CO_2 Storage in Depleted Fields and Enhanced Oil Recovery

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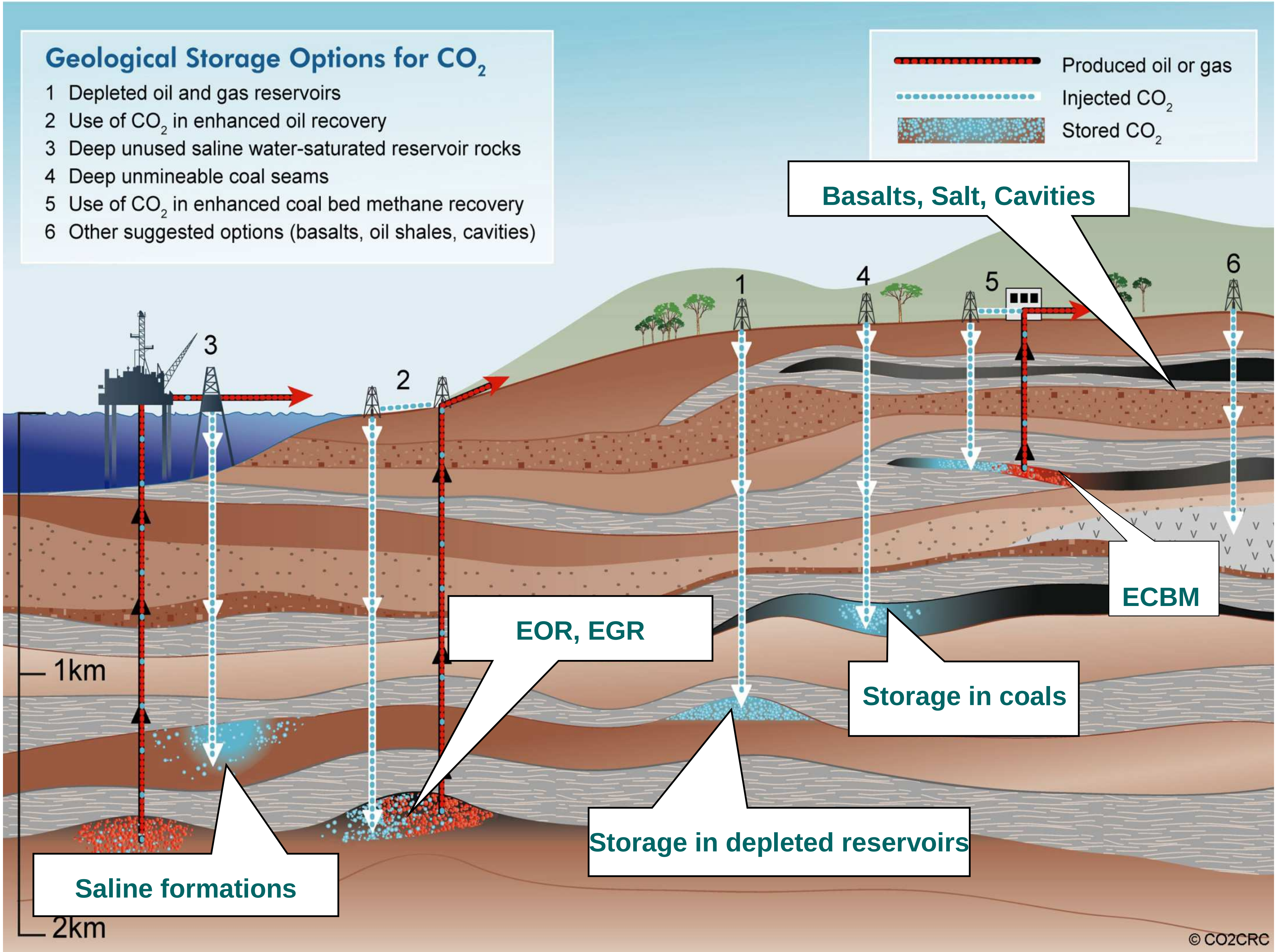
cags
China Australia Geological Storage of CO_2
中澳二氧化碳地质封存


Geological Storage Options for CO_2
1 Depleted oil and gas reservoirs
2 Use of CO_2 in enhanced oil recovery
3 Deep unused saline water-saturated reservoir rocks
4 Deep unmineable coal seams
5 Use of CO_2 in enhanced coal bed methane recovery
6 Other suggested options (basalts, oil shales, cavities)
Produced oil or gas
Injected CO_2
Stored CO_2
Basalts, Salt, Cavities
1
2
3
4
5
6
ECBM
EOR, EGR
Storage in coals
1km
2km
Storage in depleted reservoirs
Saline formations
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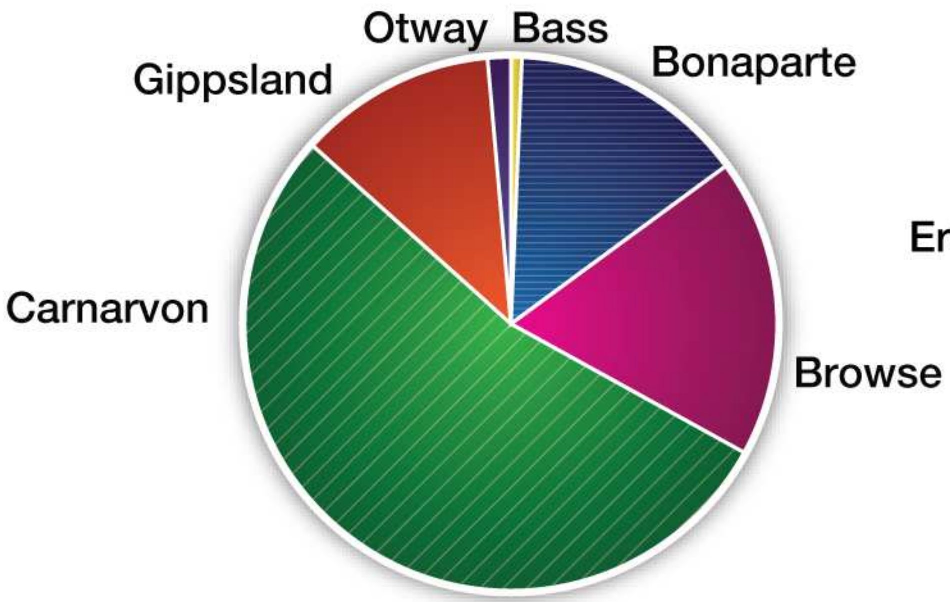
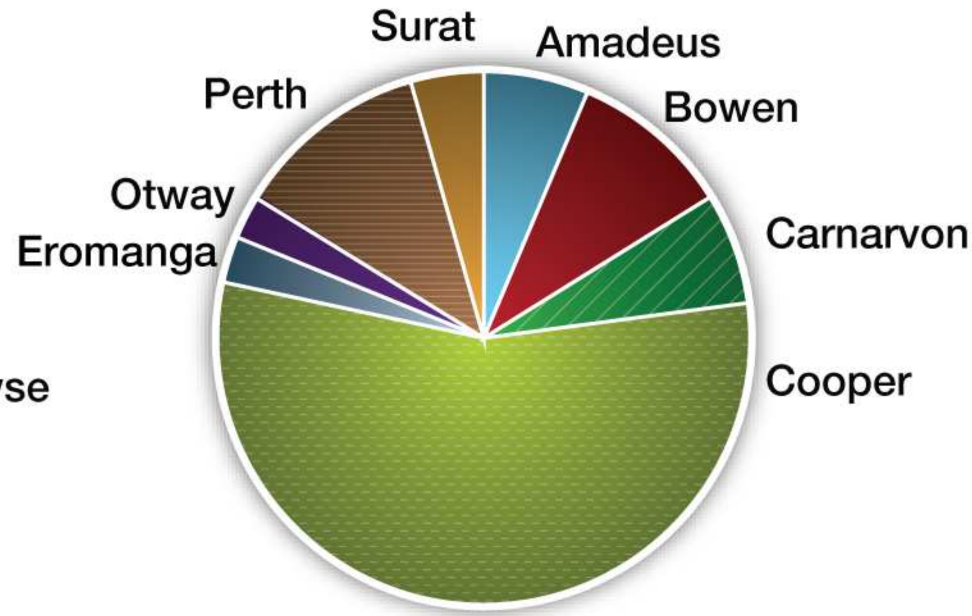
CO_2 Storage potential in Australia's oil and gas reservoirs



