

CO₂ Storage and CO₂ EOR – comparison & standardisation



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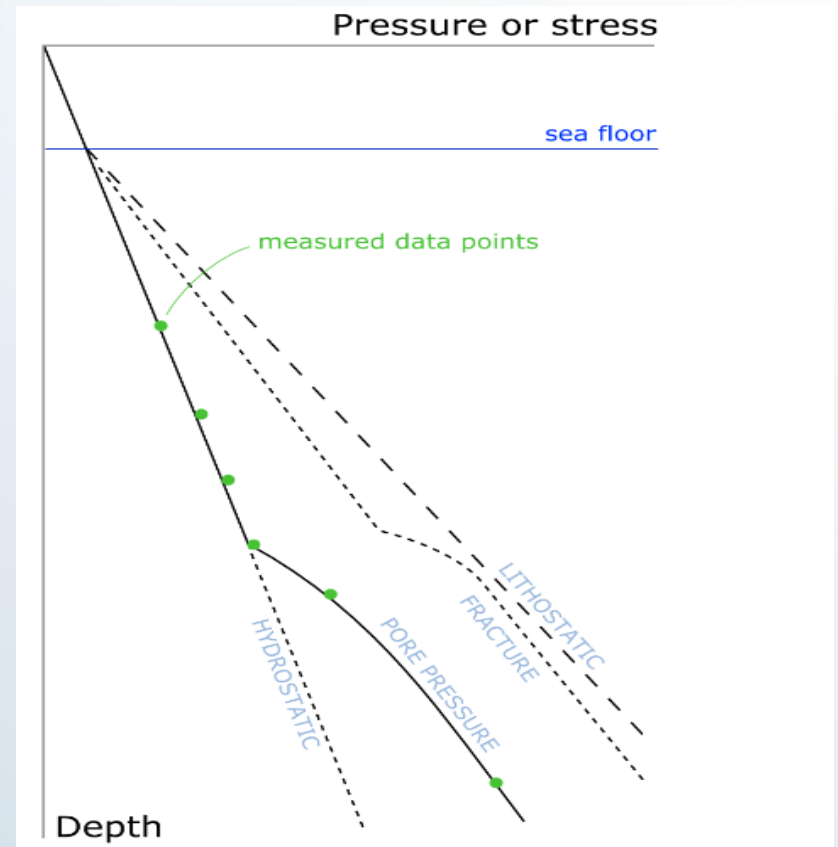
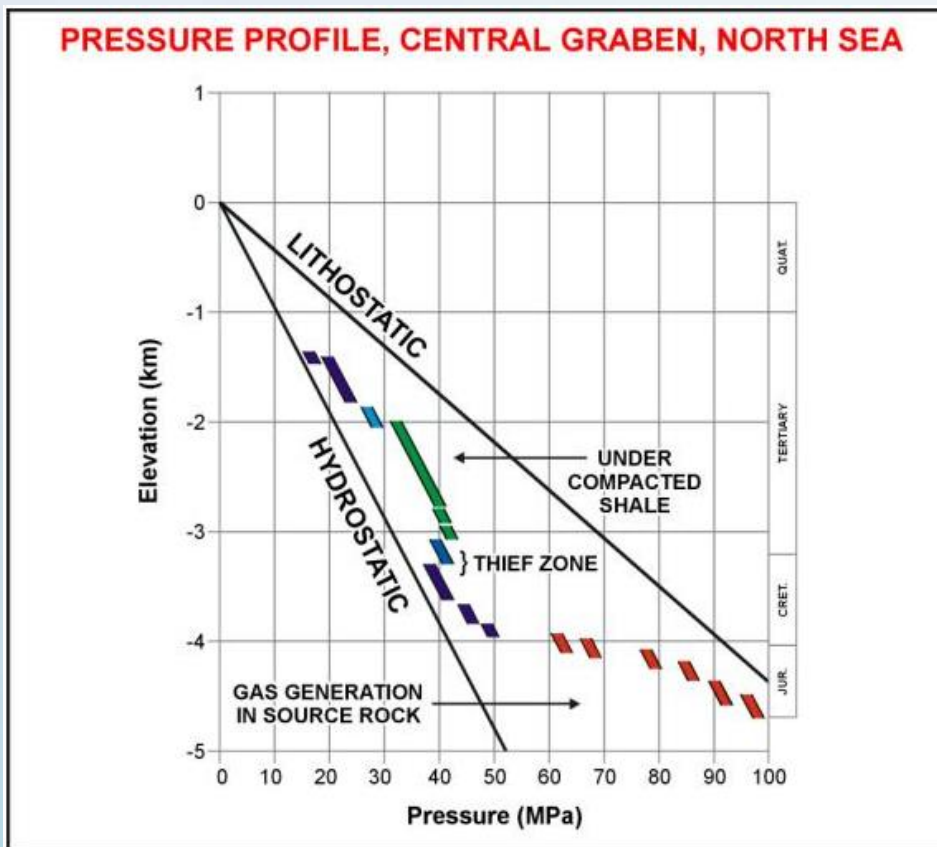
Professor Niels Peter Christensen
Chief Geologist

Storage in saline aquifers



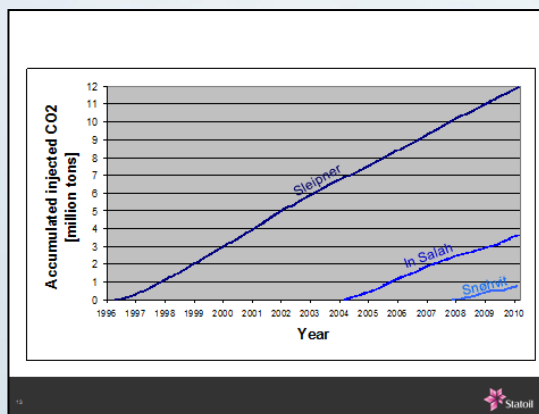
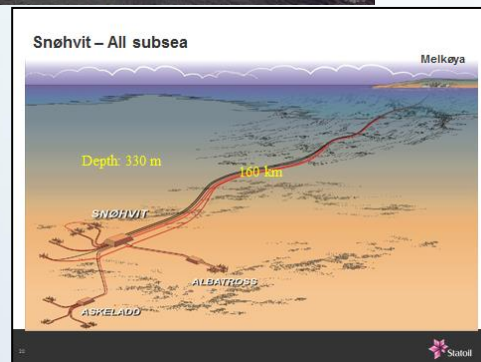
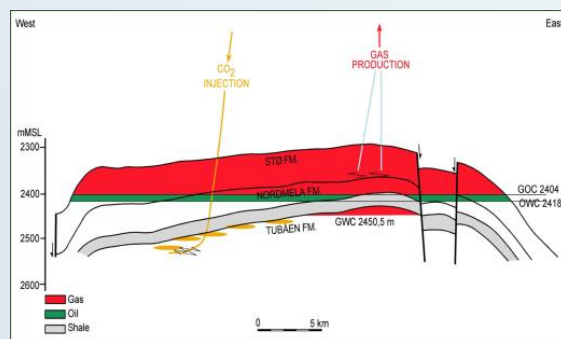
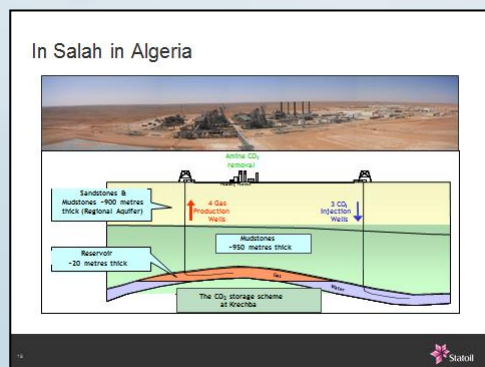
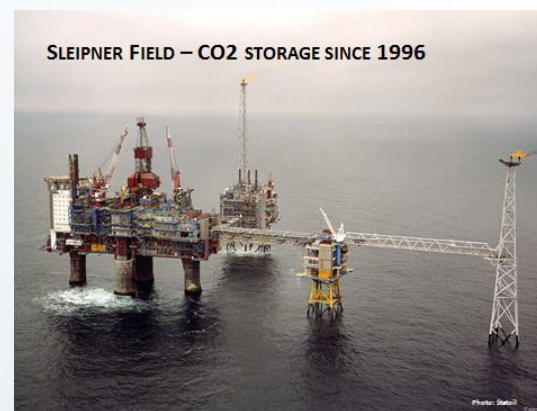
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THE SUBSURFACE PRESSURE ENVELOPE



LARGE OPERATING 'EUROPEAN' CCS PROJECTS

- Sleipner – 1 mill t CO₂ p.a. since 1996
- Snøhvitt – since 2008
- In Salah – since 2004



Incentives:

