Storage resource assessment for offshore CO_2-EOR in Norway

OLJEDIREKTORATET

3rd International Workshop on Offshore Geologic CO_2 Storage, Oslo May 3-4 2018

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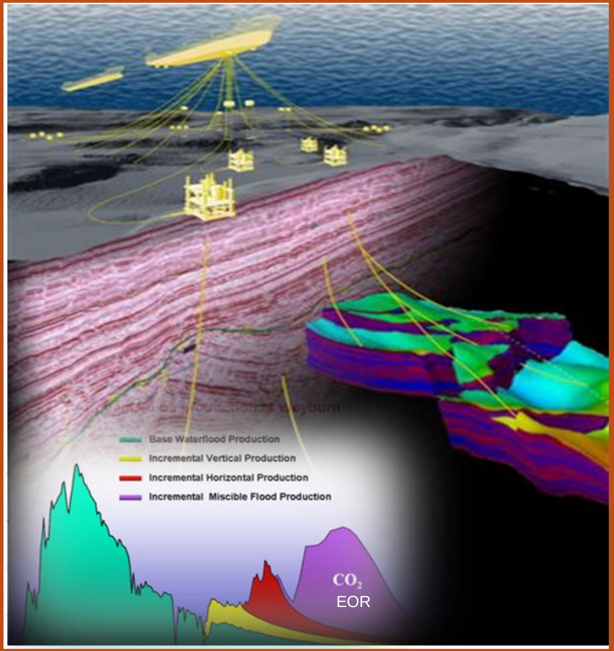
The Norwegian CO2 Storage Atlas was launched by the Minister of Petroleum- and Energy Department May 20th 2014

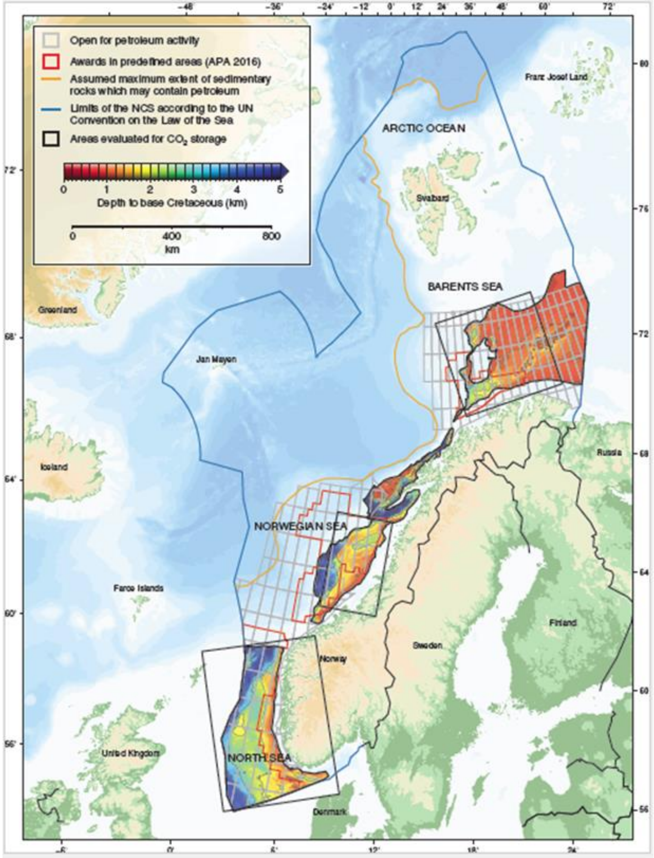


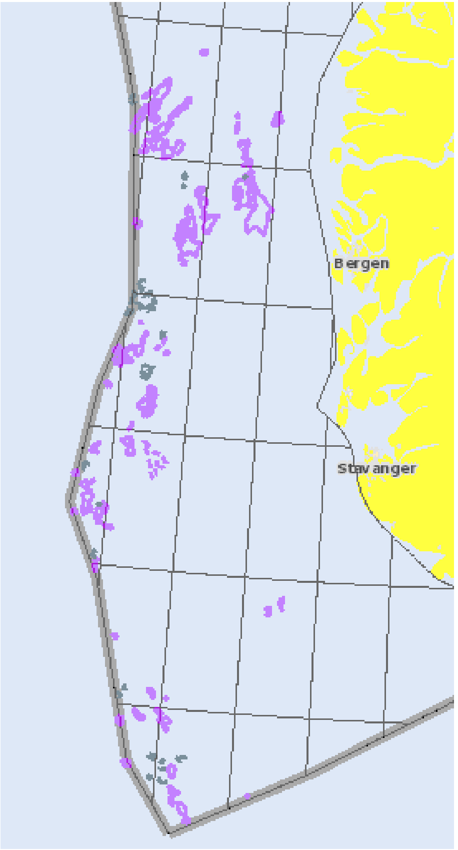
My talk

- CO_2 Storage capacities and Hydrocarbon Fields offshore Norway
- EOR Screening
- CO_2 EOR – How does it work?
- CO_2 Injection for EOR and Storage in The Norwegian North Sea
- Any optimist out there?

