CO_2 Storage on Norwegian Continental Shelf

CO_2 for EOR as CCUS Conference, Houston Oct.4th-6th 2017

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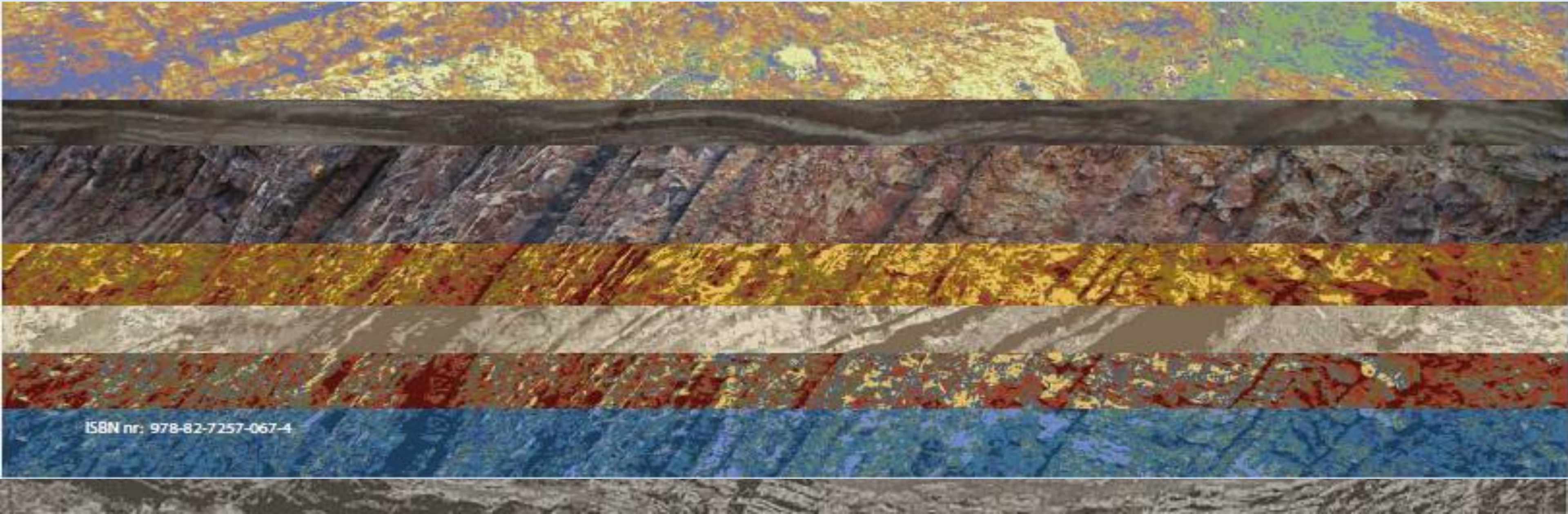
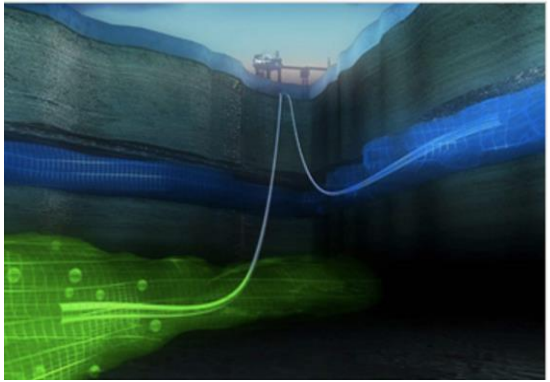
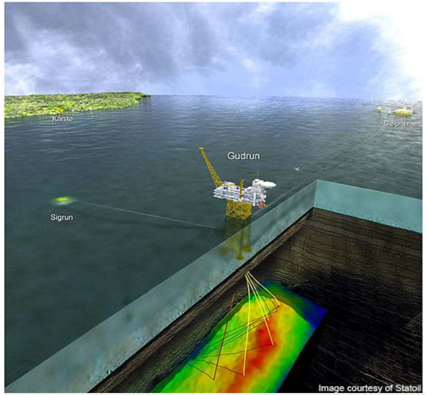
NORWEGIAN PETROLEUM DIRECTORATE



More than 20 years of experience with CCS and CO2 storage in Norway



The Sleipner gas field in The North Sea. CO2 is captured on Sleipner T platform and injected and stored in the Utsira formation.



The Gudrun platform is connected to the Sleipner field and to the Kårstø processing plant.
At Sleipner T, carbon dioxide is removed from the gas

The Snøhvit gas field in the Barents Sea. The well stream, with natural gas, CO2, natural gas liquids (NGL) and condensate, is transported in a 160-kilometre pipeline to the facility at Melkøya near Hammerfest. The gas is processed and cooled down to liquid natural gas (LNG). The CO2 is separated and returned to the field by pipeline for reinjection into the aquifer (Stø reservoir).

