Methodology for selection and qualification of sites and project development for geological storage of CO_2

by
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CO_2 Capture and Storage – Response to Climate Change
Regional workshop for the Baltic Sea Region and C&E European Countries
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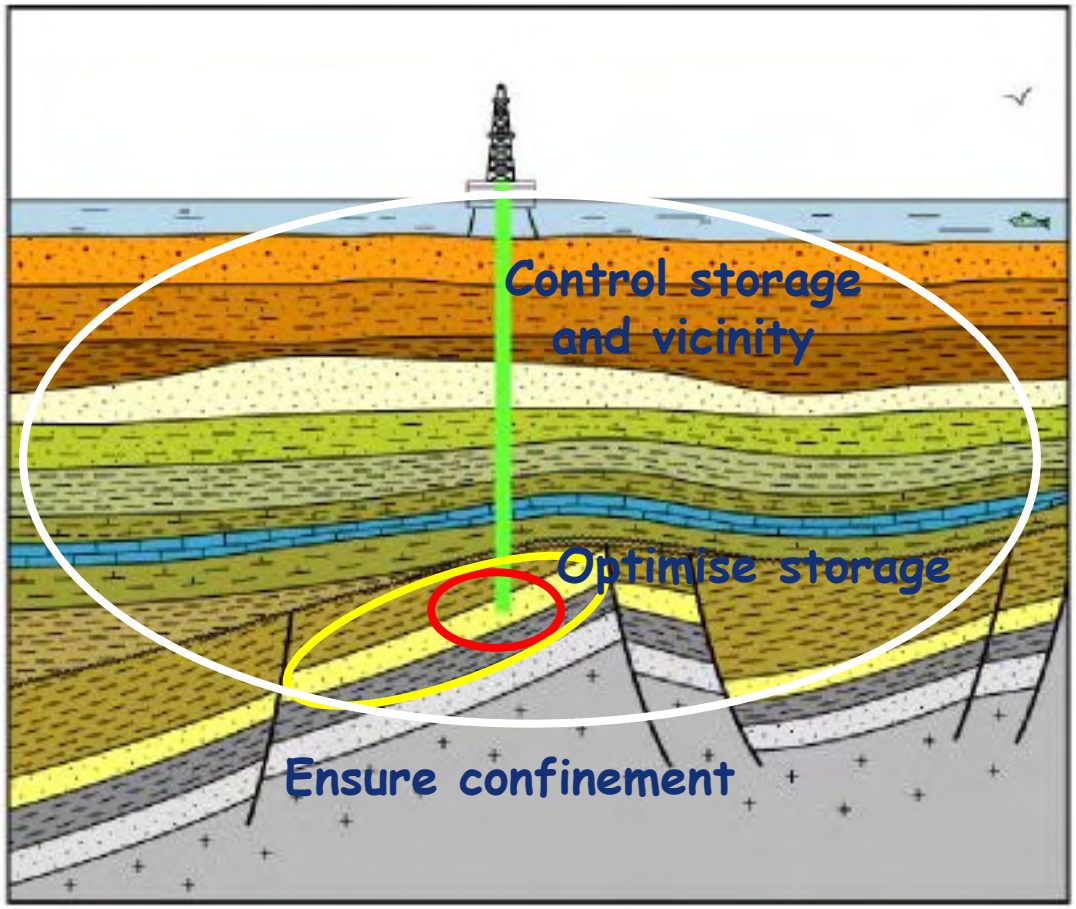
Agenda

- Introduction
- Site selection and characterization
  - Basic criteria
  - Geological parameters
  - Storage assessment
  - Modelling
  - Geochemical parameters
  - Ranking criteria
  - Conflicts of interests
- Risk assessment
  - Safety criteria
  - Legislation, regulations and guidelines
- Monitoring plan
  - Legislation, safety and operation

What is to be done when a potential operator or government decides to find and develop a storage site

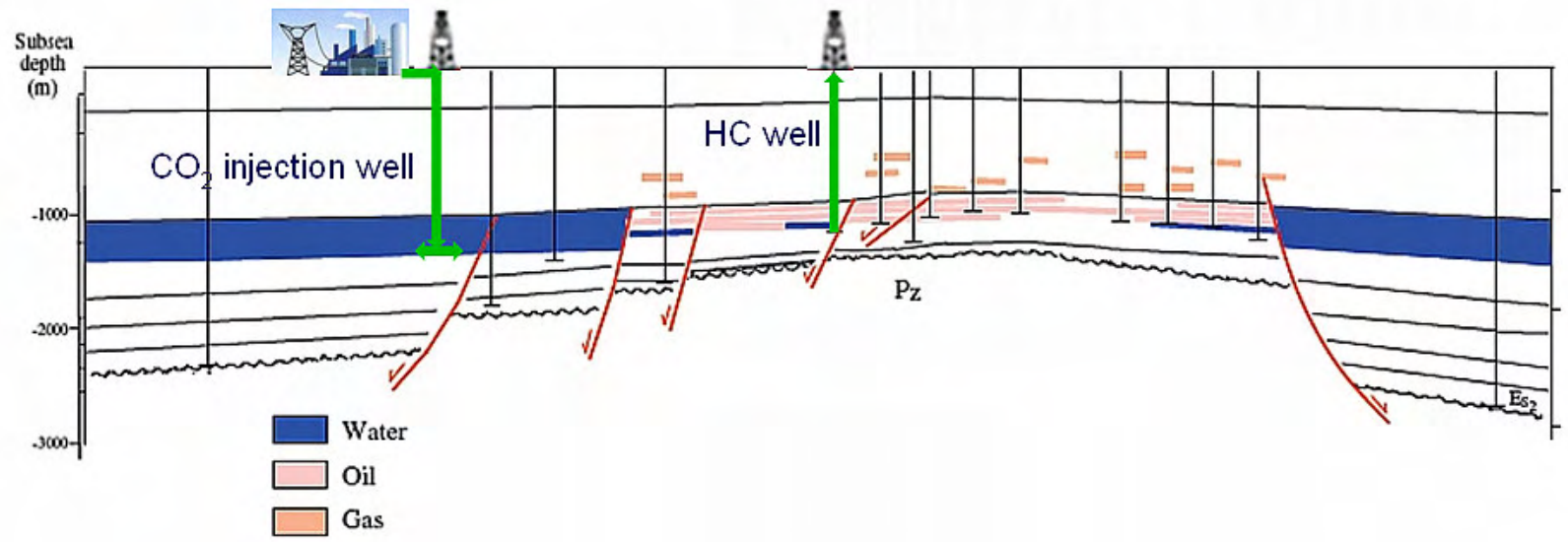
- Site selection
- Characterisation
- Predictive models
- Risk assessment and remediation
- Monitoring (plan)



