Geologic Sequestration of CO₂

Trapping Carbon Dioxide (CO₂) in the Earth

Course #101

John Henry Beyer, Ph.D.
WESTCARB Program Manager, Geophysicist
510-486-7954, jhbeyer@lbl.gov

Lawrence Berkeley National Laboratory
Earth Sciences Division, MS 90-1116
Berkeley, CA 94720
Course syllabus

- What is CO₂ and how are we making it?
- Why is CO₂ a problem?
- Where would CO₂ go in the earth and how would it be trapped?
- Would there be a big bubble of CO₂?
- For a small-scale test project, what are we testing?
- What are we not testing and why?
- What’s involved in field operations?
- Who else is doing projects like this?
What and where is carbon dioxide?

- The bubbles in carbonated beverages are CO₂
- The dry ice in old ice cream trucks was frozen CO₂
- CO₂ is in the air we breathe

**Sources of CO₂**
- Fire
- Cars, trucks, airplanes
- Electricity generation at coal and gas fired power plants
- Oil refineries
- Cement plants
- Forest fires
Why is carbon dioxide a problem?

- CO₂ in the atmosphere acts like the glass in a greenhouse – it traps in heat
- Plants absorb CO₂ and produce oxygen, but we produce more CO₂ than can be absorbed
- The amount of CO₂ in the atmosphere is increasing
- The average temperature of the atmosphere is increasing
- The polar ice caps and glaciers are melting
- Sea level is rising
- Storm frequency and severity is increasing
- Weather patterns are changing
- Many crop lands are threatened

Image Credit: National Snow and Ice Data Center, W. O. Field, B. F. Molnia
CO₂ concentration and Earth’s temperature

Source: IPCC Working Group 1 as presented at http://www.oneclimate.net/2008/01/15/climate-change-the-truth-greenhouse-gases/

Geologic CO$_2$ storage

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)

Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)
Important rock types for CO₂ storage

**Cap Rock**
Commonly, Shale
- In sedimentary basins it is laterally extensive, thick, and has very fine grains, which makes it relatively impermeable.
- Has held oil and gas in reservoirs for millions of years.

**Reservoir (storage) Rock**
Commonly, Sandstone
- In sedimentary basins it is laterally extensive, thick, and has high porosity and permeability.
- Most common oil and gas reservoir rocks.


http://library.thinkquest.org/05aug/00461/images/sandstone.jpg

Bureau of Economic Geology, University of Texas
Reservoir rock porosity and permeability

Microscopic view of sandstone

The pores in deep rock formations are filled with saline water (brine).

In oil and gas reservoirs, the pore space is filled with hydrocarbons.

CO₂ both dissolves in and displaces some of the brine.

Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)
How CO₂ is trapped deep in the earth

1. Dissolves in saline water in the reservoir rock (like CO₂ dissolved in a soda)

2. Impermeable overlying cap rock and dome-shaped structures (the way oil and gas are trapped)

3. If the plume moves from buoyancy, water fills in behind it, trapping bits of CO₂ in tiny capillaries between the pores of the reservoir rock

4. Chemical combination with minerals dissolved in the formation brine to form new rock
Will there be a big bubble of CO₂ in the ground? No - CO₂ is very compressible

CO₂ compresses by a factor up to 370 from its volume at the surface.

The hydrostatic (water) pressure in the rocks increases by about 1/2 psi per foot of depth in the earth.

So the CO₂ stays compressed by the pressure that naturally exists deep in the earth.

The compressed CO₂ is liquid-like, with about 2/3 the density of water.
For a small-scale CO$_2$ injection test project, what are we testing?

- Do the deep potential reservoir rocks have high porosity to contain large quantities of CO$_2$?
- Do these reservoir rocks have high permeability so CO$_2$ can be injected?
- Are there impermeable rock formations or structures above the CO$_2$ reservoir that will contain the CO$_2$ indefinitely?
- How will the CO$_2$ interact with the rock and the saline water in the pores of the rock? - so we can predict when and where the CO$_2$ plume will stabilize
- What techniques will work best to monitor the movement of the plume until it stabilizes?
For a small-scale CO$_2$ injection test project, what are we NOT testing?

- Can we safely drill deep wells and pump large quantities of CO$_2$ down them?
  
  In the United States today, the oil industry is pumping more than 85,000 tons of CO$_2$ into the ground every day (31 million tons/year)

- Can we safely transport CO$_2$ from industrial sources to the wells?
  
  For small quantities, many CO$_2$ tanker trucks are traveling on our highways every day to supply CO$_2$ to beverage manufacturers.
  
  For large quantities, the oil industry has a 2,200-mile CO$_2$ pipeline network that has operated safely for decades.
Why are the oil companies injecting large quantities of CO₂ into the ground?

Enhanced Oil Recovery (EOR)

- CO₂ EOR recovers 206,000 BOPD, 12% of lower US oil production
- Started in 1972, it is responsible for more than 1 billion barrels of oil from the Permian Basin
- There are more than 72 US oil fields using the 85,000 tons per day

- The source of CO₂ for EOR is deep geologic formations where nature has stored it for millions of years!
Field operations for test
Step 1 – Drill wells

An oil & gas drill rig capable of drilling to several thousand feet is used

This rig is drilling a natural gas well in northwestern California.

Drill site for Midwest Regional Carbon Sequestration Partnership 9,000-foot well in Edwardsport, Indiana.

Source: Shell

Source: Midwest Regional Carbon Sequestration Partnership, David Ball, Battelle
Field operations
Step 1 – Drill wells

- Two wells will be drilled more than 2 miles deep and 150 feet apart
- CO₂ will be injected into a permeable sandstone layer beneath multiple impermeable shale layers
- The CO₂ plume is expected to be about 800 feet wide
Field operations for test
Step 2 – Inject CO₂

20-ton tanker trucks will transport CO₂ to the site for injection

Source: Gulf Coast Carbon Center, part of The University of Texas at Austin's Bureau of Economic Geology
Field operations for testing
Stage 3 – Testing and Monitoring

A crane will lower tubing and test equipment into the well.

A module with office space, computer, and valves (U-Tube System) will obtain brine samples from the reservoir formation.

Source: Midwest Regional Carbon Sequestration Partnership

U-Tube System at Frio, Texas, CO₂ site

¼-inch tubes from bottom of well to surface module

Wellhead
Stage 4 – End of small-scale test project

Field site after small-scale test project

Wellhead on-site if operator retains the well for future testing or other options

If operator decides to plug & abandon the well, which would require restoring the site
Stage 5 – Optional - Large-scale injection

Whether this would happen depends on many factors

- Appropriate geologic information from the small-scale test
- Federal laws regulating CO$_2$ emissions
- Cost of CO$_2$ emissions
- Nearby sources of CO$_2$
- Pipeline from sources to injection site
- Acceptance by regulators and the public
CO₂ Storage Projects Around the World

Source: The Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC)