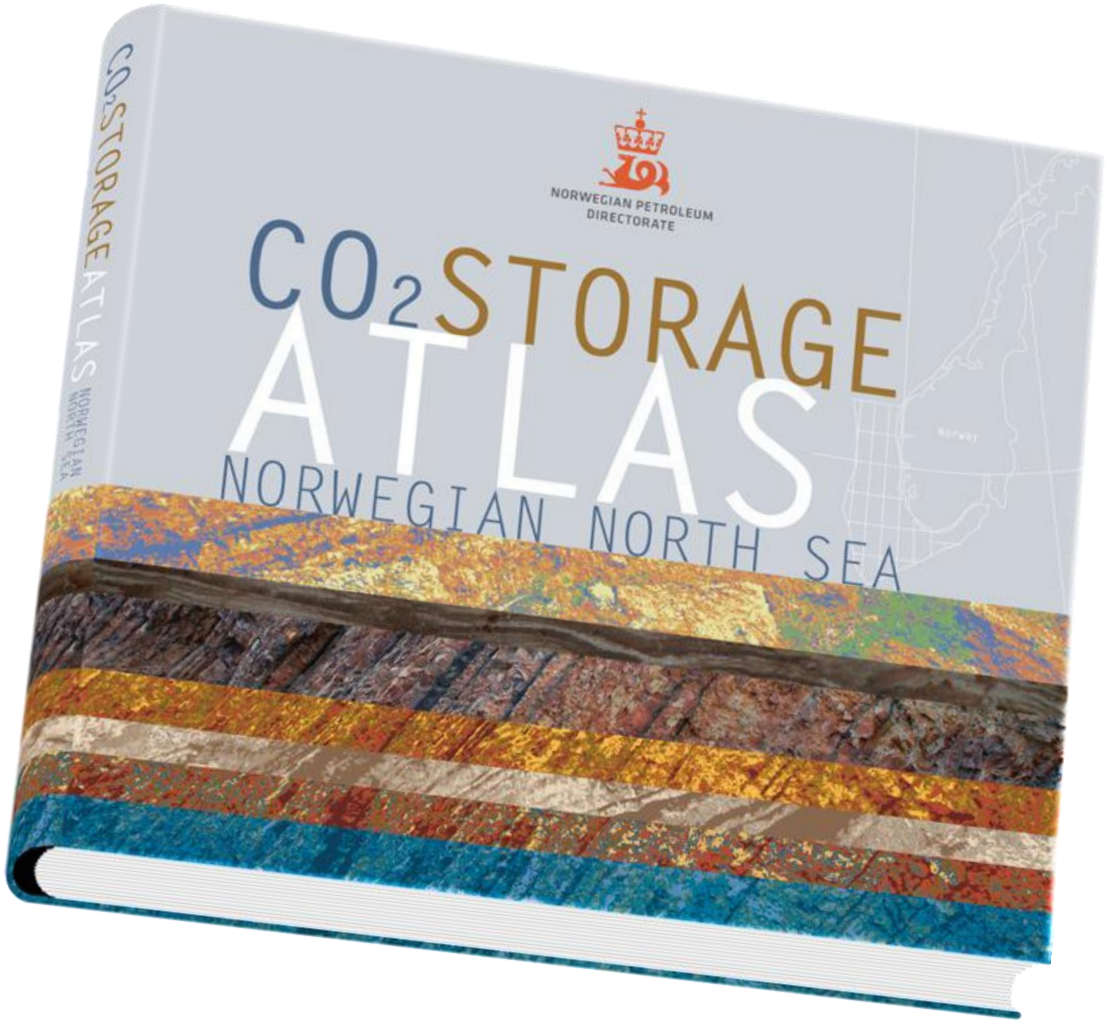
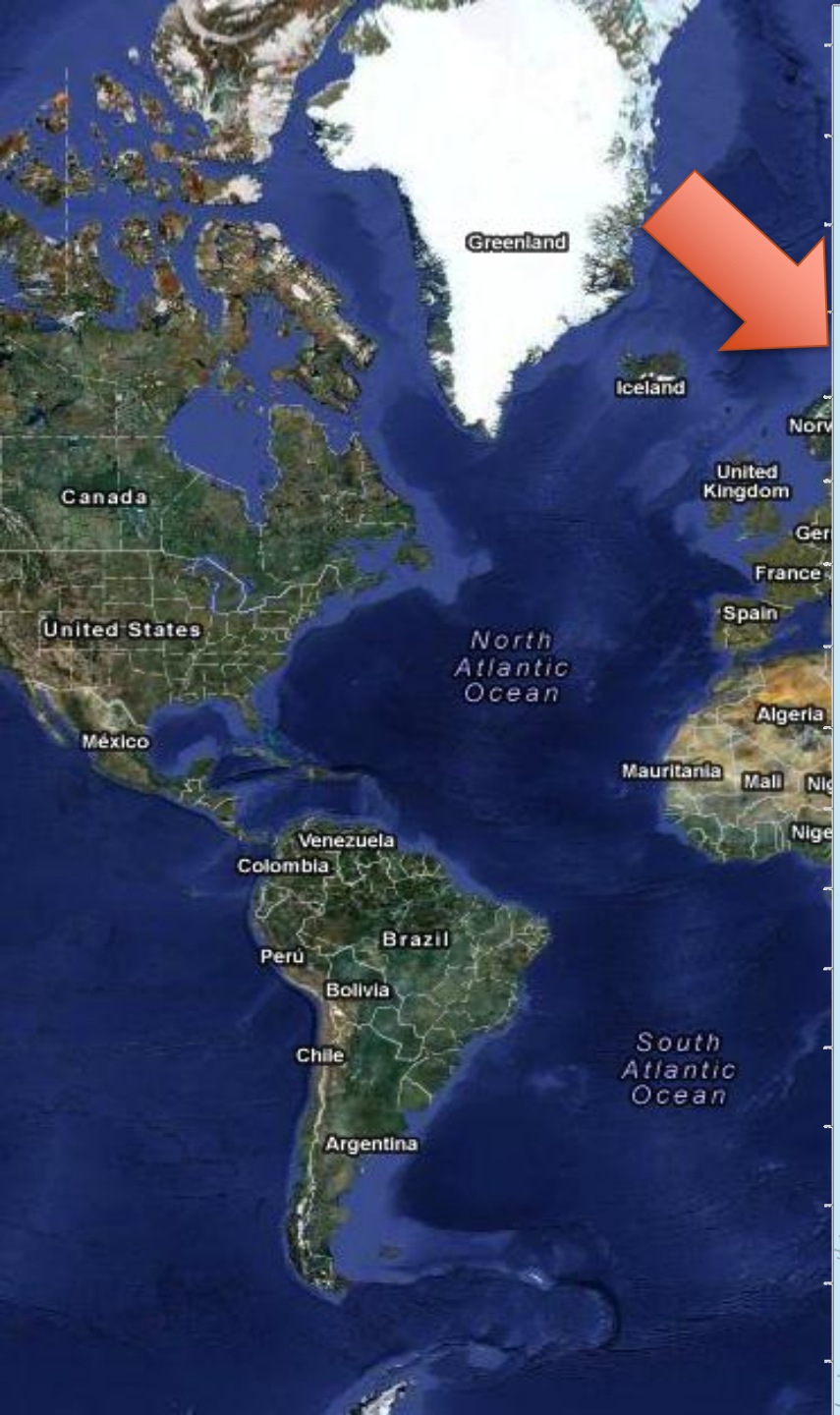


Overview of geological storage of CO2

Bandung
December 2013

Project Director Eva Halland
Norwegian Petroleum Directorate

www.npd.no



Den norske kontinentalsokkel

Utvinningstillatelser per 2. november 2009

Utarbeidet av Oljedirektoratet

www.npd.no

OLJEDIREKTORATET

Projeksjon, UTM senterm. 21 Ø

Målestokk: 1:1 900 000

TFO 2009

Seismikkområder

Olje

Gass

Olje m/gass

Gass/kondensat

NORSKEHAVET NORD

NORSKEHAVET SYD

BARENTSHAVET

SLEIPNER- OG HALDDENOMRÅDET

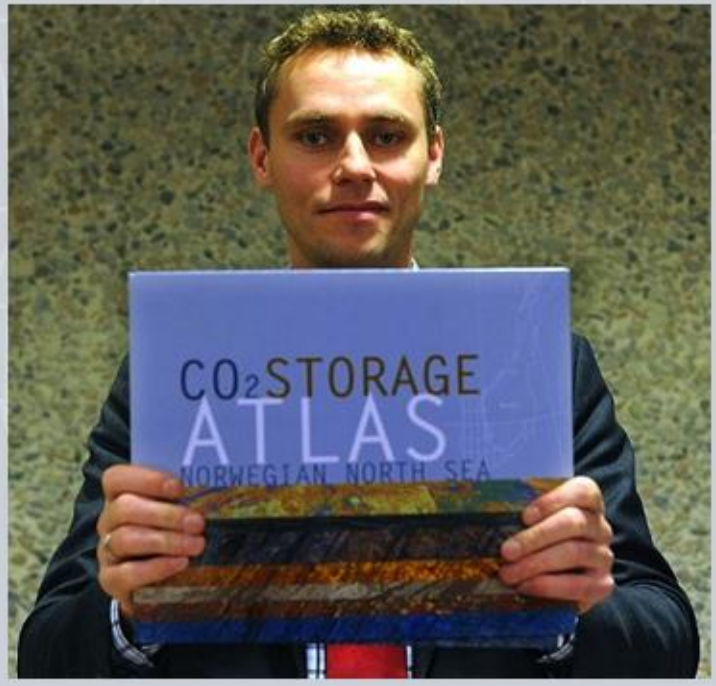
OSEBERG- OG TROLLOMRÅDET

GULLFAKS-, STATFJORD- OG SNORREOMRÅDET

FRIGGOMRÅDET

EKOFISKOMRÅDET

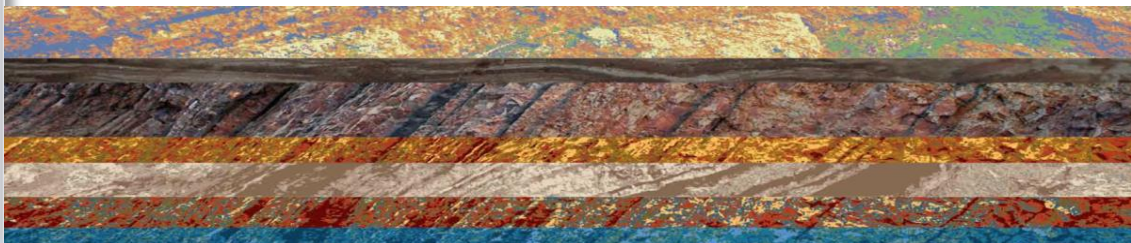
CO_2STORAGE ATLAS
NORWEGIAN NORTH SEA



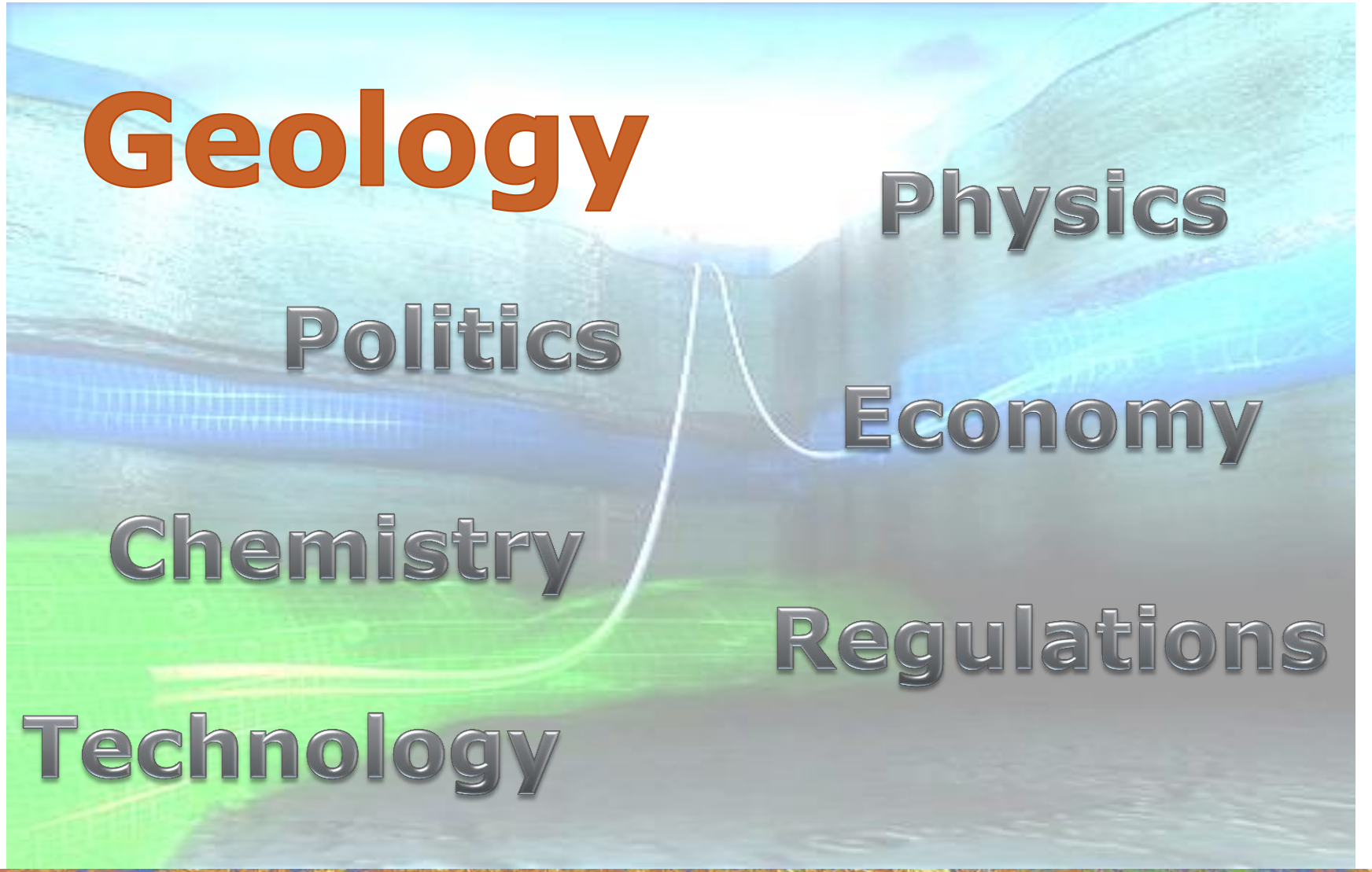
Launched by the Minister of Petroleum and Energy
December 13th 2011

Objectives and requirements

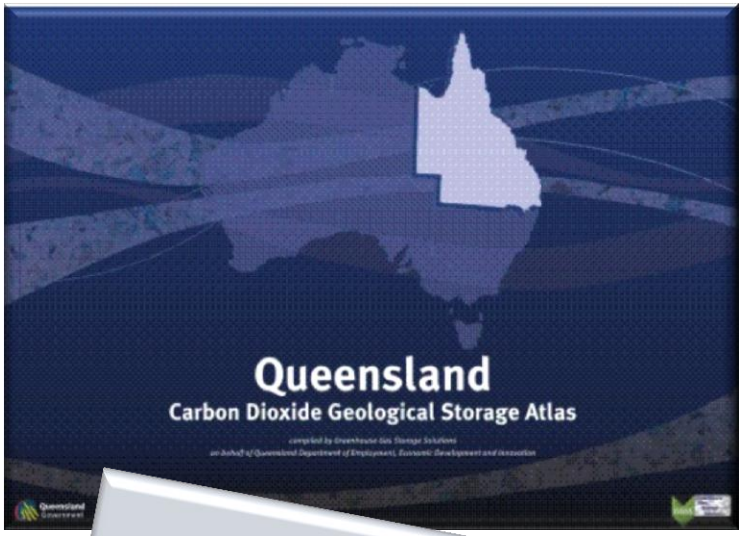
- Find the safe and effective areas for storage of CO_2
- No interference with the petroleum activity
- Build on the accumulated knowledge from the Norwegian petroleum activity
- Build on the experience we have with CO_2 storage
- Mapping and volume calculations should be verifiable
- The work will define relevant storage areas and estimated storage capacities
- The evaluation will form the basis for any terms and conditions set for a development of a storage site offshore Norway



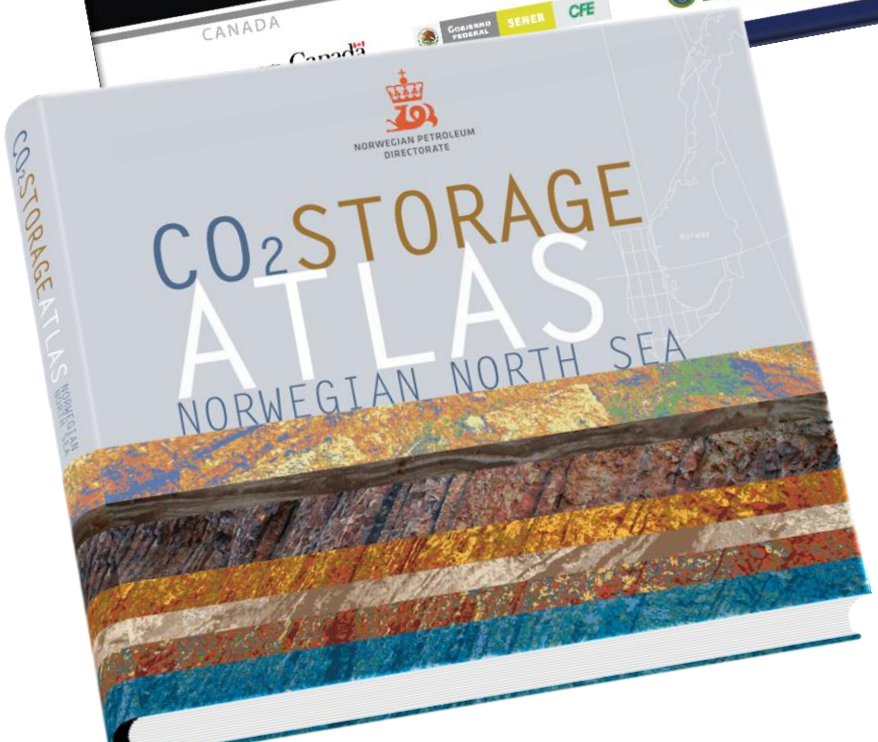
Storage of CO_2 is about:

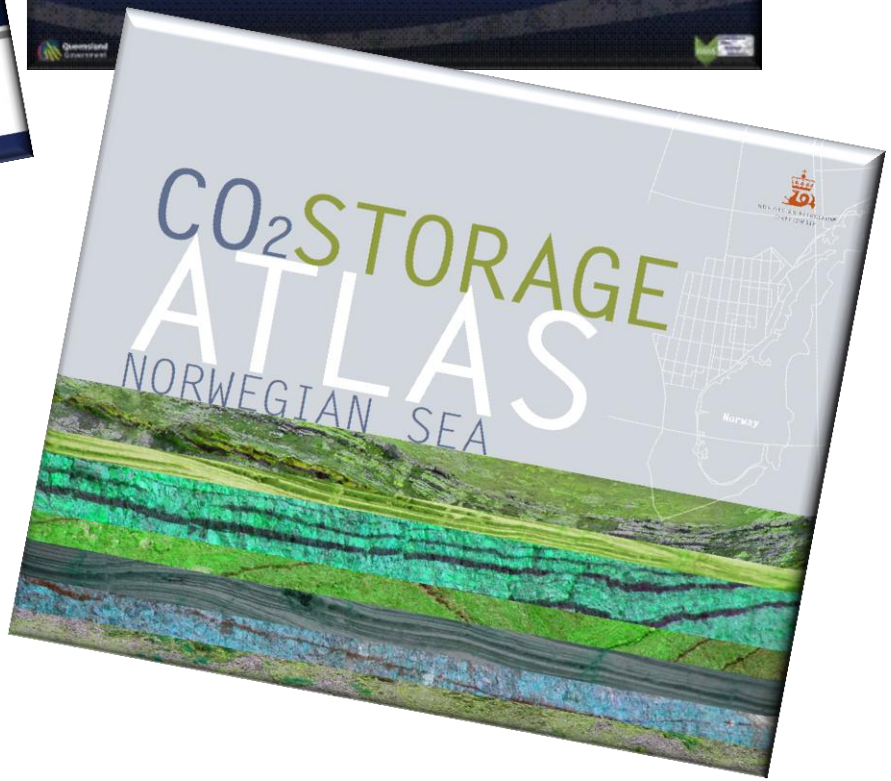



THE NORTH AMERICAN CARBON STORAGE ATLAS
www.nacsa.org
NACSA
2012
First Edition
CANADA
MEXICO
UNITED STATES
ENERGY
NETL
SENER
CFE