Basic site selection criteria

Sufficient depth and storage capacity

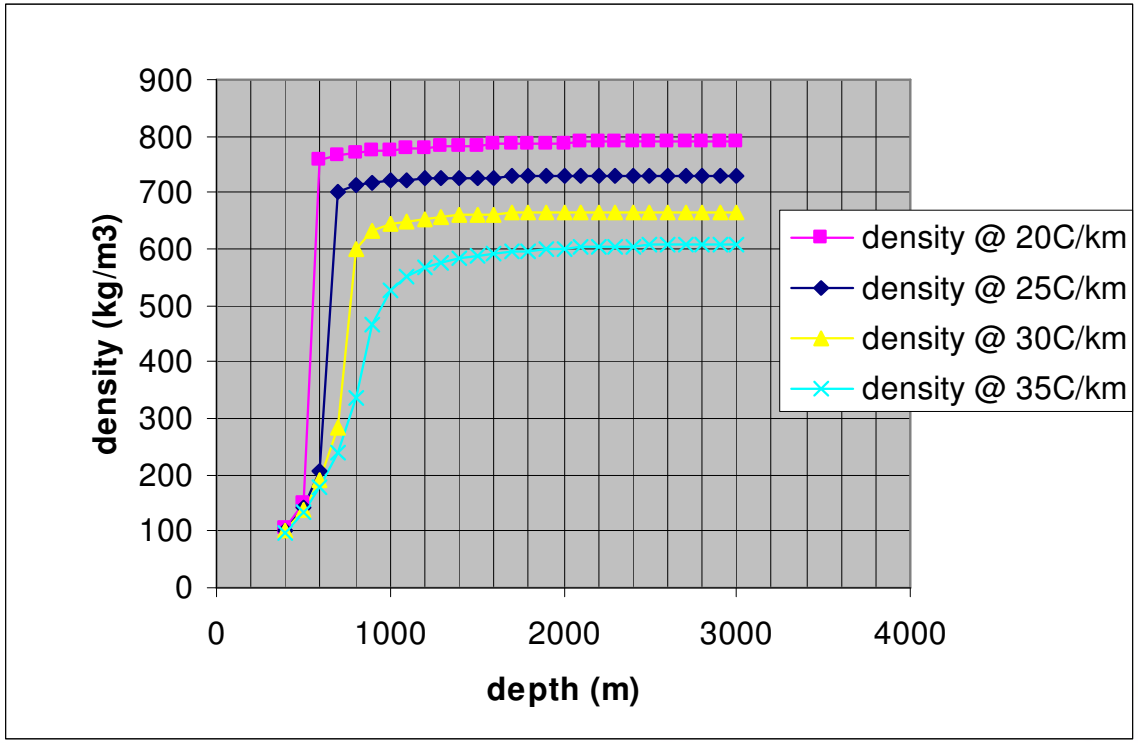
- Below 800 m
- Above 2500-3000 m
- Trap type / areal extent / thickness / complexity
- Storage capacity



Basic site selection criteria

Sufficient depth and storage capacity

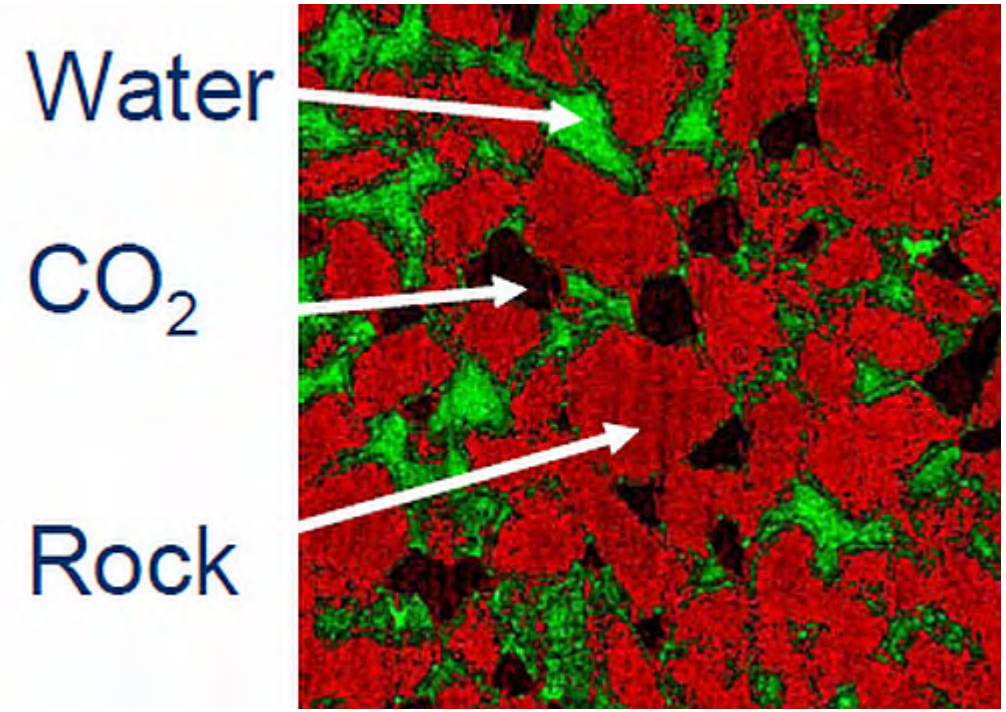
- supercritical CO_2 below 800 m



Basic site selection criteria

Porosity

- may deteriorate below 2500-3000 m

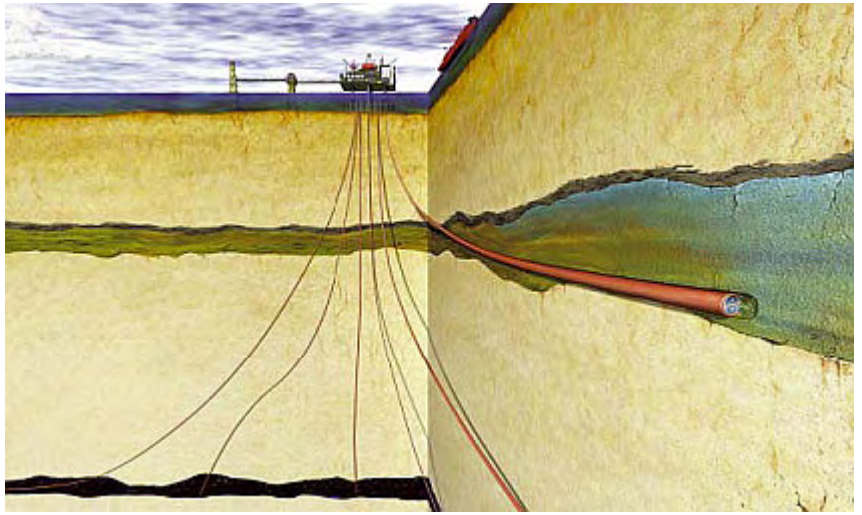


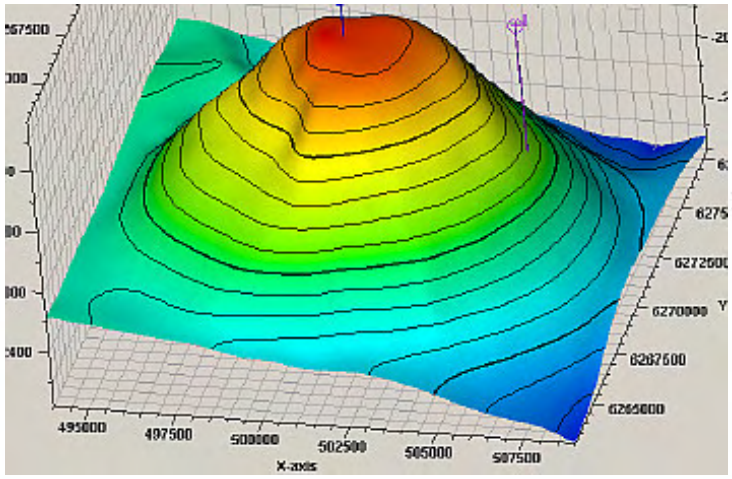
Geological parameters

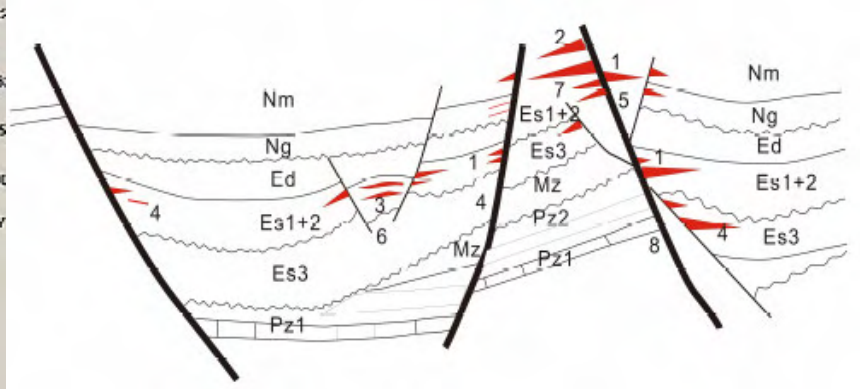
- **Trapping mechanisms**
  - Reservoir trap type and size
  - Seal = cap rock
  - Tectonic activity - faults, fractures
- **Reservoir properties**
  - Permeability and porosity
  - Storage capacity (calculations/modelling)
  - Injectivity
  - Mineralogy and geochemistry
    - Types of minerals
    - Interaction of CO_2 with rocks and pore fluids
    - Geochemical simulations

