CSLF International Workshop on CSLF Projects,

Potsdam 29 September 2005

The CO2STORE project – Status

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The Sleipner field – CO_2 Treatment and Injection

CO2STORE participants

Statoil (coordinator)
BP Exploration
Energi E2
ExxonMobil
Hydro
Industrikraft MidtNorge
Progressive Energy
Schlumberger Research
Total
Vattenfall

BGR
BGS
BRGM
GEUS
IFP
NGU
NITG-TNO
SINTEF

European Commission
IEA Greenhouse Gas R&D Programme

CO2STORE – the work packages (1)

Work Package 1 – Transfer

- Expected results: Conclude on the feasibility of four new prospective reservoirs for CO_2 storage and to transfer knowledge gained for Sleipner to these case studies
- WP leader: GEUS
  - Case: Kalundborg (GEUS)
  - Case: Midt Norge (NGU)
  - Case: Schwarze Pumpe (BGR)
  - Case: Valleys (BGS)

Work Package 2 – Long Term

Expected results : Models backed by observations for final-fate prediction of CO_2 in the Utsira reservoir (Sleipner)

- WP Leader: SINTEF
  - Team 1: Geochemistry (BRGM)
  - Team 2: Reservoir Simulation (SINTEF)

CO2STORE – the work packages (2)

Work Package 3 – Monitoring

- Expected results: Analyze two seismic surveys (2002 and 2005) and conclude on the feasibility of more cost-efficient gravimetric techniques
- WP Leader: NITG-TNO
  - Team 1: Seismic (NITG-TNO)
  - Team 2: Gravimetry (Statoil)

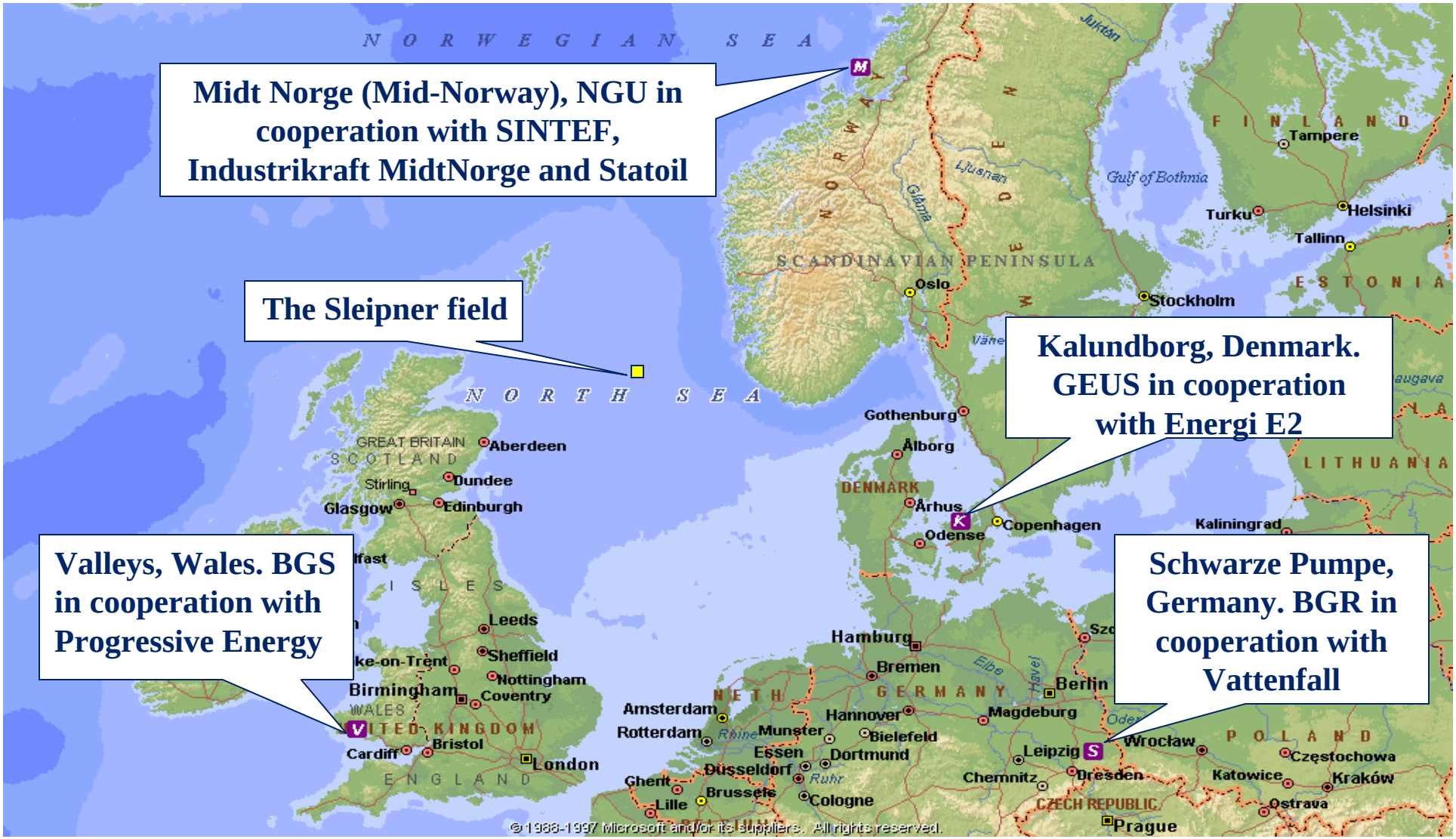
Work Package 4 – Management

- Expected results: Updated Best Practice Manual and other public documentation for dissemination of the technology
- WP leader: Statoil
  - Team 1: Reporting (Statoil)
  - Team 2: Best Practice Manual (BGS)

Risk assessment work in CO2STORE

- According to Description of Work for CO2STORE, all 4 case studies in Work Package 1 shall produce ”Outline risk assessments (FEP and scenario analysis)”
- Case Studies have chosen somewhat different approaches based on local conditions
  - Risk assessment ←→ Potential risks
- Common for all work packages: One day seminar/technical meeting autumn 2004
- Risk assessment work is still ongoing and conclusions are preliminary

CO2STORE – the case studies



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CO2STORE – the case studies

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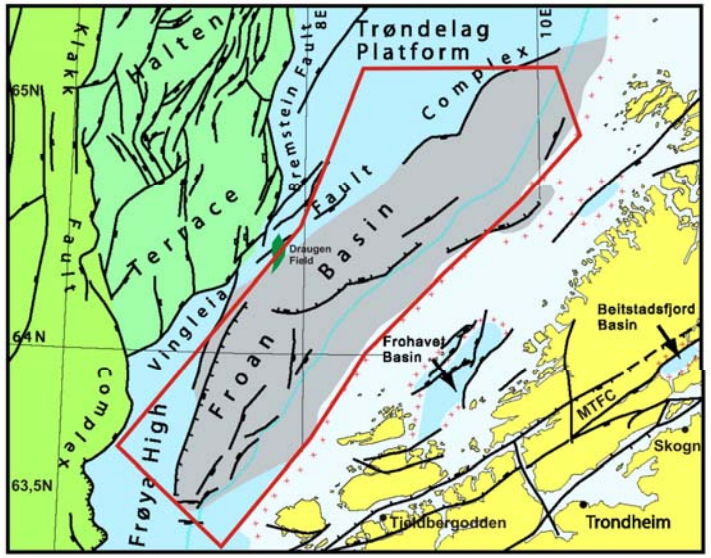
Froan Basin area of the Trøndelag Platform



None of the simulations with up to 100 Mt injected CO_2 resulted in any leakage over periods of 5000 years

Most of the CO_2 was trapped in subtle structural traps

Dissolution of CO_2 into formation water and trapping as residual gas will aid local fixation of the CO_2

The overall storage potential of the Jurassic formations of the Trøndelag Platform is estimated to be several 1000 Mt

Seismic data indicate that there will be no CO_2 leakage to the seabed along faults

More data is needed for a detailed risk analysis

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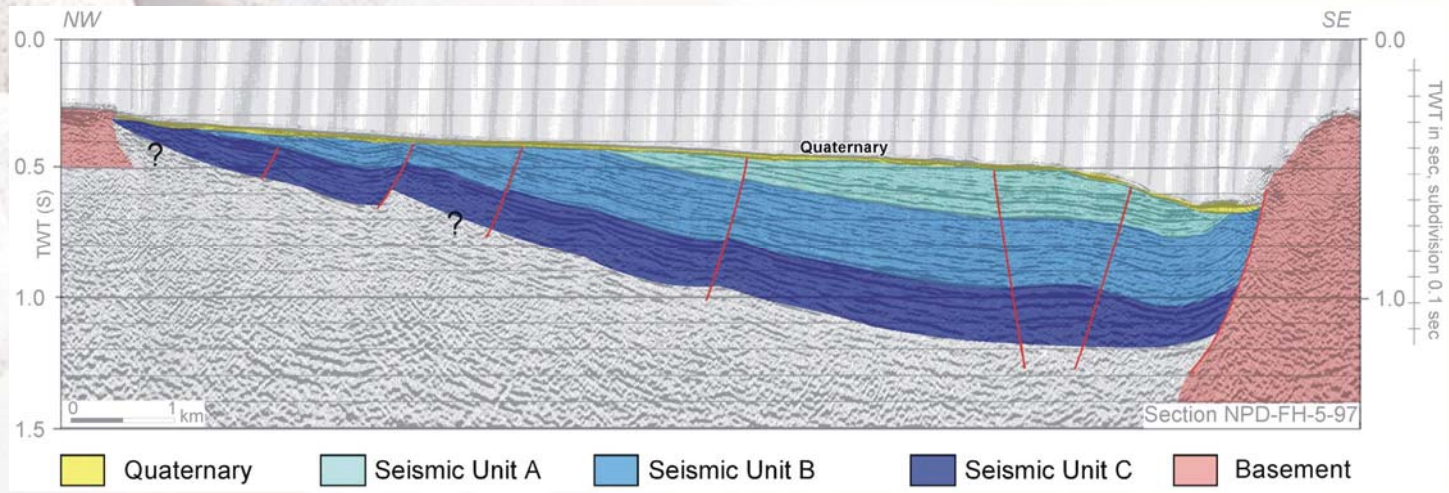
Frohavet Basin



CO_2 will start to leak after few years if reservoir permeability is high, if the k_v/k_h ratio is high, or if the relative perm. to gas is high.