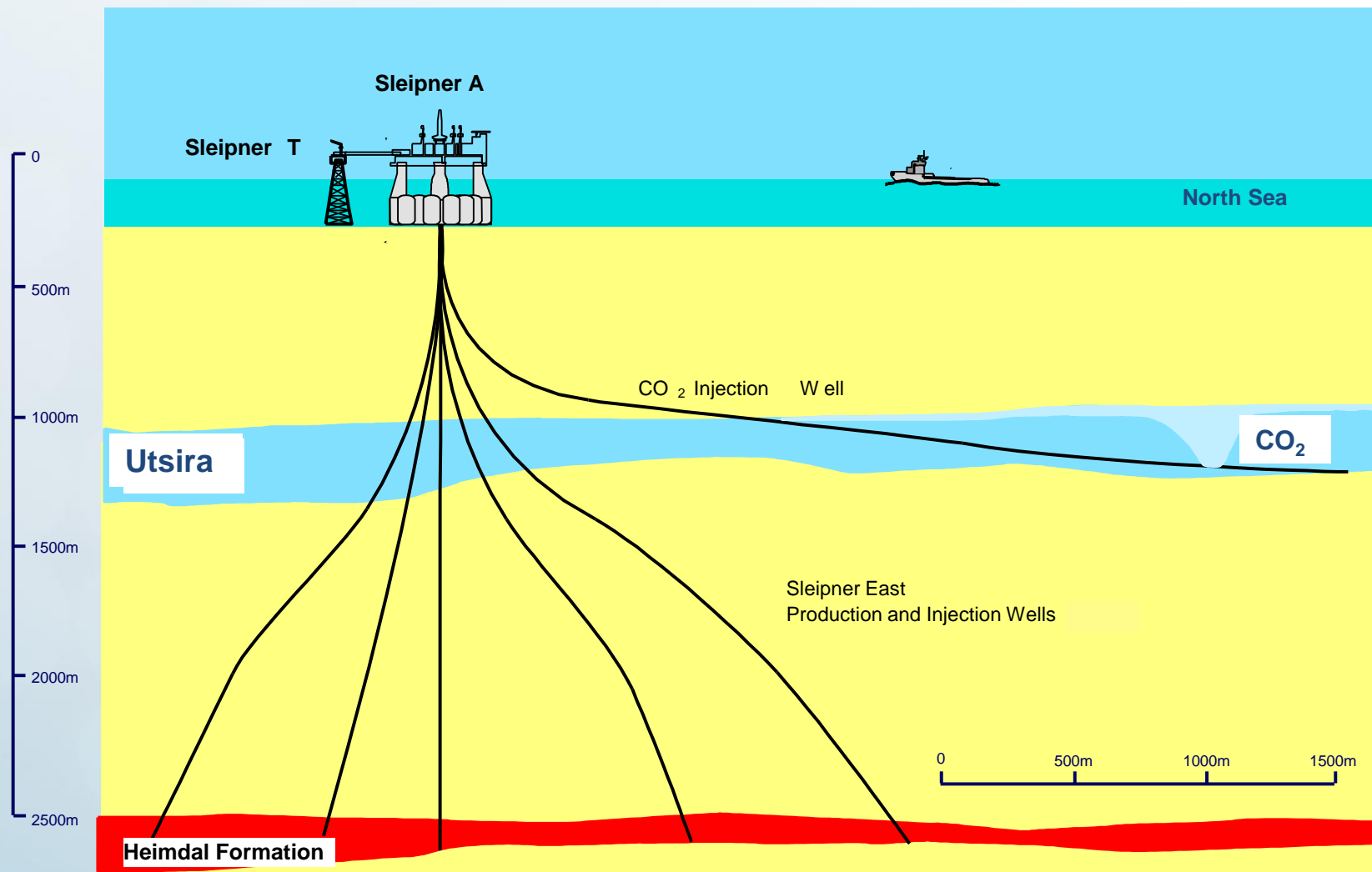
Norway: gas sales + CO₂ tax of 350 NOK/t

Algeria: 'EGR'/pressure maintenance

SLEIPNER COMPLEX – CO₂ STORAGE SINCE 1996

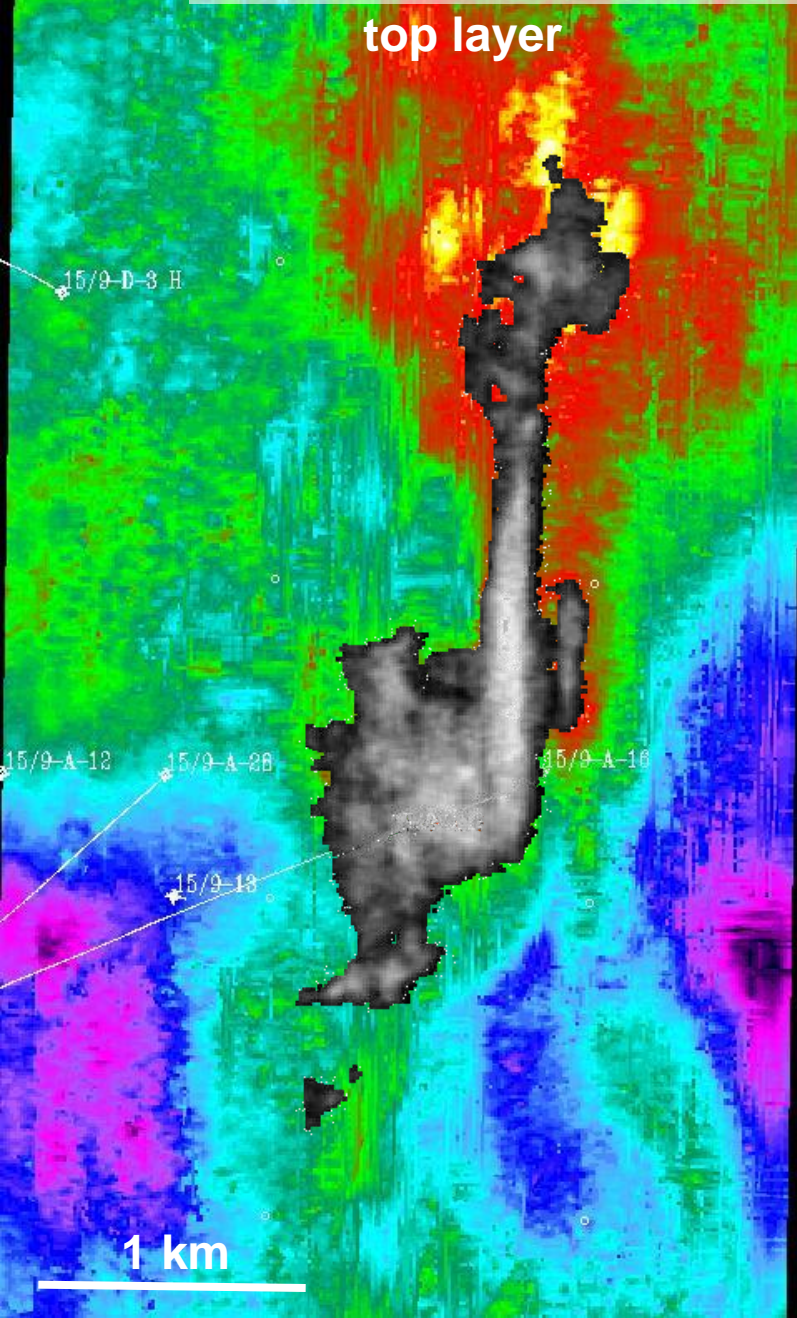


CO₂ Injection well in "Utsira"

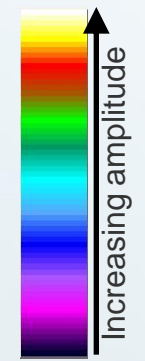
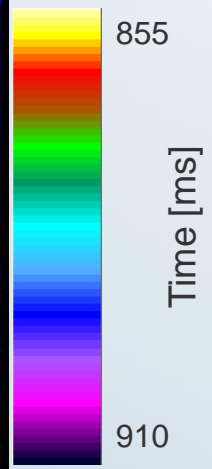
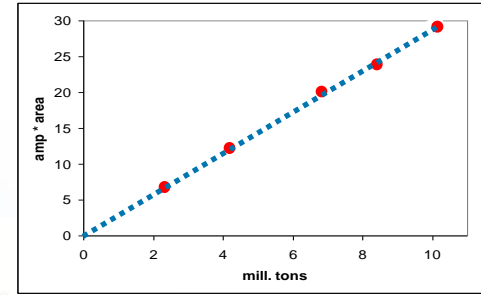
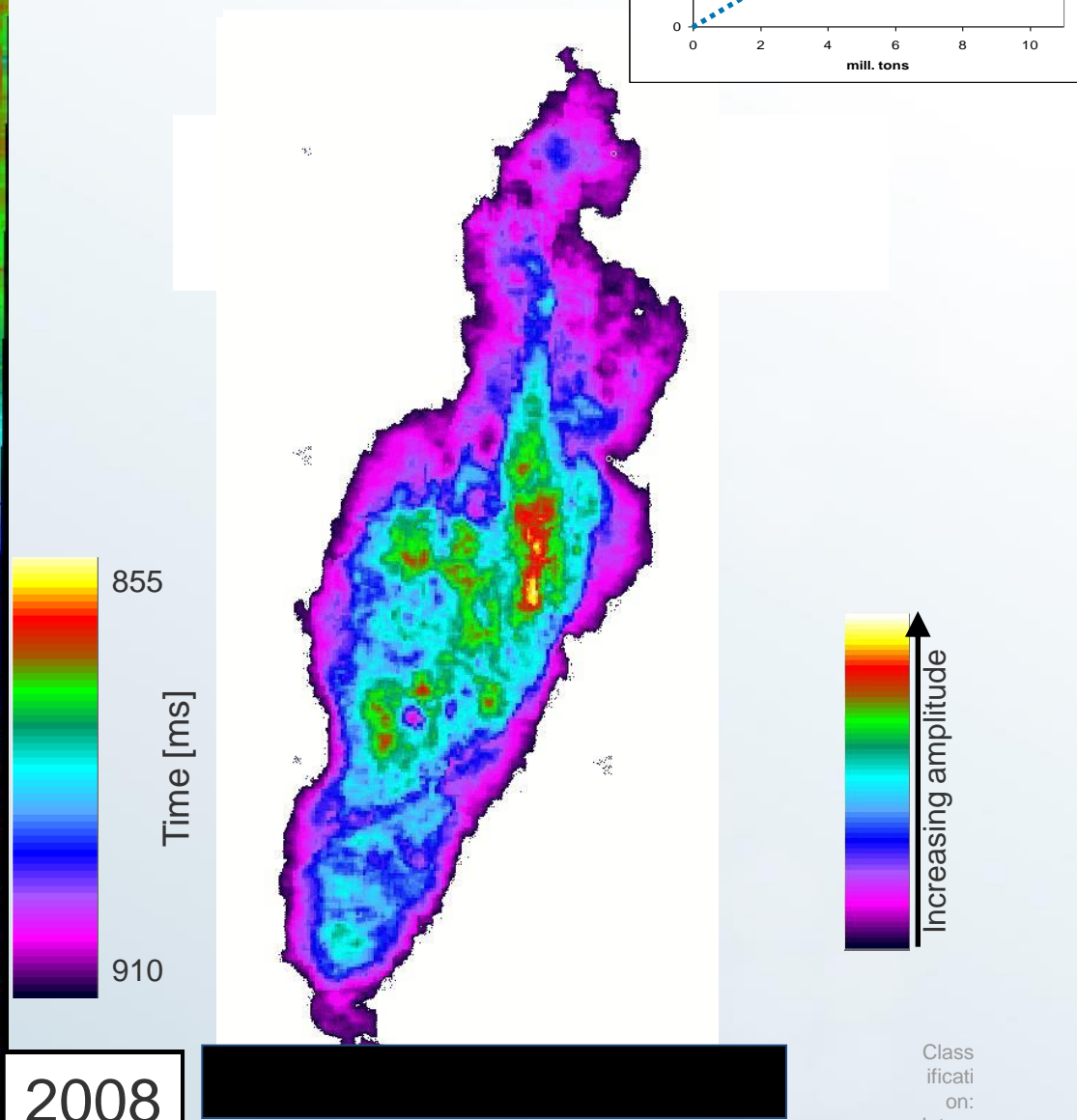