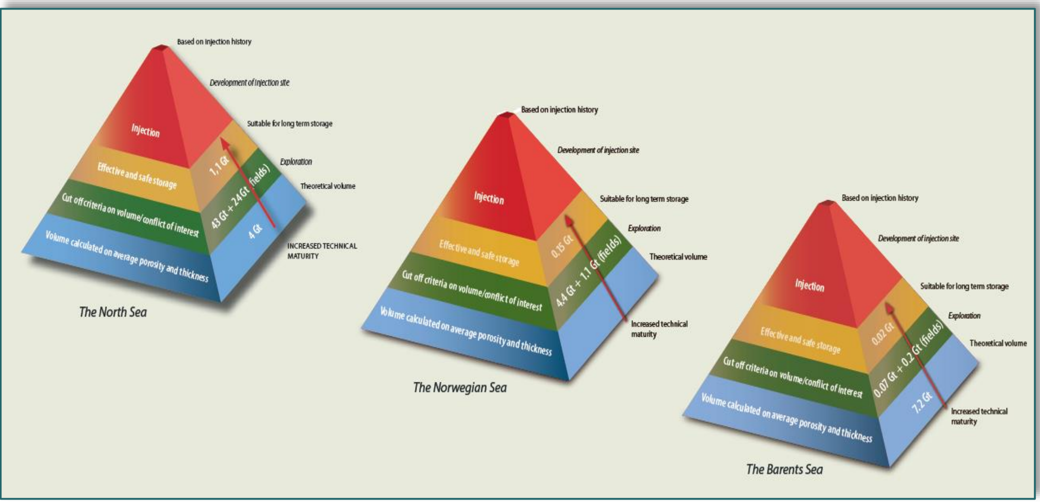
Potential CO_2 Storage sites
and
Oil and gas fields in the North Sea Basin

NPD

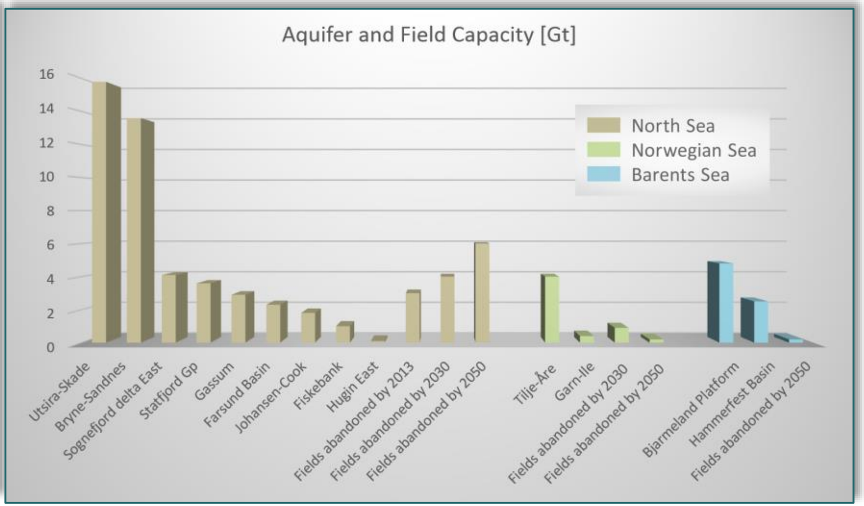




CO_2 Storage Capacity
Norwegian Continental Shelf



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



Storage capacities in the different geological formations and basins.

Source: NPD

The Norwegian Petroleum Directorate

NPD

Main goal

Contribute to realizing maximum value for our society from the oil and gas activities through prudent and efficient resource management which also safeguards consideration for health, safety, the environment and other users of the sea.