Trapping mechanisms

Trap type
- Areal extent
- Thickness
- Complexity
  (compartmentalised)

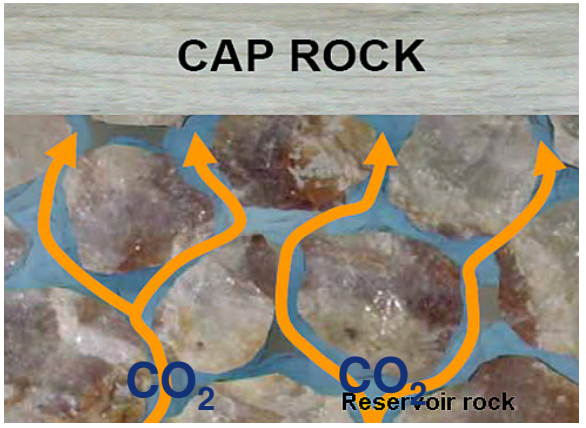






Buoyancy and trapping

- Seal (cap rock) lithology and permeability
- CO_2 does not mix with water but it dissolves in water
- Faulting, tectonic activity, fracture pressure



Porosity and permeability

CO_2 Injection at Sleipner
- 38% porosity and 1000-8000 mD permeability (Ringrose 2009)

CO_2 Injection at Snøhvit
- permeability c. 350 mD (Ringrose 2009)

The Ketzin CO_2 Storage Project
- Porosity 23%, Permeability 500-1000 mD (Bernstone 2009)

The Altmark CO_2 Storage Pilot
- Porosity 4-28%, Permeability 30 mD (Bernstone 2009)

The Vedsted CO_2 Storage Demo
- Porosity 30%, Permeability 2000 mD (Bernstone 2009)

The Birkholz/Neutrebbin CO_2 Storage Demo
- Porosity 14-18%, Permeability 450-600 mD (Bernstone 2009)

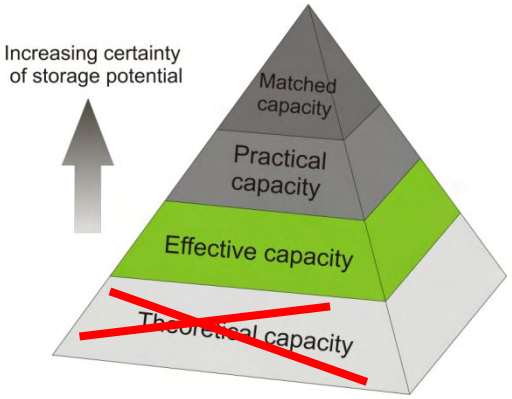
In-Salah Gas Project
- Porosity 13-17 %, Permeability 13 mD (Rutqvist et al., 2009)

As a rule of thumb > 200 mD

Storage capacity calculations

Methodological resources

- **CSLF Task Force on CO_2 Storage Capacity Estimation**
  - **Joule II, GESTCO, Castor, GeoCapacity, COACH and US DOE**
    - **Aquifers**
    - **Hydrocarbon fields**
    - **Coal beds**

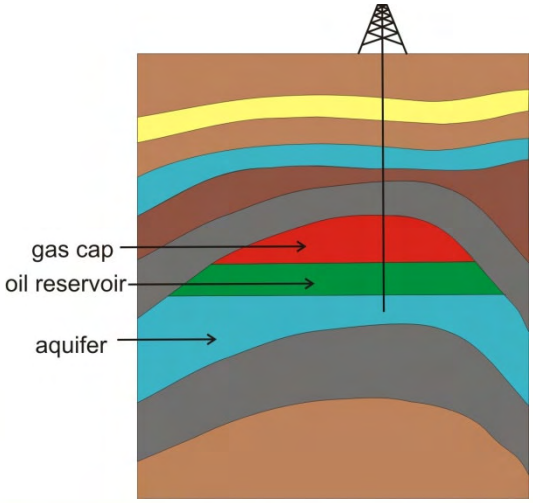


Example: Aquifers capacity estimates

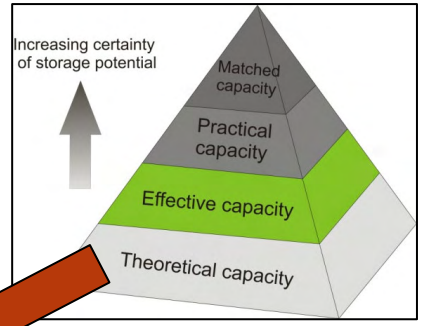
$$MCO2 = \rho CO2r \times URp \times B \times Seff \Leftrightarrow$$

CO_2 storage capacity =

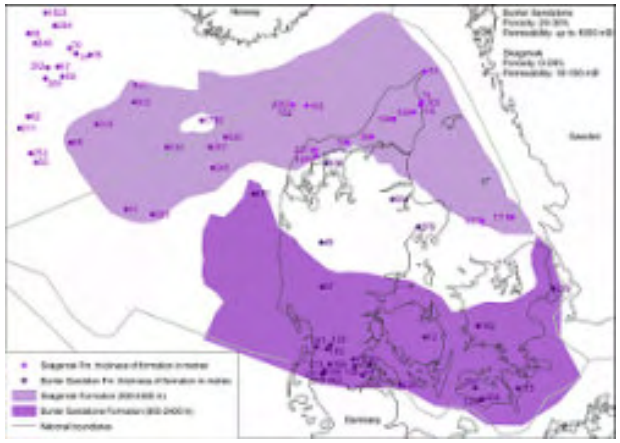
(CO_2 density) × (displaceable volume)

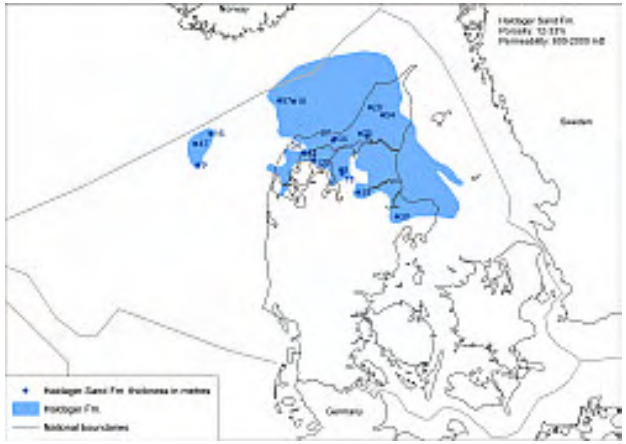


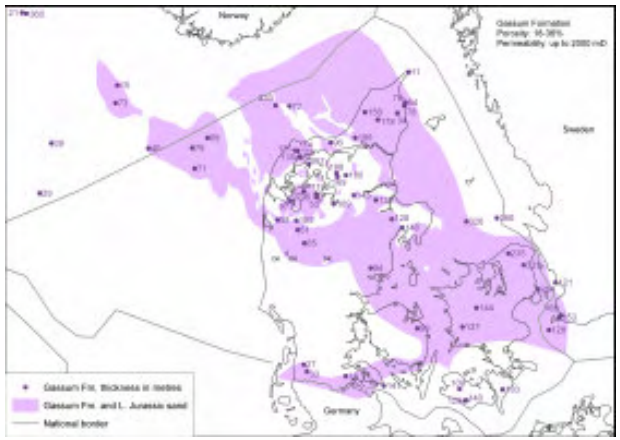
Theoretical reservoirs within the depth interval 800-2500 m