SLEIPNER CO₂ SEISMIC MONITORING

top layer



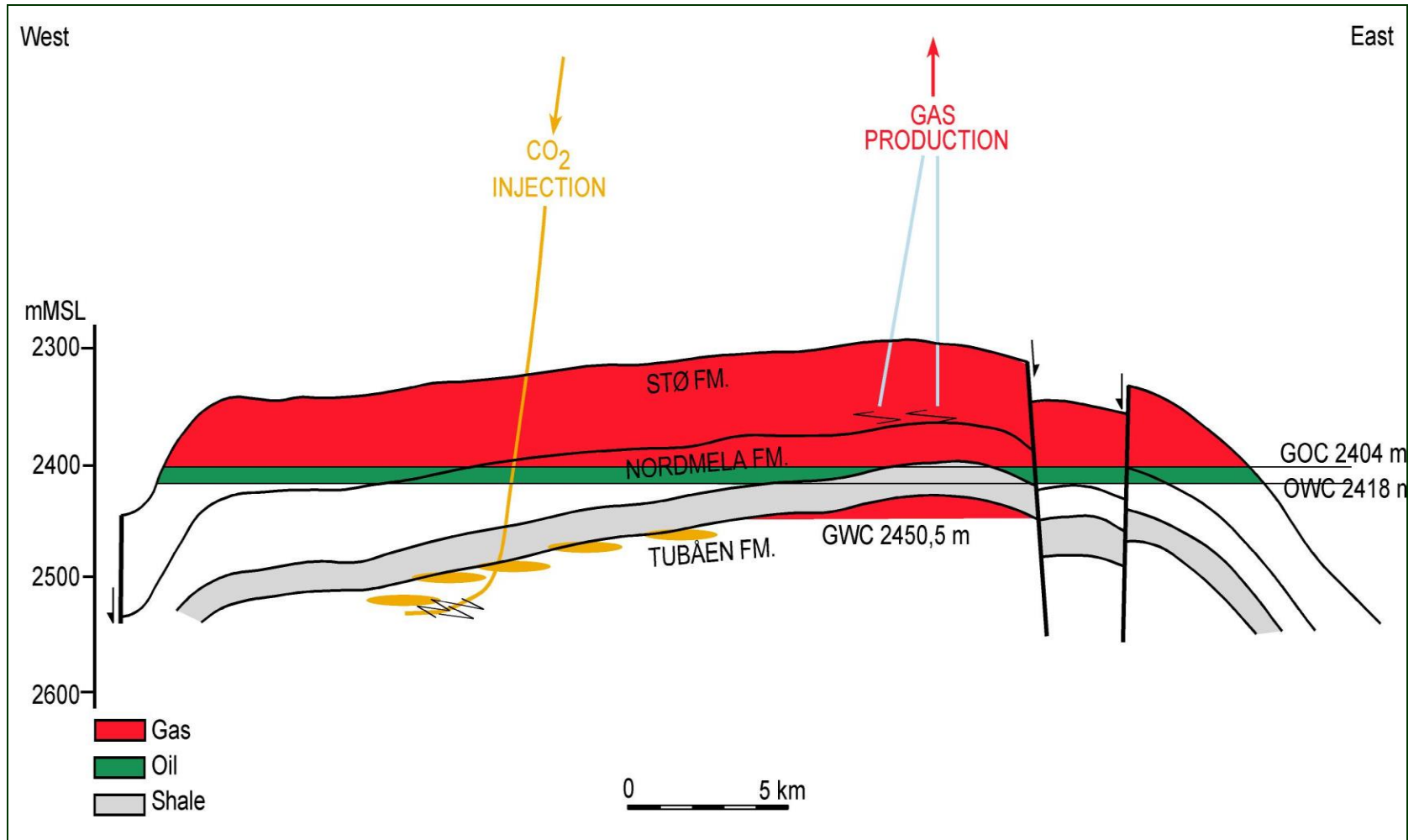
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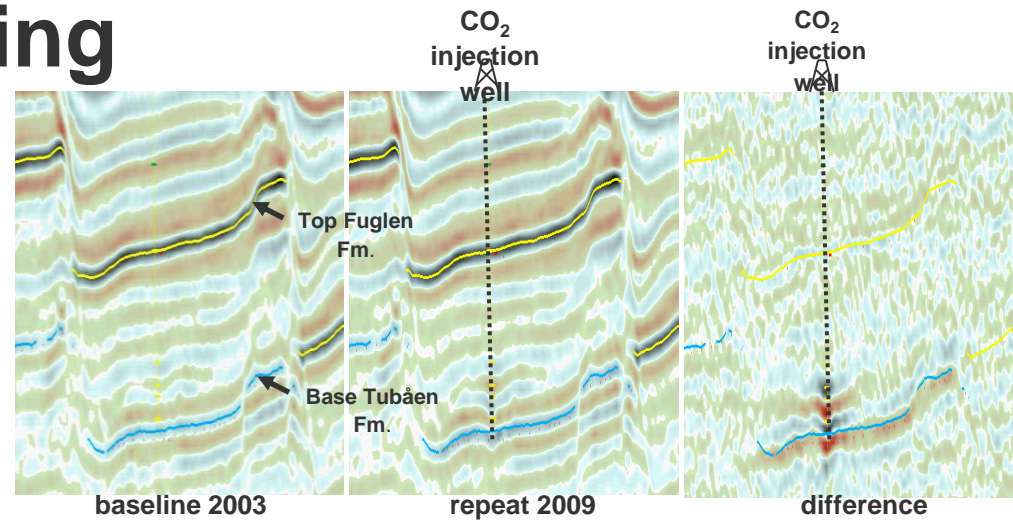
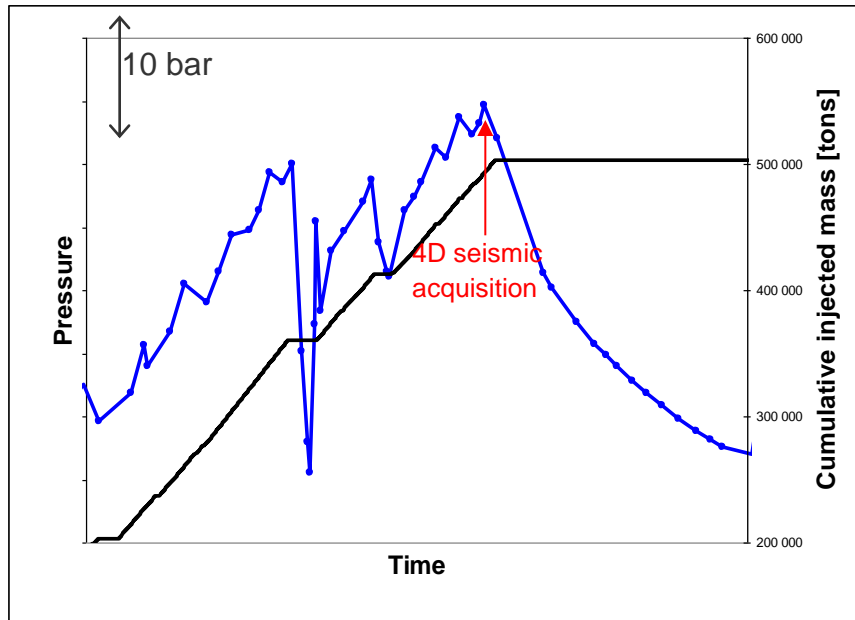
2008