The Petroleum Act
Section 4-1: Prudent production

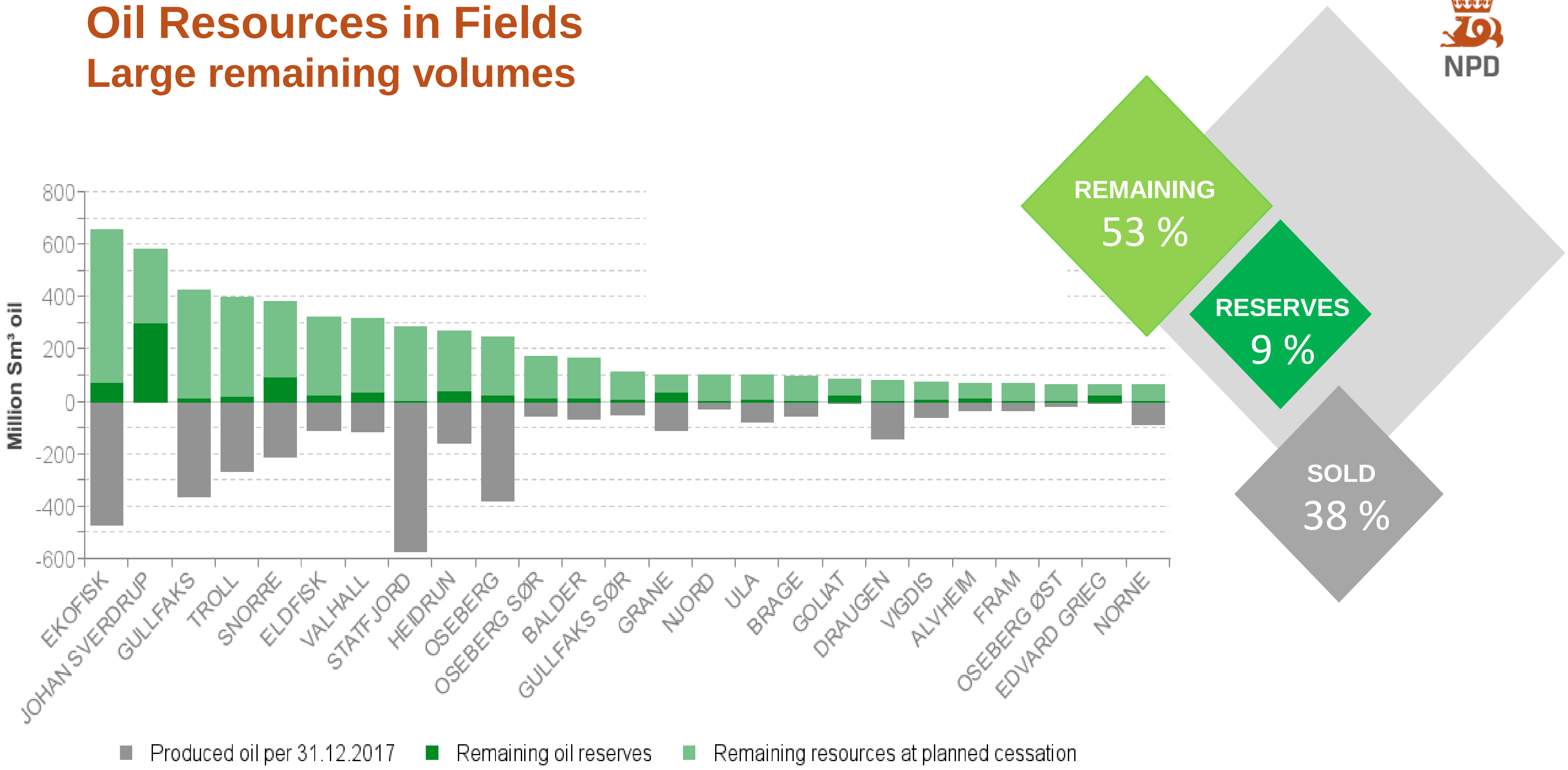
- Production of petroleum shall take place in such a manner that **as much as possible of the petroleum in place** in each individual petroleum deposit, or in several deposits in combination, will be produced.
- The production shall take place in accordance with **prudent technical and sound economic principles** and in such a manner that waste of petroleum or reservoir energy is avoided.

“Technical Challenges in the Transition from CO_2-EOR to CCS”

(sept.2013 CSLF)

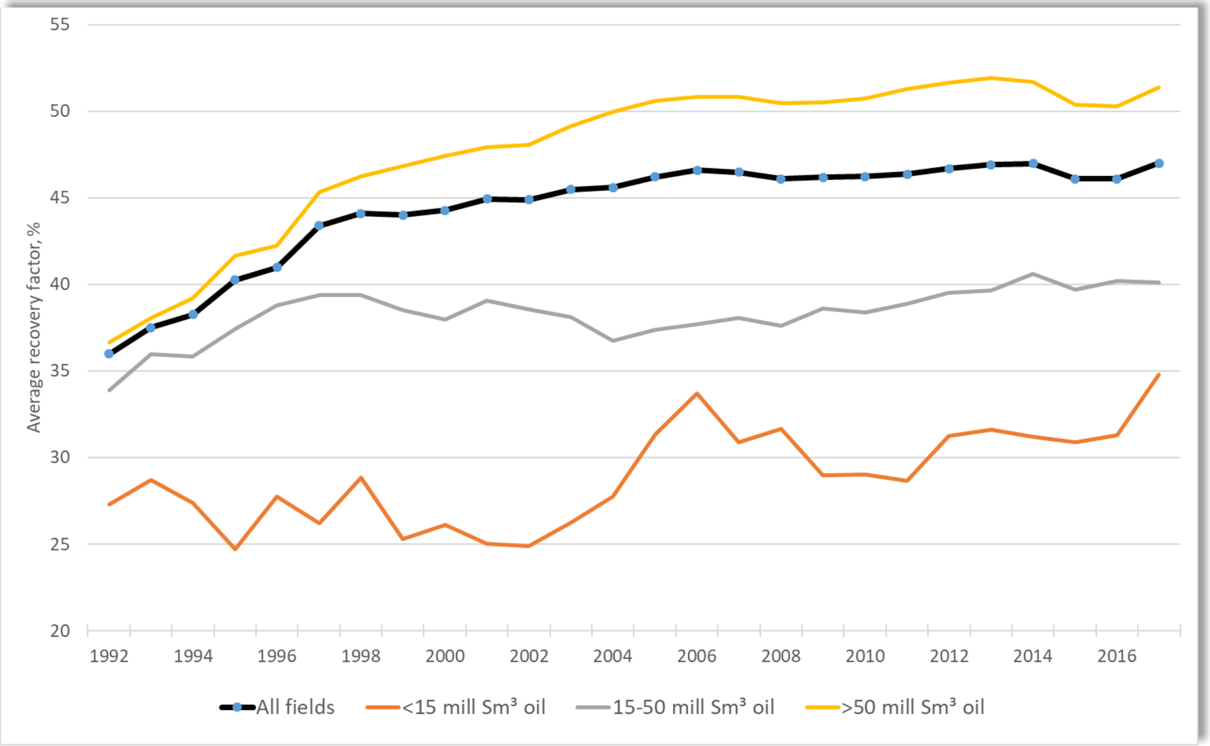
- Forty years of experience and more than 120 CO_2-EOR operations currently active in the world
- with an associated storage rate of 90-95 % of the purchased CO_2.
- sufficient operational and regulatory experience for this technology to be considered as being mature