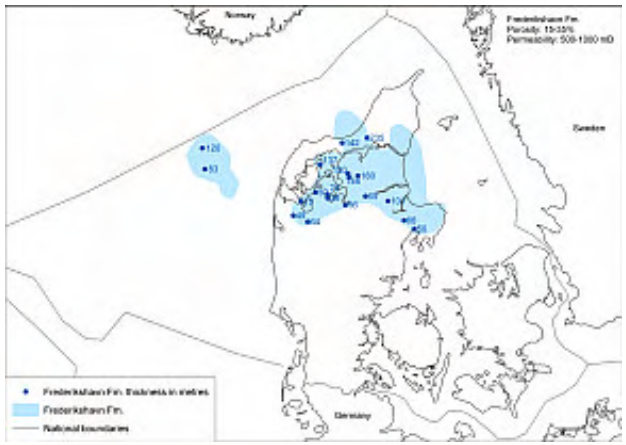


Hole porevolume



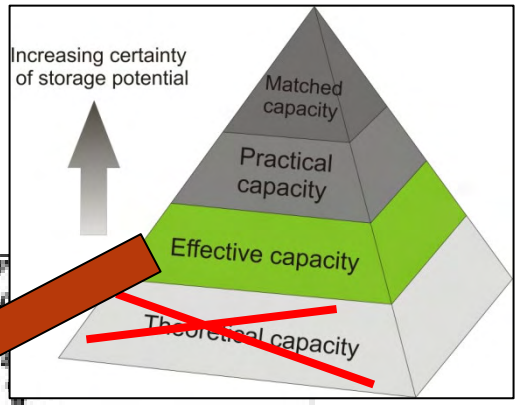


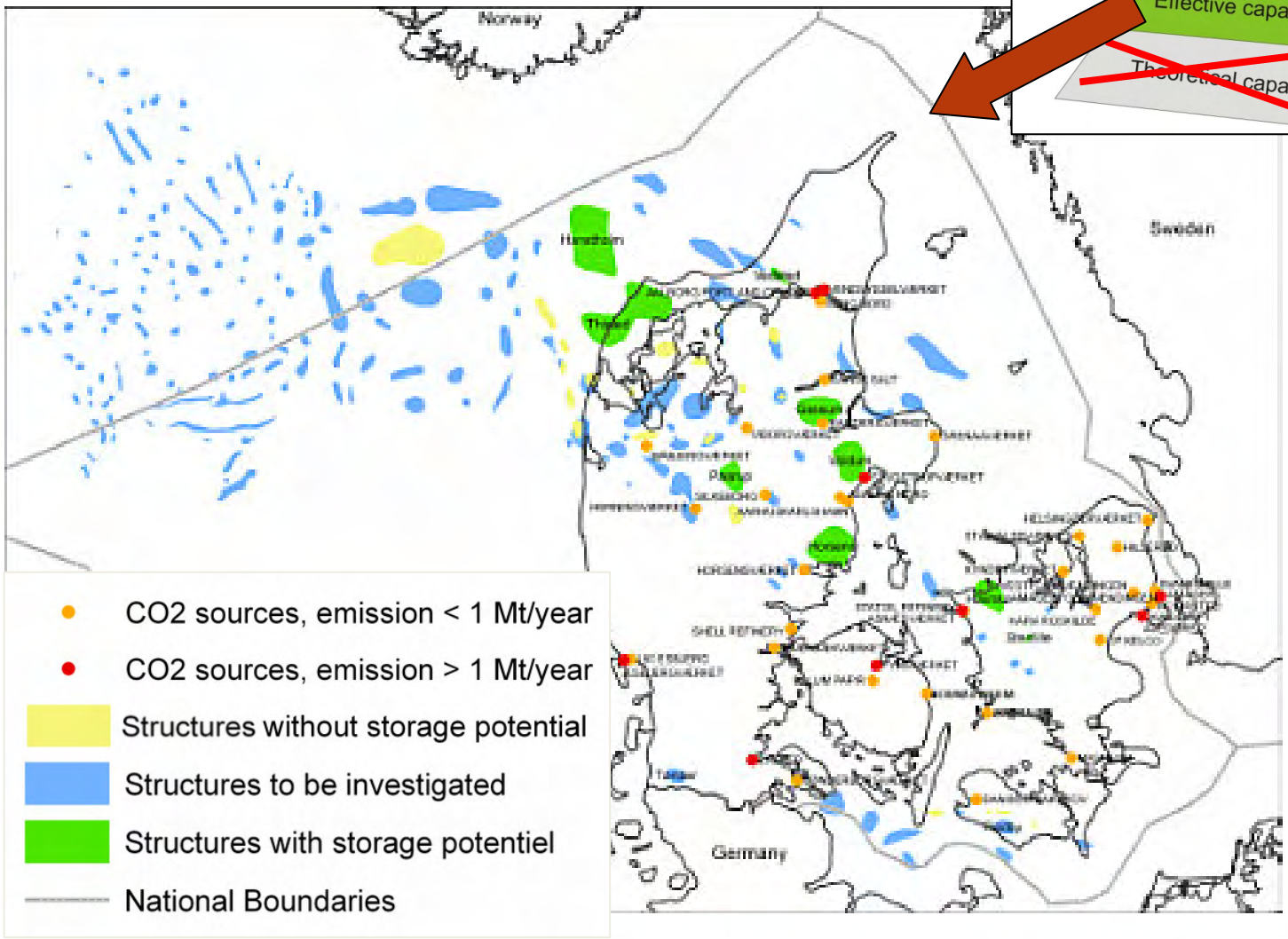




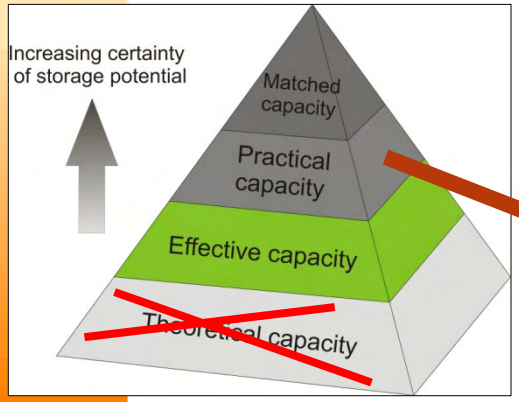
Identify reservoir potentials

Geological limits





Storage coefficient S_{eff} for open and semi-closed aquifers



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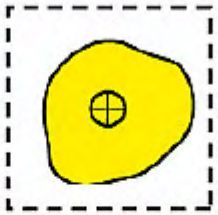
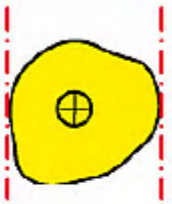
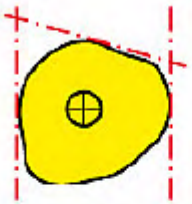
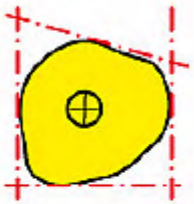
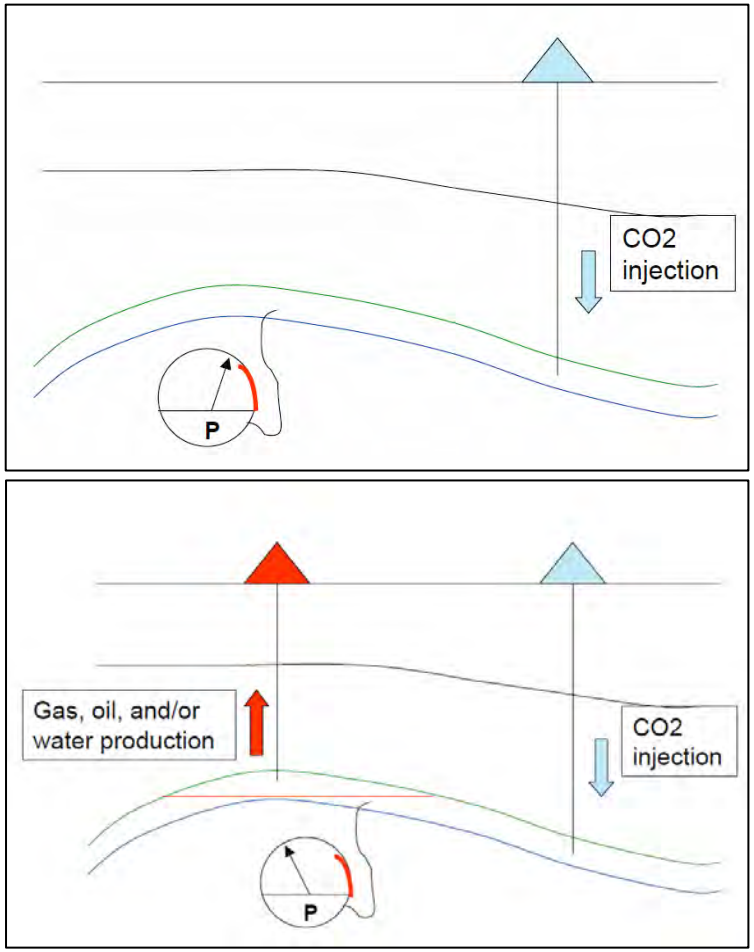
				
High quality reservoir	40 %	20 %	10 %	3–5 %
Low quality reservoir	20 %	10 %	5 %	<3 %

*Volume of bulk reservoir shall be 5-10 times the volume of the reservoir

–·–·– Fault

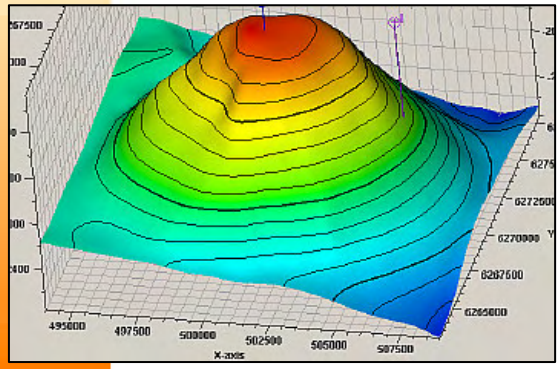
CCS and EOR

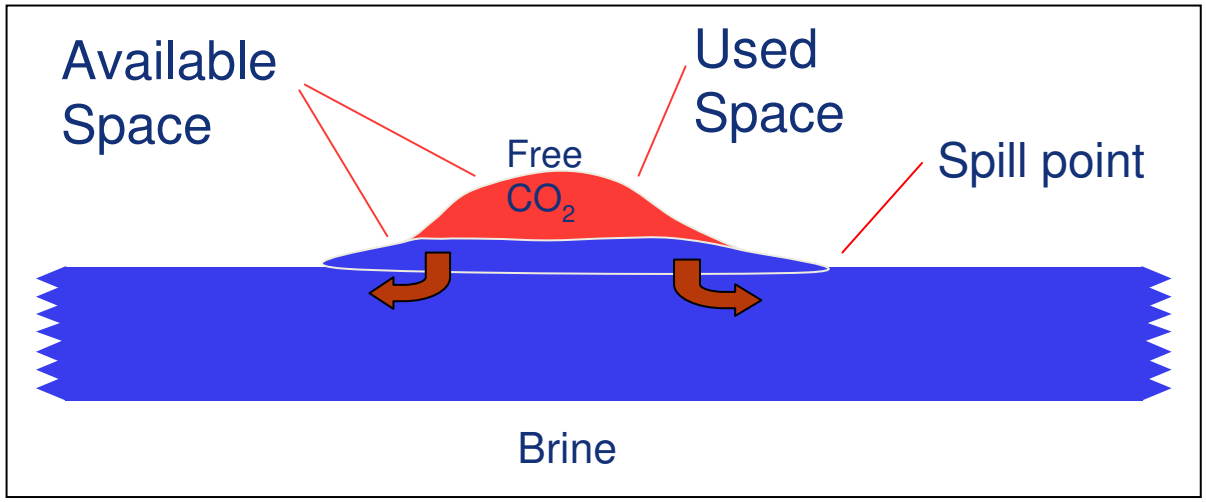
- CCS: Aquifer volume needs to be large to keep pressures reasonable
- EOR: Production keeps pressures reasonable