Classification:
Internal
2010-

Snohvit CO₂ Injection

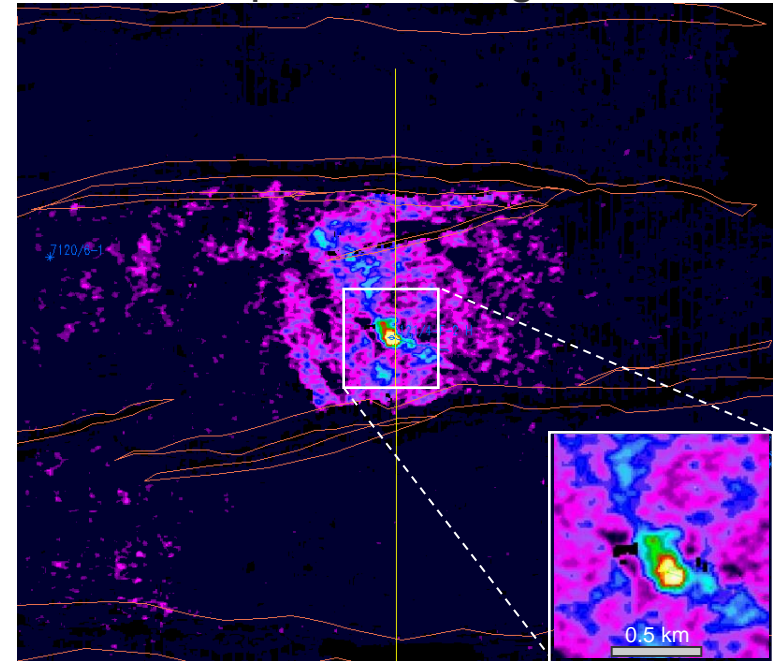


Snøhvit CO₂ monitoring

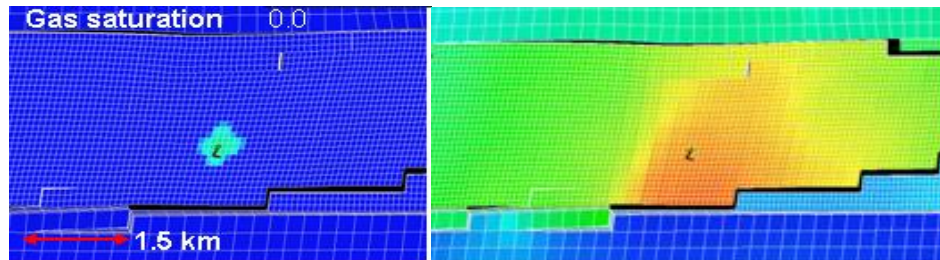


Amplitude changes

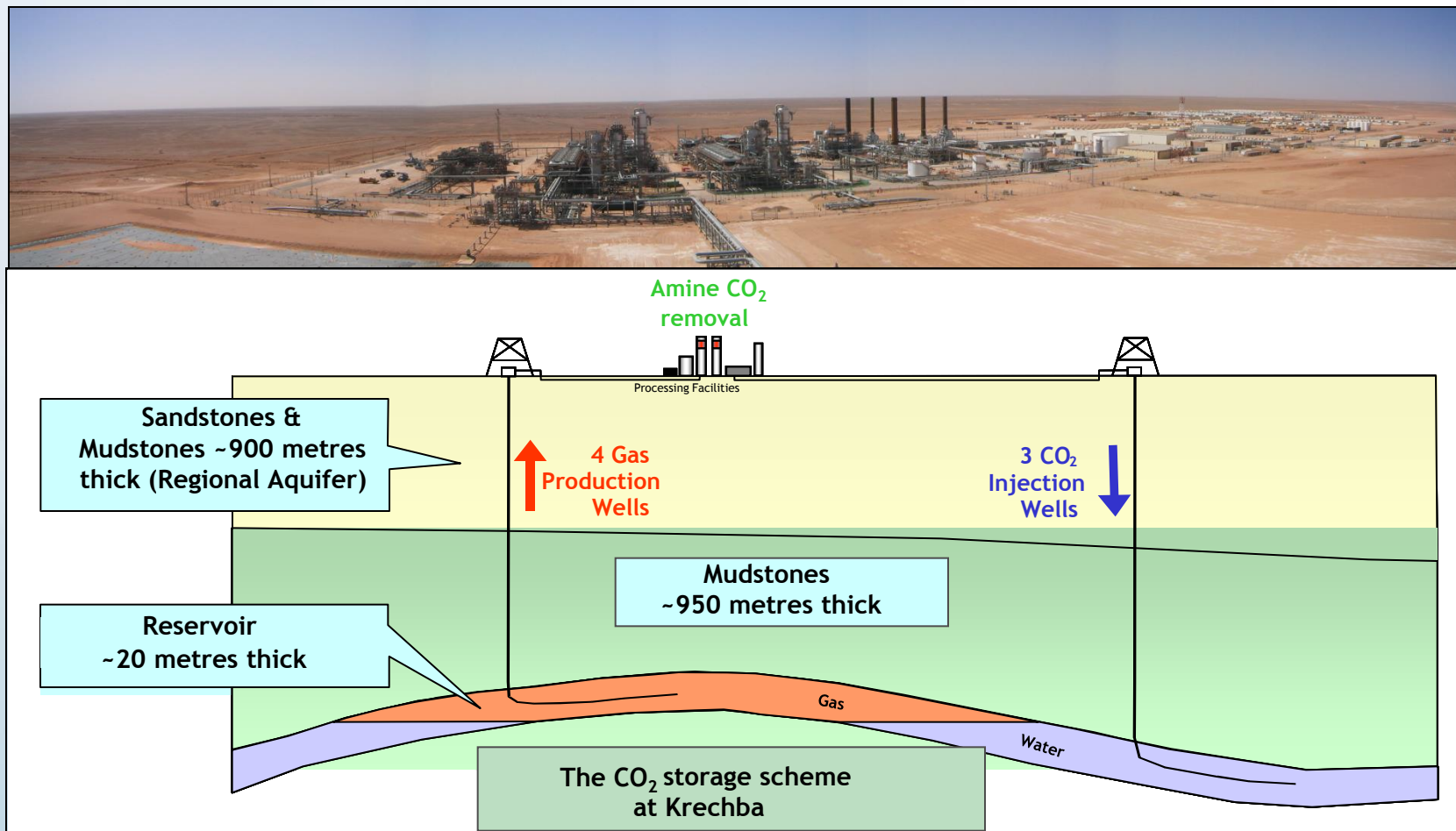
Increasing amplitude
↓



Modelled CO₂ saturation and pressure increase



IN SALAH IN ALGERIA



CCS PROJECT LIFE-CYCLE

- Up-front cost
- Long lead-time
- Long post-injection obligations

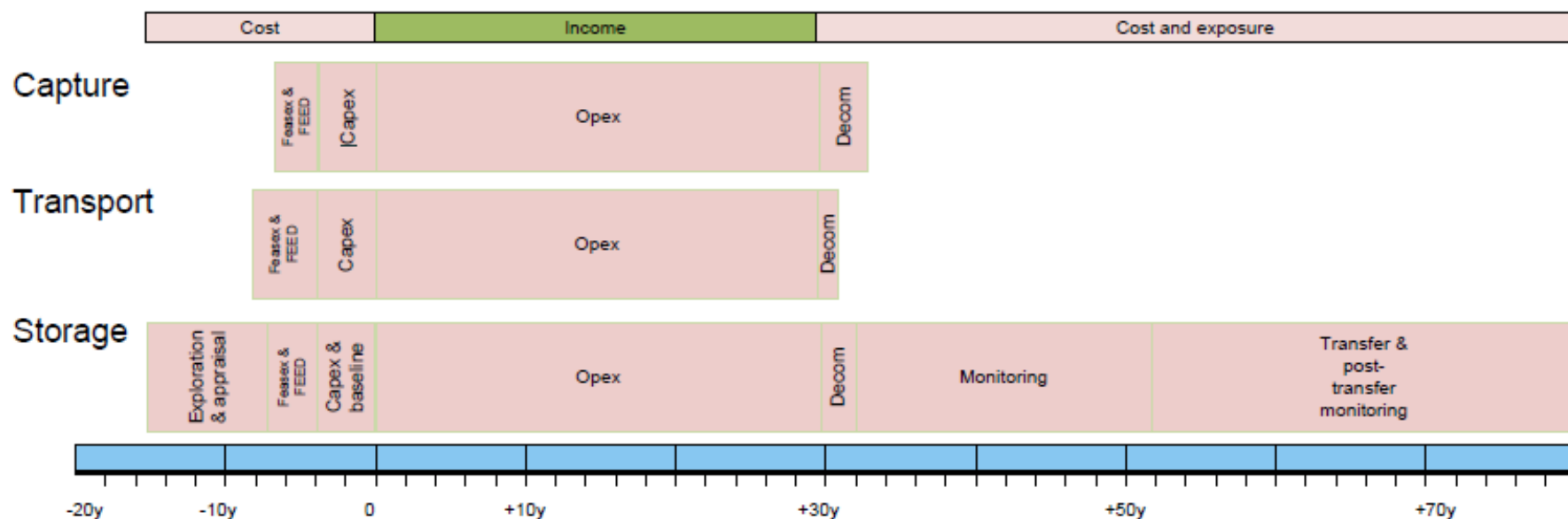
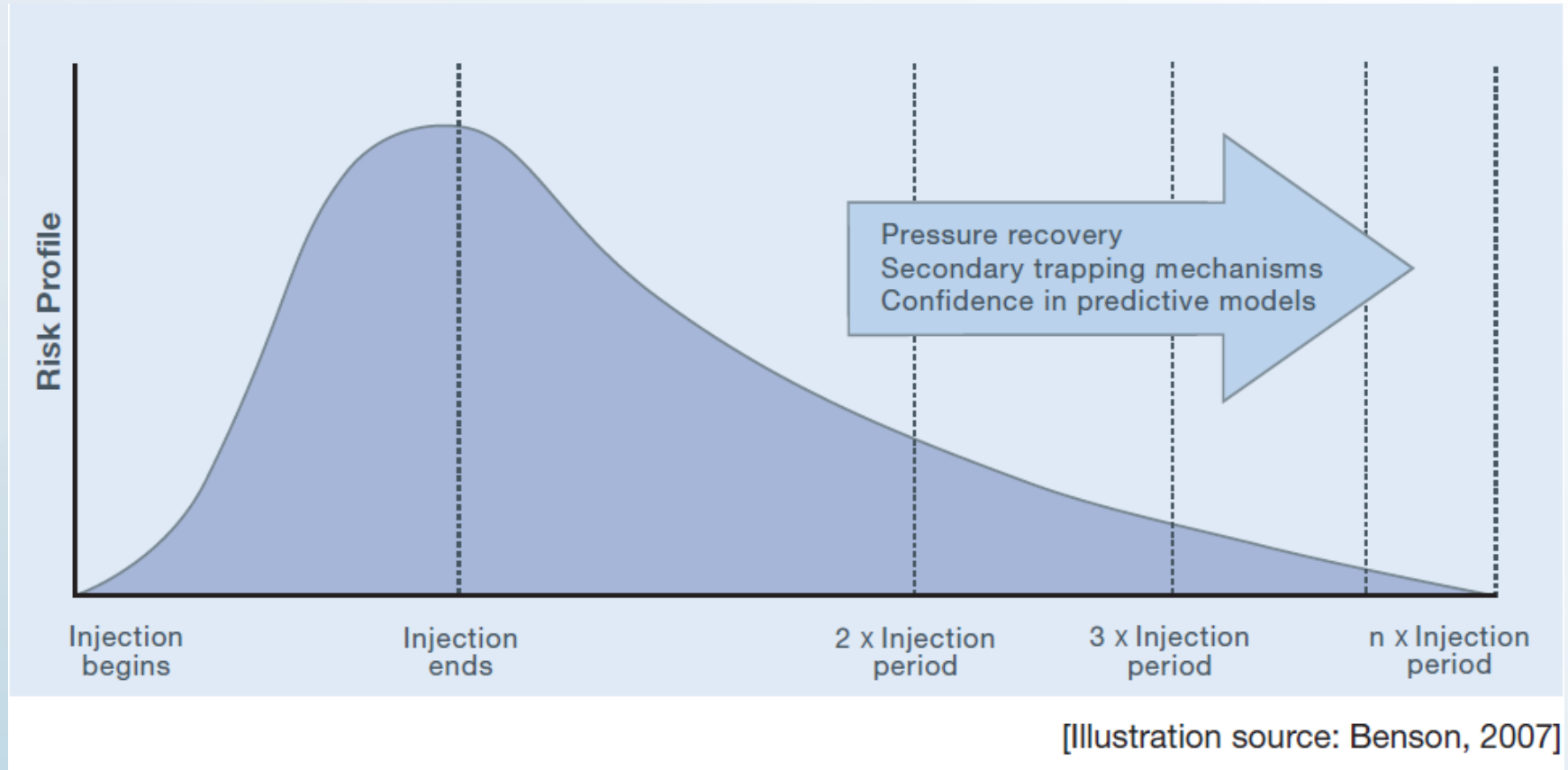