Oil Resources in Fields
Large remaining volumes



Source: NPD

Average oil recovery factors for oilfields on NCS



Source: NPD

Screening for a recovery process

First process

Second process

First process → / Second process ↓	Waterflood	HC Miscible WAG	HC Immiscible WAG	CO2 Miscible WAG	CO2 Immiscible WAG	Alkaline	Polymer	Surfactant	Surfactant/polymer	Low salinity	Low salinity/polymer	BrightWater/TAP	Gels	Blowdown
Waterflood	Reduced increment	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible	Not compatible			Not compatible
HC Miscible WAG		Reduced increment	Not compatible	Reduced increment					Not compatible					Not compatible
HC Immiscible WAG		Not compatible	Reduced increment	Not compatible	Reduced increment	Not compatible			Not compatible					Not compatible
CO2 Miscible WAG		Reduced increment		Reduced increment	Not compatible				Not compatible					Not compatible
CO2 Immiscible WAG		Not compatible	Reduced increment	Not compatible	Reduced increment	Not compatible			Not compatible					Not compatible
Alkaline		Not compatible		Not compatible		Reduced increment			Not compatible	Not compatible	Not compatible			Not compatible
Polymer							Reduced increment	Reduced increment	Not compatible		Not compatible		Reduced increment	Not compatible
Surfactant		Not compatible		Not compatible				Reduced increment	Reduced increment					Not compatible
Surfactant/polymer		Not compatible		Not compatible					Reduced increment		Reduced increment		Reduced increment	Not compatible
Low salinity		Not compatible		Not compatible					Not compatible	Reduced increment	Reduced increment			Not compatible
Low salinity/polymer		Not compatible		Not compatible					Not compatible	Reduced increment	Reduced increment		Reduced increment	Not compatible
BrightWater/TAP									Not compatible		Not compatible	Reduced increment	Reduced increment	Not compatible
Gels							Not compatible	Not compatible	Not compatible		Not compatible		Reduced increment	
Blowdown														Reduced increment