Storage space is generated by displacing existing fluids and distributing pressure increase in surrounding aquifer system

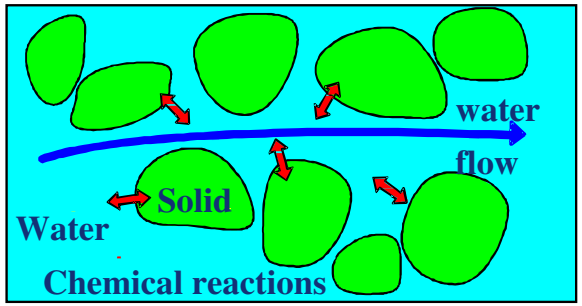
Model for open aquifers





Storage space is generated by displacing existing fluids and distributing pressure increase in surrounding aquifer system

Geochemical parameters



- **CO_2-water-rock interactions can affect:**
  - CO_2 storage capacity
  - Sealing efficiency
  - Design of the injection/storage operations
  - Safety and stability of storage
- **Highly complex interactions, that can occur in the reservoir, in the cap rock as well as in fractures and well cements**
- **Beneficial or detrimental**
- **Short-term and long term effects**
- **Site specific modelling essential to address processes**

(Czernichowski-Lauriol et al., 1996)

Modelling

COMMISSION OF THE EUROPEAN COMMUNITIES

Brussels, 23.1.2008
COM(2008) 18 final

2008/0015 (COD)

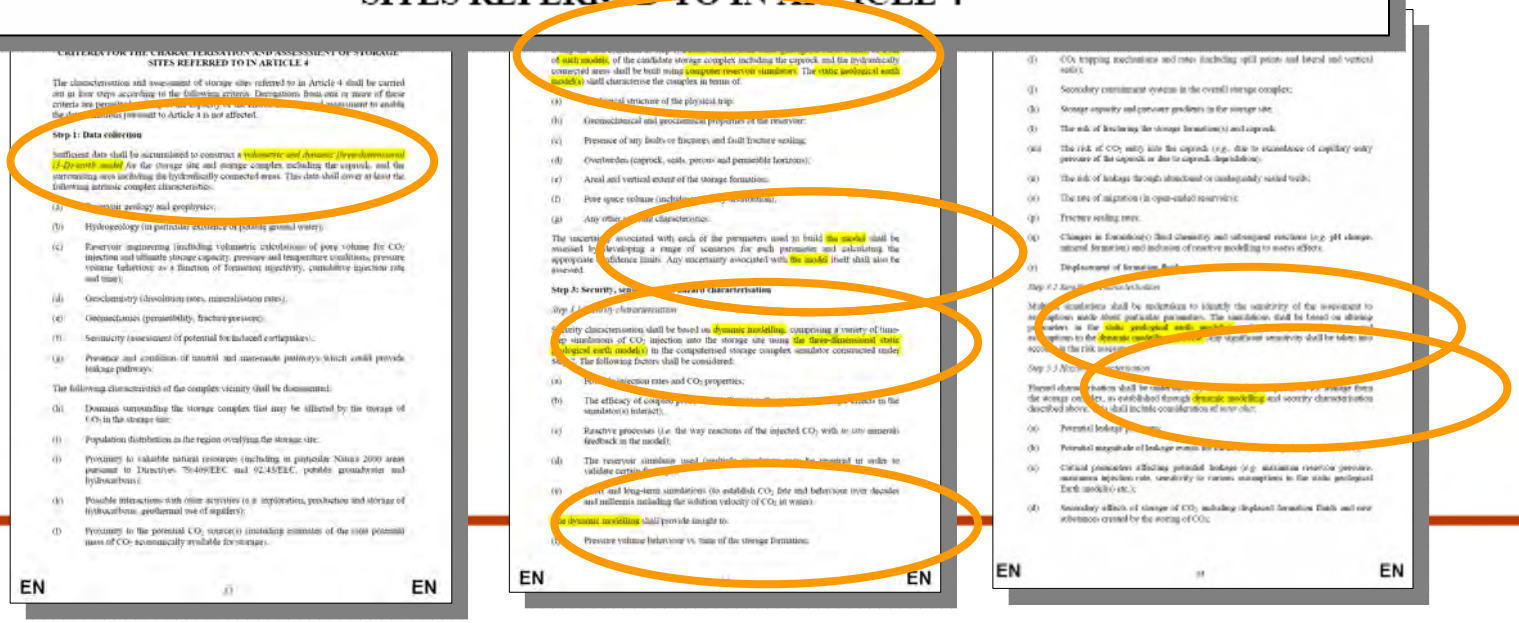
Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