Offshore potential storage volume
15,591 Mt CO_2

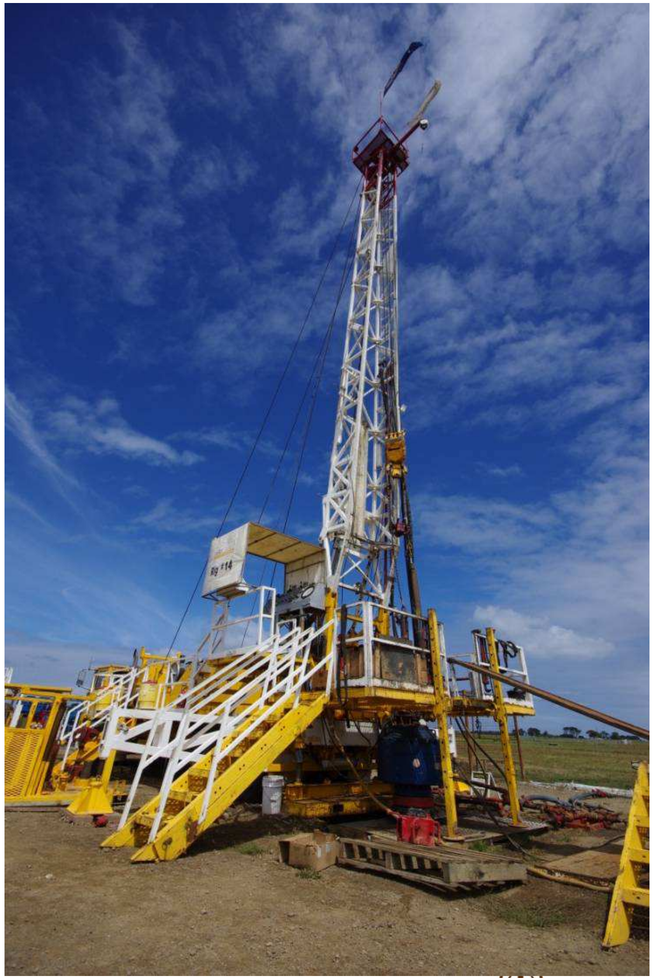


Onshore potential storage volume
938 Mt CO_2

Carbon Storage Mapping Taskforce (2010)

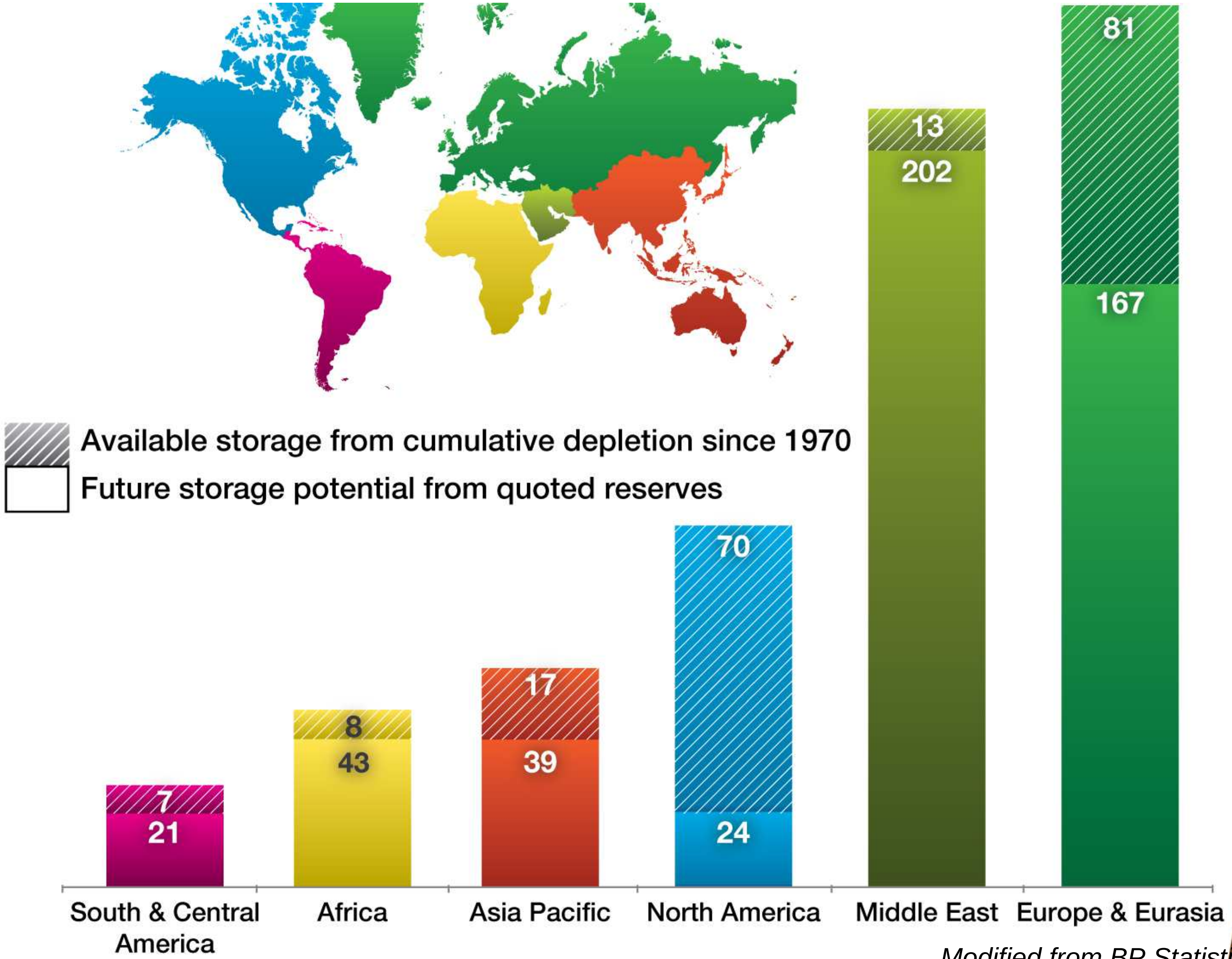
Storage potential in worldwide gas reservoirs