If these parameters are low, no leakage may occur for several centruries, and thereafter leakage rates may be acceptable.

In the case of very good parameter combinations, no leakage at all may occur.

The Frohavet Basin may be an option for CO_2 storage.

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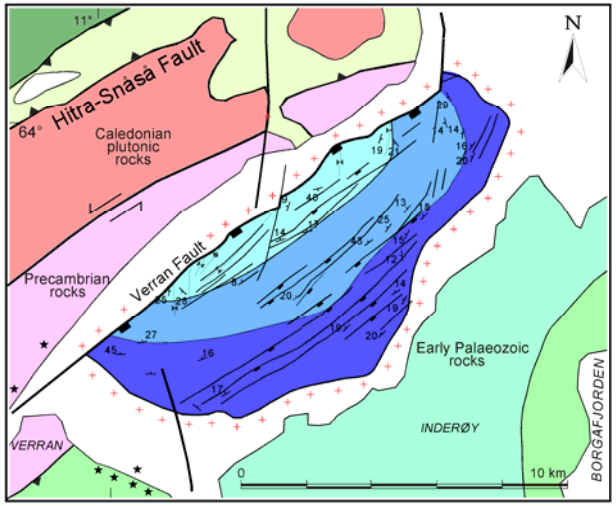
Storage capacity needed for a gas-fired power plant at Skogn

50 million tonnes CO_2 over a period of 25 years, i.e. 2.9 millioner Sm^3 CO_2 per day



Structural data modified from Bøe & Bjerkli (1989)

Beitstadfjorden Basin

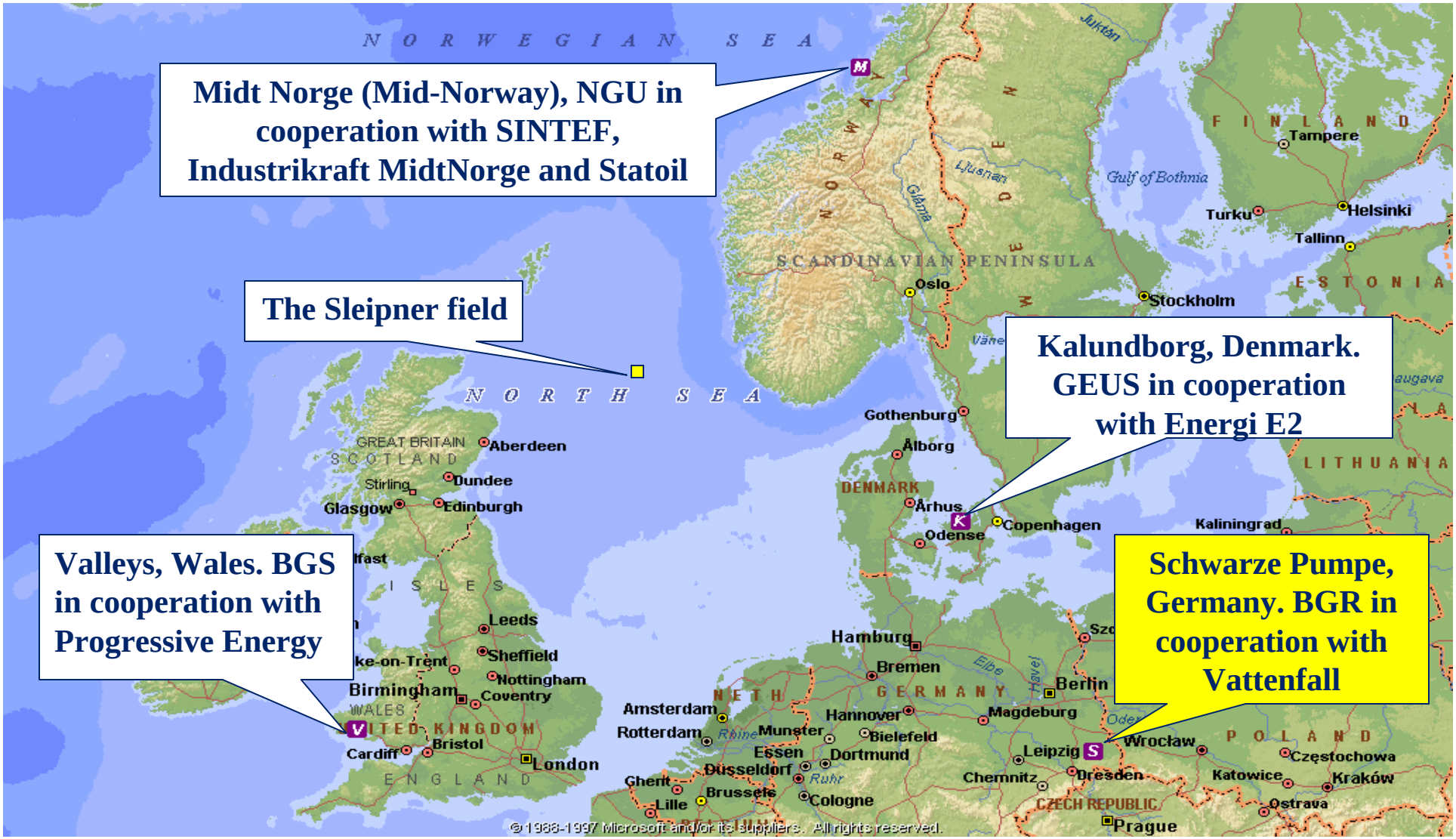
CO_2 will start to leak after few years of injection
If leakage starts after 4 or 40 years depends on permeability

A maximum of ca. 70 000 tonnes CO_2 can be stored in the Beitstadfjord Basin

The Beitstadfjord Basin is not an option for CO_2 storage

SINTEF

CO2STORE – the case studies



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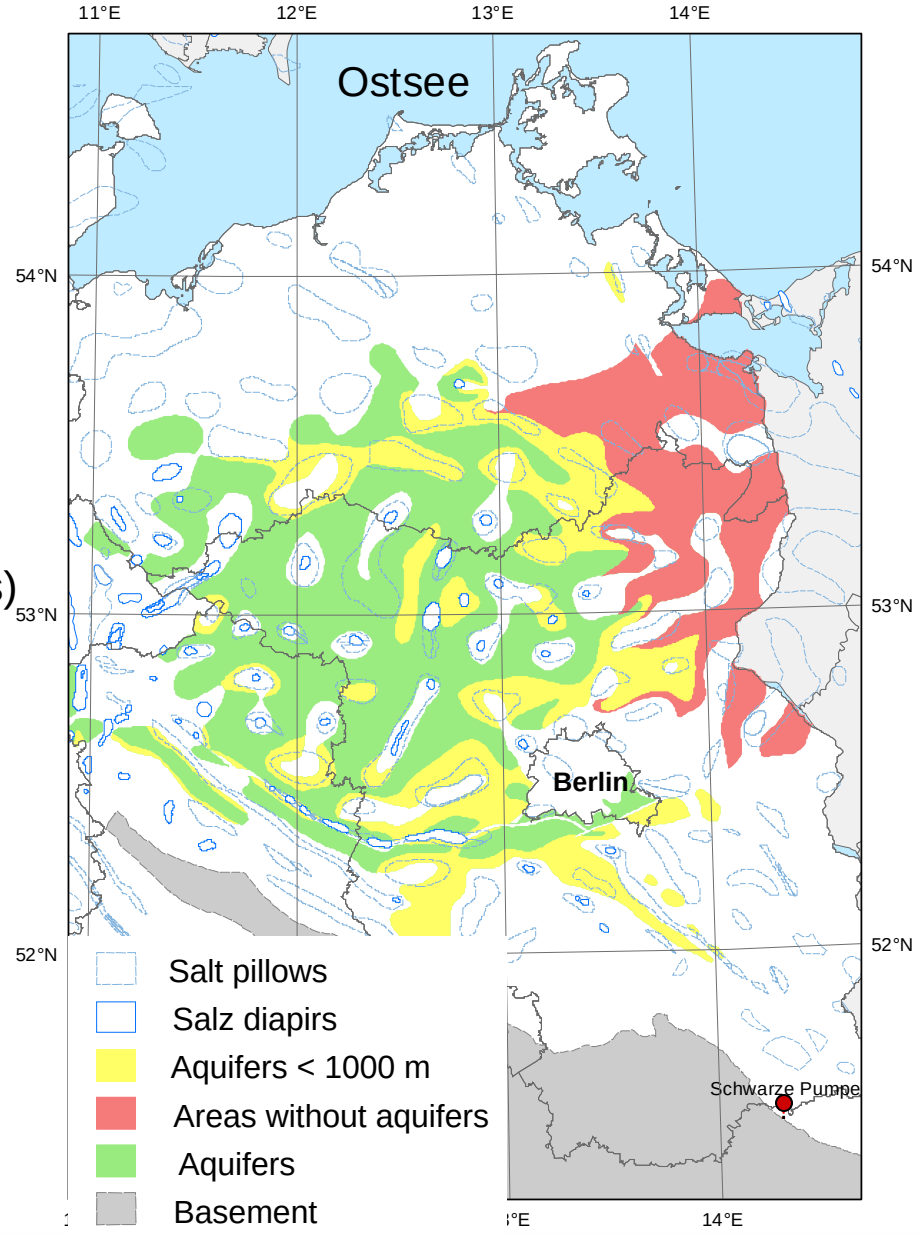
Implementation of Site Selection

- Systematic, area-wide application of site selection criteria
- Focus on anticlines/structural traps
- Calculation of storage capacity
- Ranking (geology, data availabilty, others)
    - Selection criteria:
        - Structural closure
        - Suitable cap rock
        - Depth: 900 to 4000 m
        - Storage capacity 400 Mt
        - Single site/layer
        - Thickness of reservoir > 20 m
        - Porosity > 20%