on the geological storage of carbon dioxide and amending Council Directives 85/337/EEC, 96/61/EC, Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC and Regulation (EC) No 1013/2006

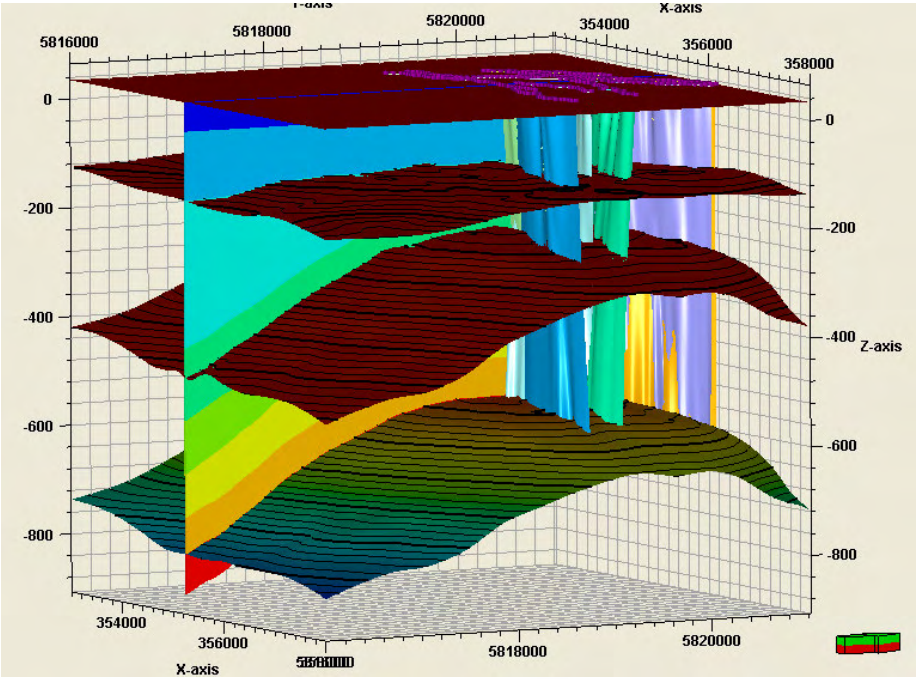
ANNEX I

CRITERIA FOR THE CHARACTERISATION AND ASSESSMENT OF STORAGE SITES REFERRED TO IN ARTICLE 4

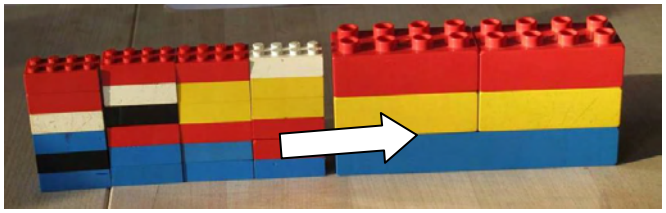


What is new for CO_2 site modelling compared to oil/gas

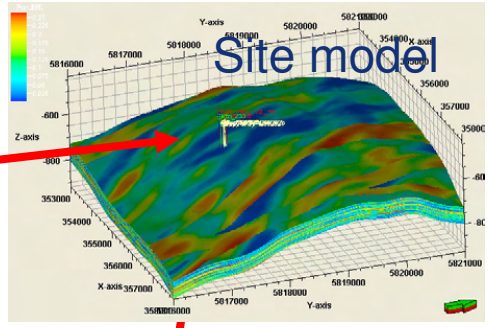
- Few data to start with in saline aquifers
- Longer time perspective for predictions
- Pressure rise from injection in aquifers
- Mobility and gravity
- Trapping mechanisms
- Geochemical reactions and geomechanics
- Continue in symbiosis with monitoring activities