Figure 2: Timeline for income and expenditure for CO₂ capture, transport and storage

RISK (PRESSURE) PROFILE IN AN AQUIFER STORAGE



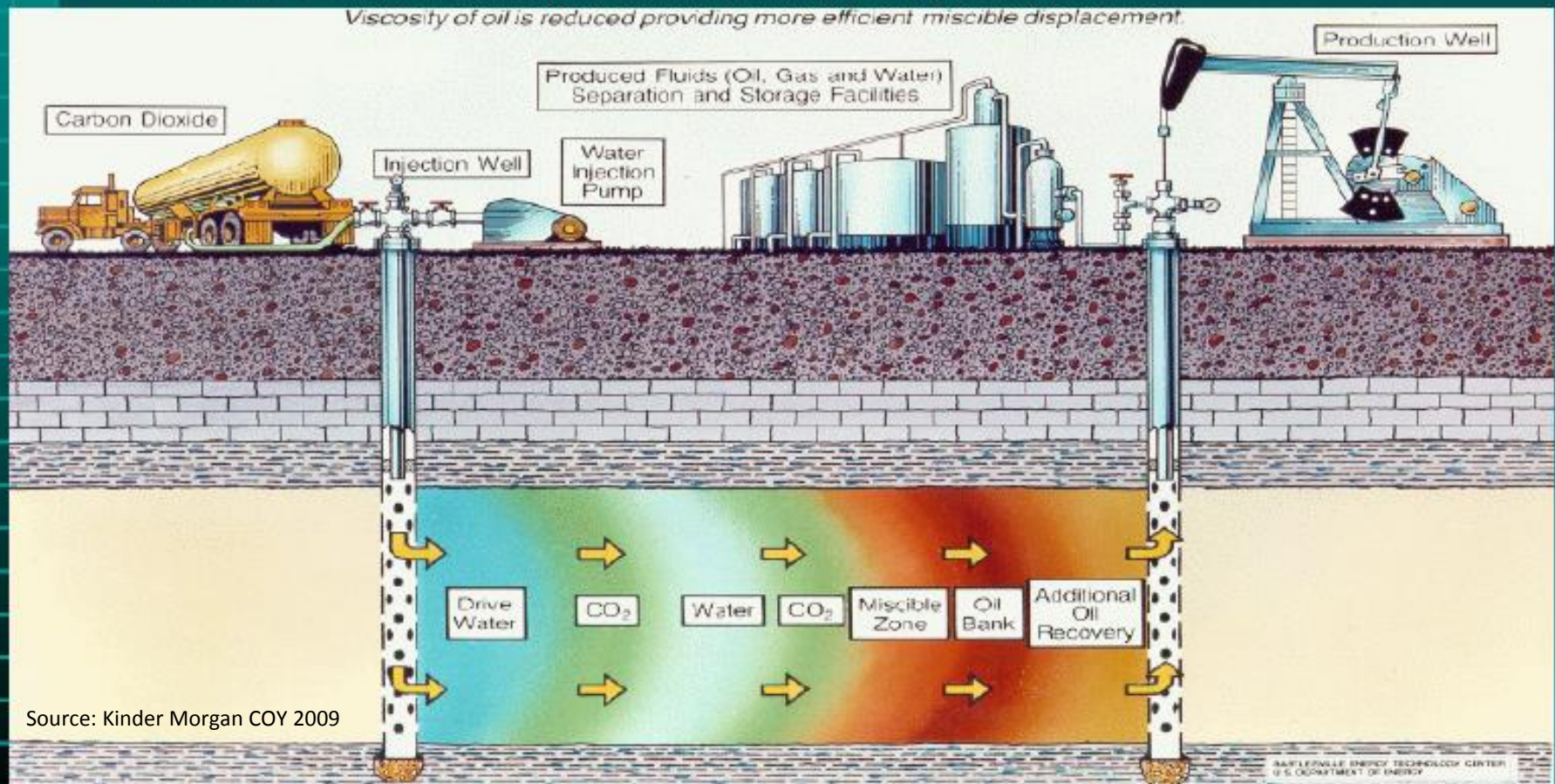
Storage as part of CO₂ EOR



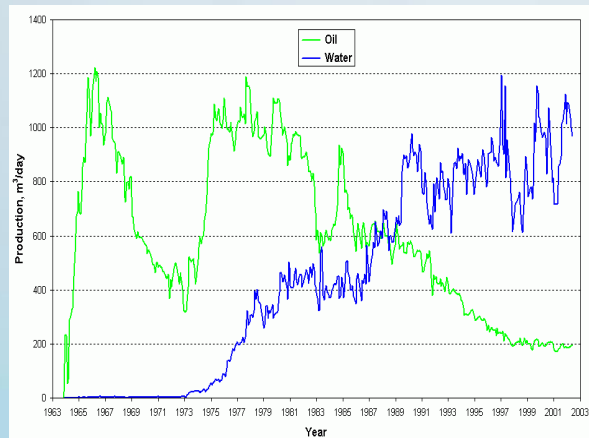
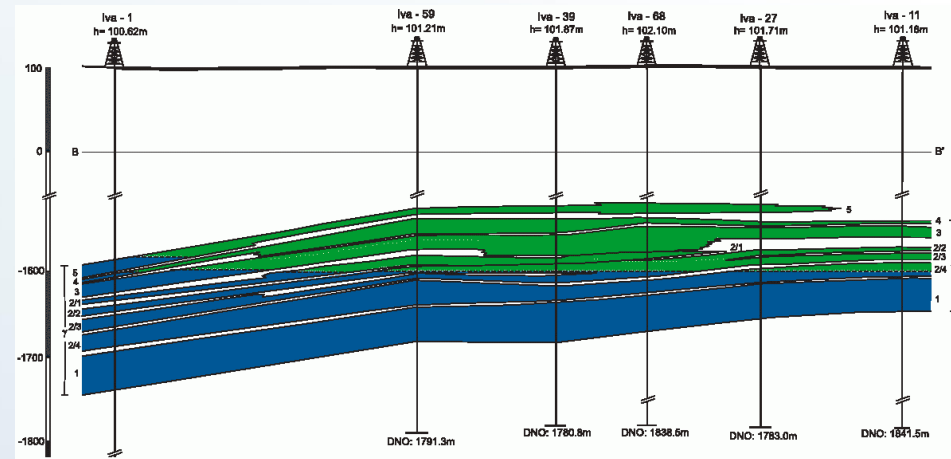
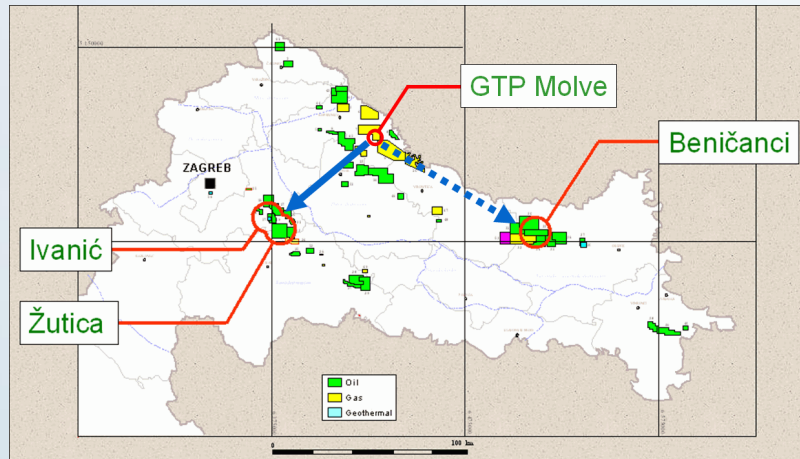
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CO₂ Enhanced Oil Recovery: Process Schematic

- CO₂ mixes with oil much like turpentine cleans paint from a brush
- Inter-phase mass transfer typically yields NGL rich gas production
- CO₂ produced with the oil is captured, dehydrated, and reinjected - a closed system
- Chase water injection helps control mobility and gas recycle

