Introduction to Geologic Sequestration of CO$_2$

Susan D. Hovorka
Gulf Coast Carbon Center, Bureau of Economic Geology
Jackson School of Geosciences, The University of Texas at Austin
What is Geologic Sequestration?

To reduce CO₂ emissions to air from point sources...

CO₂ is captured as concentrated high pressure fluid by one of several methods...

CO₂ is shipped as supercritical fluid via pipeline to a selected, permitted injection site...

CO₂ injected at pressure into pore space at depths below and isolated (sequestered) from potable water.

CO₂ stored in pore space over geologically significant time frames.
Is geologic sequestration ready to be used as part of a greenhouse gas emissions reduction program?

- Are subsurface volumes are adequate to sequester the volumes needed to impact atmospheric concentrations?
- Is storage security adequate to avoid inducing hazards and to benefit atmospheric concentrations?
- Is the whole system (pipeline, well construction, permitting) mature enough to proceed forward?
Assessing Adequacy of Subsurface Volumes: the Value of Compression

- At depths >800 m CO$_2$ is stored as a dense phase (1 metric ton = about 1.6 cubic m)

Seven Gigatons (7 x 10$^9$ T) CO$_2$/year US emissions from stationary sources:
if spread evenly over US:

- 30 cm/year at @STP (surface temperature and pressure)
- 0.4 mm/year at reservoir conditions
What is Known about Storage Capacity?

• Storage volume is in abundant microscopic spaces (pores) between grains in sedimentary rocks that are now filled with brine (or locally oil or gas).

Assessing Adequacy of Subsurface Volumes: Microscope View

Sandstone thin section photomicrograph, Frio Fm. Blue areas were filled with brine now are 10-30% filled with CO₂
Assessing Adequacy of Subsurface Volumes: Distribution

- Pores to store and seals to prevent leakage upward are typical of sedimentary rocks found widely in the US and globally
  - Economically acceptable estimation of pore space commonly done for oil and gas reservoirs using available tools is adapted to brine-filled volumes
  - Not all sedimentary rocks are equally well known – confidence of estimates of storage volume is variable.
Assessing Adequacy of Subsurface Volumes – map view

[This 2000 data soon to be superseded by DOE Regional Partnerships summary]
Assessing Adequacy of Subsurface Volumes

- New study of capacity by DOE - NETL Regional Carbon Sequestration Partnerships to be released soon
- Major result: making conservative assumptions*: Space for 1000 Gigatons CO$_2$ at reservoir conditions - adequate space for >120 years of all CO$_2$ at current point source emission rates
  * only fairly well known rock volumes assessed
  * Assume that CO$_2$ fills 1% of the volume
- Uncertainty is risks incurred when very large volumes are injected
Is storage security adequate?

What are the risks?

Substitute underground injection for air release

Escape of brine or CO₂ to groundwater, surface water, or air via long flowpath

Earthquake

Escape of CO₂ or brine to groundwater, surface water or air through flaws in the seal

Failure of well cement or casing resulting in leakage
Is Security of Sequestered CO$_2$ Adequate? Types of Risks:

• Catastrophic or rapid escape of CO$_2$ or brine – death or damages
  – Well-known volcanogenic CO$_2$ outgassing: examples at Lake Nyos, Cameroon; Mammoth Lakes, CA; industrial confined space risks

• Slow escape of CO$_2$ – storage becomes ineffective for atmospheric benefit, cost without benefit
  – Slow leakage of either CO$_2$ or brine within ranges of normal variability is probably acceptable in environmental and resource conservation context
  – However leakage rates < 0.1% of stored volume/year are required to benefit atmosphere
Is Security of Sequestered CO2 Adequate?

- Pores to store and seals to prevent leakage upward are typical of sedimentary rocks found widely in the US and globally
  - Economically acceptable estimation of pore space commonly done for oil and gas reservoirs using available tools is adapted to brine-filled volumes
  - Not all sedimentary rocks are equally well known – confidence of estimates of storage volume is variable.
Techniques to Assure Safe Injection of CO$_2$ Used Currently

- Health and safety procedures for CO$_2$ pipelines, shipping, handling, and storing
- Pre-injection characterization and modeling
- Isolation of injectate from Underground Sources of Drinking Water (USDW)
- Maximum allowable surface injection pressure (MASIP) to prevent earthquakes.
- Mechanical integrity testing (MIT) of engineered system
- Standards for well completion and plug and abandonment in cone of influence and area of review around injection wells.
- Reservoir management; extensive experience in modeling and measuring location of fluids
How can Security of Sequestration be Better Assured?

• Rigorous site selection requirements
• Comprehensive monitoring requirements and mitigation plans
• Additional research
• Need for a balanced and phased approach

Not too restrictive: encourage early entry into CCS – gain experience

Mature = standardized, parsimonious but adequate approach

Adequate rigor to assure that early programs do not fail
Assuring Security: Monitoring Options

- Atmosphere
  - Ultimate integrator but dynamic
- Biosphere
  - Assurance of no damage but dynamic
- Soil and Vadose Zone
  - Integrator but dynamic
- Aquifer and USDW
  - Integrator, slightly isolated from ecological effects
- Above injection monitoring zone
  - First indicator, monitor small signals, more stable.
- In injection zone - plume
  - Oil-field type technologies. Will not find small leaks
- In injection zone - outside plume
  - Assure lateral migration of CO₂ and brine is acceptable
System mature enough to proceed: Global experience in CO$_2$ injection

From Peter Cook, CO2CRC
System mature enough to proceed: US experience in gas storage

Slide from Sally Benson, LBNL
Geologic storage is ready to be used as part of a greenhouse gas emissions reduction program

- Subsurface volumes are adequate to sequester the volumes needed to impact atmospheric concentrations
- Using available technology, adequate storage security can be assured to avoid inducing hazards and to benefit atmospheric concentrations
- The whole system (pipeline, well construction, permitting) is mature enough to proceed forward—some work remaining
What needs to be done next?

• Prior to injection, CO$_2$ has to be captured at high concentration and compressed to about 2200 psi
  – Capture is major limit on utilization of geologic storage

• Assurance provided to industry on property rights and permitting
  – Legal precedents for large volume injection into brine in most states are inadequate

• Consensus on Best Practices for monitoring injection and post injection clarified
  – This should be a result of research in coming year – how much monitoring is adequate?
Geologic Sequestration of Carbon – Put it back

Carbon extracted from coal or other fossil fuel...

Returned into the earth where it came from