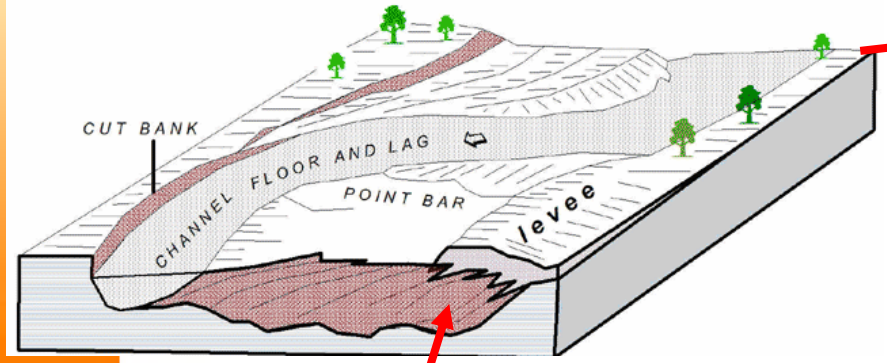


Building a model

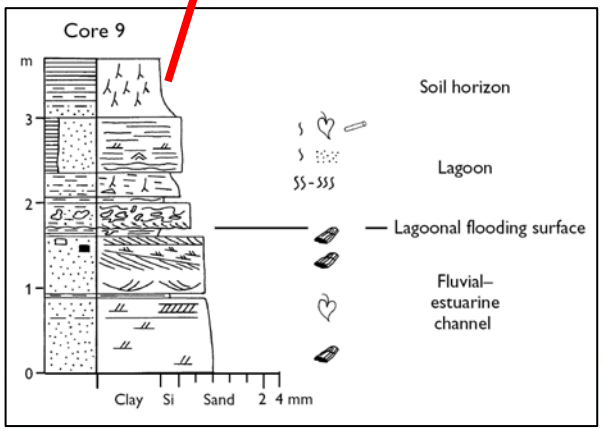


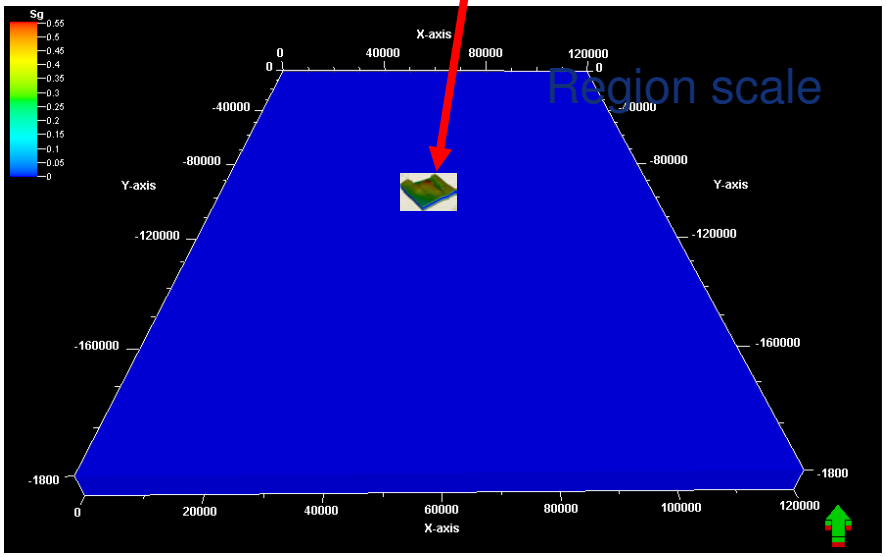
10 m – 100 scale





Meter scale



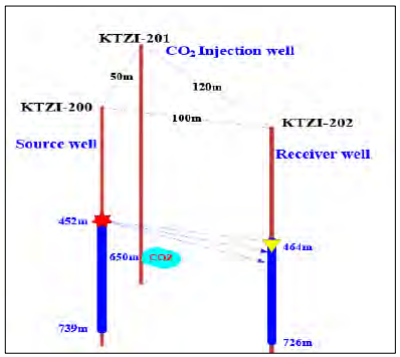


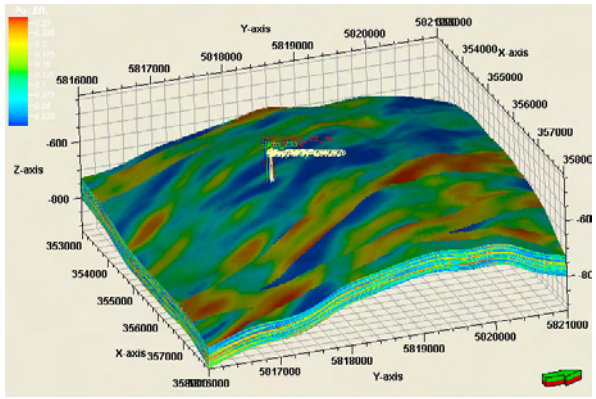
Region scale

120x190 km region model

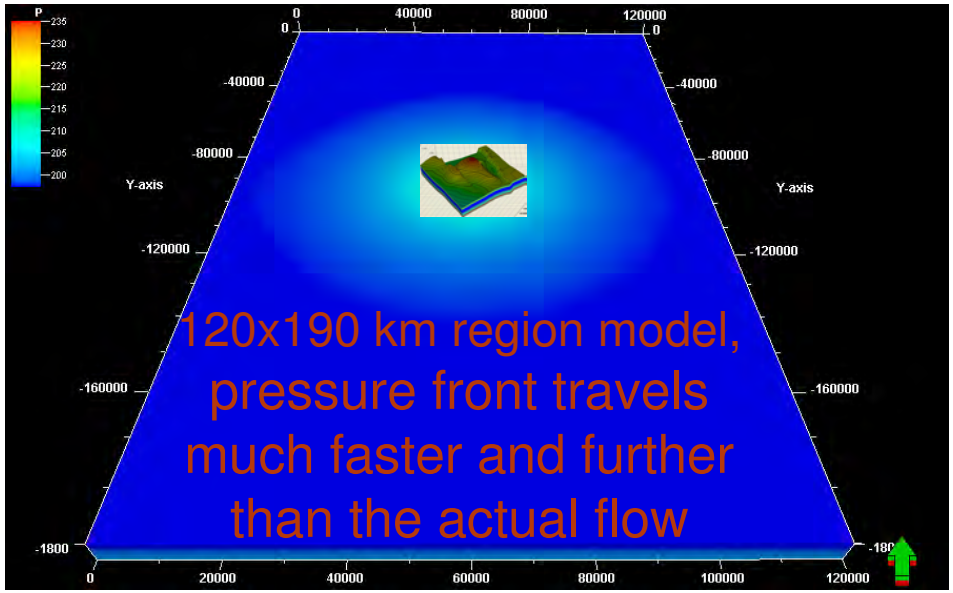
Large-scale interaction

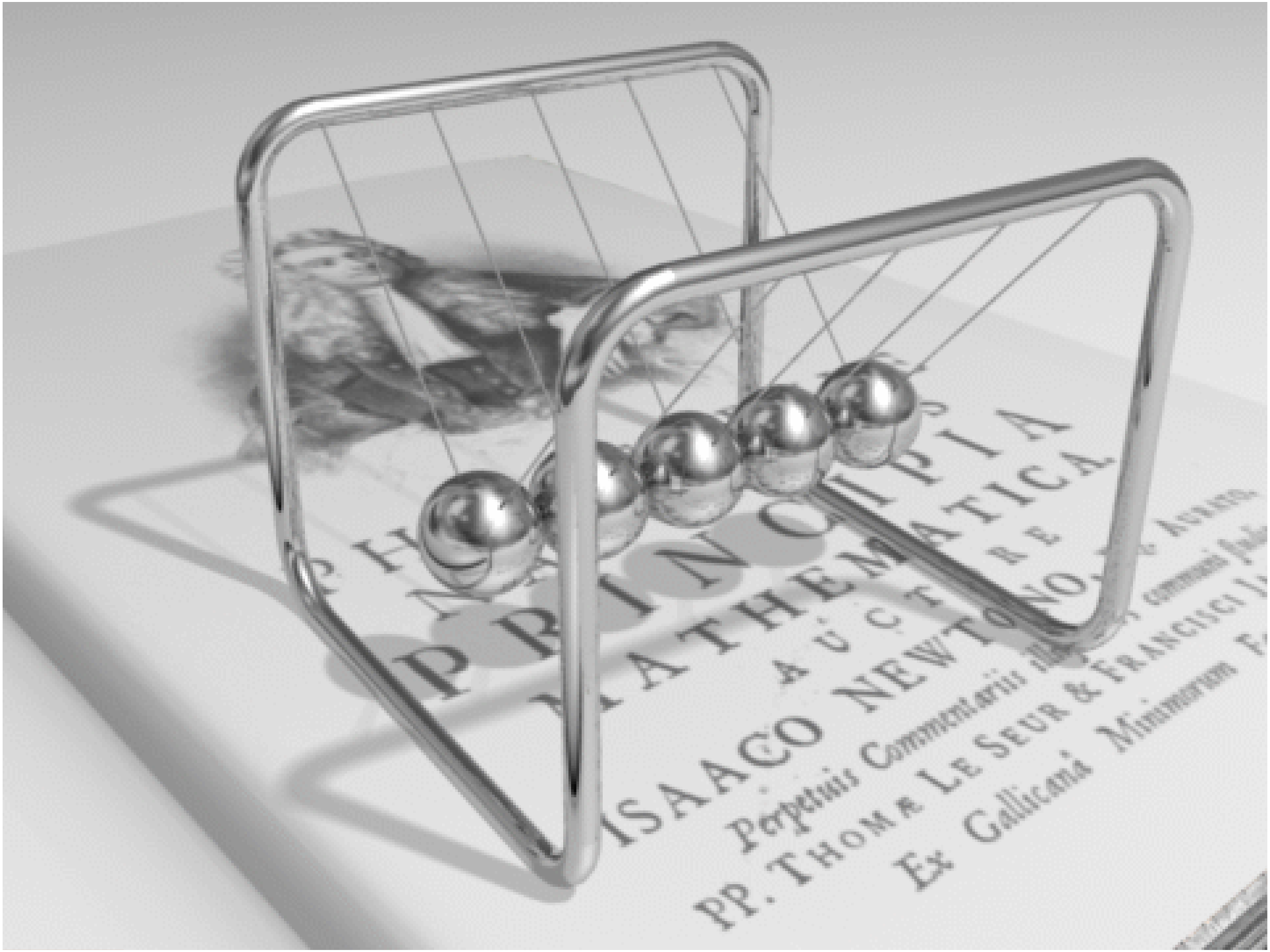
- Site model looks OK “at a distance”, but what have we missed?
- Test of storage site





➢ Improvement of the geological model based on data from monitoring




PRINCIPIA
MATHEMATICA
ISAACO NEWTONO
PP. THOMÆ LE SEUR & FRANCISCI

Ranking criteria

Sufficient depth and storage capacity

- Below 800 m
- Above 2500-3000 m
- Trap type / areal extent / thickness
- Storage capacity

Sufficient injectivity to be economically viable

- Permeability
- Reservoir lithology
- Heterogeneity of reservoir

Conflicts of interests

- Other use of area or the underground
  - Recreation, geothermal energy, etc.