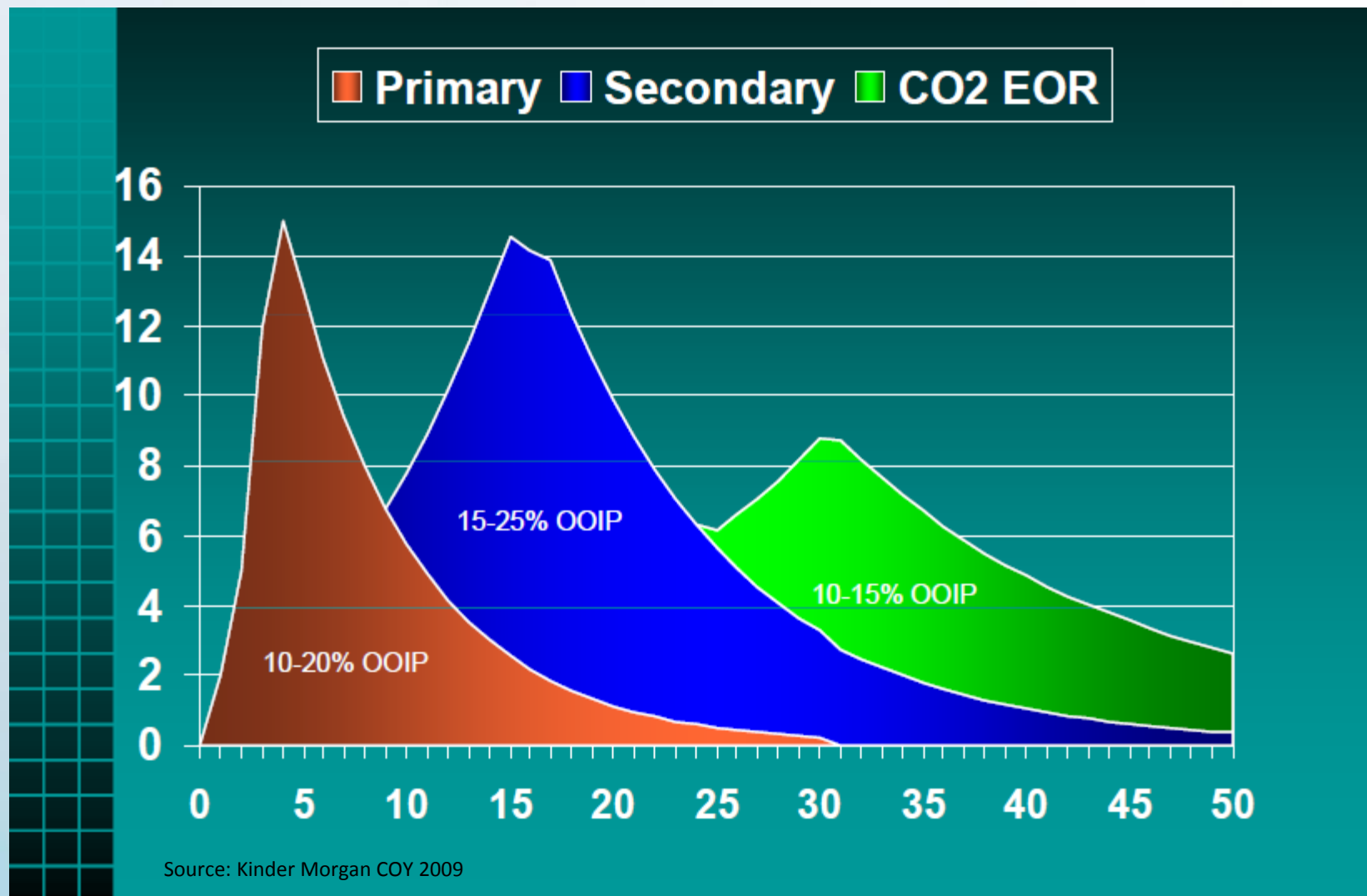


The IVANIĆ CO₂ EOR PROJECT IN CROATIA

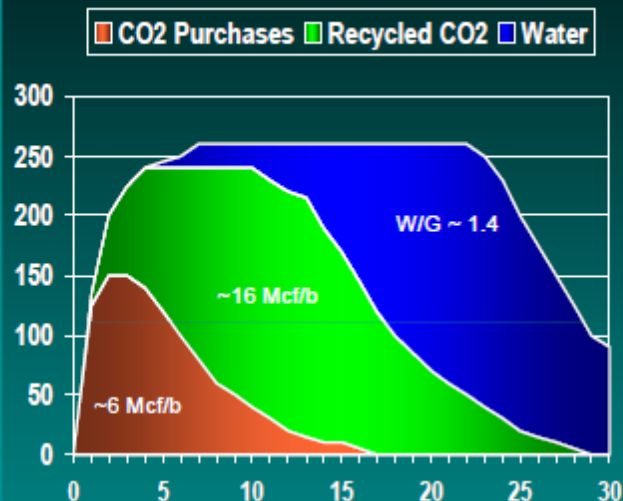


Source: DRAGUTIN DOMITROVIĆ , INA-Naftaplin, Šubićeva 29, Zagreb, Croatia

A REPRESENTATIVE OIL FIELD DEVELOPMENT SEQUENCE



A REPRESENTATIVE* PERMIAN BASIN CO2 EOR PROJECT



Volumetric Summary

Original Oil In Place: 600 MMB

67 MMB EOR 11% 400 BCF purchased

Net CO2 Utilization 6 Gross CO2 Utilization 15.8

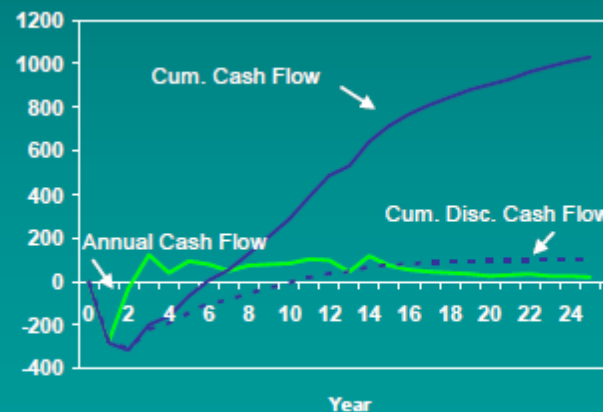
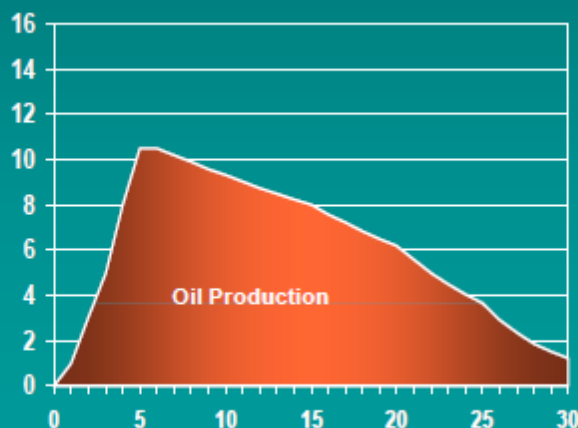
Economic Summary

Capex: 8% of oil price per bbl

CO2 Cost: 2.5% of oil price per MCF

Payout: 5 years

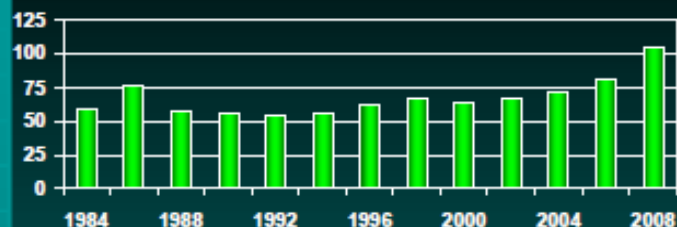
IRR: 20%



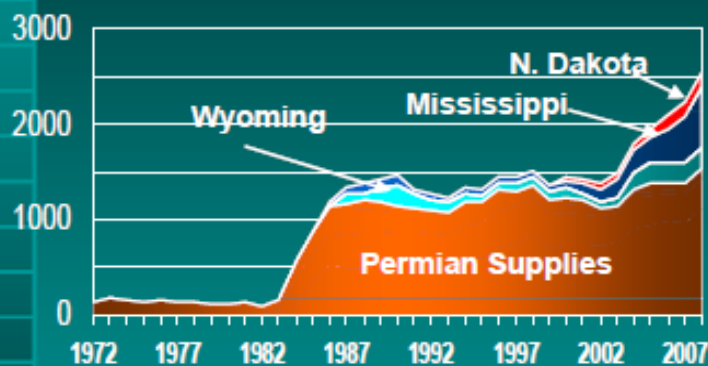
Source: Kinder Morgan COY 2009

*Not necessarily typical

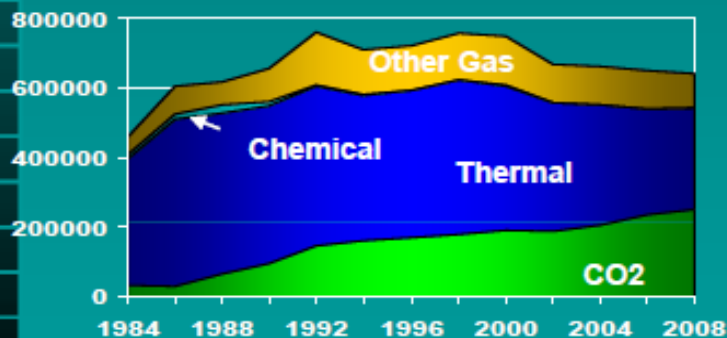
US Active CO₂ EOR Projects



US EOR CO₂ Deliveries, MMCF/d



US EOR Oil Production, B/D



Sources: Oil & Gas Journal, Personal Knowledge

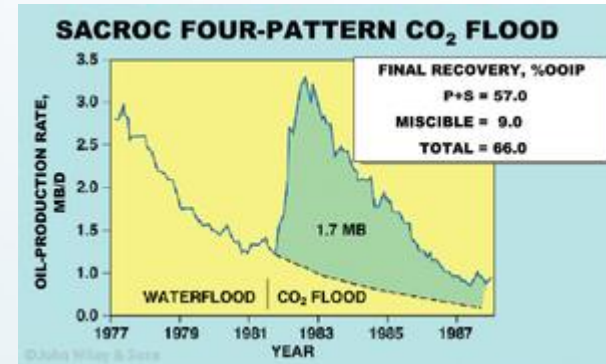
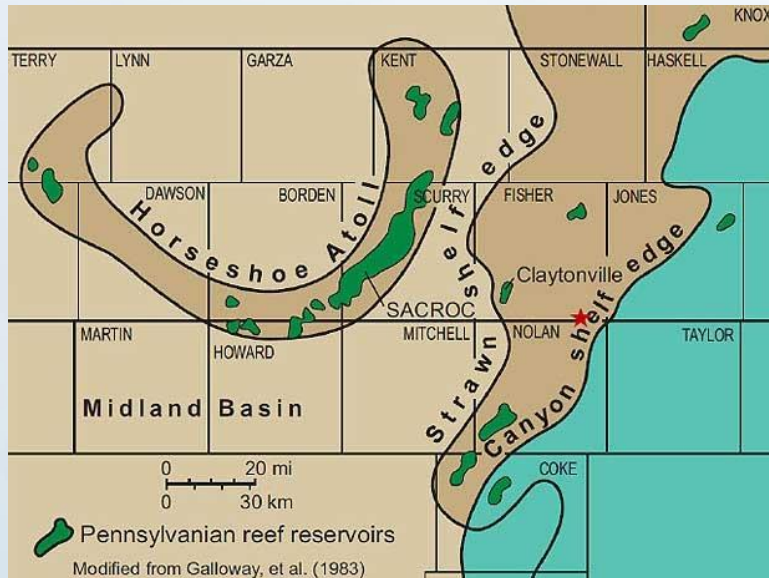
Domestic CO₂ EOR Achievements