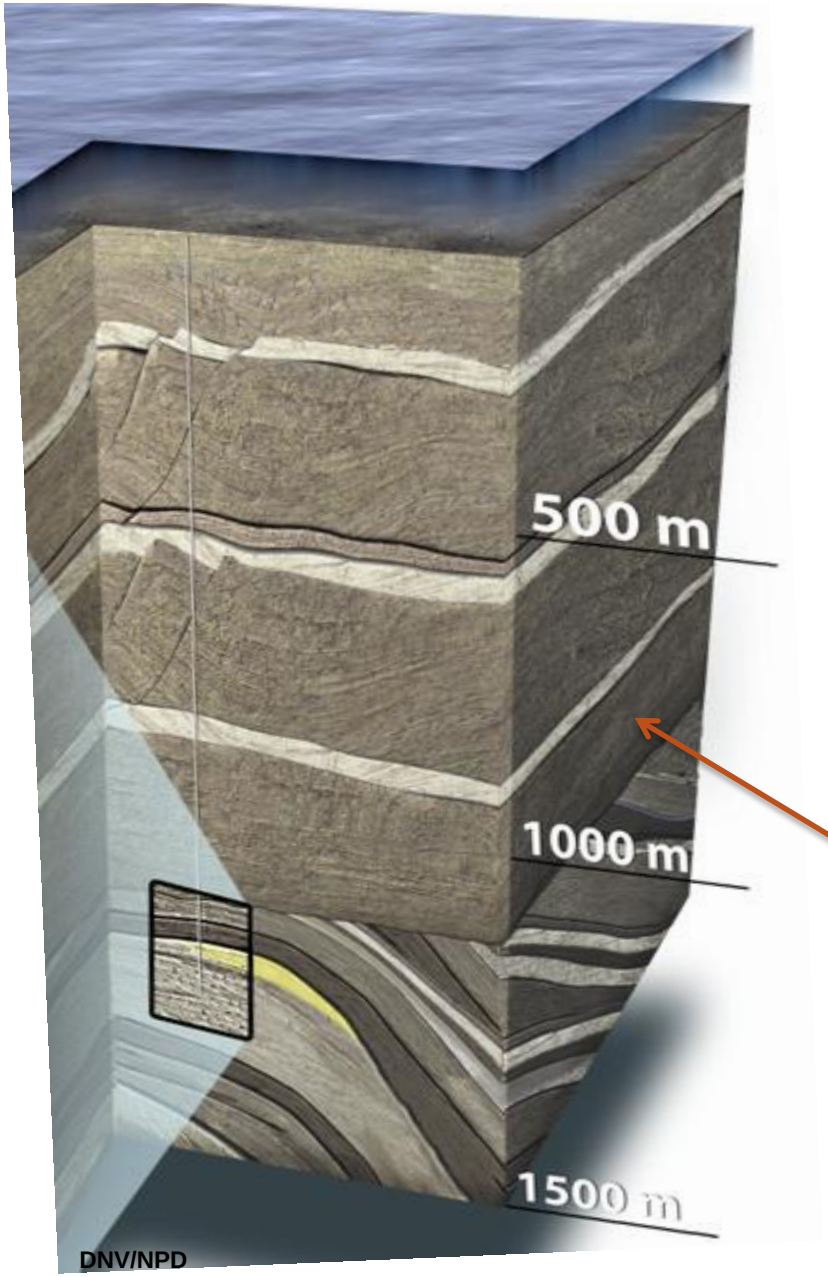

Queensland
Carbon Dioxide Geological Storage Atlas

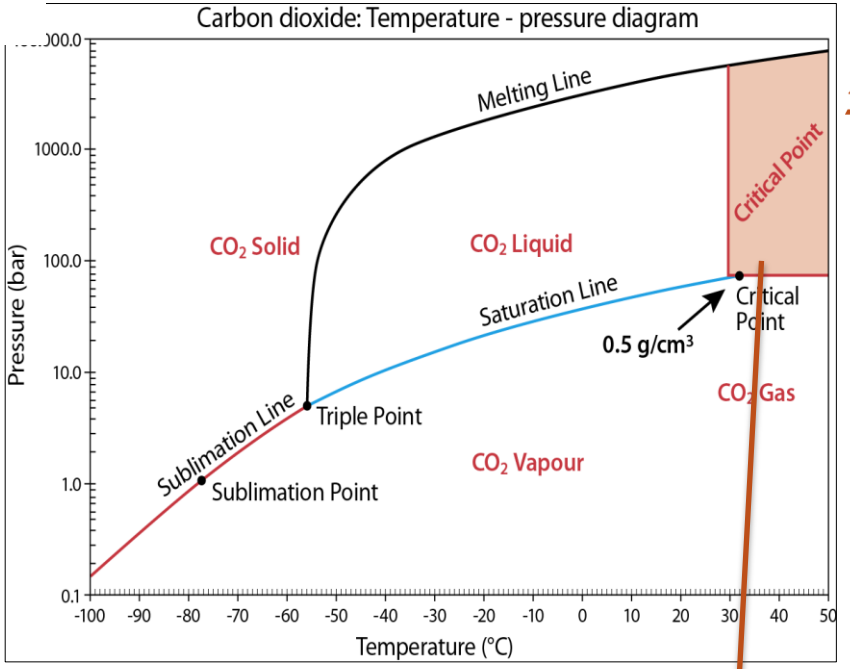
NPD

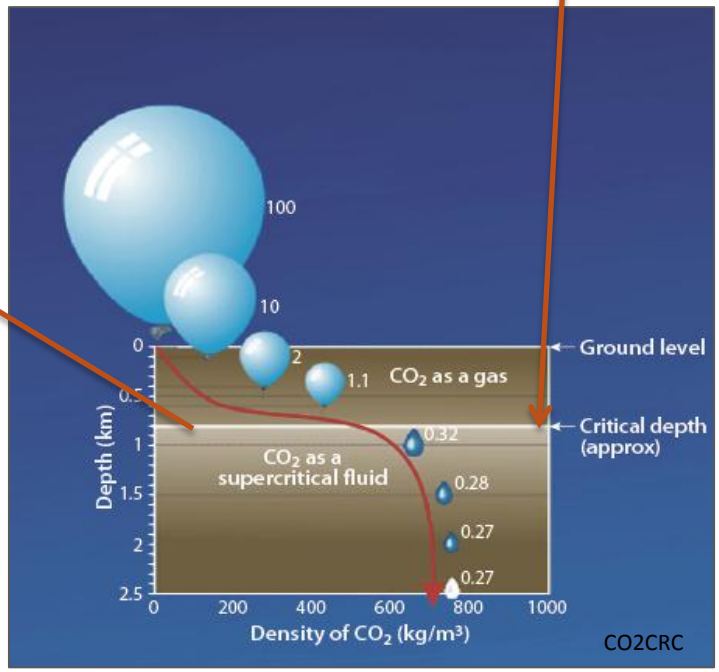

NORWEGIAN PETROLEUM DIRECTORATE
CO2STORAGE
ATLAS
NORWEGIAN NORTH SEA
CO2STORAGE ATLAS NORWEGIAN NORTH SEA

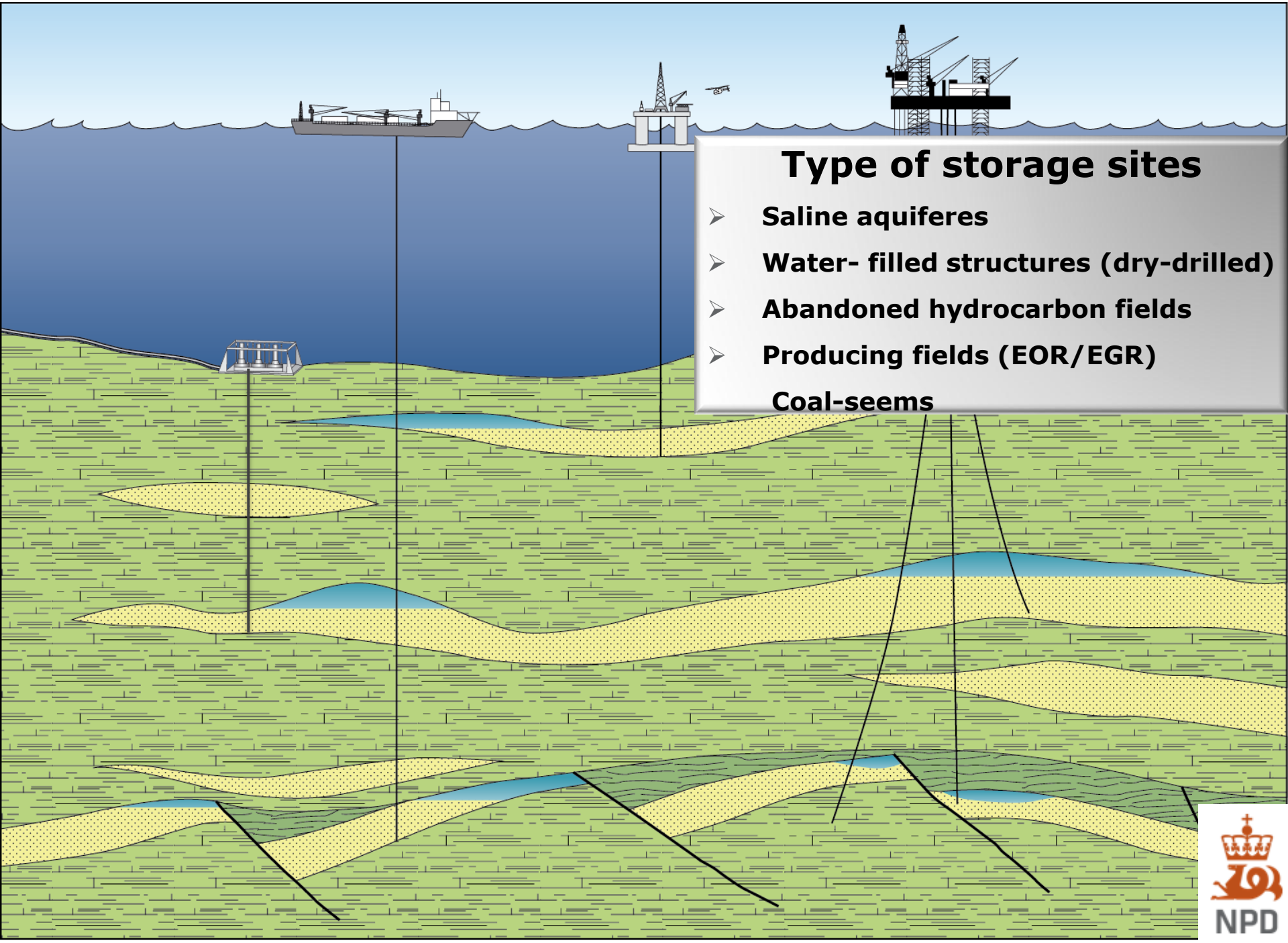

CO2STORAGE
ATLAS
NORWEGIAN SEA
Norway

Chemical and Physical conditions



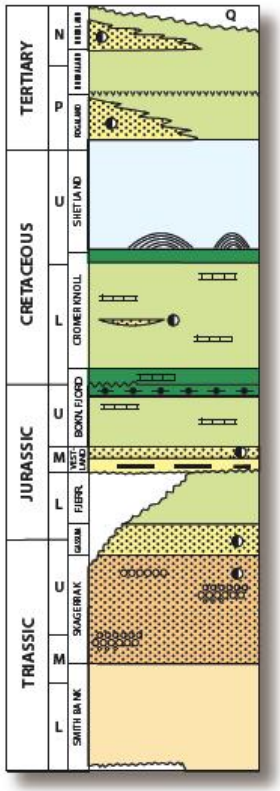


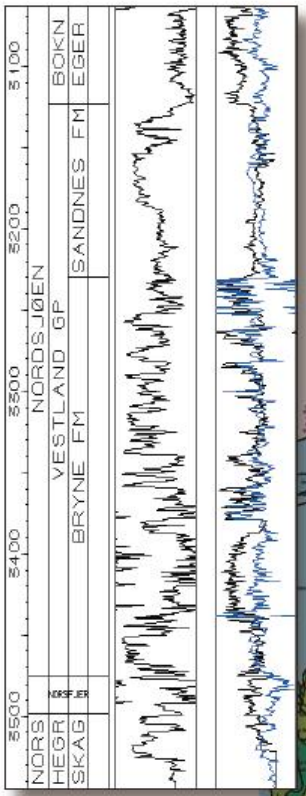