Globally, conventional gas reserves are 180 trillion m^3 and resources 210 trillion m^3 (BP Statistical Review, 2009). Using Otway results of a 'replacement' efficiency of 60% (% of pore space available for CO_2 storage following gas production) suggests a global potential storage capacity of up to 700 Gigatonnes CO_2!



Cook et al, 2011

Global storage capacity in depleted gas formations estimated at 700 Gt CO_2



Modified from BP Statistical Review (2010)

700 Gt CO_2 Storage: implications for global CCS

Whilst much of this storage capacity may not be accessible for technical or economic reasons, it is equivalent to more than 60 years of total global stationary emissions, suggesting that not only is gas a lower carbon fuel, but also storage in depleted gas fields may have a major role in decreasing global CO_2 emissions.

Cook et al, 2011

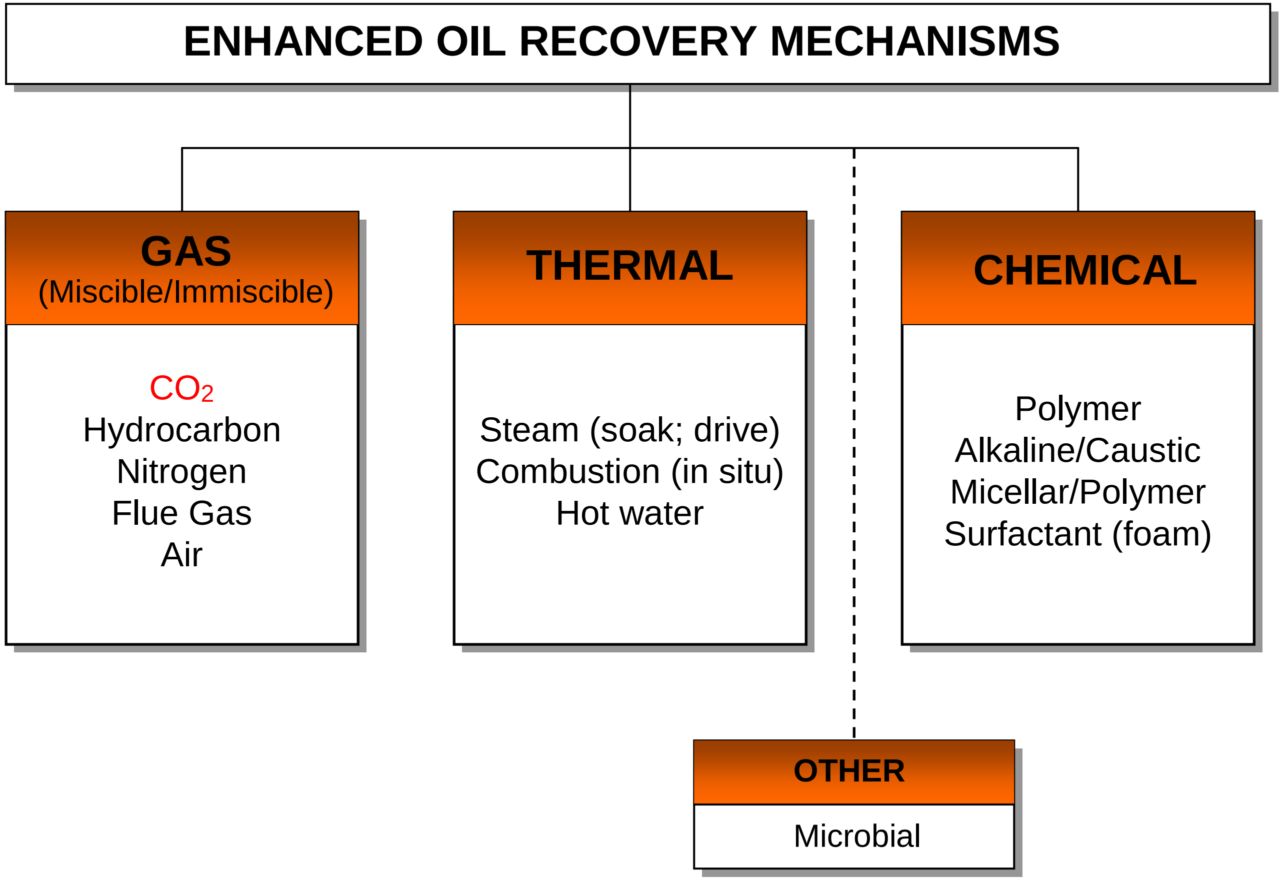
EOR

- What is EOR
- How significant is EOR
- CO_2 Displacement Process
- Field Injection Options

What is EOR?