These projects are living proof that storage of CO_2 is possible!

Source: Statoil

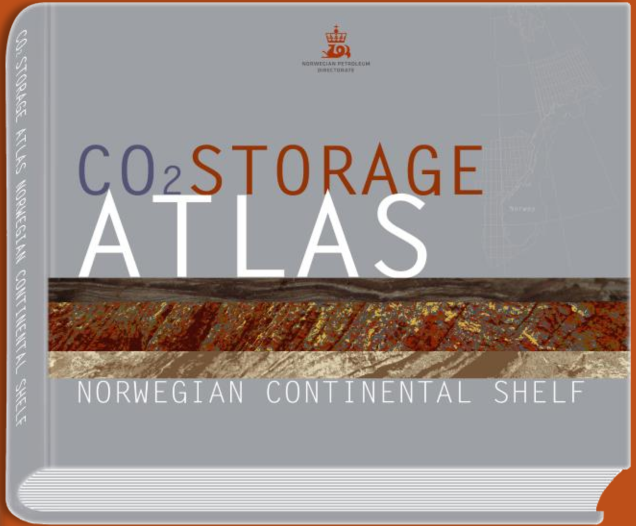
What did these CCS projects get started?

The CO_2 Tax Act on Petroleum Activites (Act 21 December 1990 no 72 relating to tax on discharge of CO_2 in the petroleum activities on the continental shelf **)**

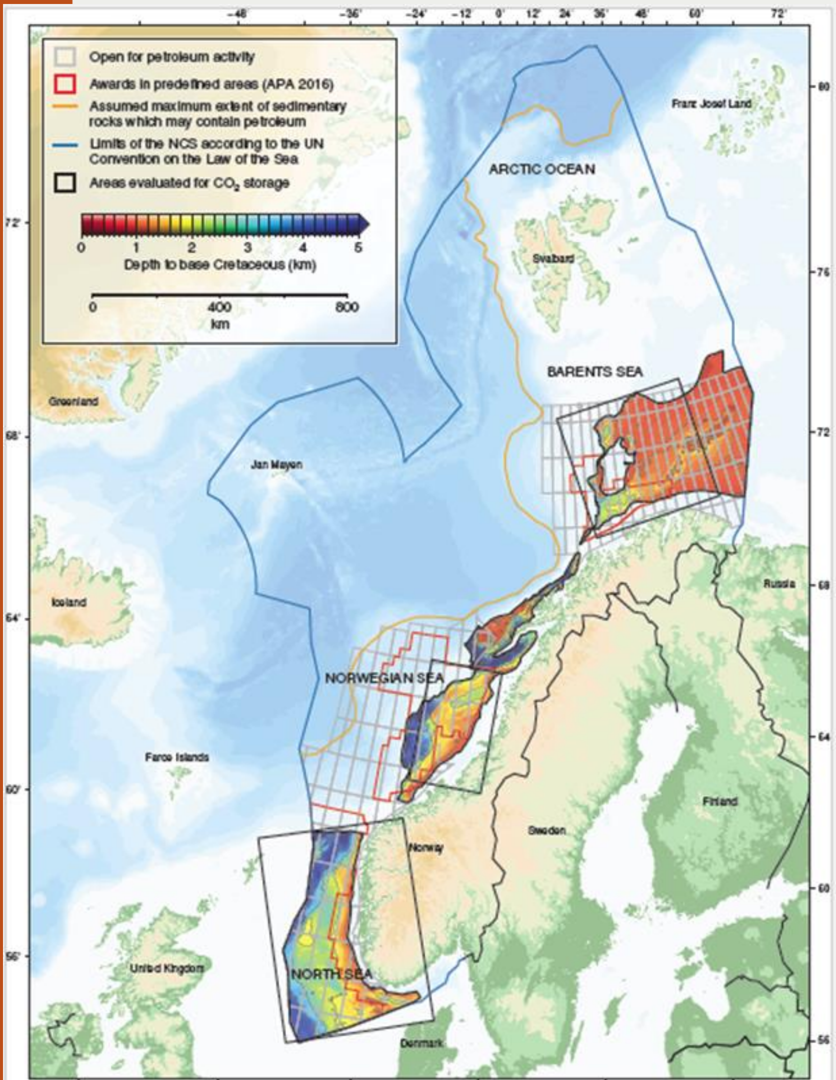
”CO_2 tax is to be charged on petroleum which is burnt and natural gas which is discharged to air and also on CO_2 separated from petroleum and discharged to air, on installations used in connection with production or transportation of petroleum”

→ **Government strategy, regulations and taxes**

Government strategy:
Where is it possible to store CO_2 offshore Norway, and what is the storage capacity?