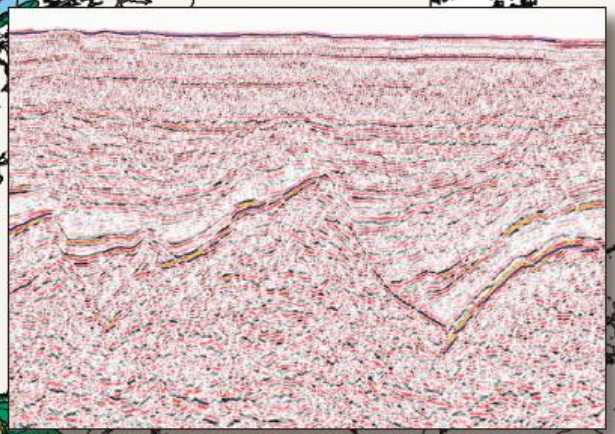

Type of storage sites
Saline aquiferes
Water- filled structures (dry-drilled)
Abandoned hydrocarbon fields
Producing fields (EOR/EGR)
Coal-seems
NPD
OD 1105007

Our playground

NPD has access to all data collected offshore Norway



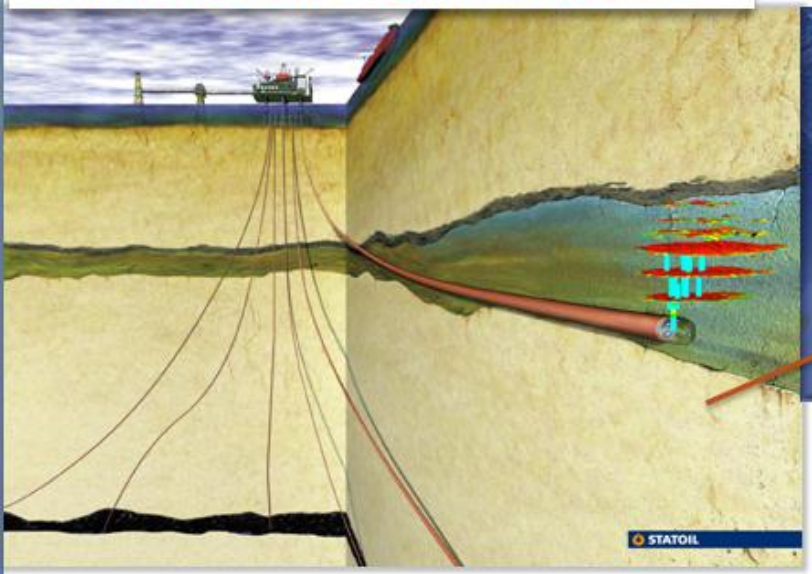




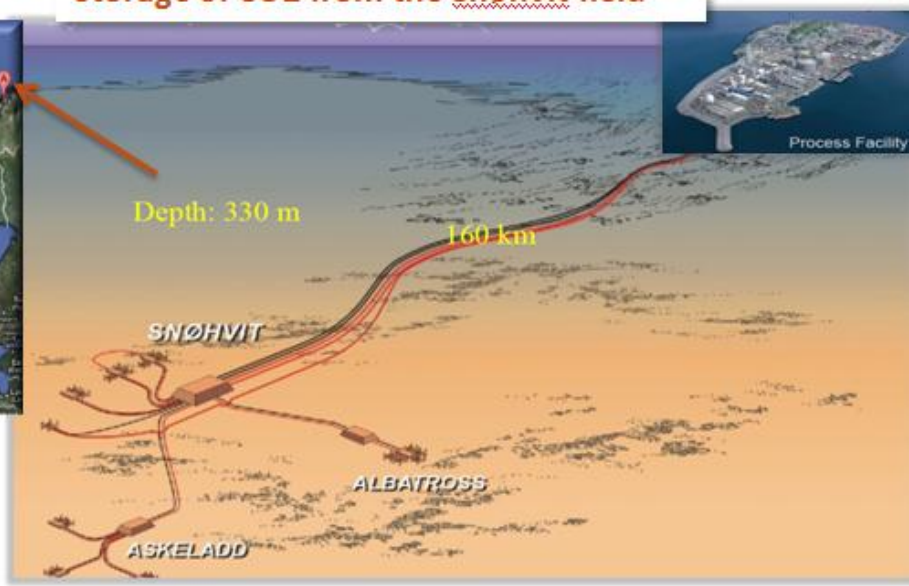
Norwegian CO_2 storage experiences

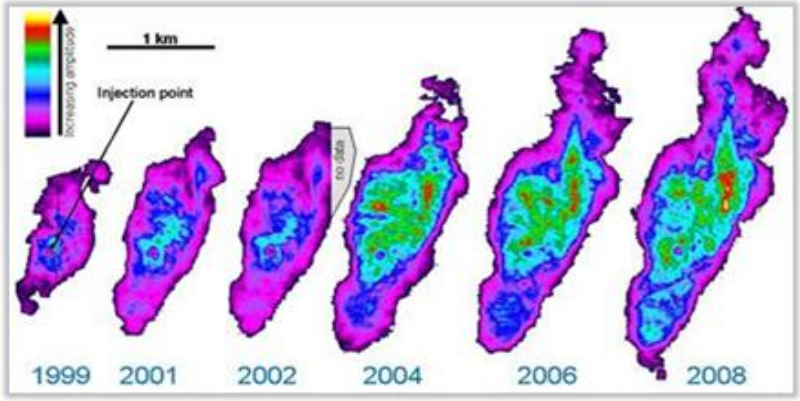
NPD

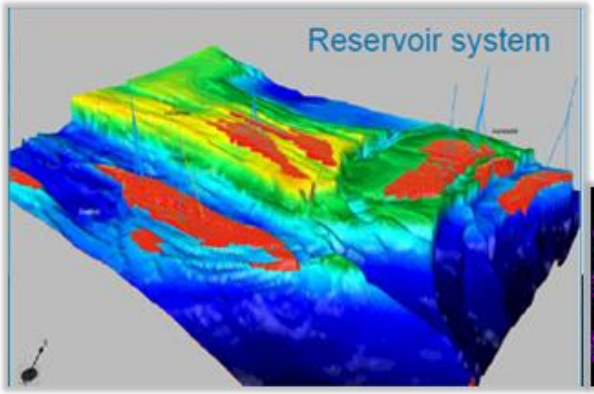
Storage of CO_2 from the Sleipner Vest field

