Principles of the Geological Storage of Carbon Dioxide

Rick Causebrook
Geoscience Australia (retired)
Key Messages

1. Evidence from petroleum studies show that oil, gas and CO₂ can be stored in the deep subsurface for geological time

2. CO₂ can be stored in depleted oil and gas fields and deep saline formations

3. CO₂ injected as a fluid into reservoirs (sandstones) is trapped by seals (mudstones)

4. The technology for the geological storage of CO₂ is mature
What is Geological Storage?

- Carbon dioxide captured from industrial processes is transported to a storage site
- Injection via a well bore into a deep geological formation as a dense (supercritical) fluid
- Monitoring the migration of the fluid under buoyancy away from the injection point
- Eventual the CO2 is permanently trapping – structural (buoyancy), dissolution, residual and geochemical
Options for Geological Storage

Geological Storage Options for $\text{CO}_2$

1. Depleted oil and gas reservoirs
2. Use of $\text{CO}_2$ in enhanced oil recovery
3. Deep unused saline water-saturated reservoir rocks
4. Deep unmineable coal seams
5. Use of $\text{CO}_2$ in enhanced coal bed methane recovery
6. Other suggested options (basalts, oil shales, cavities)

Source IPCC
Reservoirs and Seals

- Reservoir rocks have spaces (pores) between the grains which can hold fluids and connections between the pores which can allow the fluids to flow through them (permeability). Sandstones and limestones.

- Sealing rocks are very fine grained with no practical permeability. Mudstones or shales.
How can you store anything in rock?

The geological characteristics of the subsurface can be seen exposed in coastal outcrops

Adapted from CO2CRC
Mudstone SEAL rock (Lid)

Sandstone RESERVOIR rock (Container)

Adapted from CO2CRC
CO₂ trapping mechanisms in porous rocks

When CO₂ is injected into the subsurface, it will rise under buoyancy until it becomes immobilised by a combination of factors:

1. Structural and stratigraphic trapping
2. Residual trapping
3. Solubility trapping
4. Mineral trapping

Unless residual storage occurs, the buoyant free phase CO₂ will ultimately rise to accumulate under the top seal of the reservoir.
Why Supercritical CO$_2$

- At Pressures higher than 7.39 MPa and Temperatures higher than 31.1°C, CO$_2$ becomes a supercritical fluid: gas like but with 400x the density.

- Generally these conditions are found below about 800m in the subsurface.

Source
CO2CRC
Sedimentary basins and geological storage

- Saline aquifers suitable for storage occur almost exclusively in sedimentary basins.
- These are depressions in the crust of the earth in which sediments have accumulated over millions of years and which have not experienced significant uplift and folding.
- They may be tens of kilometres thick and occur both on the continents and under shallow seas.
- All oil and gas accumulations occur in sedimentary basins.

Oil and gas accumulations in a basin help demonstrate that the necessary trapping conditions exist there.
All Basins Are Not Equal

- Sedimentary basins are the regions that offer the opportunity for geological storage of CO$_2$.
- But all sedimentary basins do not have the same potential for storage.
- We need to consider the tectonic settings and reservoir characteristics of each basin when assessing storage.
An example of the ranking of basins for carbon dioxide storage from a recent Australian Government Study conducted by Geoscience Australia.
How long will it stay there?

- Naturally occurring fluids have been trapped underground for many millions of years
- Oil, natural gas and CO$_2$
- This can be shown by the study of petroleum systems.
Time Of Petroleum Charge Into Traps

- **Alaska**
  - Ellesmerian
  - 96 My

- **Venezuela**
  - Maracaibo
  - 20 My

- **North Sea**
  - Central Graben
  - 20 My

- **Nigeria**
  - Niger Delta
  - 45 My

- **Arabia**
  - Greater Ghawar Uplift
  - 25 My

- **North West Java**
  - 25 My

- **NW Shelf Australia**
  - 80 My
Is This New Or Unproven Technology?

- The critical components of the CCS process are currently in use within the Oil & Gas Industry.

- **Capture:** Natural gas processing, ammonia plants other industrial processes.

- **Transport:** 5650 km of CO$_2$ pipeline in the USA.

- **Injection:** EOR – 70 projects in West Texas. Acid gas disposal

- **Storage:** Subsurface storage of natural gas for 100yrs, storage of CO$_2$ since mid 1990s

- **CO$_2$ storage in the North Sea since 1996**

Source: IPCC
Thank You For Your Attention
Pores not Caverns