Not compatible

Reduced increment

Source: NPD

Screening dashboard

NPD

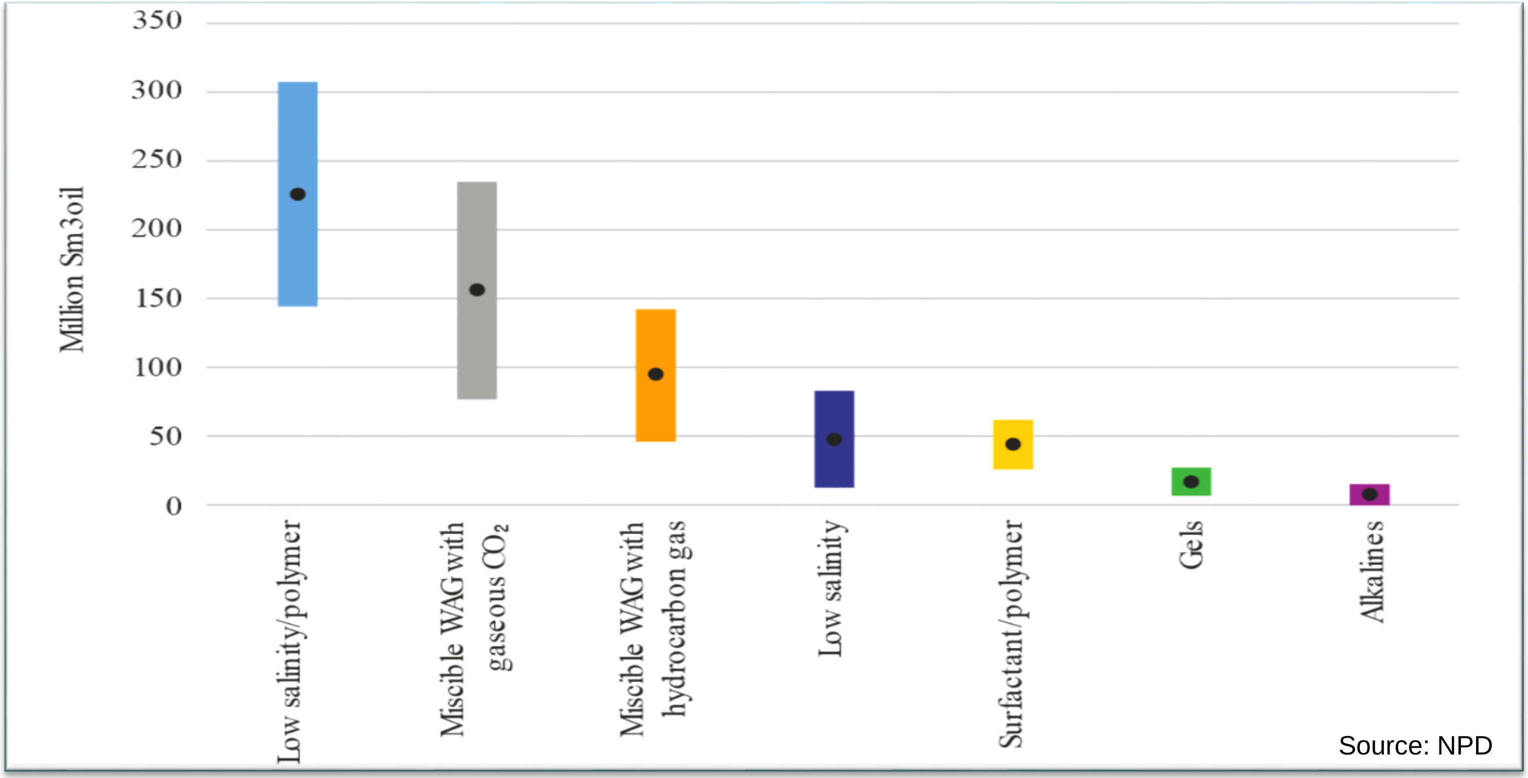
Field A: Reservoir 1	SCREENING CRITERIA																			Suitability score
	Lithology	Depth	Pressure	Temperature	API gravity	Viscosity	Crude acidity (TAN)	Wetting behaviour	Porosity	Permeability	Thickness net	Fracturing	Hetrogeneity	Clay content	Clay type	Salinity formation water	Salinity injection water	Remaining oil	Current process	
Units		m	bar	C		cP			frac	mD	m					mg/l	mg/l	frac		
Field Data	Sandstone	3200	350	130	41	0.35	High acidity (TAN>1)	Weakly oil wet (AHI of -0.3 to 0)	0.2	175	80	No fracture flow	Some layering	10-15% clays	Kaolinite, Smectite	120000	35000	0.80	Waterflood	
Recovery processes																				
HC miscible gas/WAG		1	1	1	1	1			1	1	0.6	1	1					1	1	0.9
HC immiscible gas/WAG		1			1	1					0.6	1	1					1	1	0.9
Nitrogen and flue gas/WAG		1	0.2	0.6	1	1				1	0.6	1	1					1	1	0.9
CO2 miscible/WAG		1	1	0.7	1	1			1	1	0.6	1	1					1	1	0.9
CO2 immiscible/WAG		0.4	0		1	1					0.6	1	1					1	1	0
Alkaline	1	0.5			0.8	1	0.5		1	1				0.5		0.1		1	1	0.7
Polymer	1			0.1	1	0			1	1	1	1	1	0		0		1	1	0
Surfactant	1			0.4	1	1			1	1	1		1	0		0.1		1	1	0
Surfactant/polymer	1			0	1	0			1	1	1		1	0		0.1		1	1	0
Low salinity	1					1	0.5	1		1		1	1	1	1	1		1	1	1.0
Low salinity/polymer	1			0.1	1	0	0.5	1	1	1	1	1	1	0.5	1	0.7		1	1	0
Bright Water	1			0.7		1			1	1	1	1	0.5			1	1	1	1	0.9
Gels				0.5		1				1		1	1				0.3	1	1	0.8

- 1 (green): Optimal process with maximum recovery increment
- 0 (red): Unsuitable with zero recovery increment
- Intermediate: Technically feasible but with reduced recovery increment

Source: NPD

EOR Screening

27 fields, 7 methods:



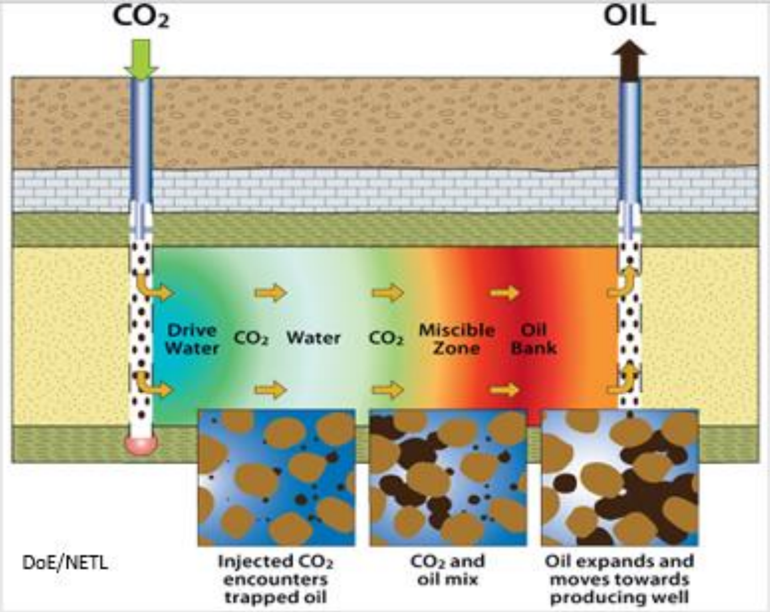
CO_2 EOR – How does it work?