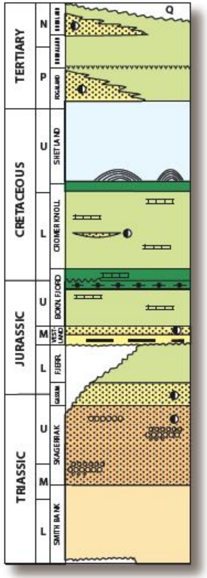


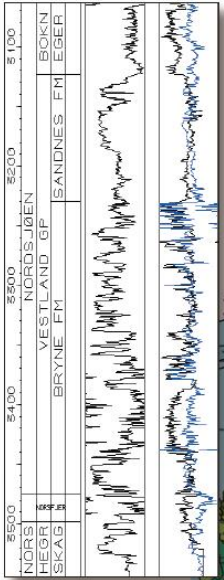
The Norwegian CO2 Storage Atlas was launched by the Minister of Petroleum- and Energy Department May 20th 2014

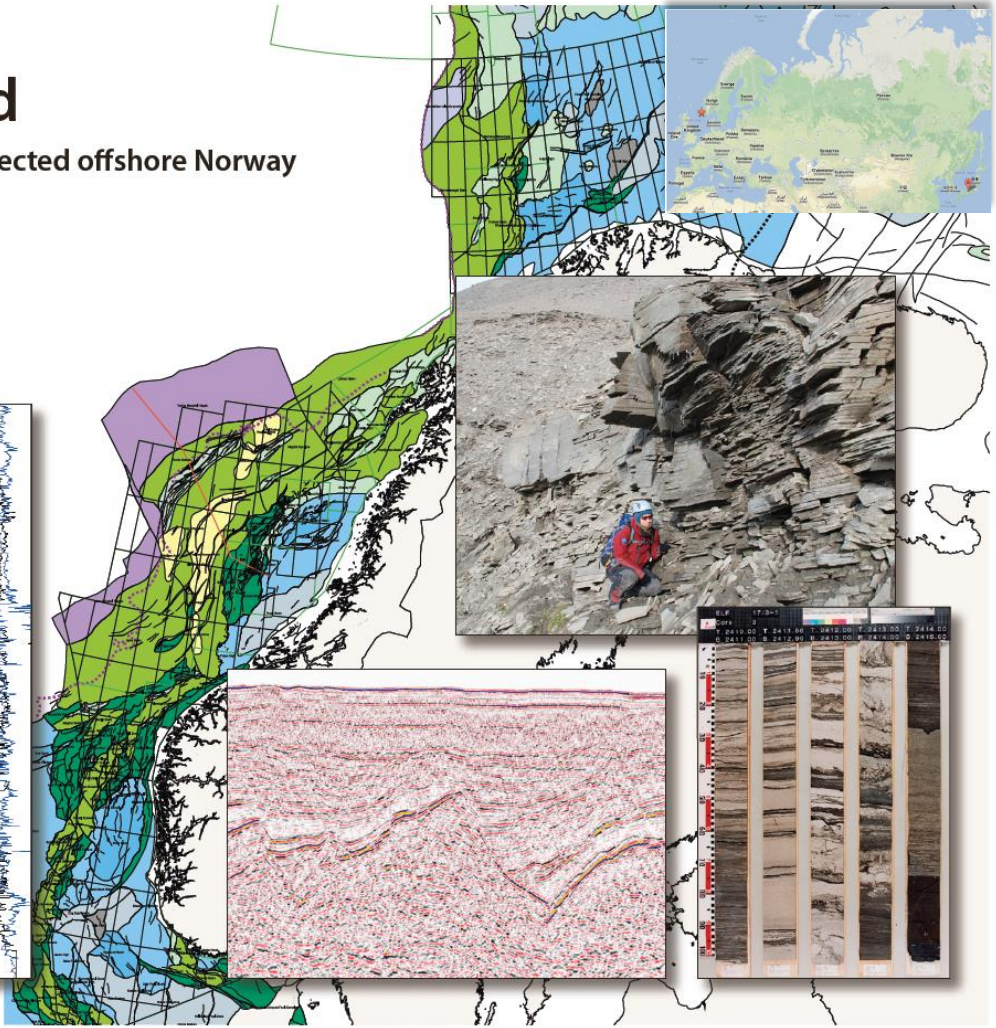


Our playground

NPD has access to all data collected offshore Norway







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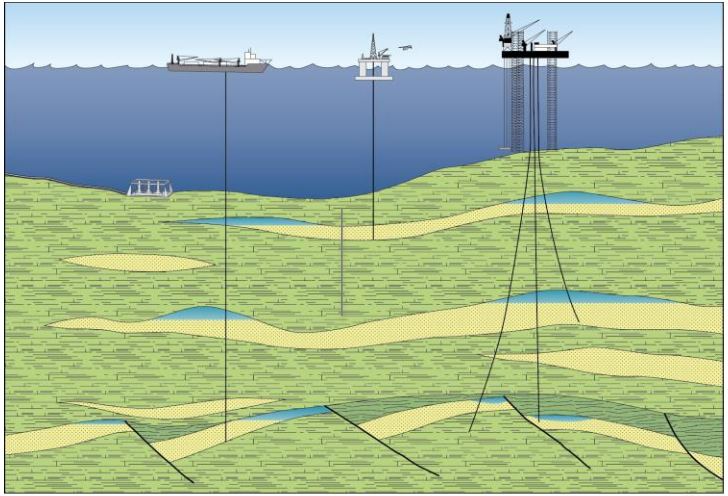

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Type of storage sites

- Saline aquiferes
- Water- filled structures (dry-drilled)
- Abandoned hydrocarbon fields
- Producing fields (EOR)

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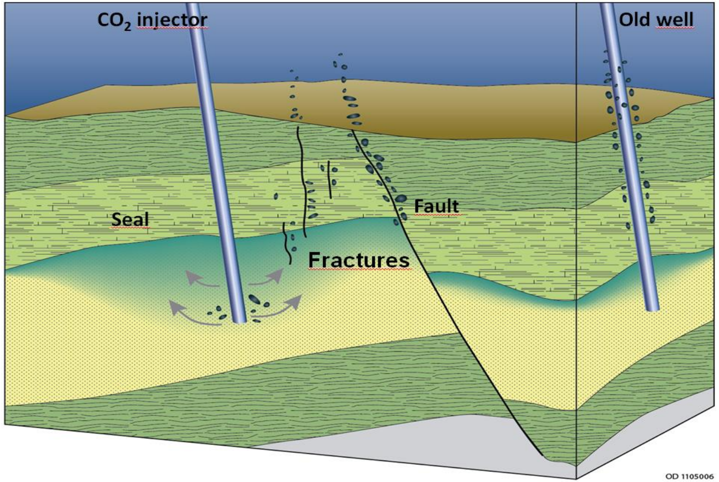

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Potential leakage points

- Faults
- Seal
- Old wells
- Injection wells

Characterization of potential CO_2 storage sites

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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 coverage	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.

CHECKLIST FOR RESERVOIR PROPERTIES

Typical high and low scores		
Reservoir Properties	High	Low
Aquifer Structuring	Mapped or possible closures	Tilted, few /uncertain closures