Over the past 30+ years, the oil and gas industry has:

- Produced and injected more than 10.8 TCF of CO₂ from 7 sources.
 - 1.2 TCF of which came from sources that otherwise would have been vented.
- Constructed over 3100 miles of CO₂ mainline pipeline systems.
- Produced in excess of 1.2 billion barrels of incremental oil.
- Secured operating practices of:
 - Corrosion management, Metallurgies, Elastomers
 - Separation, Dehydration and Hydrocarbon extraction
 - Compression/pumping
 - Injection and production well completion and operation

Source: Kinder Morgan COY 2009

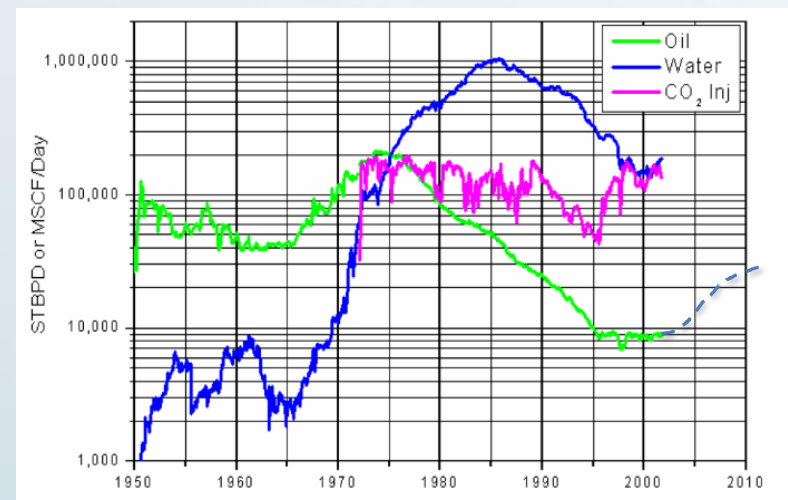
SACROC - CANYON REEF (LIMESTONE)



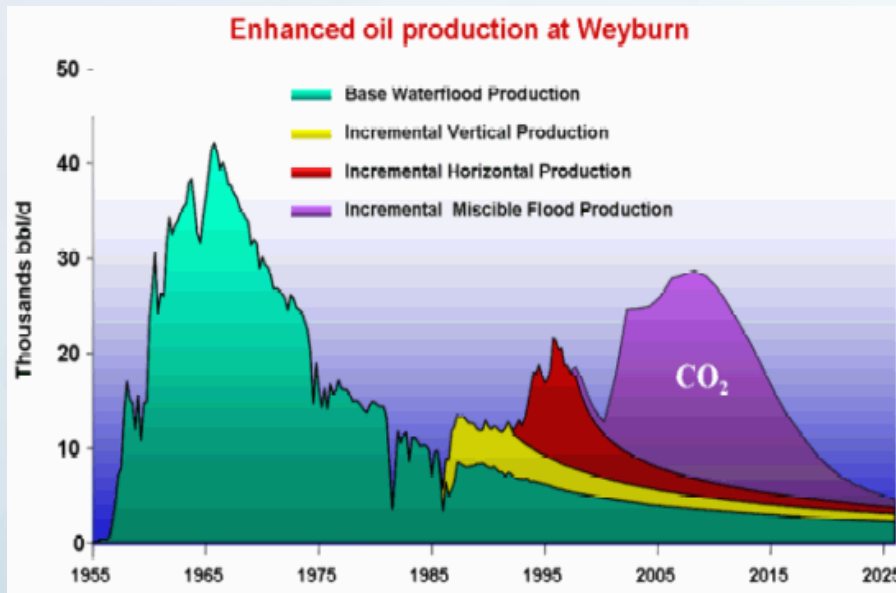
Discovered in 1948, the SACROC unit is one of the largest and oldest oil fields in the United States using carbon dioxide flooding technology. The field is comprised of approximately 56,000 acres located in the Permian Basin in Scurry County, Texas.

Kinder Morgan has expanded the development of the SACROC carbon dioxide project initiated by previous owners and increased production.

In 2012, the average purchased carbon dioxide injection rate at SACROC was 118 million cubic feet per day. The average oil production rate for 2012 was approximately 29,000 barrels of oil per day.



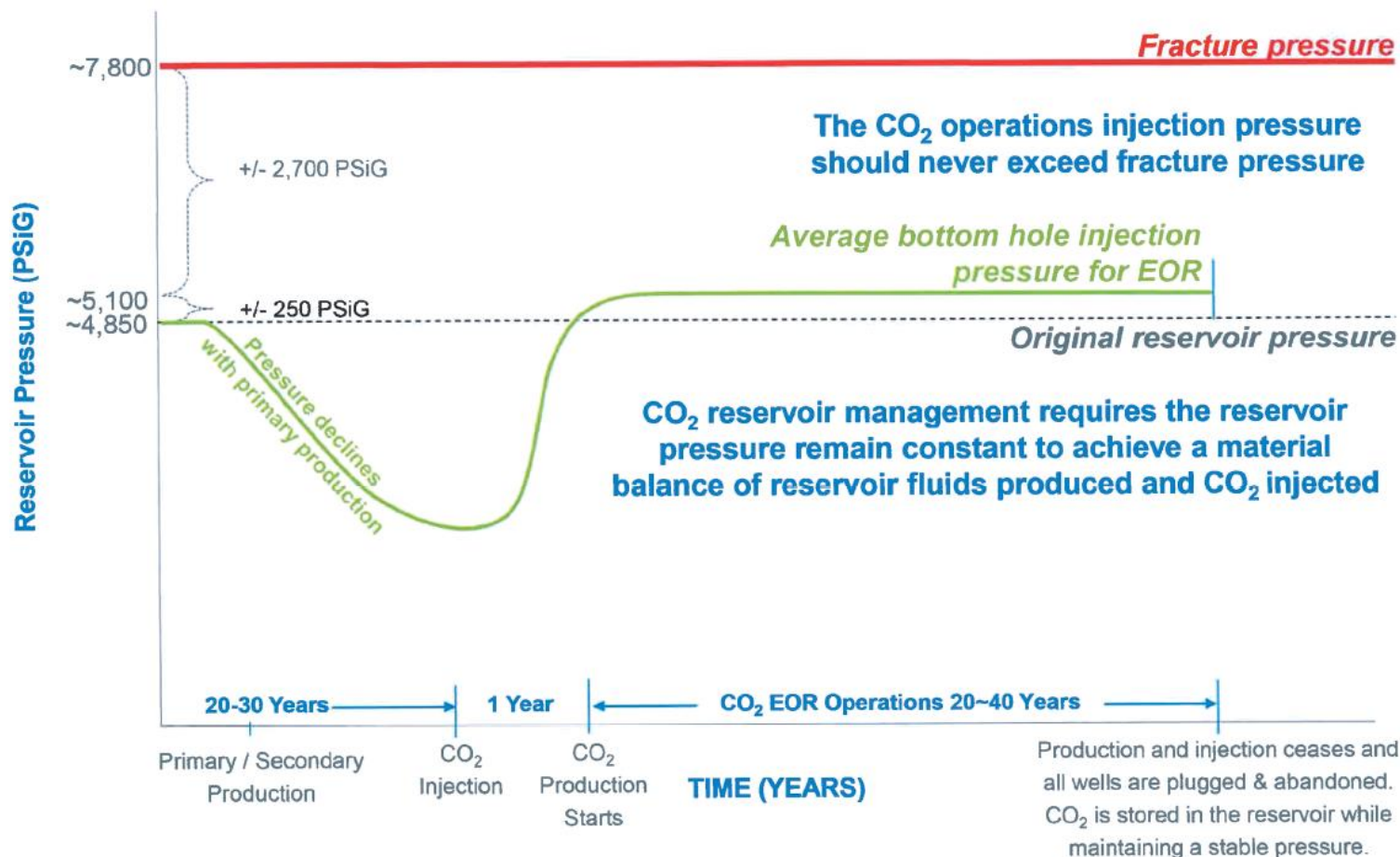
WEYBURN CO₂ EOR



CO₂ injection commenced in October 2000 and ten years later oil production had increased to daily volumes not recovered since the 1970s with 20,000 barrels of oil/day incremental production, or two-thirds of the total field production, due to the CO₂ EOR process.

At the onset of a CO₂-flood only a subset of the total patterns within a large oil field may receive CO₂ and with time the flood is rolled-out in stages more broadly across the field. CO₂-floods are long-lived operations spanning decades;

PRESSURE PROFILE OF A CO₂ EOR OPERATION



* Bottom hole injection pressure data derived from information reported to State authority from an actual EOR field
 * Fracture pressure is the amount of pressure required to permanently deform the rock structure of the formation