Available Data…

- Sound data set available from several surveys:
  - Exploration for hydrocarbons (60^{th} – 80^{th})
  - Hydrothermal energy survey (80^{th})
  - Nuclear waste repository

- Well data (60^{th} – 80^{th})
- Geophysical surveys (2D seismic, gravimetry, magnetotelluric (60^{th} - 70^{th})

Summary:

- area-wide sound knowledge of geological framework
- Data from former surveys: formation boundaries, lithotypes, facies, …
- no new seismic shot / no new wells drilled…

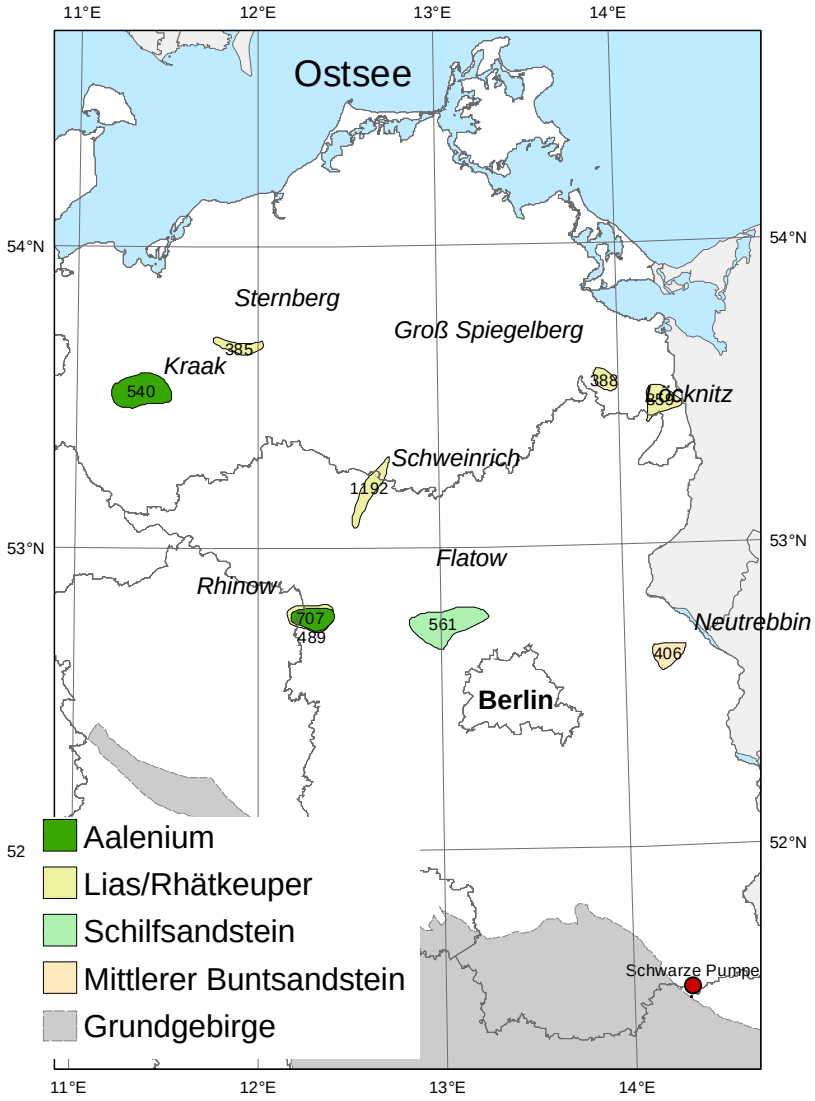
Findings from Site Selection

- 9 (26) potential storage sites

  ⇒ **Schweinrich**

- area-wide sound geological/geophysical dataset for site selection and site pre-evaluation
- data with variable quality standards dependent on state-of-the-art (60^{th}/70^{th}/80^{th})
- great number of structures “more or less” well explored (penetrated/unspoiled)

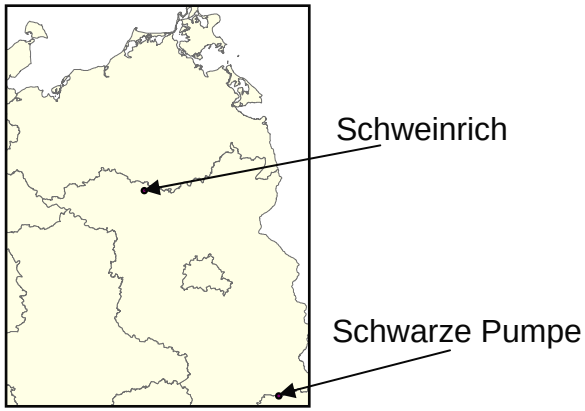
⇒ **no problems conducting the site selection**

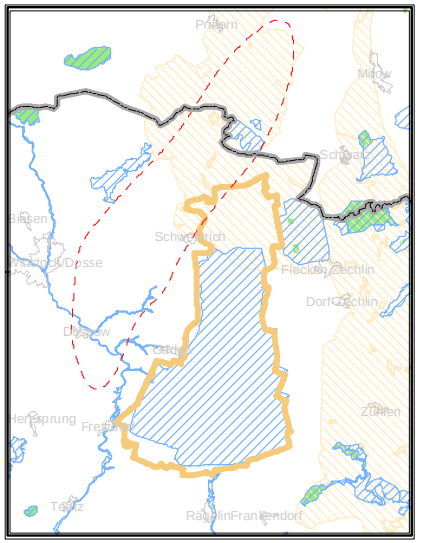


Study area and method

- The Schweinrich site in NE Germany

- Method
  - a scenario approach using the TNO developed FEP database
  - Reservoir modelling of selected scenarios
  - Results compared to environmental effect levels





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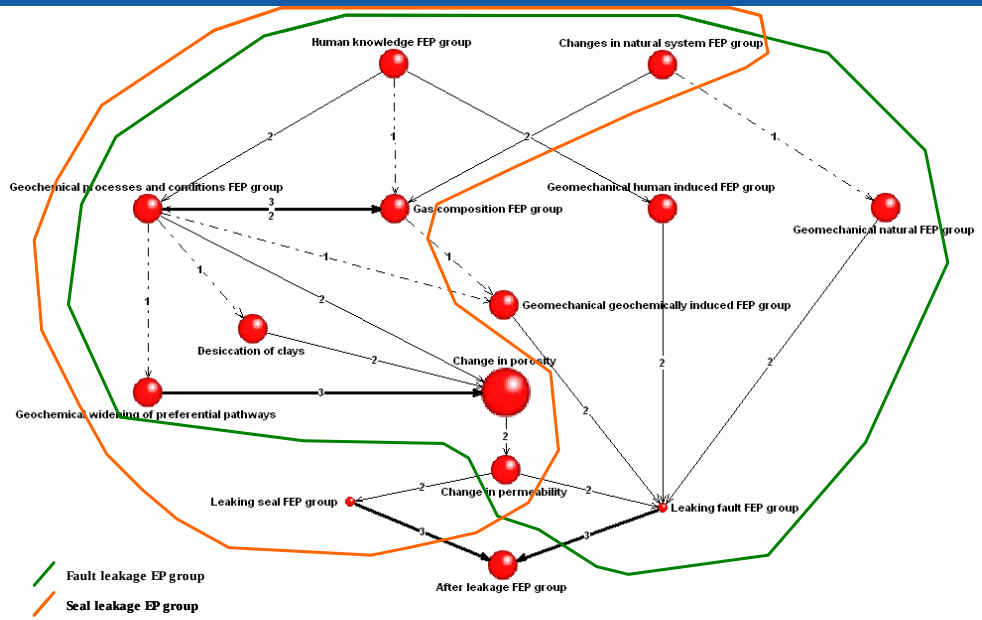
FEP analysis results and evaluated scenarios

FEP analysis

- No pre-existing wells
  - Leakage through drilled injection wells
- Two leakage possibilities
  - Leaking fault
  - Leaking seal

Evaluated scenarios

- Reference scenario
- Leaking fault
- Leaking seal
- Leaking well



Influence diagram with scenario defining EP groups

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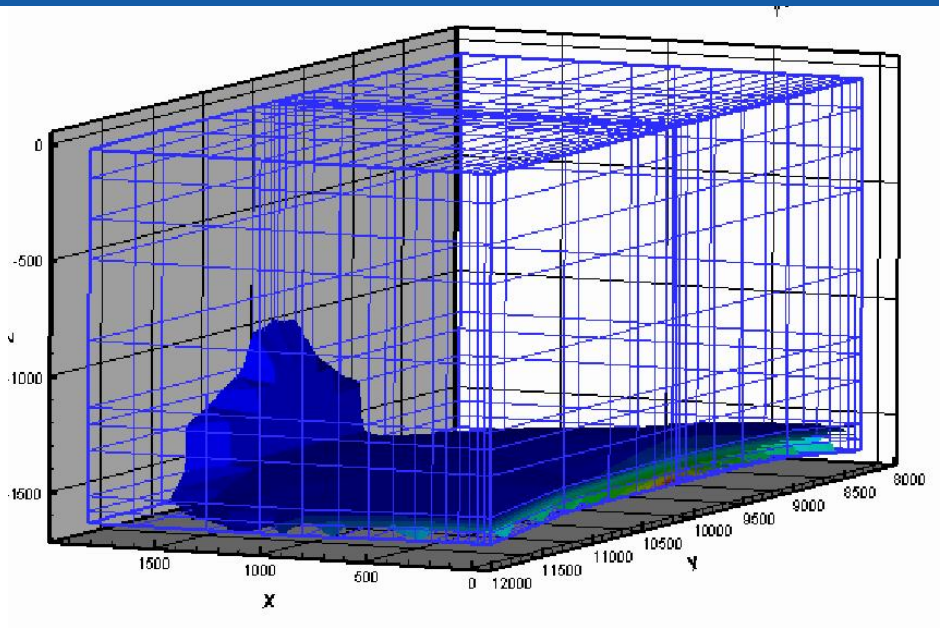
Modelling example and results

- Models have been developed in SIMED II
- Modelling ongoing
- Shallow subsurface will be developed
- Commonly accepted criteria for risk assessment do not exist. In the mean time, levels above which no adverse effects have been detected are used.