Traps	Defined sealed structures	Poor definition of traps
Pore pressure	Hydrostatic or lower	Overpressure
Depth	800- 2500 m	< 800 m or > 2500 m
Reservoir	Homogeneous	Heterogeneous
Net thickness	> 50 m	< 15 m
Average porosity in net reservoir	> 25 %	< 15 %
Permeability	> 500 mD	< 10 mD

FOR SEALING PROPERTIES

Typical high and low scores			
Sealing Properties	High	Low	Unacceptable values
Sealing layer	More than one seal	One seal	No known sealing layer over parts of the reservoir
Properties of seal	Proven pressure barrier/ > 100 m thickness	< 50 m thickness	
Composition of seal	High clay content, homogeneous	Silty, or silt layers	
Faults	No faulting of the seal	Big throw through seal	Tectonically active faults
Other breaks through seal	No fracture	sand injections, slumps	Active chimneys with gas leakage
Wells (exploration/ production)	No drilling through seal	High number of wells	

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

CO_2 Storage Capacities
Norwegian Continental Shelf

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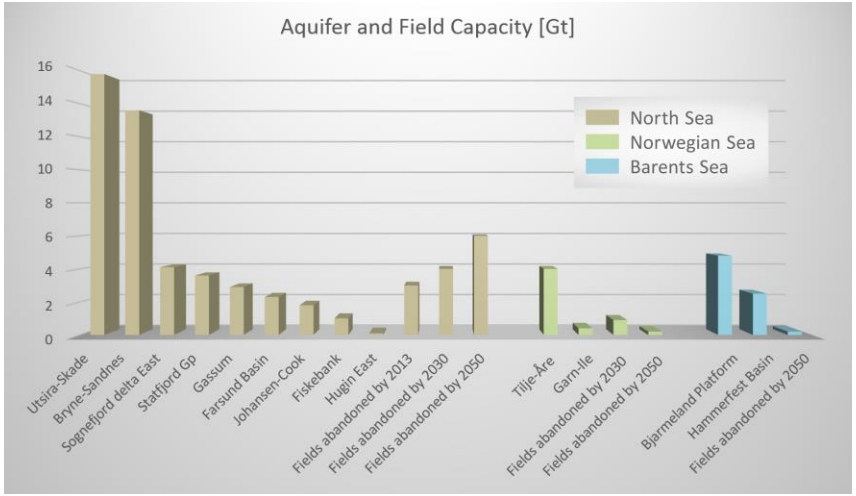
Capacity related to maturity in the North Sea, Norwegian Sea and the Barents Sea



Storage capacities in the different geological formations and basins.