- EOR = Enhanced Oil Recovery
- As little as only 10-20% of the OOIP may be produced through primary recovery (natural pressure of the reservoir)
- Options include:
  - Waterflooding
  - Gas flooding (CO_2)
  - Thermal methods
  - Plus many others
- These can do two things to assist production:
  - Increase reservoir pressure
  - Change the properties to increase the mobility of the oil

Enhanced Oil Recovery



Worldwide EOR Production

- Production is currently 2.3 MM BOPD
- Represents 3.2% of the world's production
- Some projections reach 30 MM BOPD by year 2020
- CO_2 floods will be a major contributor

The Size of the Prize

- Primary Production — 15% recovery
- Secondary Recovery recovery — 30%
- Enhanced Oil Recovery — 45% recovery

EOR with CO_2

- Two types of processes of EOR using CO2 injection,
  - **miscible**
  - **immiscible**.
- Early interest focused on immiscible displacement by carbonated water flooding. Most activity now, especially in the US is centred on miscible displacement.
- Miscible CO2 flooding is best suited to light to medium gravity crudes and the immiscible process to heavy oils.
- This is because miscibilty requires reservoir pressures above 8.3 kpa for light oils (>30API) and as high as 27.5 for heavy oils (<22.3 API)

CO_2 flooding

- But CO_2 is expensive and can be complex to handle.
- Water is cheap, easy and great for pressure maintenance.
- We need other reasons to use CO_2

CO_2/Oil Miscibility

- Above a certain pressure oil and super critical carbon dioxide become miscible that is they can completely mix with each other in all proportions forming a homogenous solution:

	Gravity	Miscibility pressure	
	^{O} API	psia	mPa
Light oil	>30	1200	8.3
Medium oil	27-30	3000	20.7
Heavy Oil	<27	4000	27.5

These pressures increase as temperature increases above 120^{o}F (49^{0}C)

EOR through miscibility

- Miscibility is the mixing of two fluids to form a homogenous solution.

Miscible: Ethanol and water

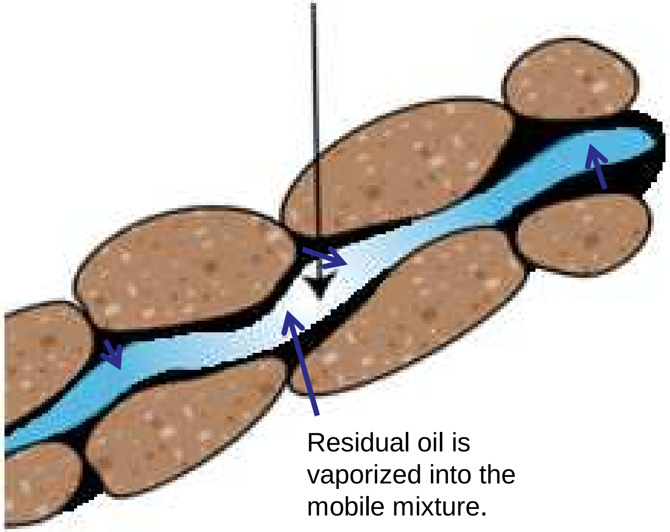
Immiscible: Oil and water

Benefits of miscibility

- Reduction in viscosity
- Reduction in density (Swelling of the oil)
- Increased mobility
- Improved relative permeability

How it works

- Intermediate hydrocarbons vaporize into the flowing, mobile single-phase mixture
- 100% oil recovery is possible if injection lasts long enough. (although this is impractical)



Miscible EOR with CO_2

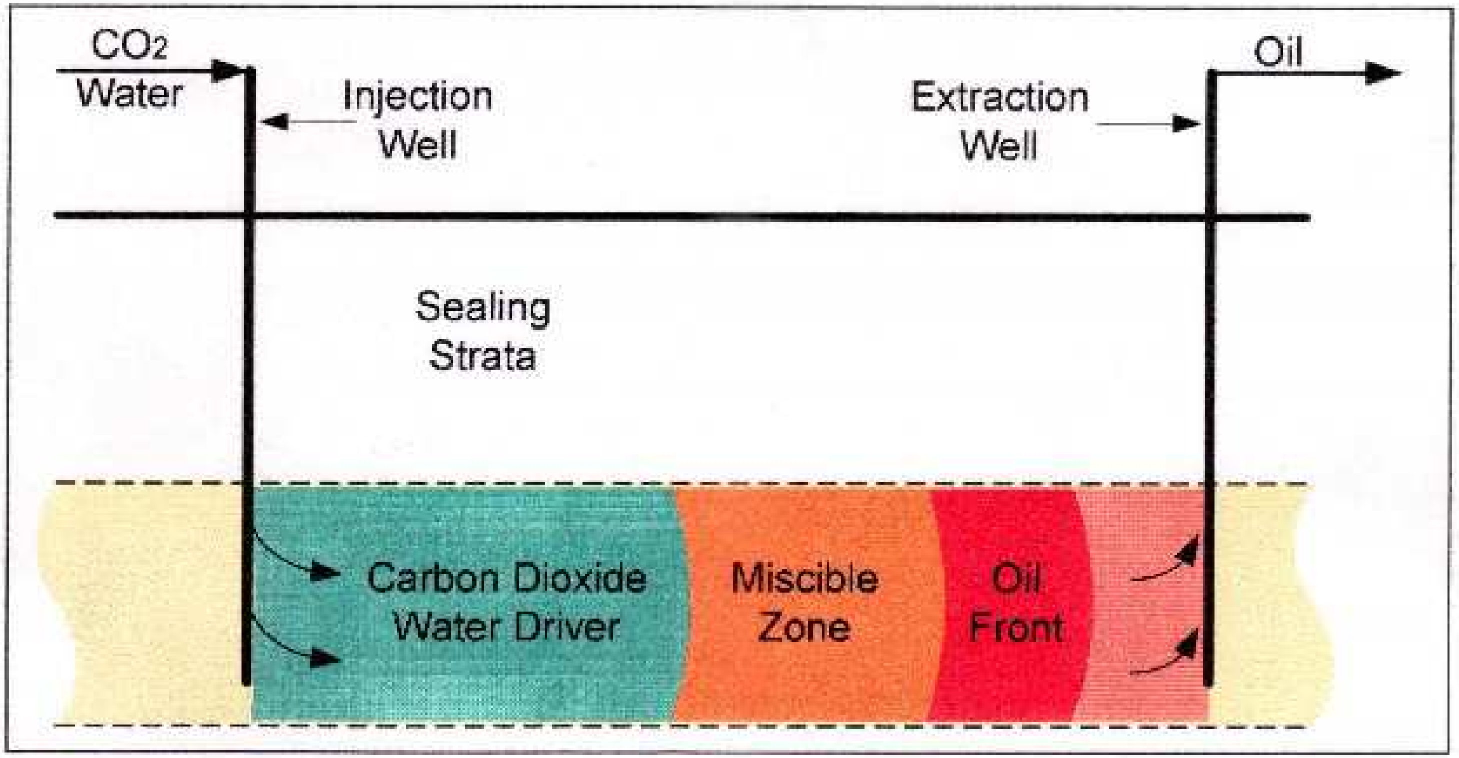


Figure 1. Miscible EOR

Immiscible EOR

- CO_2 injected into to maintain pressure and drive the oil towards the producing well.
- However CO_2 is also highly soluble in crude oil. Dissolution will swell the oil, which will decrease its viscosity and also force water out of the pore spaces to allow increased drainage.