Leaking fault model

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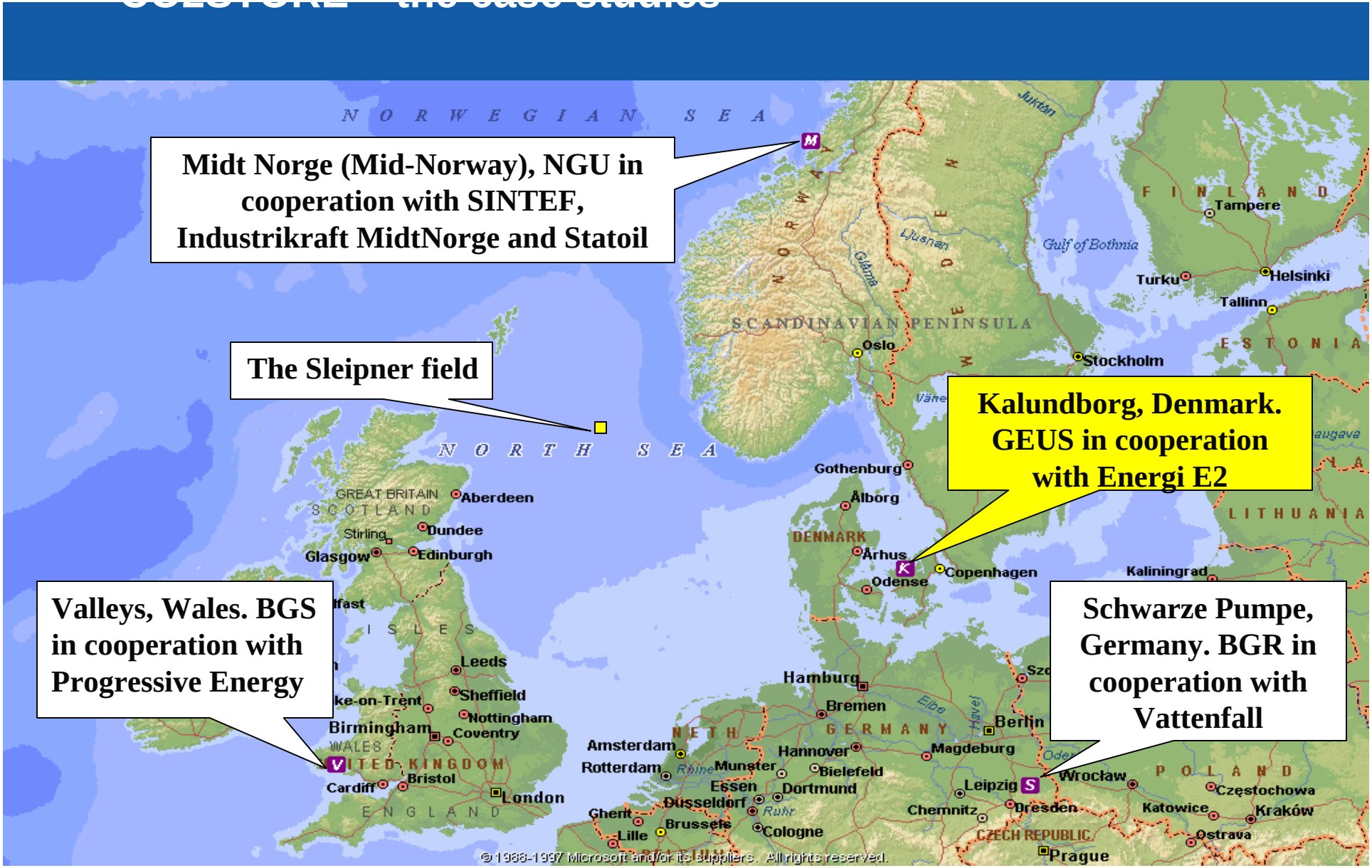

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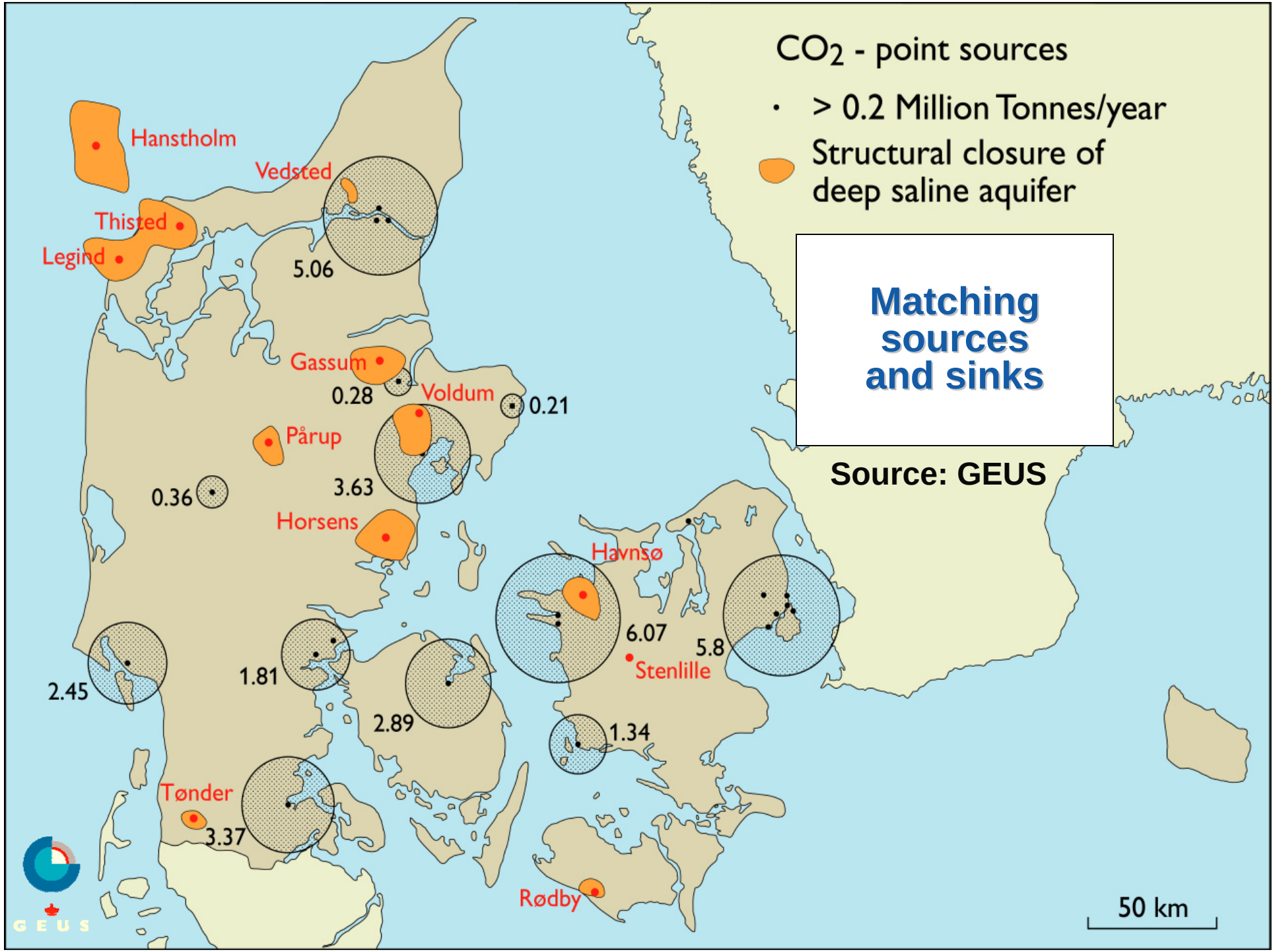
The Havnsø CO2 Storage system

- **Statoil Kalundborg refinery +**

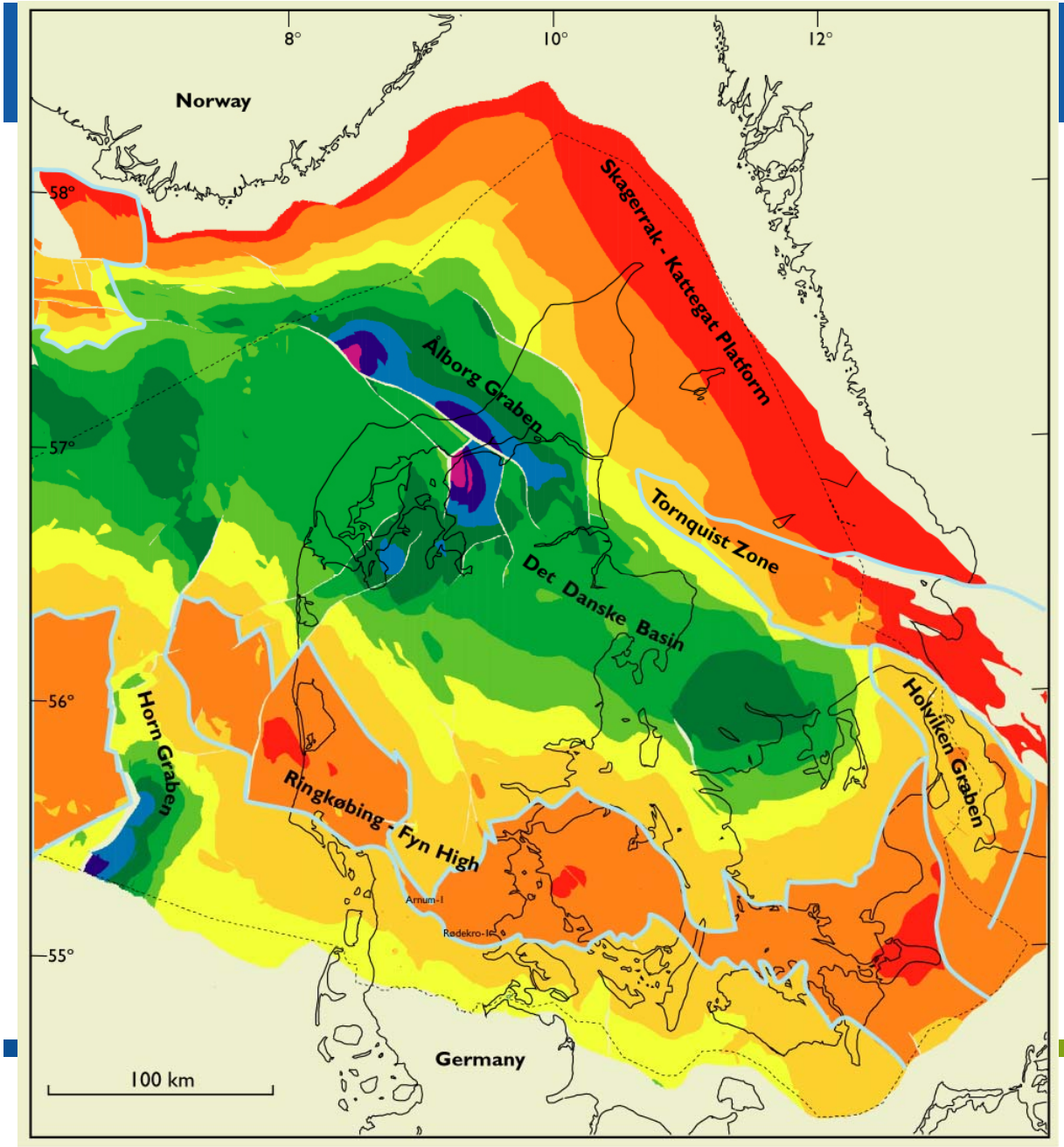
Asnæsværket 1300 MW coal fired power plant operated by Energi E2