A new large scale CCS project in Norway

Statoil:
Onshore facility with pipeline to

Storage location offshore

Klemetsrud:
- Waste incineration
- 315 000 tons CO_2 per year

Yara:
- Ammonia production
- 805 000 tons CO_2 per year

Norcem:
- Cement production
- 400 000 tons CO_2 per year

Large scale CCS in Norway

A large scale CCS project in Norway will:

- Be operational from 2022
- Demonstrate a full chain of capture, transport and storage of CO_2
- Demonstrate CO_2 capture in existing industry.
- Establish a flexible storage solution with possible extra capacity.
- Provide cost and risk reductions for subsequent CCS projects

Smeaheia CO_2 storage location

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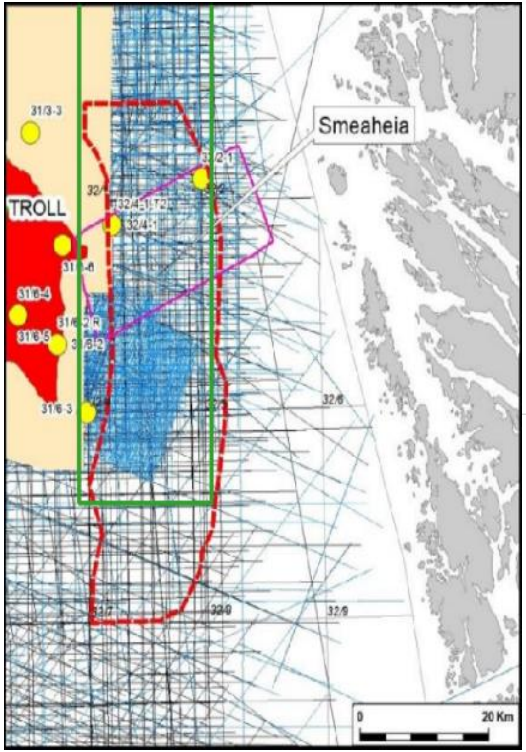
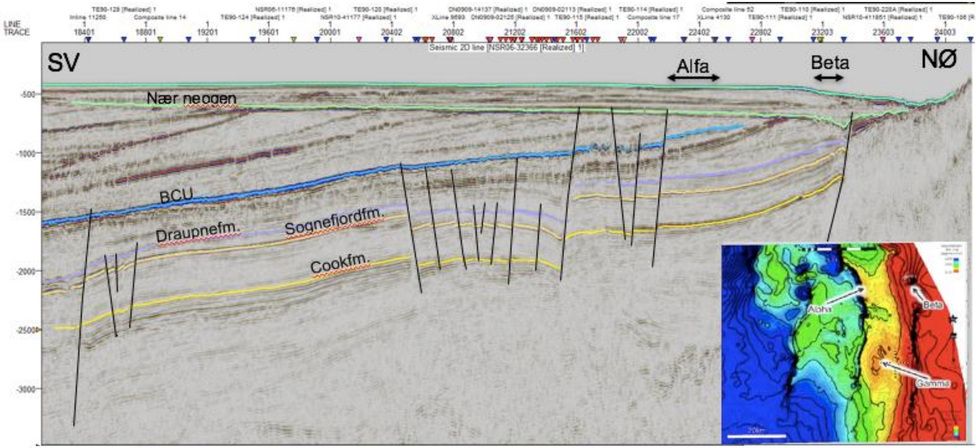
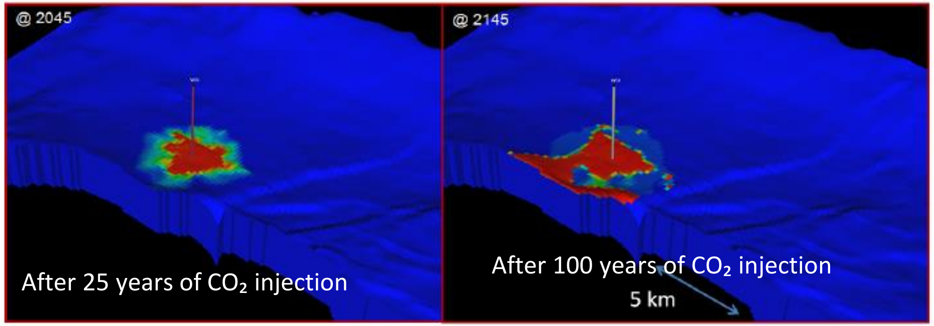
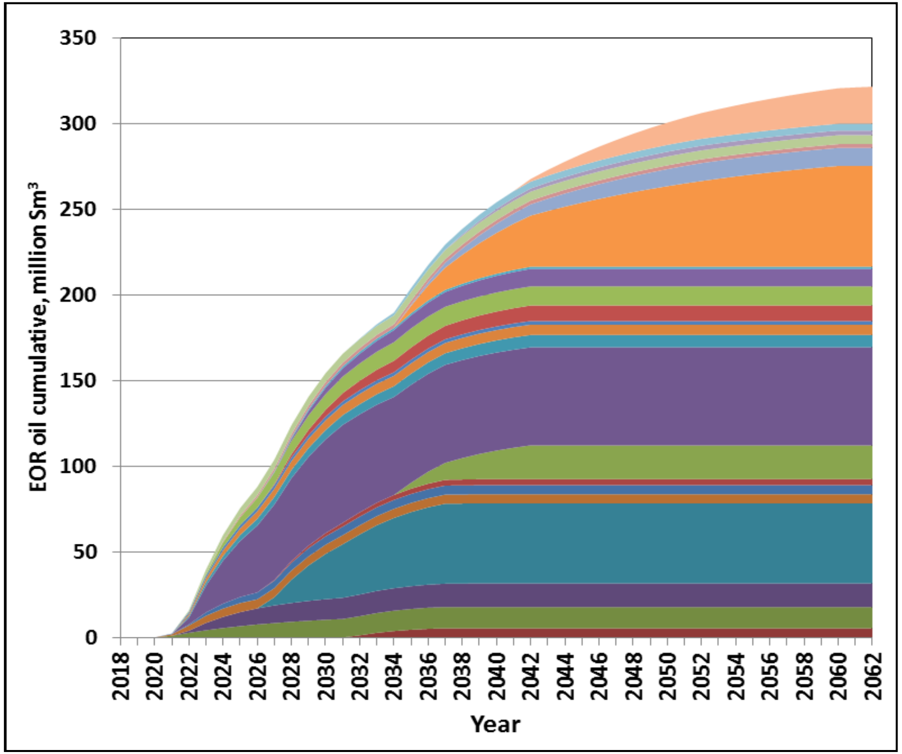






