Assessing the Geological Sequestration potential in the Illinois Basin – Successes and Challenges

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Objectives

1) Assess what it is going to take from a technical standpoint to make geological sequestration of CO$_2$ in our region possible.
   - exclusive of political, regulatory, legal and economic context/concerns

2) Define and discuss the four fundamental factors required for successful sequestration.
The sequestration challenge:

- Use the subsurface geological environment to securely store very large volumes of CO$_2$ for a very long time

- Need to have:
  - 1) volume, 2) mode,
  - 3) confinement and 4) security
Volume

How much volume is needed?

Indiana produces ~ 250 Million metric tonnes of CO$_2$/year

- About half (125 MM) comes from point sources
- Most are from coal-fired generation plants
  - e.g. Gibson Station emits ~20 mm tonnes/3100 Mw/year
  - e.g. Edwardsport will make ~ 4.5 mm tonnes/630 Mw/year
If half of the CO$_2$ emissions are to be captured and stored,
- ~125 million tonnes/year reservoir capacity required.
- To date, the largest CCS projects store 1-1.5 MM/year
  - Sleipner, Snøhvit, Weyburn, and In Salah

If 10% (25 mm/yr) of the emissions are to be stored,
- Will require ten 2.5 MM tonne/year projects
Volume – potential storage

- Mount Simon Sandstone in Indiana:
  - ~15 to 30 billion tonnes

- Mature oil fields and coal seams:
  - ~<1 billion tonnes

- Organic shales??
  - ~~ 5 billion tonnes
Storage volume = pore volume

CO₂ Storage in Sandstone Reservoir Pore Space

Pore space
Pin head
Sand grain
Volumetric calculations - initial

10% of average (14%) pore volume greater than 2,500’ depth
Volumetric considerations - revised

~8% = <5,000 feet
~5% = <7,500 feet

New NETL capacity calculations:
“1-4 % of available pore space present is useable”
Volume – accessing pore space

- To emplace the injected $\text{CO}_2$ into the pore volume, need to access it.

- Assume all $\text{CO}_2$ exists as super critical fluid that is **efficiently** displacing the existing pore water.

- Challenge of managing the reservoir:
  - Well fields or “arrays”
  - Horizontal vs. vertical wells
  - Reservoir heterogeneity (porosity and permeability)
Irregularly distributed porosity and permeability in a sandstone
Irregular flow pathways in a heterogeneous reservoir
Reservoir heterogeneity

Porter County (Well# 144456)

Mt. Simon Sandstone

10 % cutoff porosity
Volume - what is needed for a project?

- Measurements of porosity and permeability (borehole sourced, whole core derived, laboratory measured, and office interpreted)

- Geometry and composition of the pore system (as above)

- Reservoir Volume (3D extrapolation of above information; with seismic data and other boreholes)
$CO_2$ can exist in the reservoir in four ways:

- **Displacement** of brine in pore spaces
- **Dissolution** into the brine
- Saturate the capillary spaces as an **Irreducible** fluid
- Precipitation as **Mineral** phases
Modes of ‘residence’

![Diagram showing the modes of residence over time since injection stops.](image)
Storage modes

- Directly relates to efficiency of emplacement, migration and ultimately secure confinement.

- Could be positive or negative effects
  - e.g. mineral precipitation chocks pore throats and inhibits emplacement
  - or
  - Fixes CO$_2$ as mineral phase after emplaced enhancing security of confinement
Reservoir mineralogy - interactions
Complexity of interaction of these processes in both time and space is not known.
For CO$_2$ that is displacing brine, acts as a buoyant fluid:

- Vertical migration barriers – “seals”
- Lateral migration barriers – “traps”
- Seal + Trap = Confinement

Seal integrity can be compromised by:

- Reactivity
- Unplugged boreholes
- Borehole cement degradation
Regional reservoir seals

Prairie du Chien Gr.
Black River Gr.
Ancell Gr.
St. Peter Sandstone
Everton Dolomite

0    API 150  30   -10
Local trap formed by a structural dome

Subsurface Seismic Map
Tonti Field, Marion County, Mississippian

Crest
Security

MMV techniques:

- Monitoring the reservoirs and other aspects of the subsurface and surface
- Measurement of how much CO\textsubscript{2} is moving and where
- Verifying that the vast majority of the stored CO\textsubscript{2} is where it should be
Security

**MMV** tools to assure long term security include:

- Monitoring wells
- Shallow and surface sensors
- Tracer surveys
- Reservoir fluid flow models
Long Term integrity of sequestration

Modeling results – lateral migration of CO₂

Sequestration performance depends on the geology of the proposed sequestration site. (a) In an aquifer with no shale layers, the CO₂ plume rises quickly to the aquifer caprock, where it migrates laterally beneath this impermeable seal. (b) When shale units are present, they effectively retard the plume’s vertical migration while promoting its lateral extension, thus enhancing the effects of solubility and mineral trapping.
Security challenges

- Slow leakage across seals
- Displacement of saline waters into oil or fresh drinking water reservoirs
- Loss of injectivity; pressure buildup; fracturing...leakage
Summary

- Large storage volumes required
- Storage mode in reservoirs needs to be considered
- Effective confinement needed
  - Sealing and entrapment
- Long term, secure storage required
  - Protection of health and human welfare + resources