Started in 2008 (amine capture onshore at Melkøya)
- Initial pressure: 290 bar (Tubåen)
- ~0,7 MT injected (2008-2010)
- CAPEX ~1,7 BNOK (2009)



Gained experiences



Sub-sea transport and storage

- Sub-sea development including 152 km long CO_2 pipe
- CO_2 injected into a saline formation below hydrocarbon zone with moderate reservoir quality
- Sub-sea (storage) and onshore (capture and compression)
- Challenging reservoir (injection)

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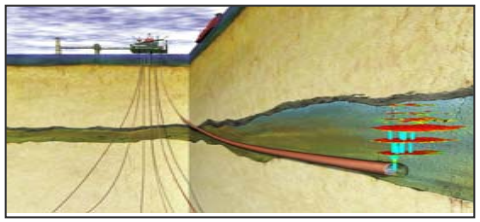
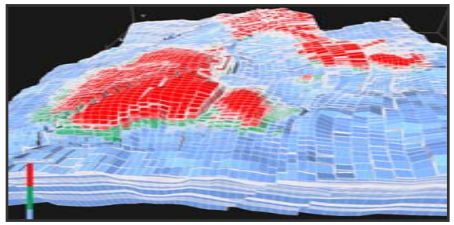
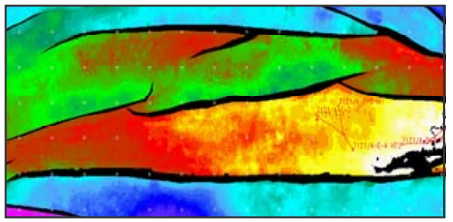
CO_2 storage - experiences

- Highly variable and complex reservoirs - good injectability
- Surface geophysical and well pressure monitor data give key information on the storage behaviour.
  - Dynamic modelling to match the data challenging.
- Plume development has been strongly controlled by geological factors.
- High-quality monitoring data key to leakage detection.
  - Sleipner and Snøhvit 4D seismic monitoring of sufficient quality to confirm no leakage into the overburden.
  - At In Salah, In SAR data valuable in monitoring pressure distribution.
- Detailed site specific knowledge – increase storage capacity







Closing remarks

- We foresee, and will participate in a **future business** within CO_2-storage
- We are assessing both **abandoned fields** and **saline formations**
- We allow **flexibility to assess** sites outside the North Sea Basin
- We welcome a regulatory framework that provides a **predictable framework**
- We focus on **safe** and **sound** storage
- We appreciate an international agreed **code of conduct**
- We see the essential, and welcome all efforts in bridging the gap between cost and value (including CO_2 price) as **conditions for commercialisation**

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Thank you

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