The Alfa structure

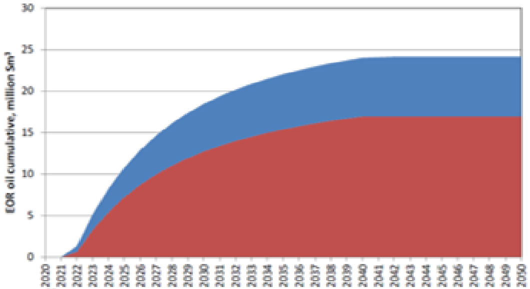
CO_2 for EOR and storage



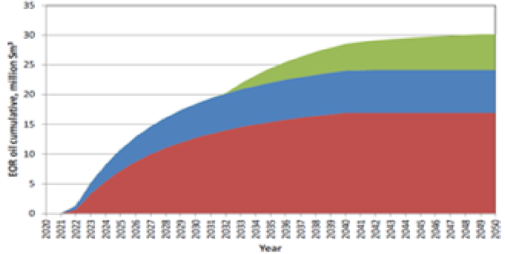
A screening-study of 23 oil fields in the Norwegian North Sea
Modeled recovery:
more than 300 MSm³ of additional oil with about 70 Mt CO_2 injected annualy.

The increased oil recovery for each field is in the range of 4 to 12 %

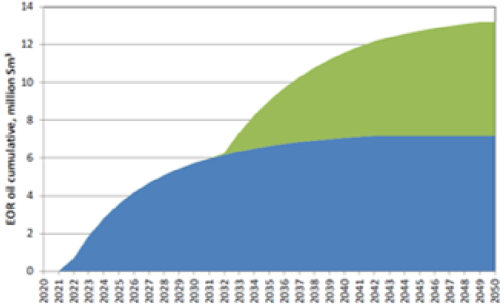
Study of three different oilfields with a yearly access of around1-3Mt of CO_2