- **CO2 emissions combined about**

6 Million Tonnes/year, almost 10% of the total Danish emissions


CO_2 - point sources
> 0.2 Million Tonnes/year
Structural closure of deep saline aquifer
Matching sources and sinks
Source: GEUS
Hanstholm
Vedsted
Thisted
Legind
5.06
Gassum
0.28
Voldum
0.21
Pårup
0.36
3.63
Horsens
Havnsø
6.07
5.8
Stenlille
2.45
1.81
2.89
1.34
Tønder
3.37
Rødby
50 km
GEUS

Danish sedimentary basin



Sedimentary succession up to 7 km thick of Palaeozoic to Recent age

Deep saline aquifers of Triassic–Early Cretaceous age

Potential for CO_2 storage in aquifers situated 900–3000 m below sea-level

Potable water production from Upper Cretaceous Chalk and shallow Tertiary and Quaternary aquifers

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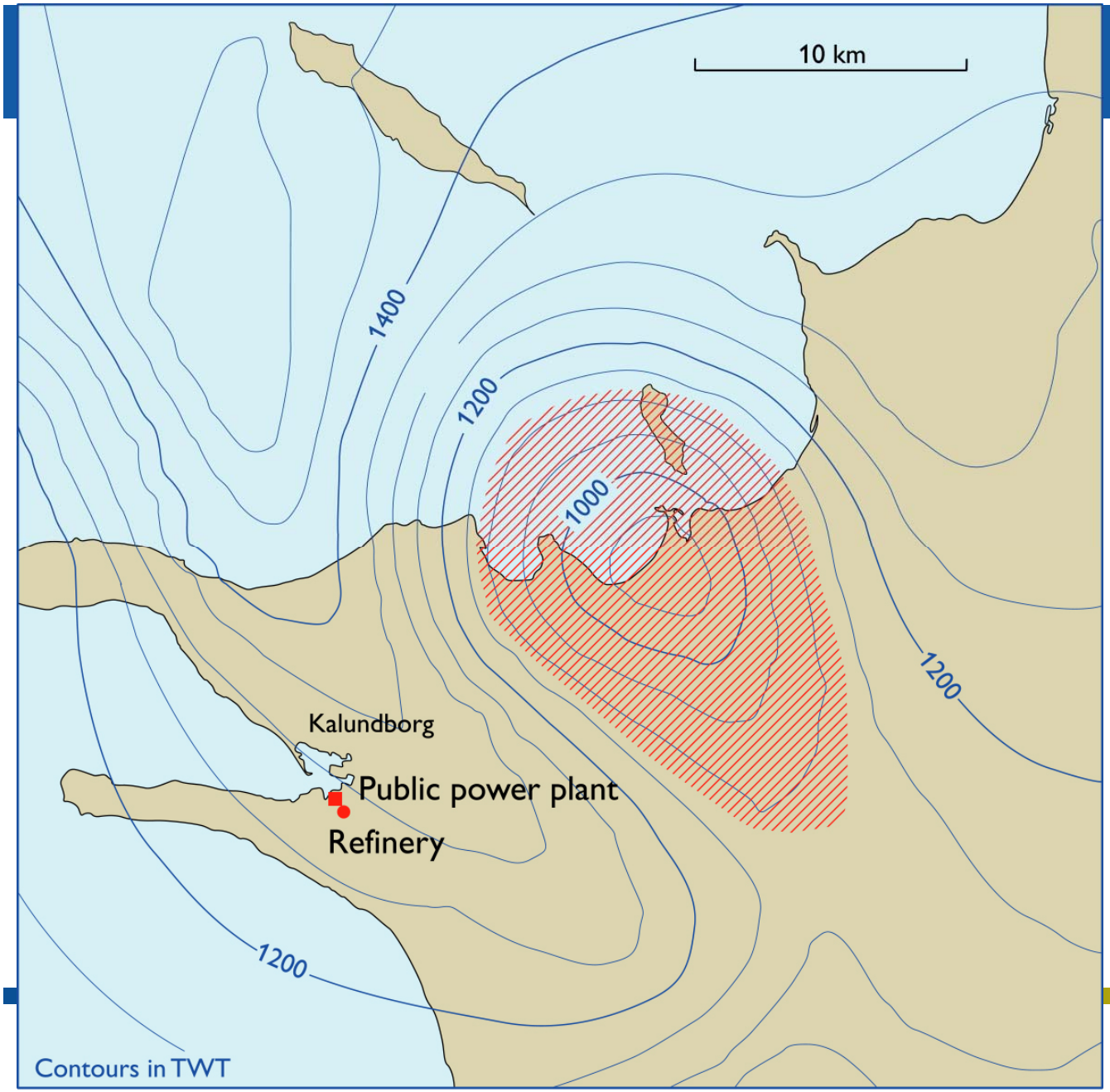
Structural map of the trap



Four-way domal closure covering 166 km²

Depth to the top of the sandstone aquifer is 1500 m

Two major CO_2 point sources situated within a distance of 15 km

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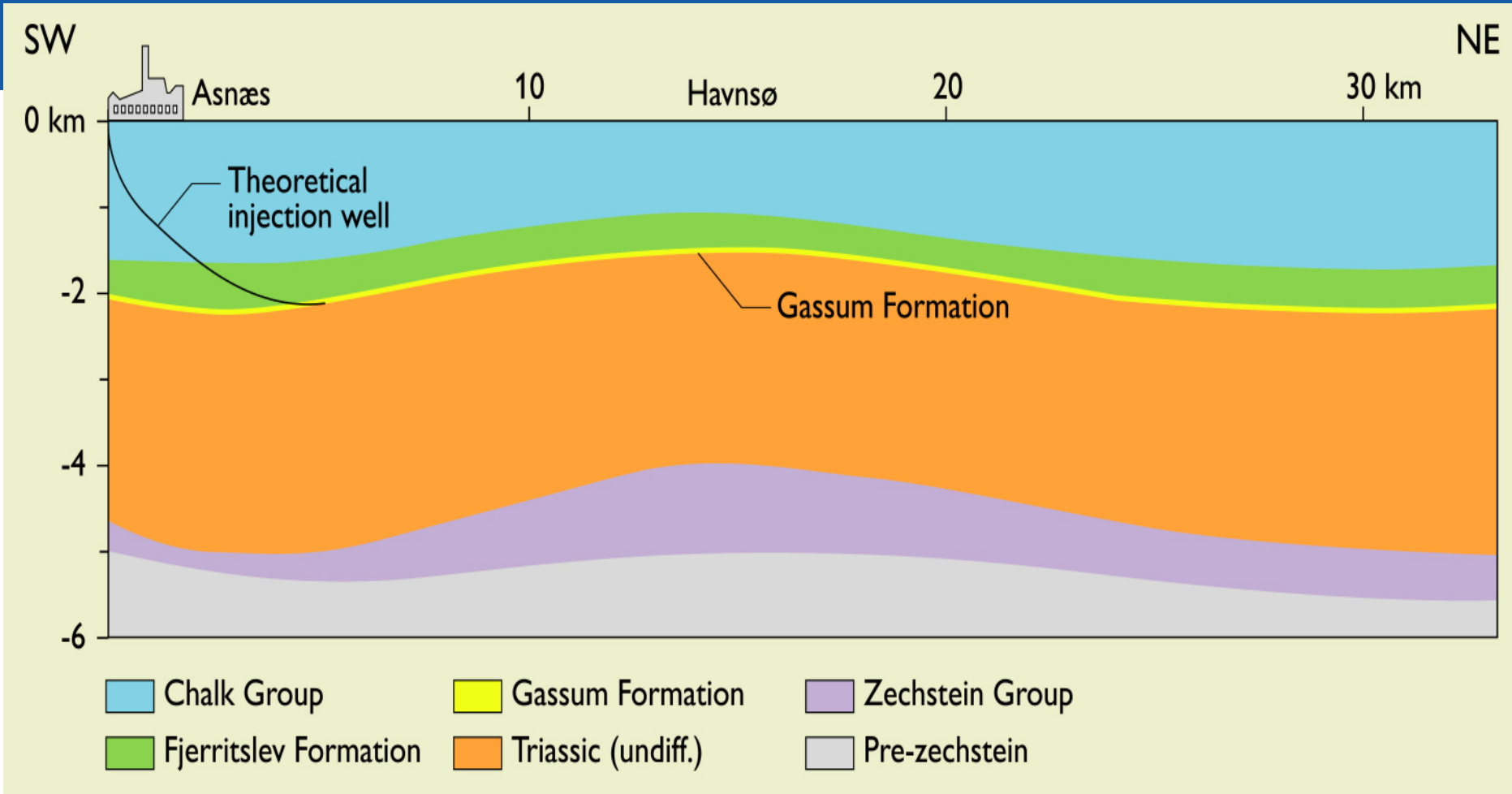
Geological cross-section