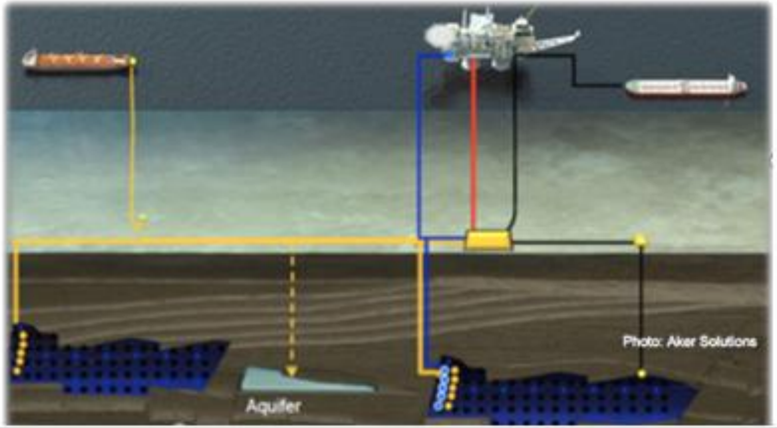
Pro's:

- ✓ Swelling → improve flow characteristics
- ✓ Vaporize → oil components recovered
- ✓ Reduce oil viscosity
- ✓ Soluble in water
- ✓ Miscibility at 'low' pressures
- ✓ Supercritical CO2 (gas viscosity and liquid density)
- ✓ Reduces oil/water IFT
  - ➢ Very efficient EOR agent

Con's:

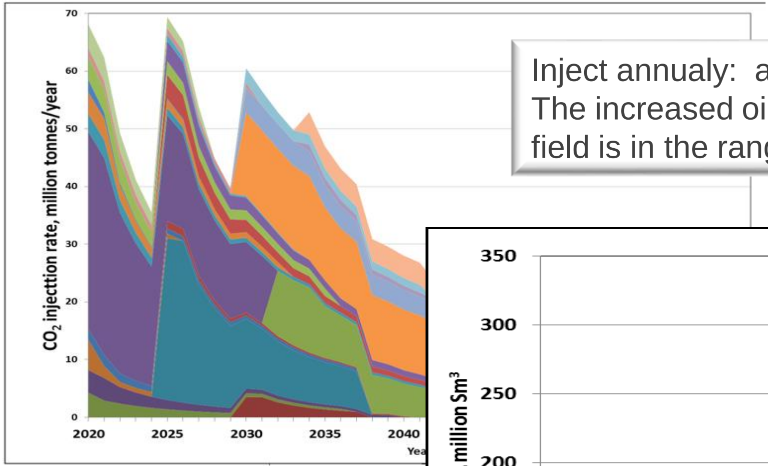
- ➢ Reliable source needed
- ➢ Corrosion on platforms, wells and pipelines
- ➢ Declining demand over time, need for storage in aquifers





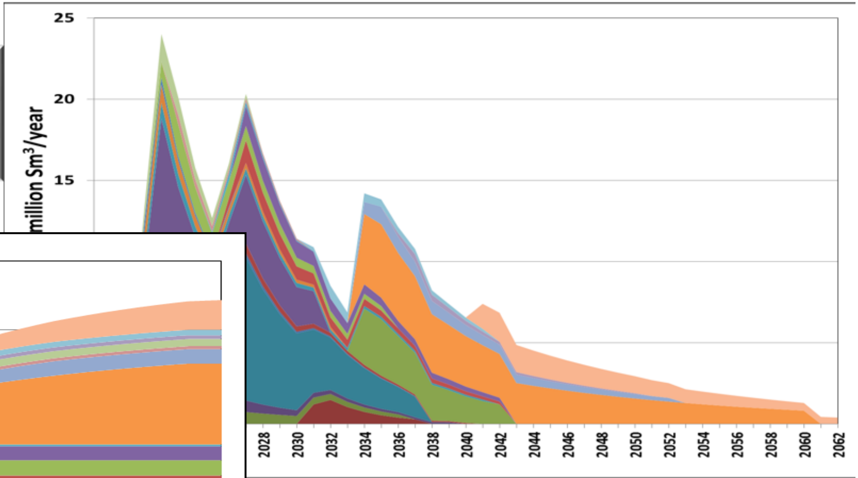
A screening-study of 23 oil fields in the Norwegian North Sea