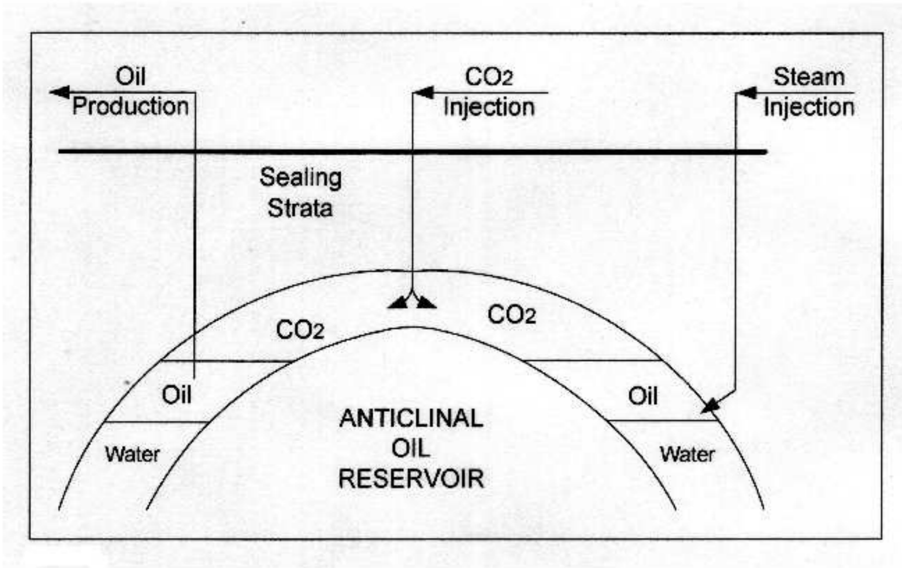


Figure 2. Immiscible EOR

This process can be very important in heavy oil fields such as are found in China and in Turkey

Miscible or Immiscible EOR

Miscible EOR	Immiscible EOR
Light to medium crude oils with API Gravities > 25° with high miscibility with CO_2	Heavy to medium crudes, with API Gravities as low as 10° API
The crudes to have low concentration of aromatic (benzene ring) compounds	Having geological structures where oil 'pushing' from above will be useful
The reservoirs to have only moderate temperatures and are appropriate to 'flooding'	Access to significant amounts of CO_2 that may or may not be 'clean'
Applicable for reservoirs in reasonable proximity to 'clean' CO_2	Applicable where the extraction of oil is not an IMMEDIATE priority

http://knol.google.com/k/clean-coal-technology-and-enhanced-oil-recovery-matches-and-mismatches - Michael C. Clarke Ph.D

Operational Concerns

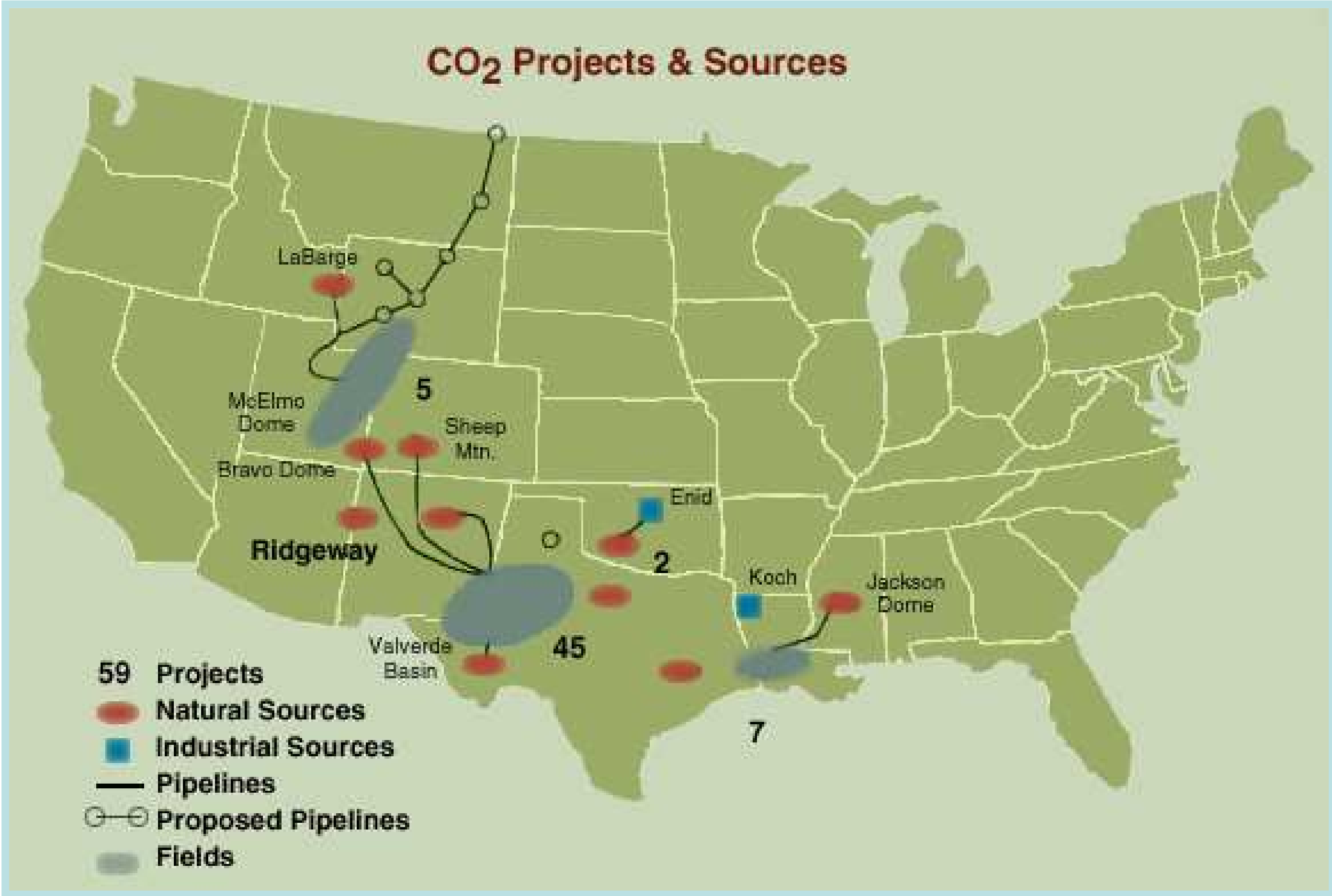
- Miscible or immiscible (Minimum Miscibility Pressure)
- CO_2 source?
- Reservoir heterogeneity
- Fractures
- Gas breakthrough
- Infrastructure for processing/handling/separating
- Wax and Asphaltene build-up
- Corrosion