Main reservoir in marine Upper Triassic–Lower Jurassic sandstones of the Gassum Formation, sealed by marine mudstones

Theoretical injection well may be drilled from the industrial site into the flank of the structure

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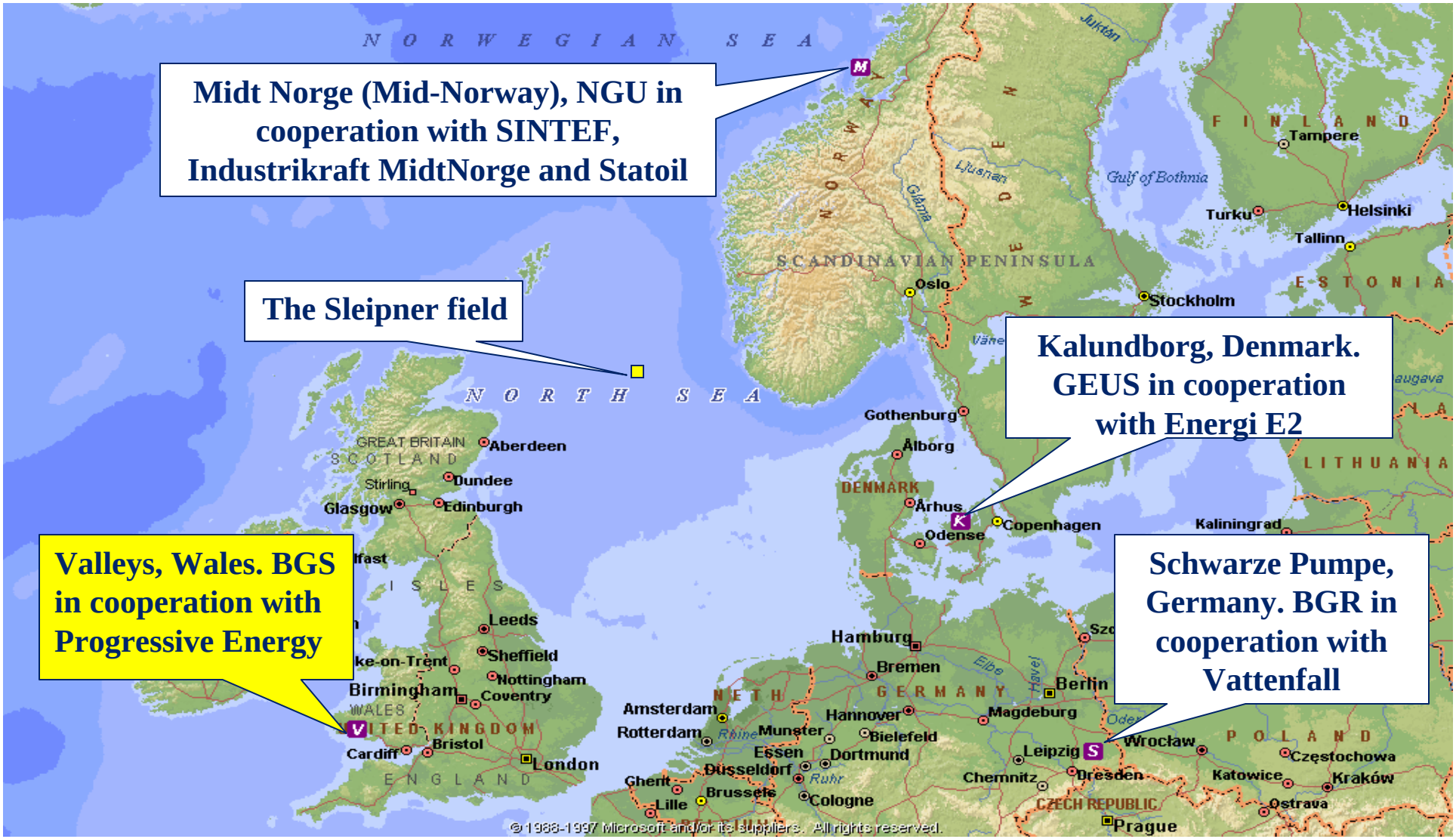
CO2STORE – the case studies



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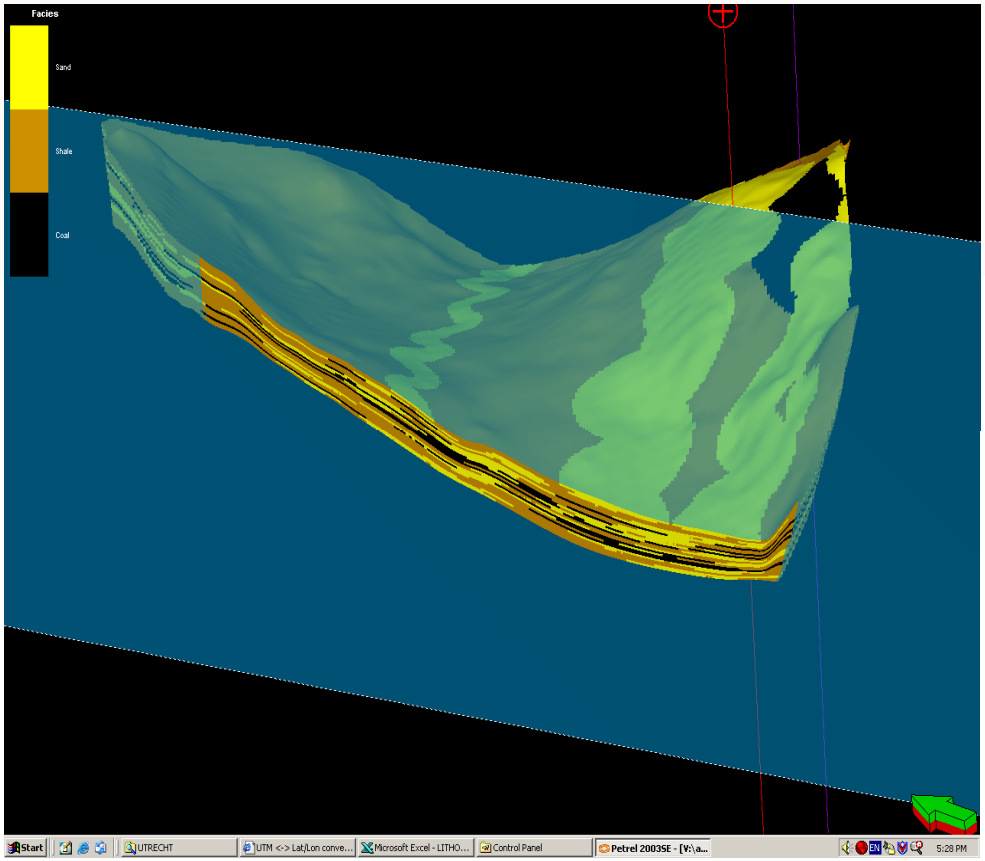
Valleys Case Study

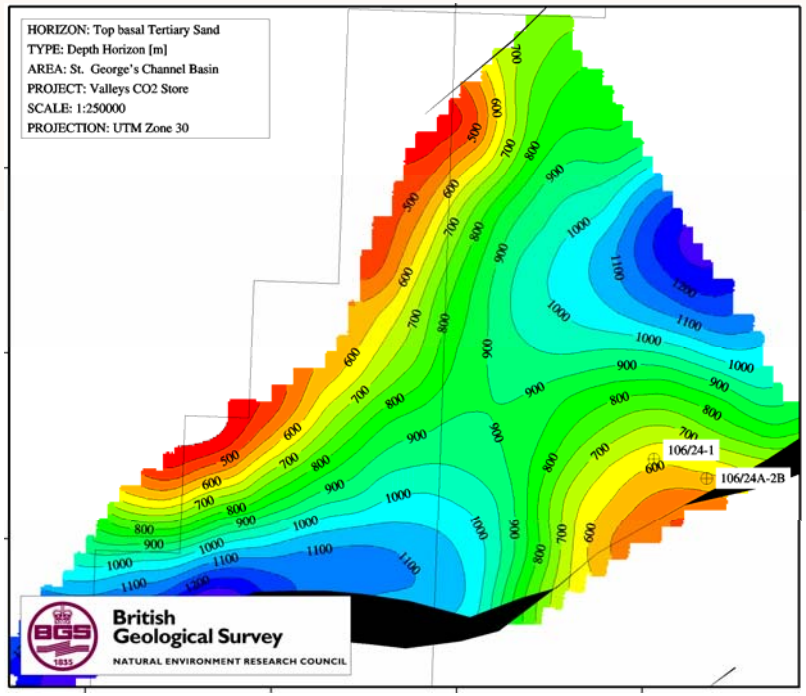
- Methodology:
  - Use FEP approach - Quintessa FEP database
- Main perceived risks:
  - Reservoir distribution
  - Fault seal at crest of storage structure
  - Existing wells
  - Top seal