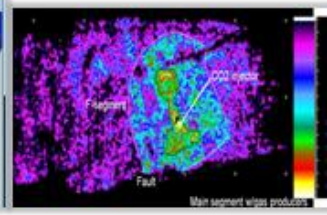


Storage of CO2 from the Snøhvit field



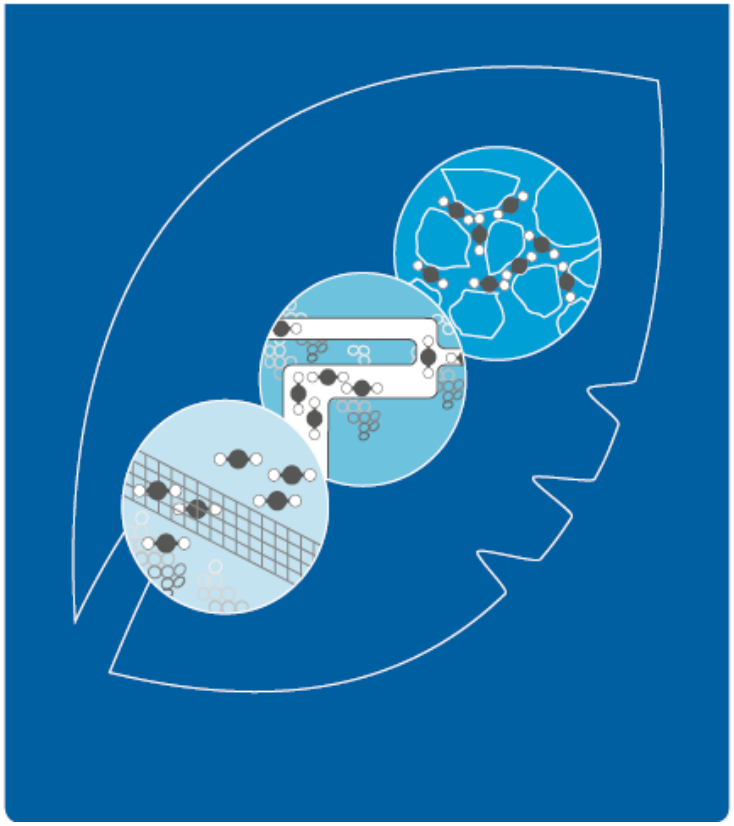






Cooperation between Universities, Research Institutions, Industry companies and the Government

CLIMIT
PROGRAMME PLAN 2010–2012

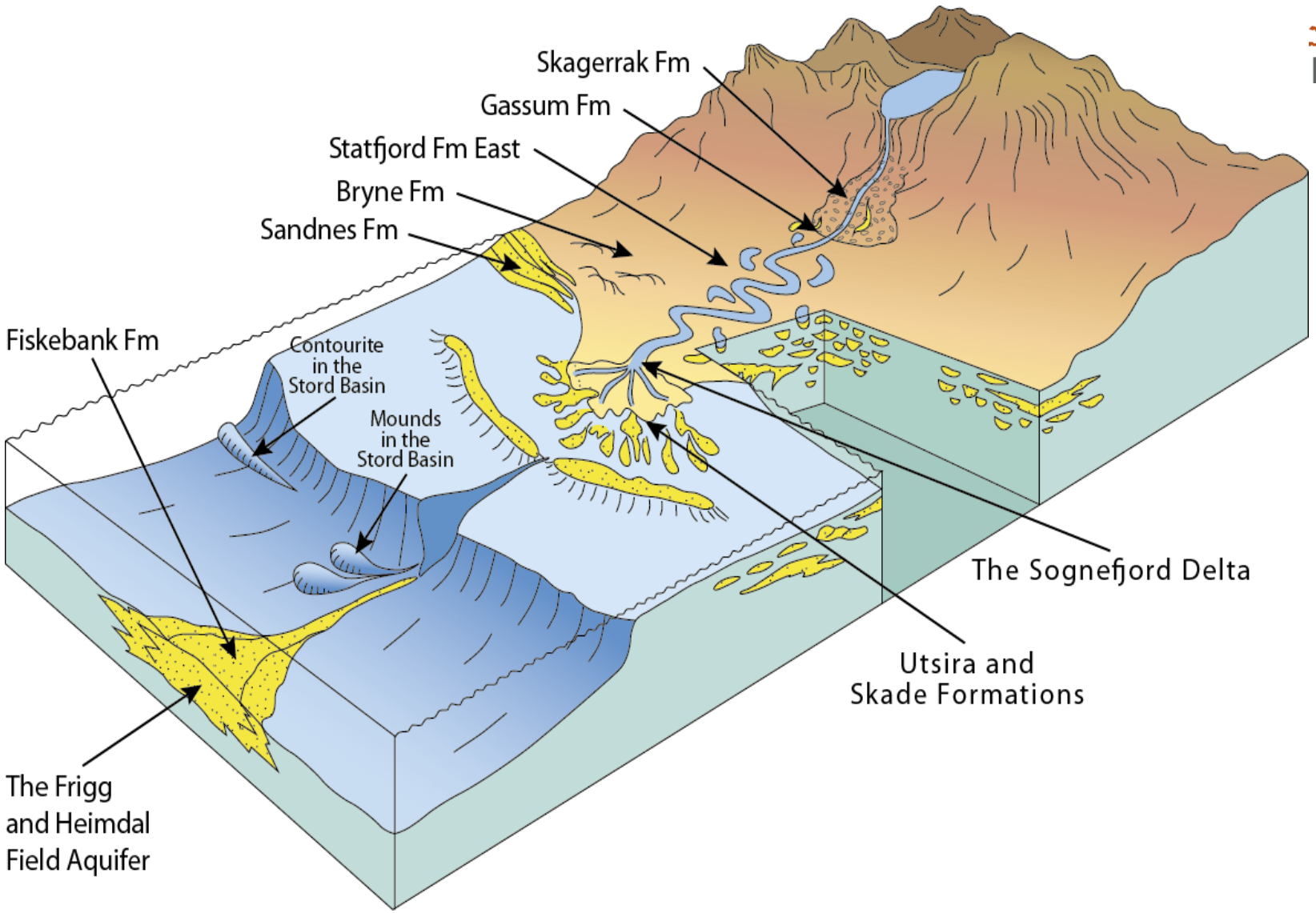


EU's Framework programme (FP7) 2007 -2013
EU budget of around €50.5billion

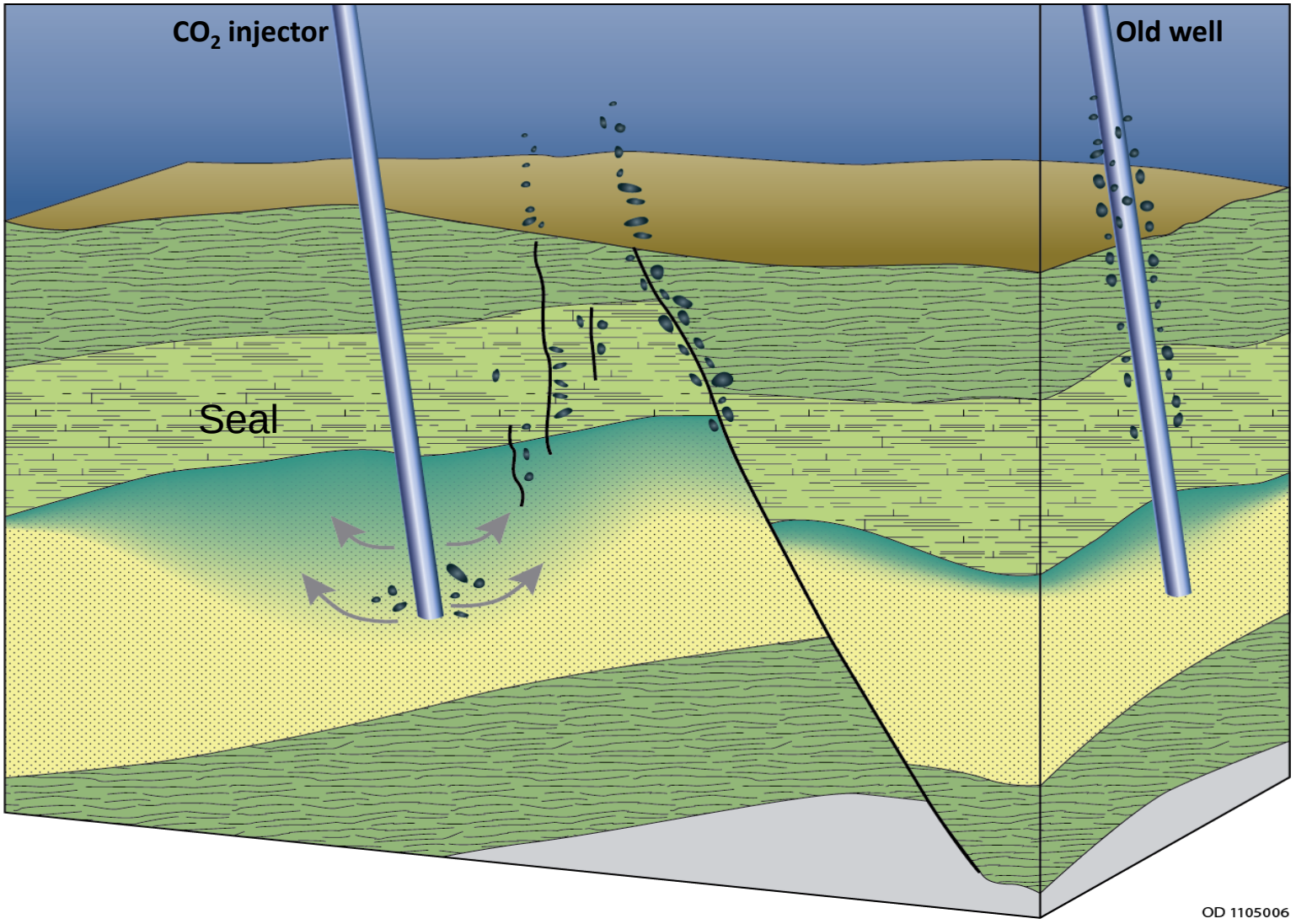
Two FME in CO_2 storage (Centre for Enevironment Friendly Energy research)