Active CO_2 EOR projects

Location BOPD	Number	Project BOPD	EOR
World	125	373,500	285,100
U.S.	105*	323,100	249,700
Canada	8	43,000	28,000

*** additional 16 projects post- 2008/2009**

US CO_2 source and project locations



Weyburn CO_2 Project

- CO_2 Source: Dakota Gasification Company
- 95 mmscfd (5000 tonnes/day) injection rate
- CO_2 purity 95% (primary feed)
- Currently 26% recycle.

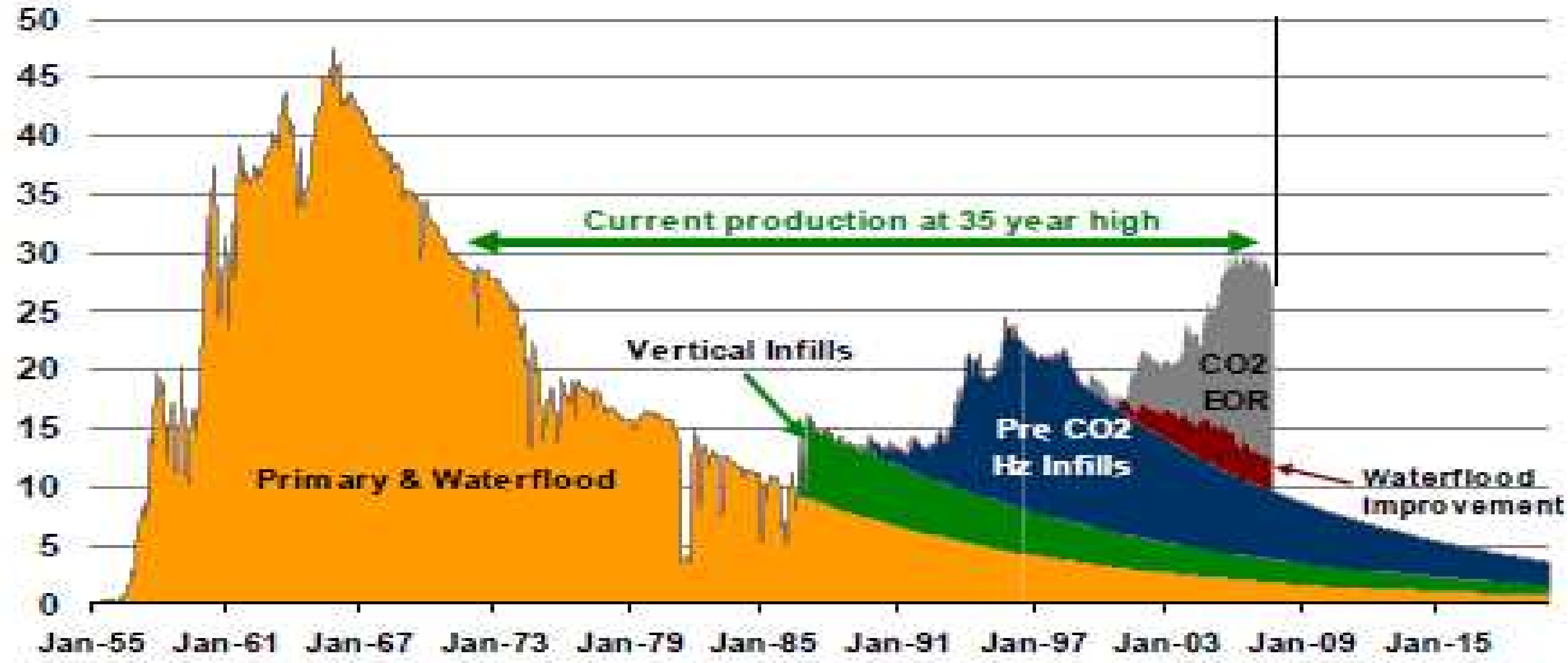
Main CO_2 pipeline enters Weyburn

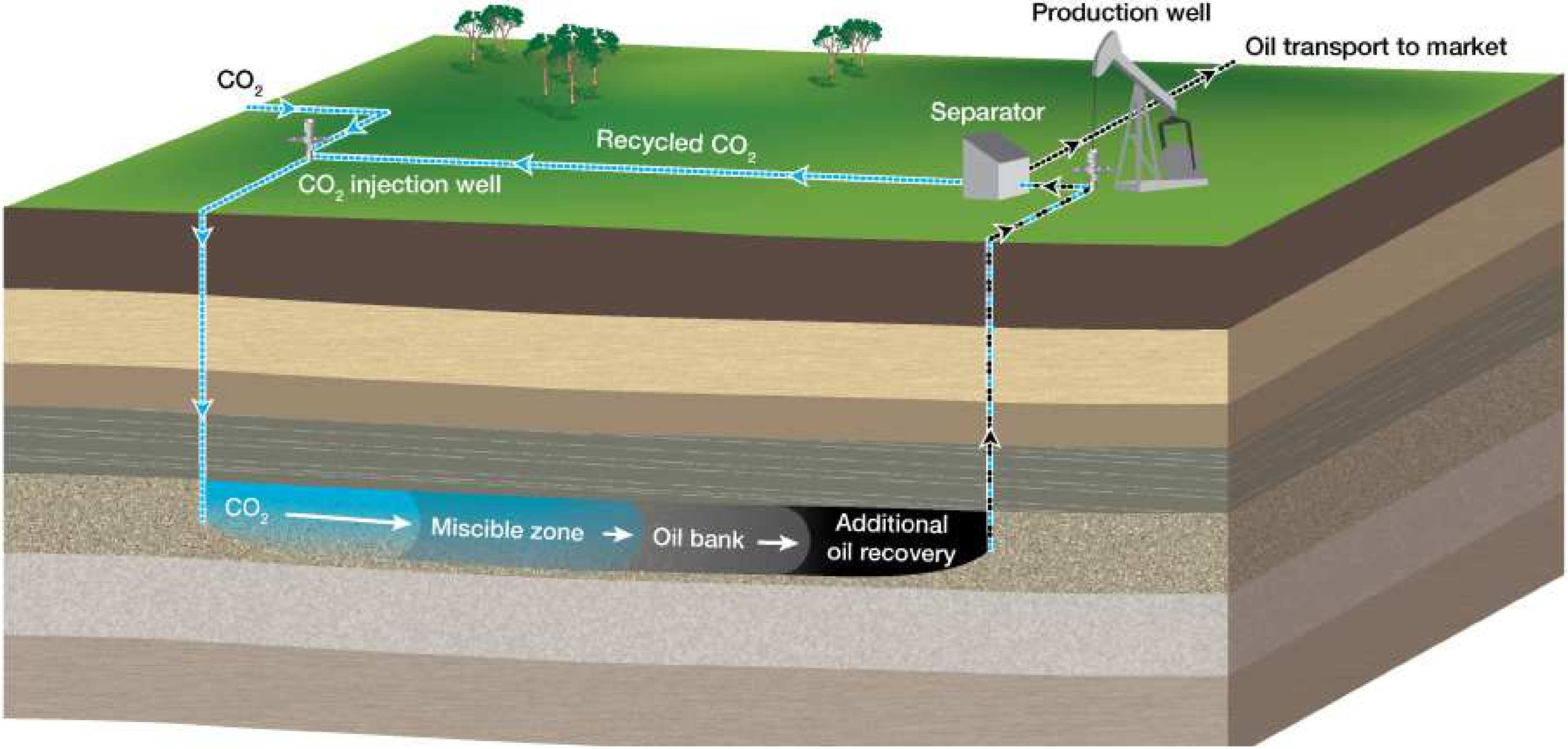
EOR with CCS – Weyburn/Midale

Oil Production: ~ 28,000 bbl/day
(approximately 20,000 bbl/d more than would be produced without the CO2 flood)

CO_2 Storage: ~ 1.3 Mt/year
(approximately 13 Mt total)

Objective: produce more oil (CO_2 storage secondary!)

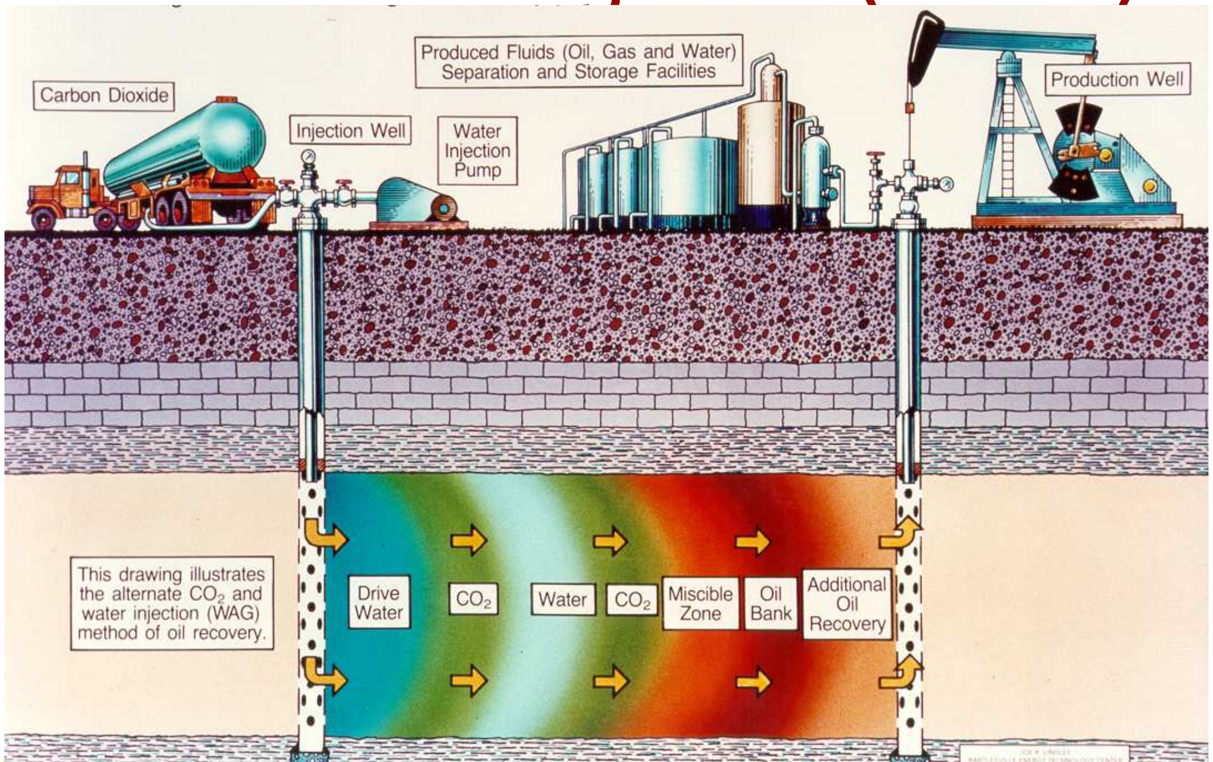




Less than 100% of the CO2, possibly as little as 26% is recovered in each cycle – therefore that percentage that is retained in the formation is stored.

Field Injection Options

- Continuous CO_2 or (CO_2 + Water)
- Water-Alternating-Gas (WAG)



Field Injection Options

- **Continuous CO_2-Disadvantages**
  - Early CO_2 breakthrough
    - Poor areal efficiency
    - Poor vertical efficiency
  - Large injection volume of CO_2/ Significant recycling

- WAG-Disadvantages
  - Water sensitive formations impaired
  - Water injection decreases with time
  - Operational: Corrosion (producing wells)

CO_2 Storage in Oil Reservoirs:

- Replaces oil and gas volume produced
- Soluble in crude oil
  - (requires post production separation)
- Soluble in water (connate and/or waterflood)
  - (some recycling)
- Adsorption to some clay minerals
- Not economically viable today without EOR

EOR Summary

- CO_2: gas-like viscosity, liquid-like density
- High Density CO_2 (liquid or high-pressure super-critical) for larger stored mass.
- CO_2 is economic to increase oil production in basins where naturally occurring CO_2 reservoirs exist.
  – Numerous commercially successful miscible field applications
  – Few commercially successful immiscible field applications

Can we do the same for gas?

Enhanced Gas Recovery - EGR

Figure 1.
K12-B platform and location.