Reservoir distribution



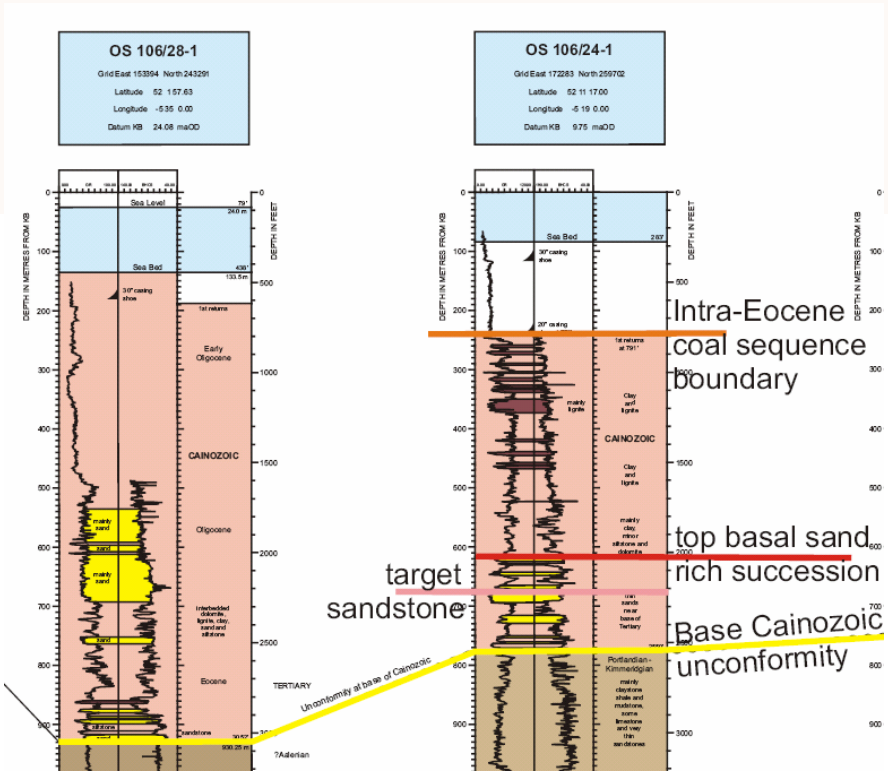
- Fluvial depositional environment
- Petrel model based on well data
- Uncertainty over sand distribution and continuity
- Difficult to resolve without drilling

Fault seal at crest of structure



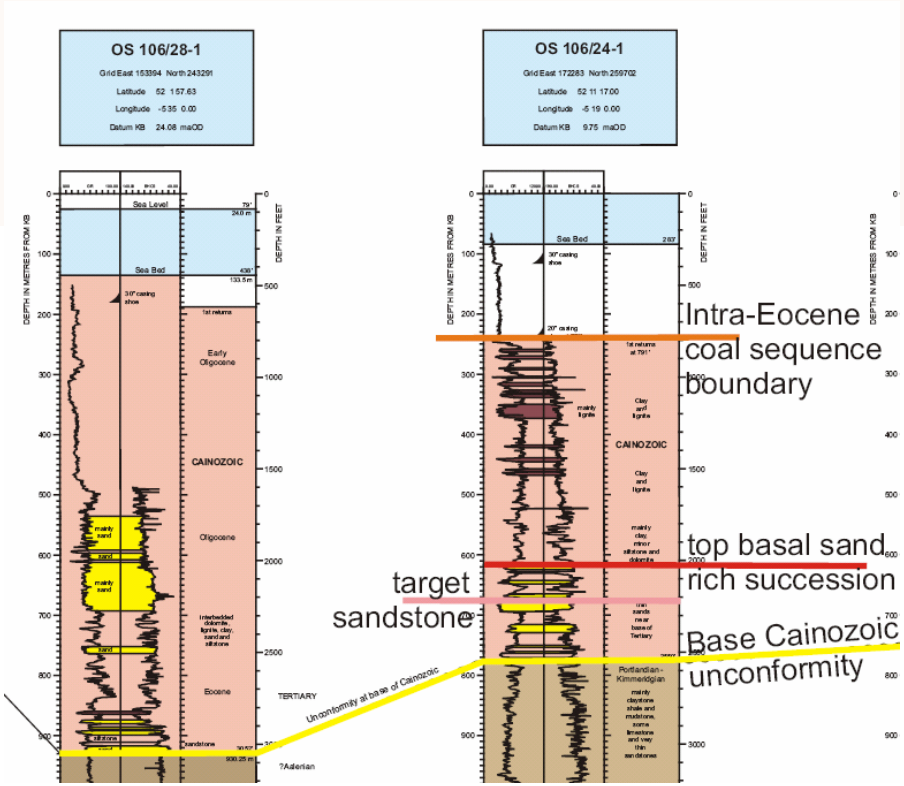
- Partially filled by salt wall
- Initial permeability of fault itself and associated damage zone highly uncertain
- Precipitation reactions predicted where fault is filled with salt
- Drilling and coring might be possible but very expensive

Existing wells



- Wells 106/24-1 and 106/24a-2B lie on migration path/ within storage site
- Plugged and abandoned to high standards, so no reason to assume they will leak
- May be possible to plug them if they do turn out to leak

Top seal



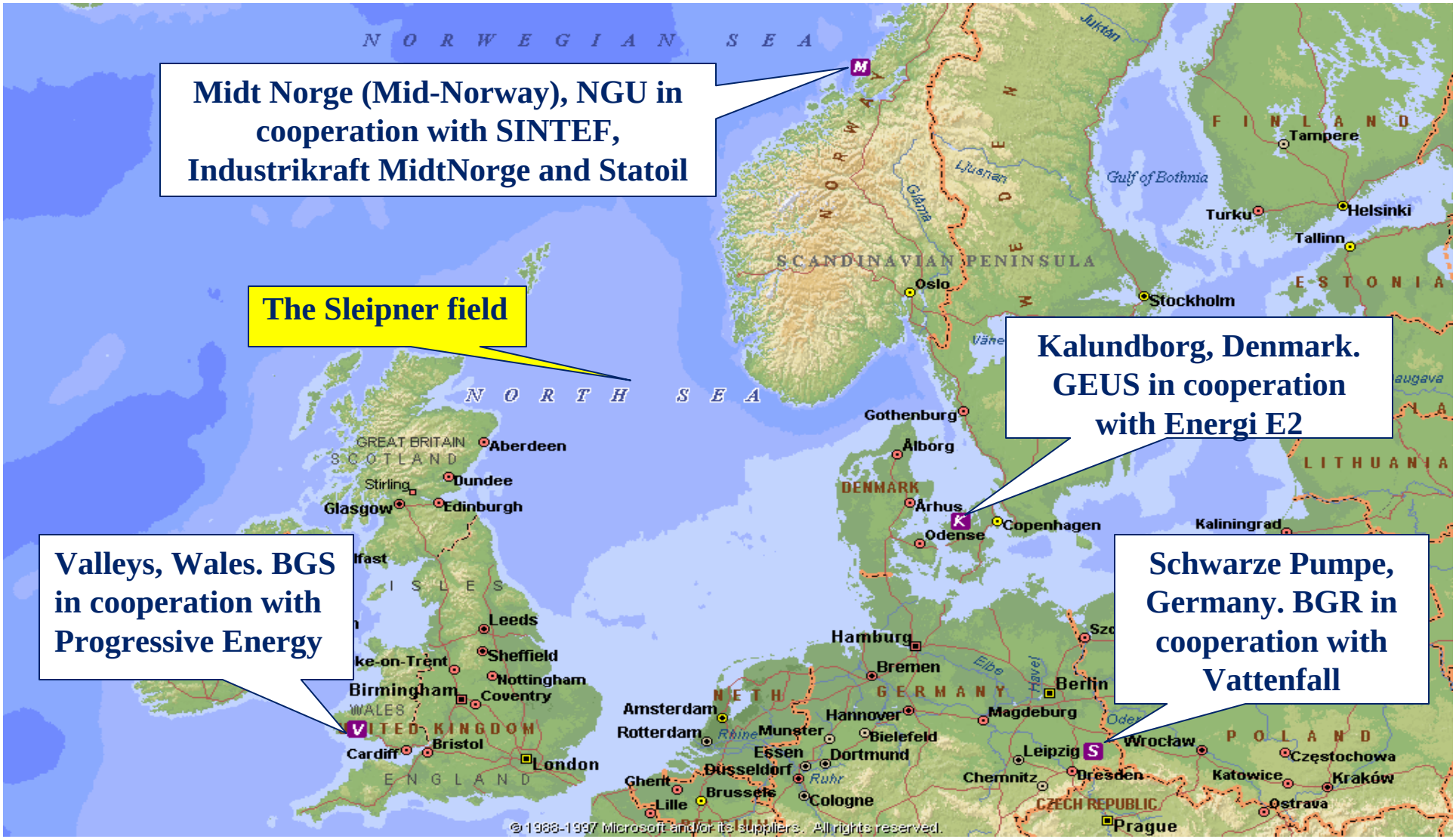
- Reservoir sands overlain by mudstones and lignite
- Permeability not known as could not be tested from cuttings material
- Expectation is of good seal
- Cap rock integrity not likely to be modified by geochemical interactions

Preliminary Conclusions Valleys

- Now in the process to go through FEP process to ensure the major risks have been identified
- Since St. George's Channel basin is poorly explored, with only a handful of wells, the geological risks are much higher than in petroleum-bearing basins
- Simulations show all CO_2 ends up next to the fault
- The cost of reaching robust conclusions about

  (1) whether the fault will leak or seal, and
  (2) whether there is sufficient reservoir sand,
  could be very high.