BIGCCS : 2009-2016, 22 partners
SUCCESS: 2009-2016, 8 partners

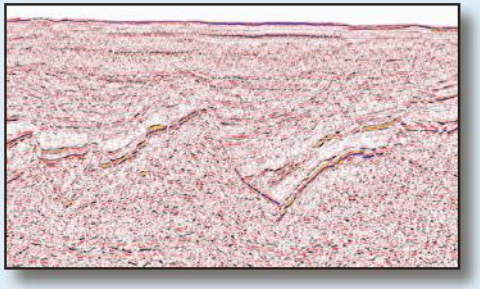
CO_2 Storage Forum, chaired by NPD


Skagerrak Fm
Gassum Fm
Statfjord Fm East
Bryne Fm
Sandnes Fm
Fiskebank Fm
Contourite in the Stord Basin
Mounds in the Stord Basin
The Sognefjord Delta
Utsira and Skade Formations
The Frigg and Heimdal Field Aquifer

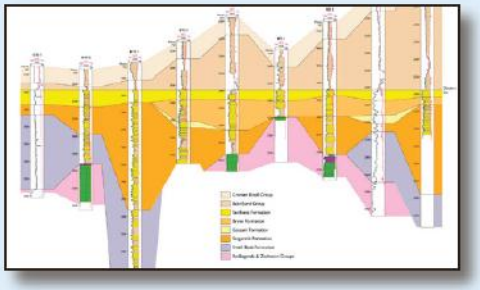
Possible leakage points



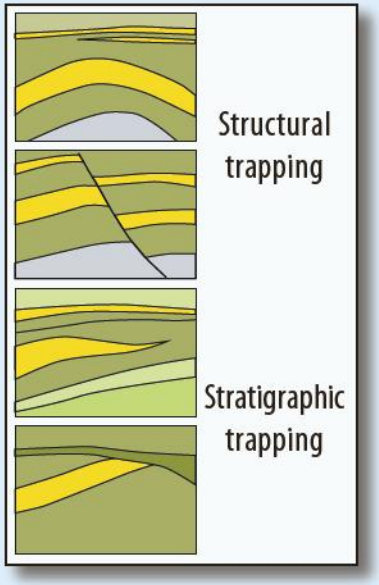
Evaluation process for safe CO_2 storage sites



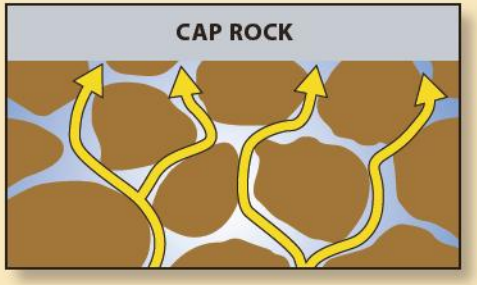
Evaluation of data coverage and knowledge



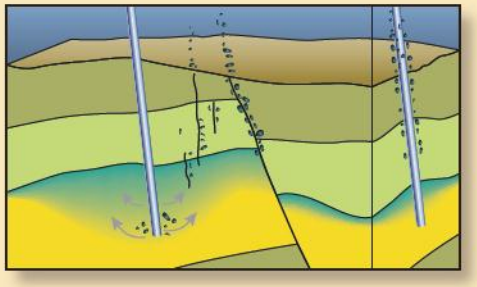
Stratigraphy (reservoir and seal)



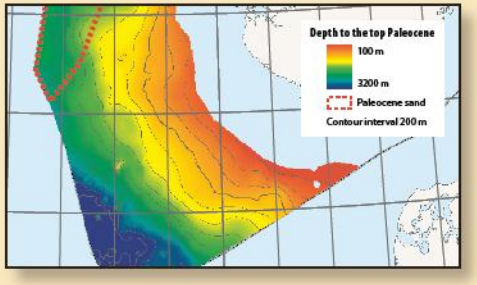
Trapping



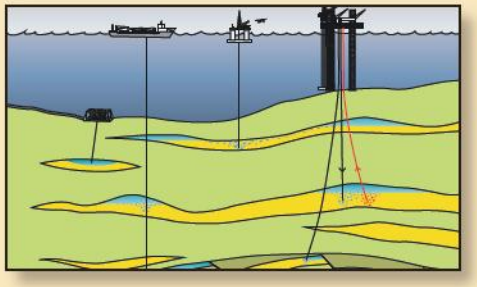
Characterization of reservoir/ injectivity