Case1:
Pipe- and ship transportation
3.25Mt/y CO_2



Case 2:
Pipe- and ship transportation
3.25Mt/Y CO_2

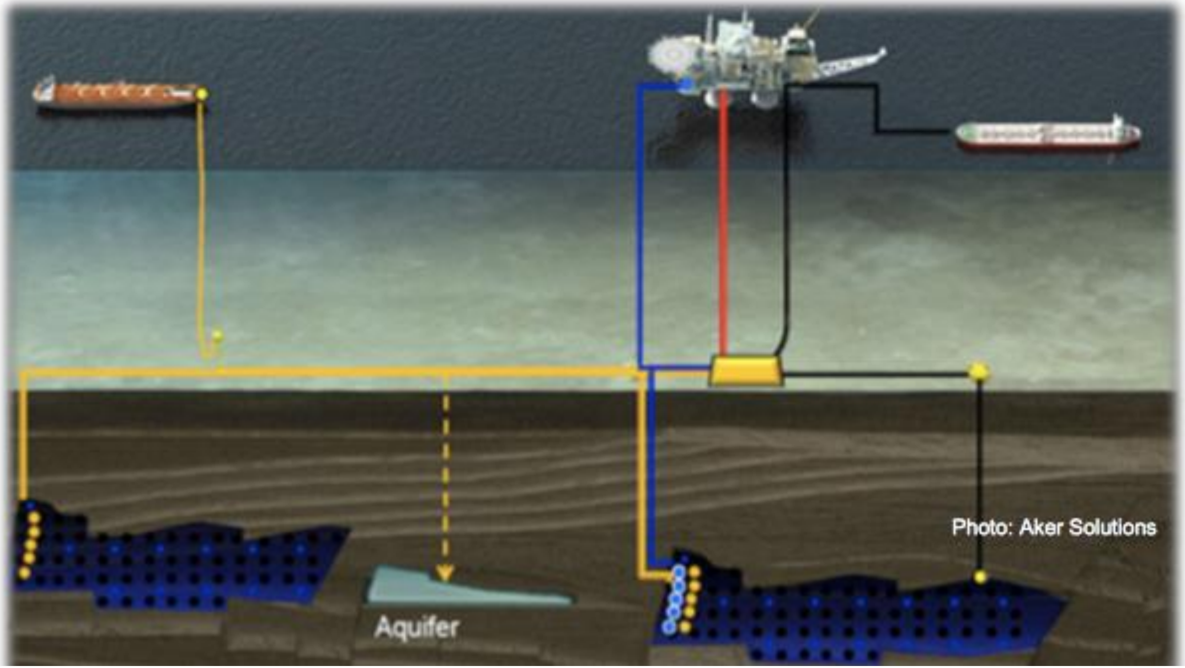


Case 3:
Ship's transportation
1.35Mt/y CO_2

	Case 1	Case 2	Case 3
Amount of available CO_2 [Mt/year]	3.25	1.35	3.25
Total EOR-oil [mill. Sm^3]	24.1	13.2	30.1
Total EOR-oil [% of OOIP]	10.9	8.8	10.3
Total stored CO_2 in oil fields and aquifers [Mt]	97	40	98

CO_2 EOR without modification on existing platforms

- CO_2 from CCS to EOR in existing oilfield in the North sea
- Separate and reinject the "breakthrough" CO_2 with subsea solution
- CO_2 will be permanent stored after EOR is finished