CO2STORE – the case studies



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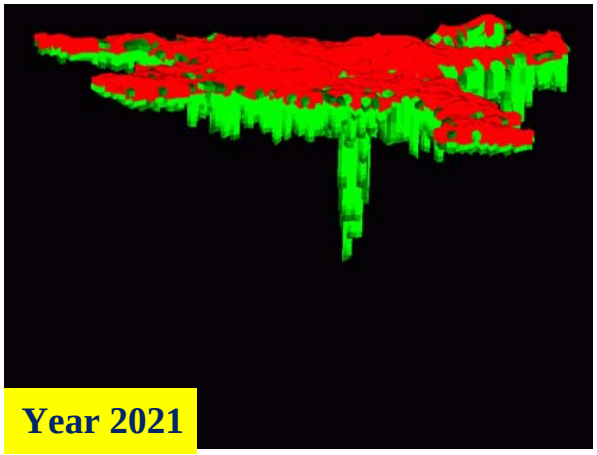
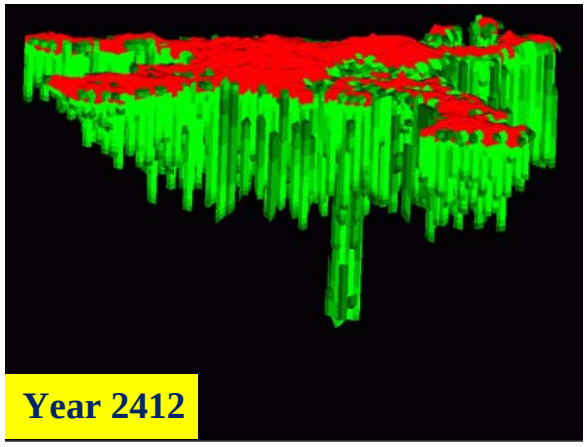
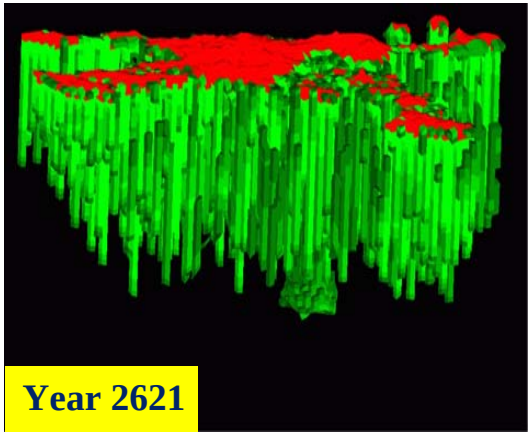
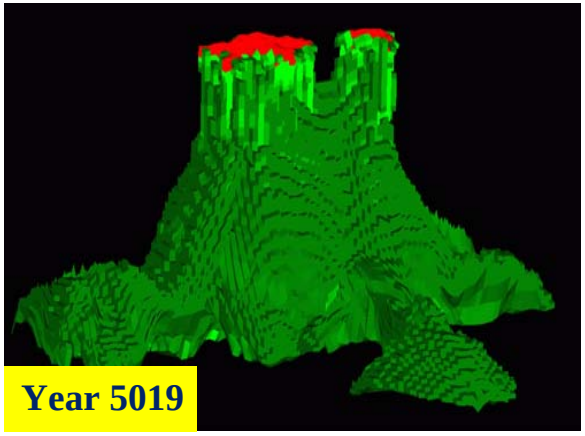
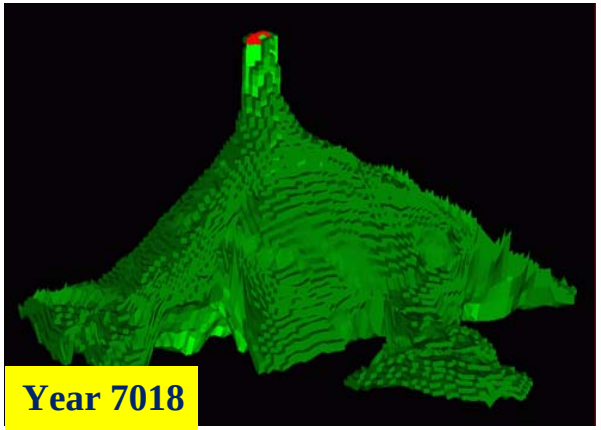
Dissolution of CO2 in the Utsira Brine











Source: Gemini No. 1, 2004 (NTNU and Sintef)

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And then: What if something leaks…??

- NASCENT: Impacts on communities and terrestrial ecosystems
- Impacts of CO_2 on marine ecosystems not well understood. Upcoming research project to study toxicological effects of CO_2 and low pH on various marine animals under real depth conditions

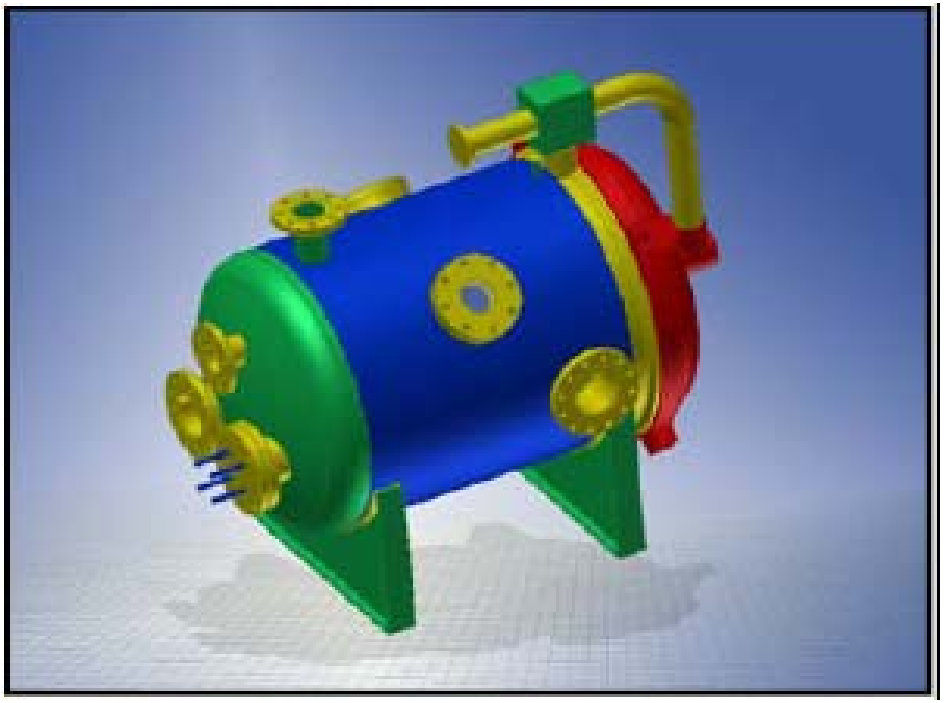
NTNU in cooperation with Statoil to build a titanium tank to simulate conditions on ca. 300 meter depth:

100 cm Ø

30 bar pressure

Sampling device

Various instrumentation



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WAY FORWARD?

BUILD TRUST

- More geological settings
- Publish work and results
- Inform regulators, policymakers and public
- Inter-continental cooperation

LEGAL CLARIFICATION

- Mining and/or Petroleum laws adaptation
- OSPAR & LONDON Conventions

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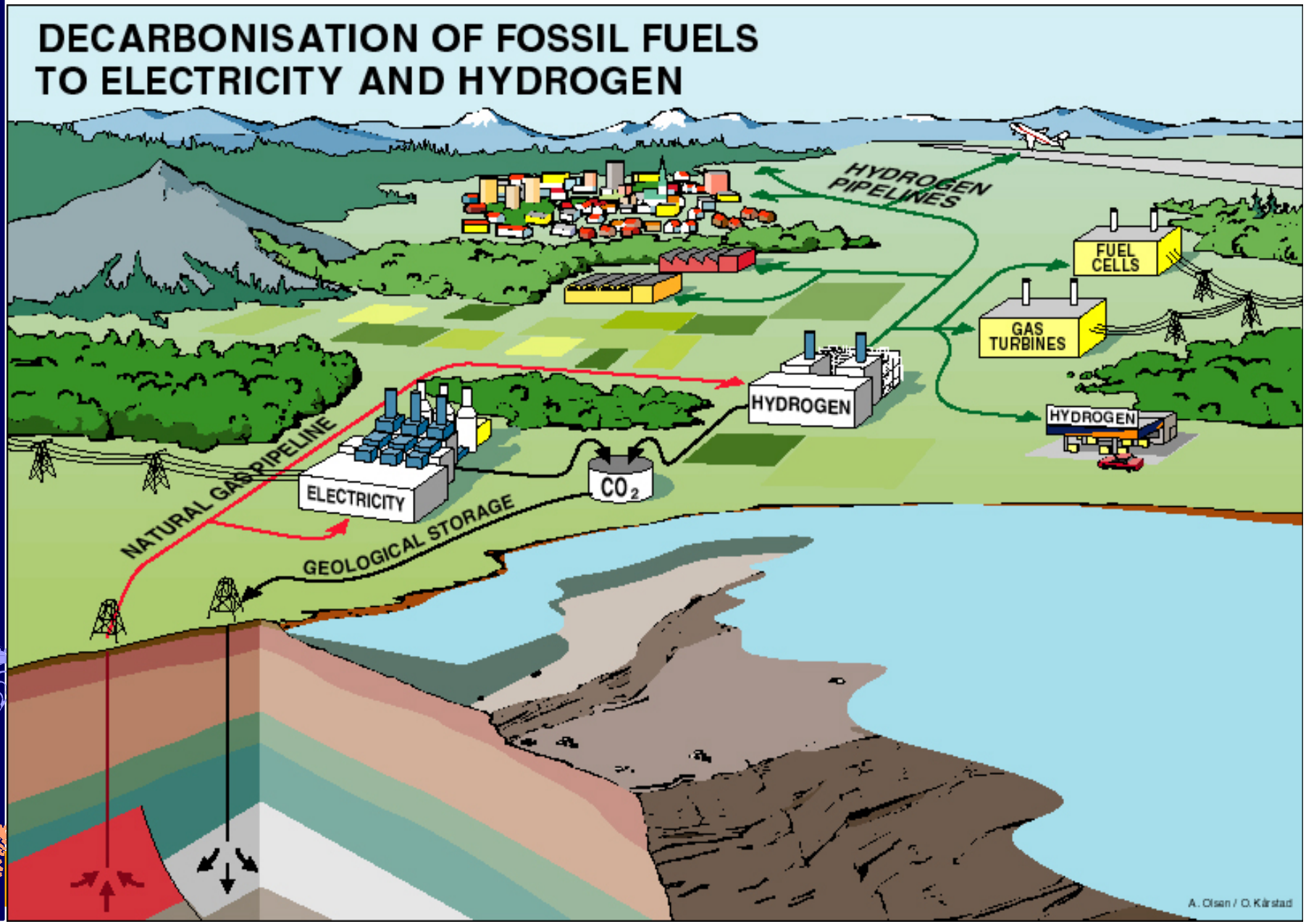
DECARBONISATION OF FOSSIL FUELS
TO ELECTRICITY AND HYDROGEN
HYDROGEN PIPELINES
FUEL CELLS
GAS TURBINES
HYDROGEN
HYDROGEN
NATURAL GAS PIPELINE
ELECTRICITY
CO_2
GEOLOGICAL STORAGE
A. Olsen / O. Kårstad