Characterization of seal efficiency

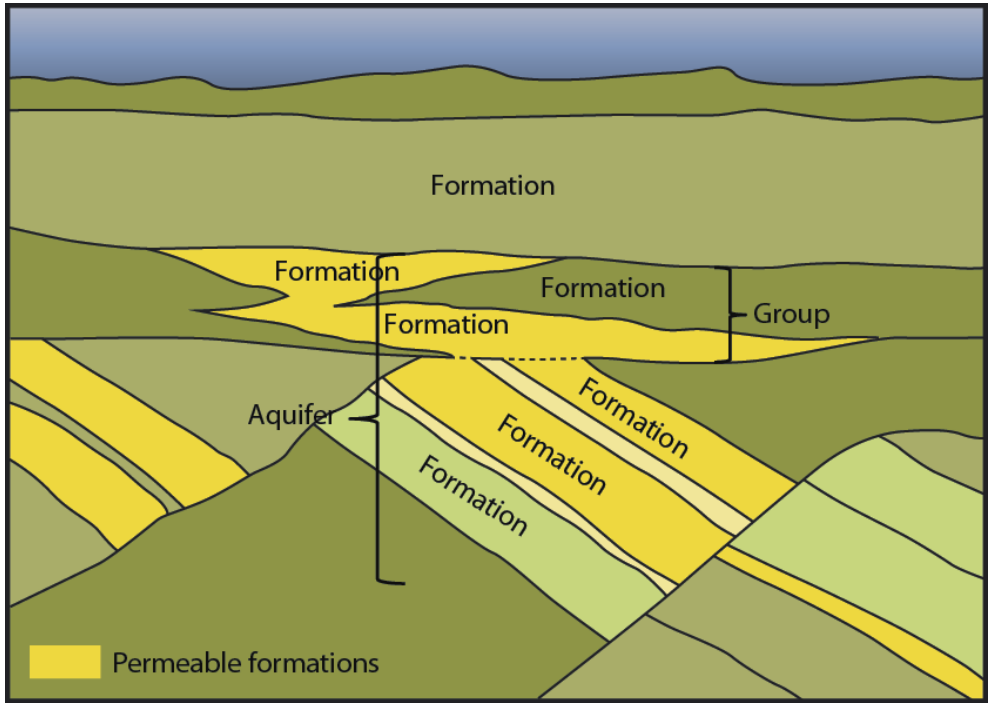


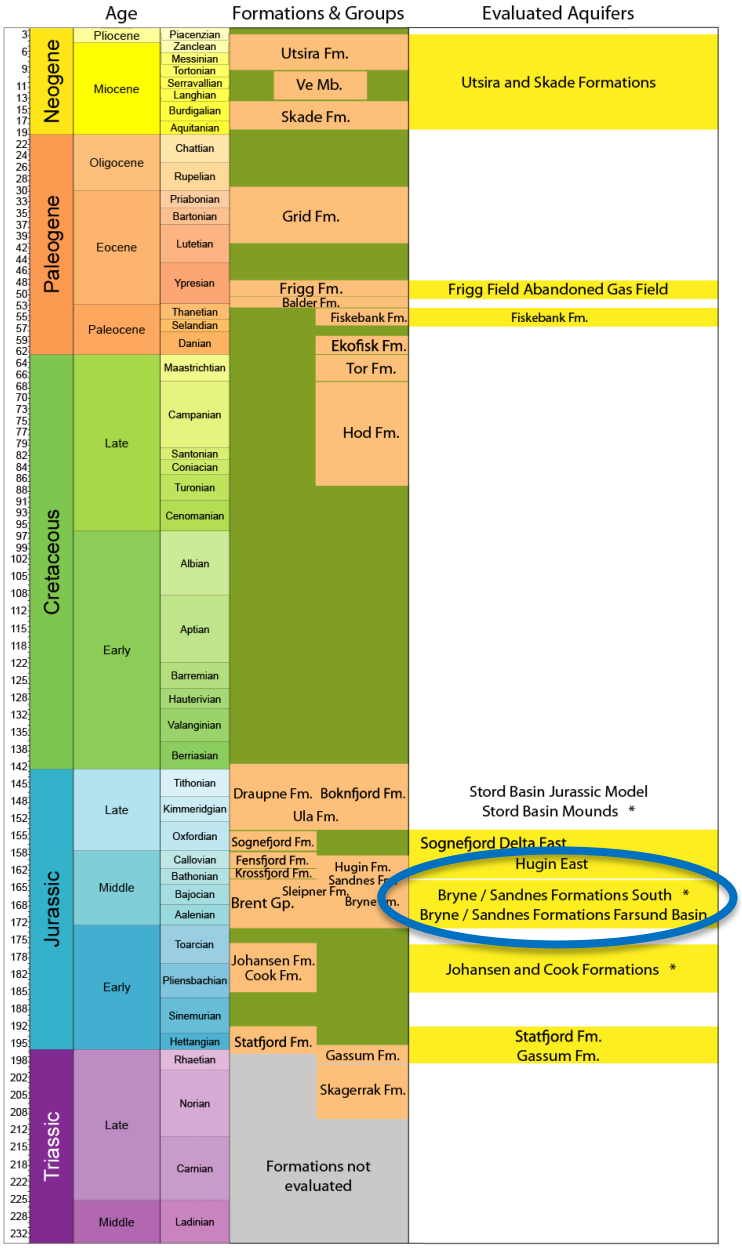
Map potential storage area



Estimate storage capacity

Geological formations and saline aquifers





* Evaluated prospects

CHARACTERIZATION OF AQUIFERS AND STRUCTURES

	Criteria		Definitions, comments
Reservoir quality	Capacity, communicating volumes	3	Large calculated volume, dominant high scores in checklist
		2	Medium - low estimated volume, or low score in some factors
		1	Dominant low values, or at least one score close to unacceptable
	Injectivity	3	High value for permeability * thickness (k*h)
		2	Medium k*h
		1	Low k*h
Sealing quality	Seal	3	Good sealing shale, dominant high scores in checklist
		2	At least one sealing layer with acceptable properties
		1	Sealing layer with uncertain properties, low scores in checklist
	Fracture of seal	3	Dominant high scores in checklist
		2	Insignificant fractures (natural / wells)
		1	Low scores in checklist
Other leak risk	Wells	3	No previous drilling in the reservoir / safe plugging of wells
		2	Wells penetrating seal, no leakage documented
		1	Possible leaking wells / needs evaluation
Data cover age	**Good data coverage**		**Limited data coverage**	**Poor data coverage**

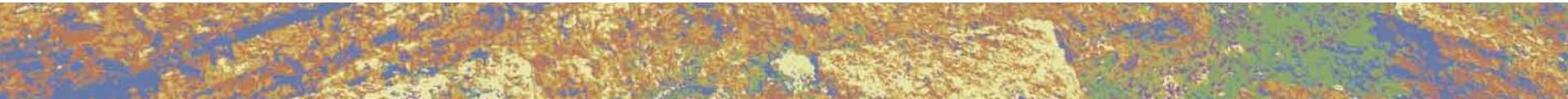
Other factors:
How easy / difficult to prepare for monitoring and intervention. The need for pressure relief. Possible support for EOR projects. Potential for conflicts with future petroleum activity.

Data coverage

Good : 3D seismic, wells through the actual aquifer/structure

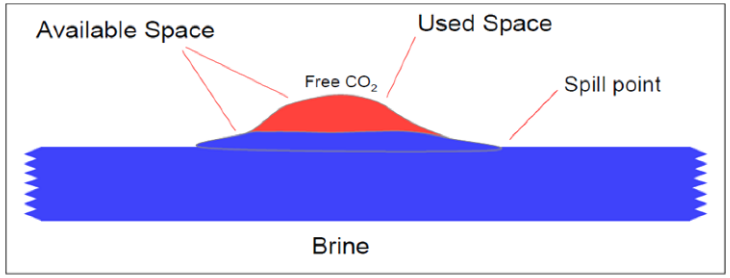
Limited : 2D seismic, 3D seismic in some areas, wells through equivalent geological formations

Poor : 2D seismic or sparse data



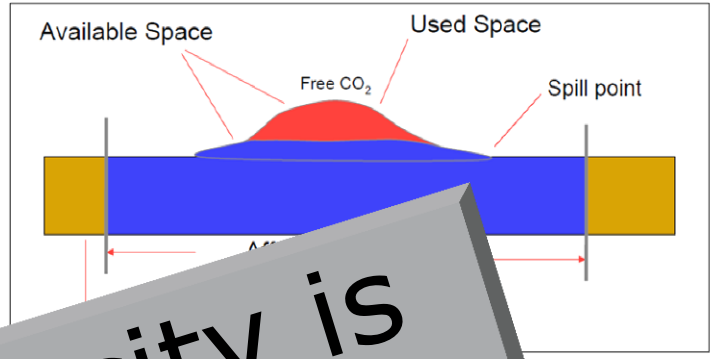
Estimation of CO_2 storage volume

Conceptual model for open aquifers



- Storage space is generated by displacing existing fluids and distributing pressure increase in surrounding aquifer system
- Storage volume = A · height · N/G · ϕ · S_{eff}
- S_{eff} depends on connectivity to surrounding aquifer
- S_{eff} = Used space/Available space

Conceptual model for closed aquifers



From Filip Neele, TNO

Storage capacity is site specific !

M_{CO_2t} = A ×

- M_{CO_2}:
- A:
- h:
- ϕ:
- ρ_{CO_2r}:

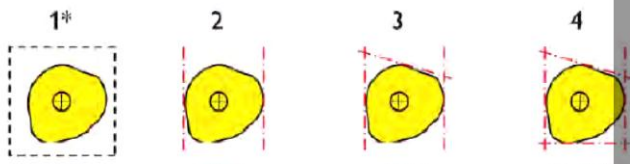
nditions

M_{CO_2e} = A × ϕ × ρ_{CO_2r} × S_{eff}

- M_{CO_2e}: effective storage capacity
- A: area of aquifer
- h: height × net to gross ratio
- ϕ: average reservoir porosity
- ρ_{CO_2r}: CO_2 density at reservoir conditions
- S_{eff}: storage efficiency factor

oretical vs. effective capacity

Storage coefficient (by the rule-of-thumb) S_{eff}



	1*	2	3	4
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