Cost and Value

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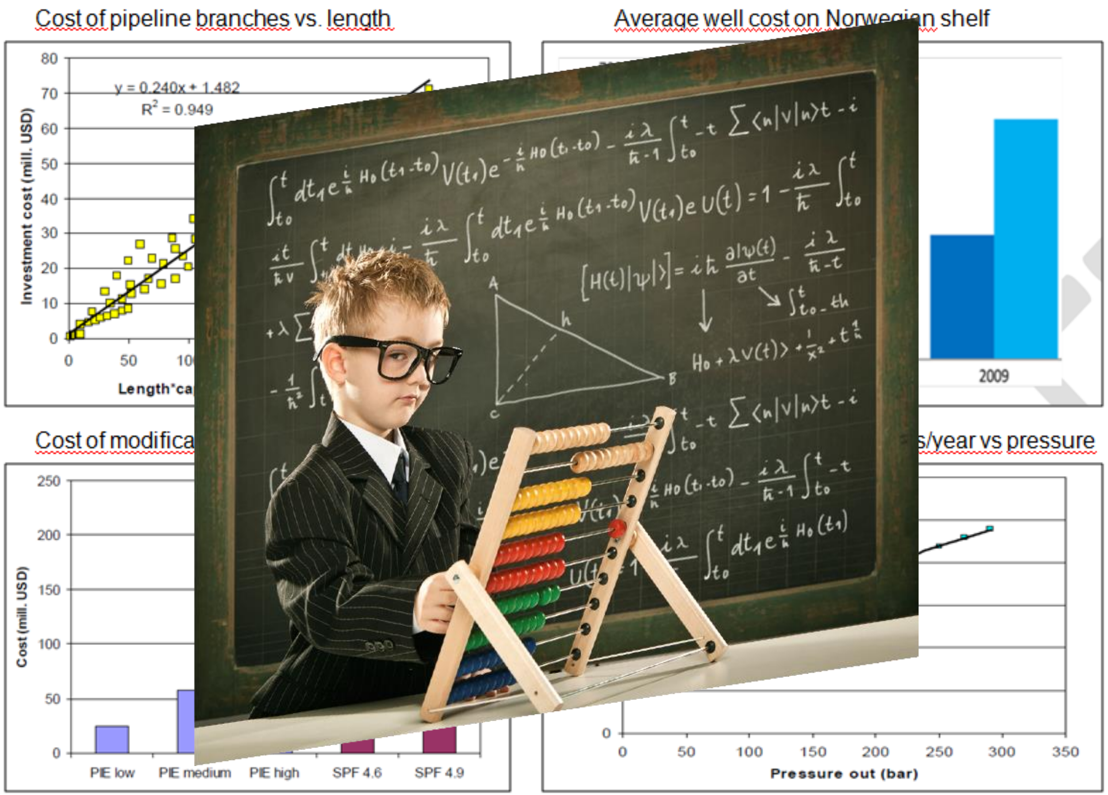
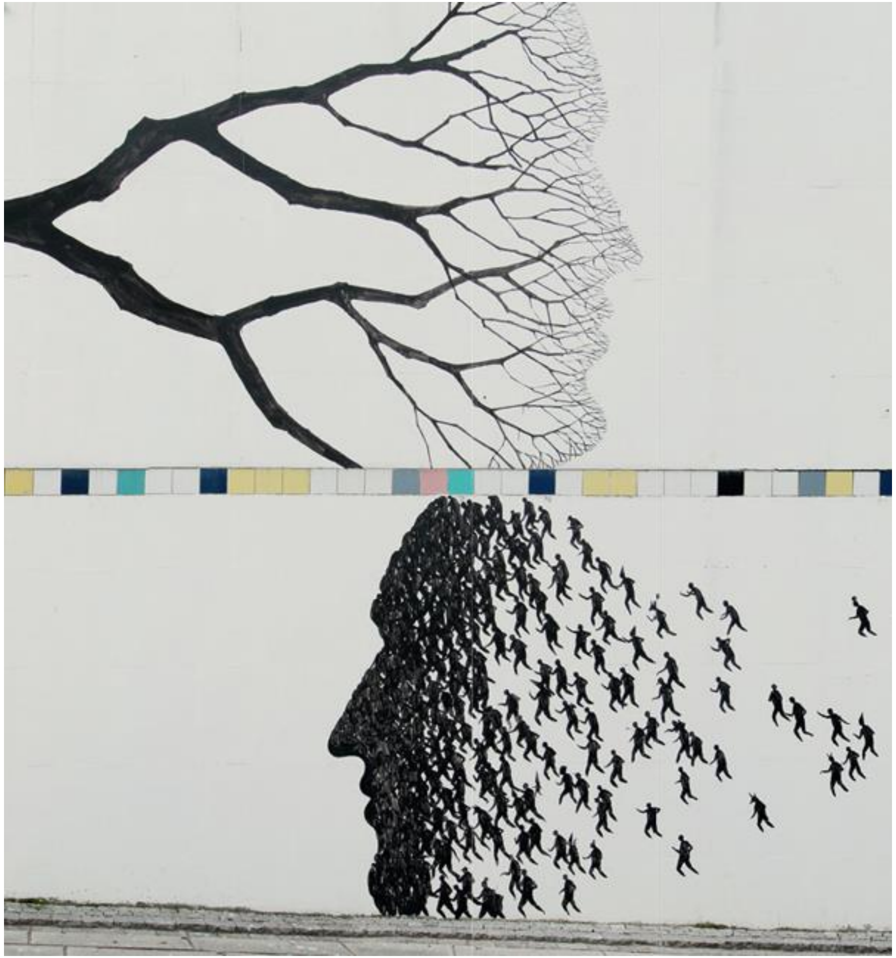


Experience indicates that it is no problem to calculate away from EOR projects on offshore fields, and it can become even more challenging with CO2 EOR.

So still: technology development, good understanding of the reservoir and someone must be willing to be the first to test it on an offshore field!



“A mind is like a parachute. It doesn't work if it is not open.”

Frank Zappa