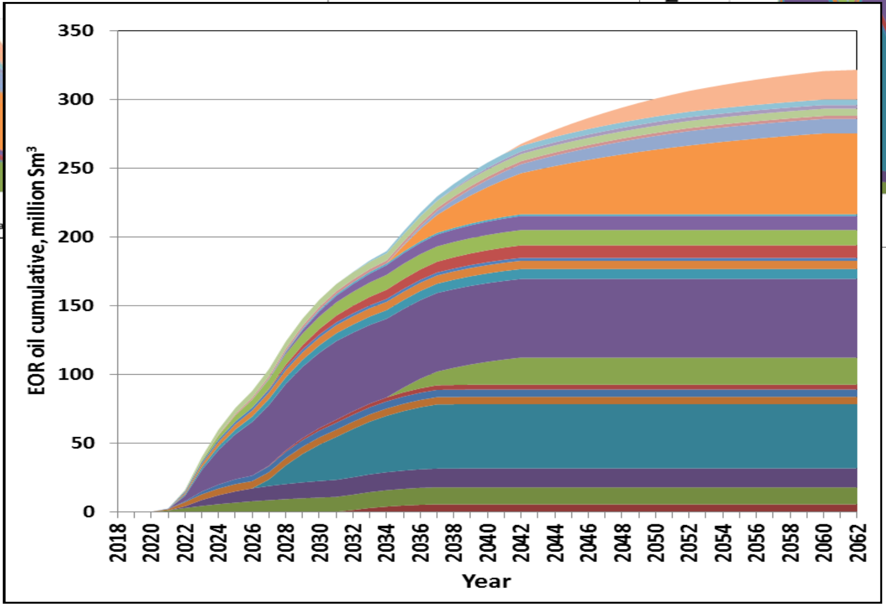
CO_2 injection rate in 23 oil fields



Inject annualy: about 70 Mt CO_2
The increased oil recovery for each field is in the range of 4 to 12 %

EOR-oil production rate (Base case)



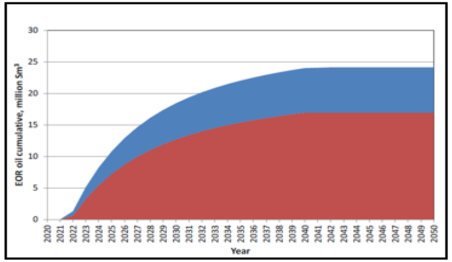


Total EOR olje, mill. Sm3	320
Total EOR, % av OOIP	7
Totalt lagret CO2 i oljefelt, mrd. tonn	1,3
Totalt lagret CO2 i akviferer , mrd. tonn	1,7

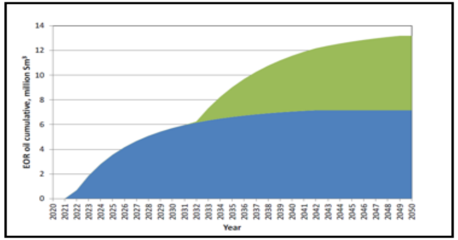
Source: NPD

The value of CO_2

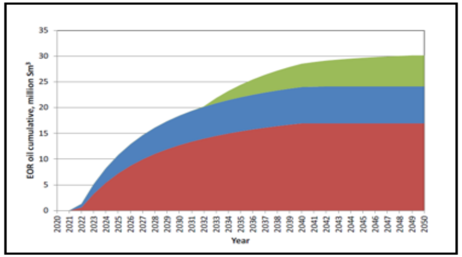
Study of three different oilfields combined with a yearly access of around1-3Mt of CO_2



Case 1: Injection in field 2 after field 1 is self-sufficient with CO_2. Pipe and ship transportation. 3.25 Mt/y CO_2



Case 2: same as case 1. Ship's transportation to both fields. 1.35Mt/y CO_2



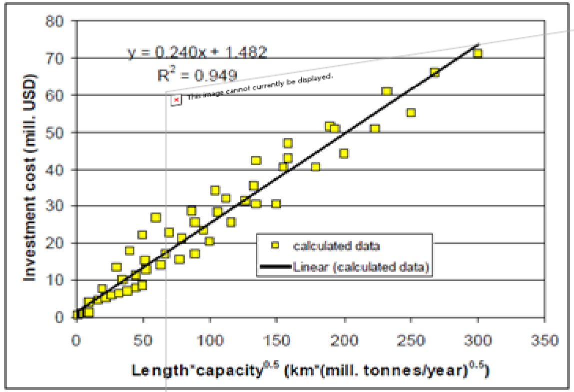
Case 3: Injection in 3 fields in series. Pipe-and ship transportation. 3.25Mt/y CO_2

	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 aquifer [Mt]	97	40	98

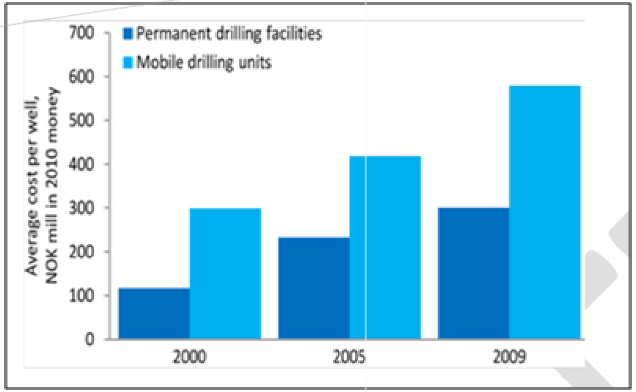
Source: NPD

Any optimist out there?