Conflict of interests?

Explore geothermal heat production with CCS

- When storing large amounts of CO_2 in deep saline aquifers, the fluid pressure of the storage system may increase to levels where production of salt water is desirable (Gorgon42 project in Western Australia)
- With temperatures ranging from 45ºC to 90ºC, production of water may be used for geothermal heat production
- In short, water production may result in increased storage capacity and benefits for local residents

Conflict of interests?

- **What does it do to house prices**
- **Not in my backyard (NIMBY)**
- **Ground water is at risk**

Risk assessment

- Risk assessment and safety criteria are essential all along the lifecycle of storage to ensure that:
  - Health, Safety & Environmental impacts are negligible
  - Impacts to underground resources are negligible
- Regulations (International, EU level, state, local) set the framework,
- States will define the level of detail of safety requirements (laws, licences, ..)
- Guidelines already exist or will be available soon
- Economy

What needs to be characterized considering CO_2 storage

- Trapping mechanisms
  - Reservoirs, trap type
  - Seal = cap rock
  - Depth
- Reservoir properties
  - Permeability and porosity
  - Storage capacity (calculations/modelling)
  - Injectivity
  - Mineralogy and geochemistry
- Stress regime and tectonic activity
  - Faults, fractures

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- Stress regime and tectonic activity
  - Faults, fractures
- Economic limitations
- Hazards
  - On shore
  - Off shore
- Regulatory limitations
- Public opinion and acceptance

Monitoring

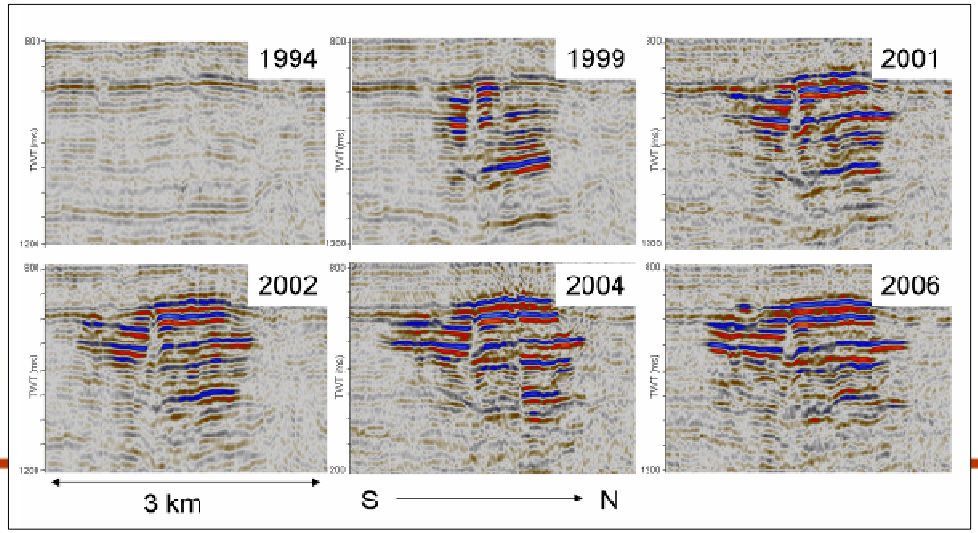
Most important legislation in the EU around monitoring

- Main focus: safety and environment
- EU directive on storage (2009)
- OSPAR guidelines (2008)

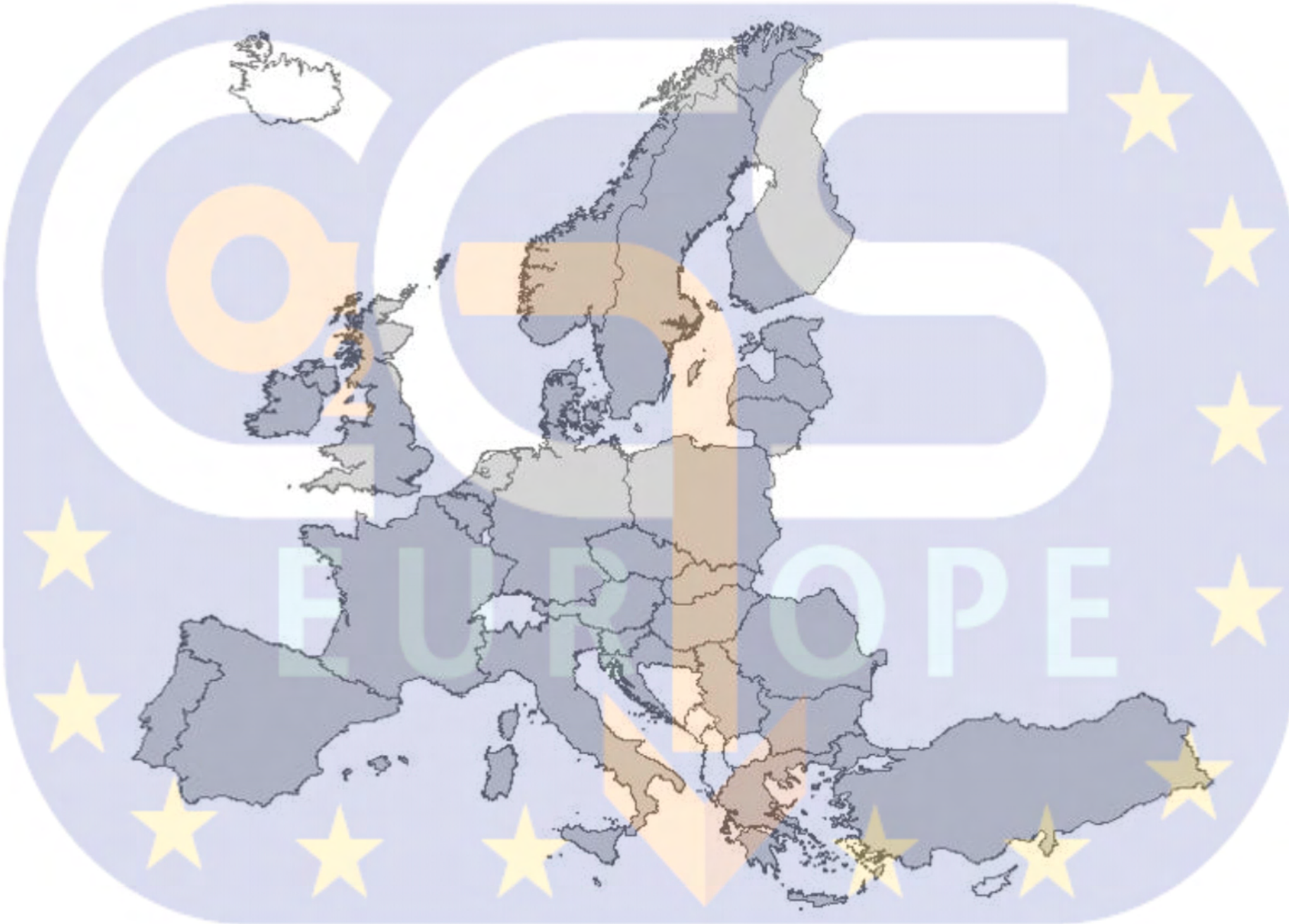
Safety

Distribution of CO_2

Optimizing storage or EOR production




Thank you for your attention


EUROPE