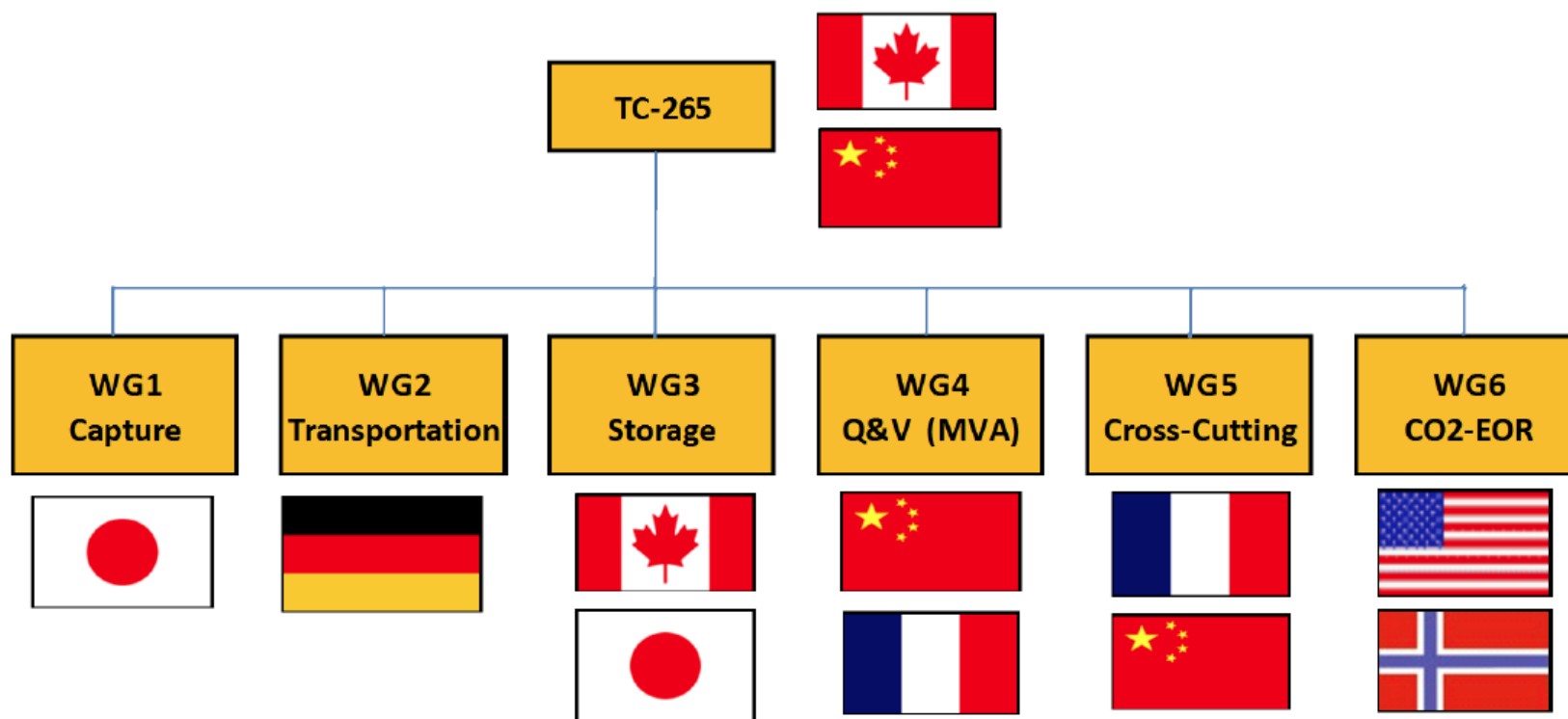
Source: Philip Marston

Standardisation: ISO TC 265

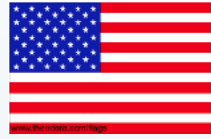


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STANDARDISATION: ISO TC 265



WG6: CO2-EOR



Carbon Dioxide Storage using EOR; Conveners: USA and Norway

1. Scope (applicability)
2. Normative references
3. Terms and definitions
4. General requirements
5. Monitoring, sampling, testing plan
6. Quantification
7. Recordkeeping
8. Closure

18	<i>US Members</i>
3	<i>Norway</i>
5	<i>Canada</i>
2	<i>China</i>
2	<i>Japan</i>
3	<i>UK</i>
2	<i>IEA</i>
1	<i>France</i>

35-40 Members

WG6: CO2-EOR

Main challenges

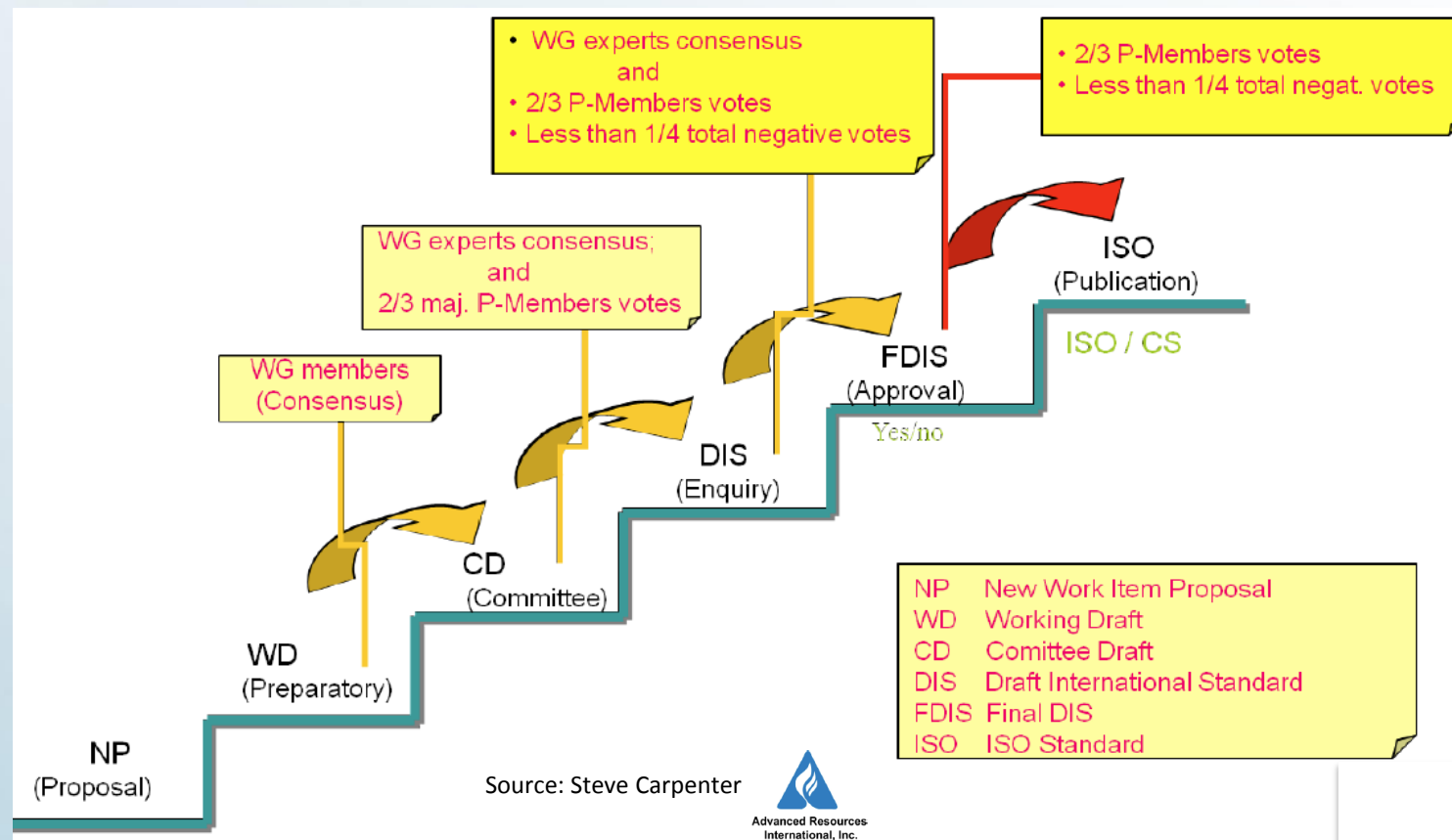
Striking a viable balance between ongoing commercial CO2 EOR operations in the US, Canada and the European regulatory requirements of 20 years of post injection liability and monitoring

Coordination with other WGs, especially

- WG3 Storage
 - WG4 Quantification
-
- *Aim for WD by September (Oslo plenary).*
 - *Work meeting in Houston 24 & 25 June (Denbury hosting + CO2 EOR field visit)*



ISO STANDARDS DEVELOPMENT



THIS IS CO₂ TECHNOLOGY CENTRE MONGSTAD



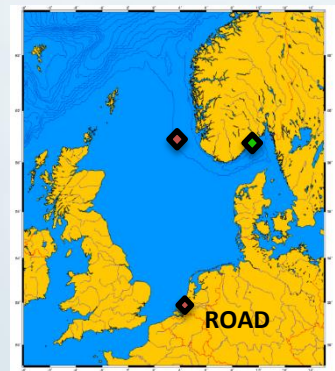
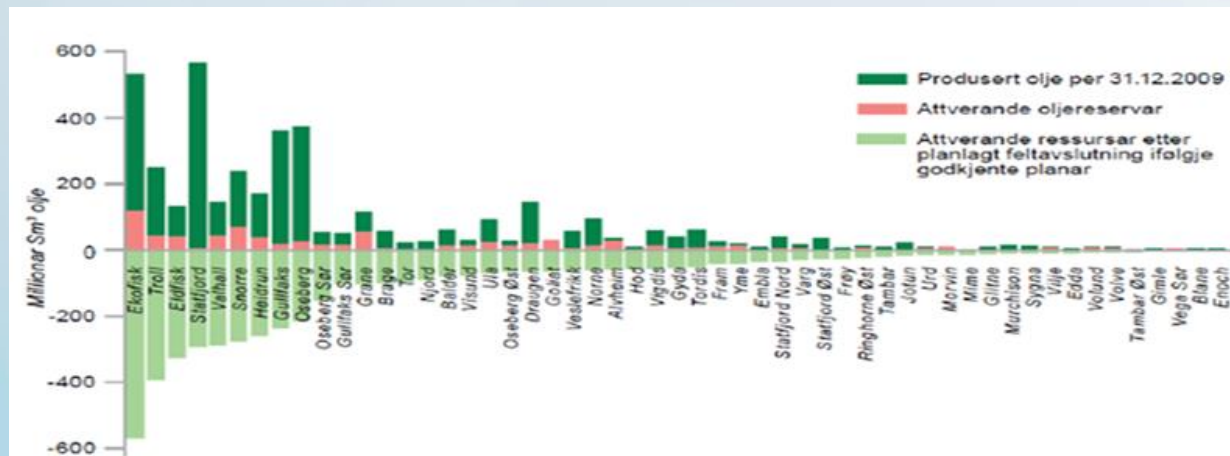
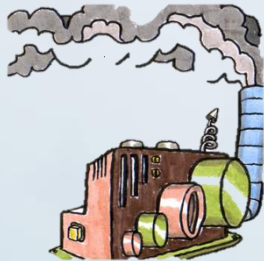
EUROPE'S FIRST CO₂ CAPTURE TEST FACILITY IN CEMENT INDUSTRY, BREVIK, NORWAY

Partners: Norcem,
HeidelbergCement and
ECRA (European Cement
Research Academy)

- Small Scale Test Centre
- Basis for qualification of CO₂ capture technologies
- Project on behalf of the European Cement Industry
- Evaluation of full scale capture
- Total budget: 93 MNOK

CCS PRE-FEASIBILITY STUDY

Work in progress.....





THANK YOU!

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www.gassnova.no/en

CLIMIT program
www.climit.no/en