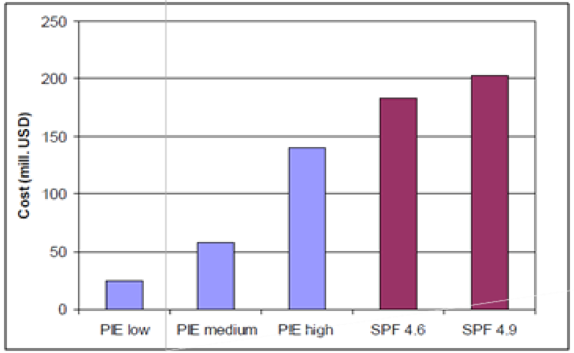
Cost of pipeline branches vs. length



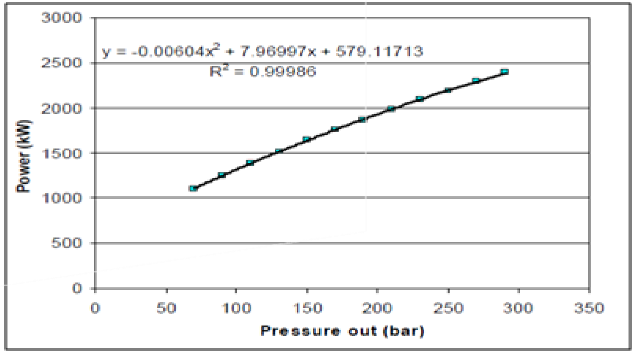
Average well cost on Norwegian shelf



Cost of modification of oil production system

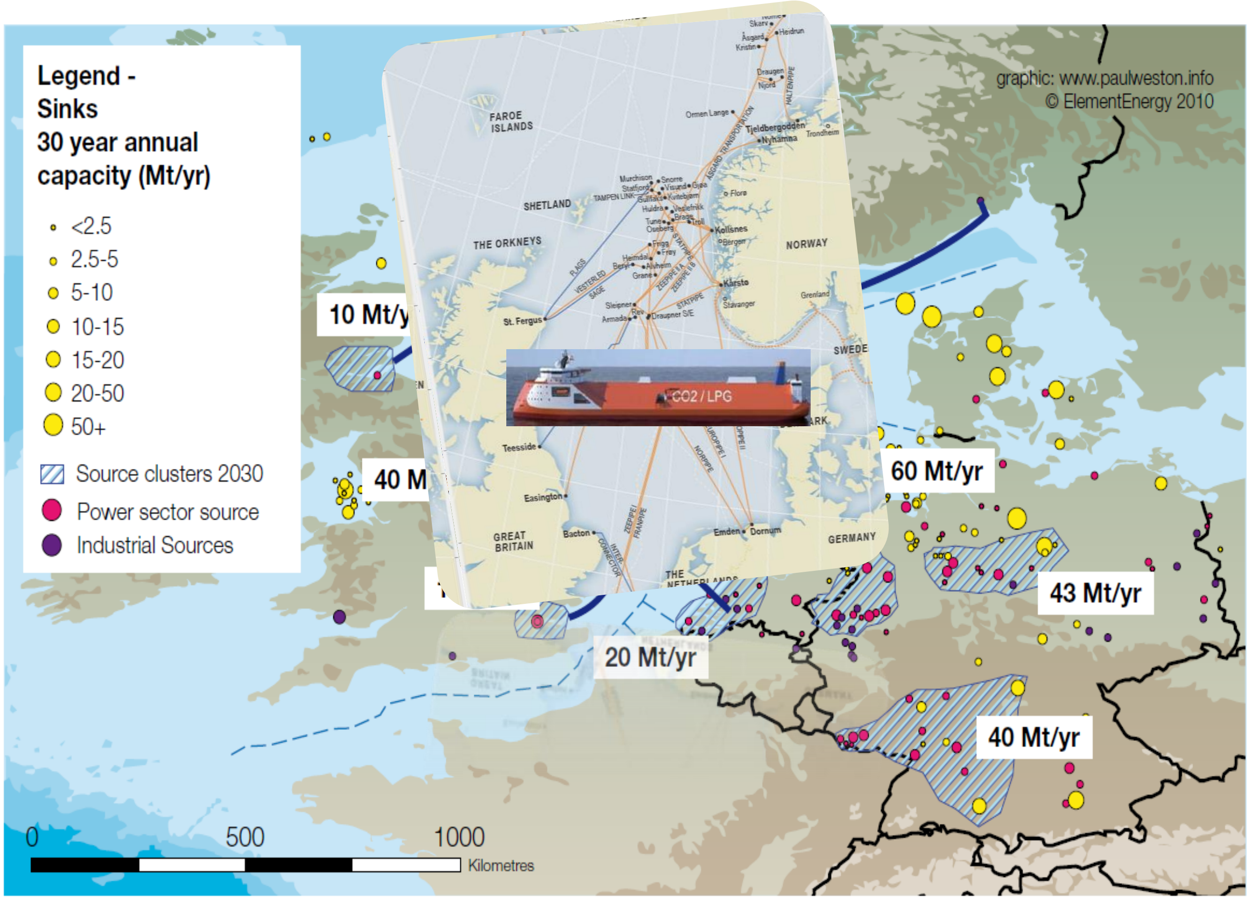


Compression power for 1 mill. tonnes/year vs pressure



Source: NPD

A possible future for the North Sea Basin



Source: One North Sea, 2010

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

Frank Zappa

NORWEGIAN PETROLEUM DIRECTORATE

Thank you for your attention !

www.npd.no