K12-B. Reinjection of reservoir CO_2 into a depleted gas field

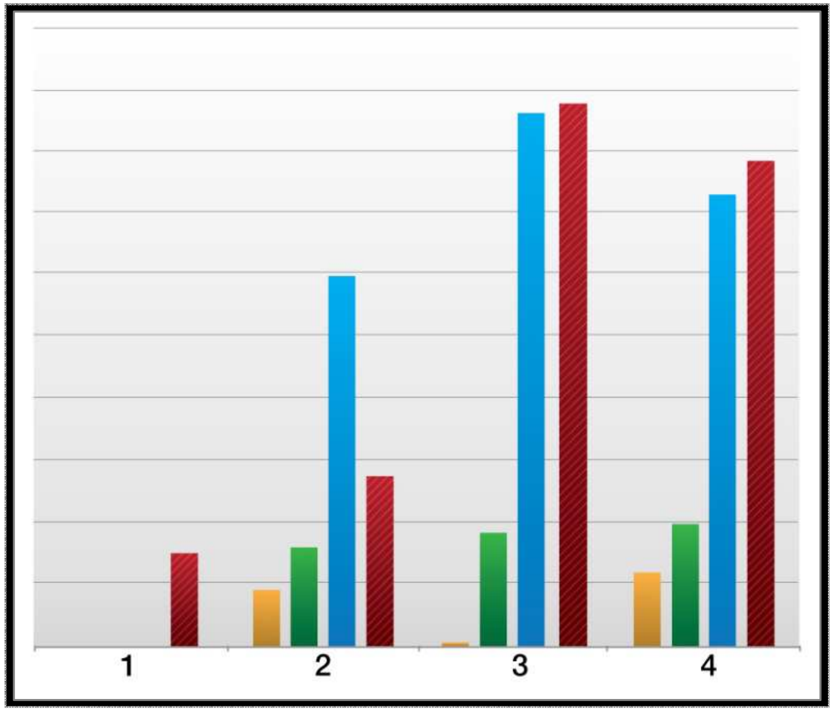
http://www.tno.nl/downloads/357beno1.pdf

Economic simulation of CO_2-EGR

- CO_2-EGR can add significant gains to a natural gas field depending on key variables such as:
  - CO_2 Injection timing
  - Existing CO_2 in the field
  - Additional HC recovery
  - Carbon penalty

Cook et al, 2011

CO_2-EGR can add value



Optimising injection timing and other key variables can add significant value to a field

1. Primary depletion

2. Injection at the start of production

3. Injection during production

4. Injection at the end of production

Methane incremental production

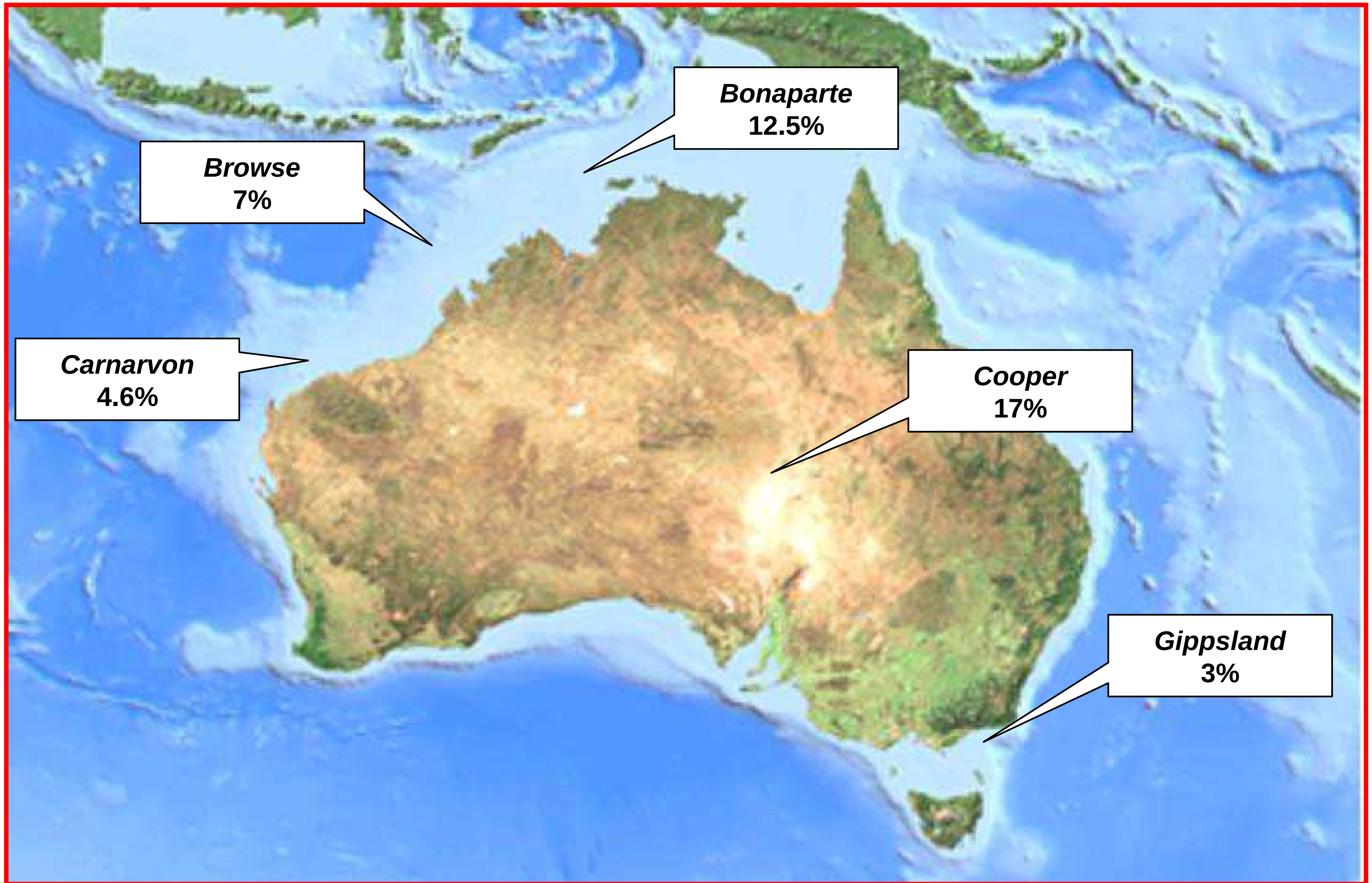
Condensate incremental production

Overall CO_2 stored

NPV

Cook et al, 2011

Natural Percentages of Carbon Dioxide in Australian Natural Gas Provinces



CO2CRC Participants

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