Progress Update SECARB “Early” Test Monitoring 3.5 Million Tons at Cranfield

SECARB Stakeholders Briefing
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Mobile, AL

Illustration by Tip Meckel
Panel Overview

- Overview and updates – Susan Hovorka
  - Organization, design, status
  - Update – Modeling and pressure response
  - Update – geochemistry in reservoir and AZMI
  - Technical and public knowledge-sharing
  - Future opportunities - CCUS
- Update on Geophysics and lab activities – Tom Daley
- Update on near surface monitoring – Katherine Romanak
Early Test Organization Chart

Gulf Coast Carbon Center
Bureau of Economic Geology
Jackson School of Geosciences
The University of Texas at Austin

Denbury Resources
Field owner and injection system
design, management, 4-D survey, HS&E

Sandia Technologies
Monitoring Systems Design, Installation, HS&E

Core Lab
UT DoG Anchor QEA

Federal collaborators
Vis FWP

LBNL
Well-based geophysics, U-tube and lab design and fabrication

LLNL
ERT

Vendors e.g. equipment

USGS
Geochemistry

Separately funded

ORNL
PFT, Stable isotopes

NRAP VSP

NETL
Rock-water interaction

Stanford, Princeton, U Edinburgh, UT PGE & ICES (CFSES), U. Tennessee, USGS RITE, BP, CCP, Durham

50 Vendors e.g. Schlumberger

MSU UMiss
Hydro & hydrochem

Curtin University, Perth
Early Project Status

Surface monitoring

- Real-time monitoring – BHP, BHT, AZMI, DST
- Baseline 3-D VSP Cross well
- Repeat 3-D VSP Cross well
- 1 million ton/year rate

Logging

- Baseline 3-D
- Start DAS injection
- Start Phase 3 injection
- Start Phase 2 injection

Geochemical monitoring

- Cumulative volume stored
- Cumulative injection

Surface monitoring

- 1 million metric tons CO₂

Timeline:
- 2008
- 2009
- 2010
- 2011
- 2012

Phase:
- Start Phase 2 injection
- Start Phase 3 injection
- Geochemical monitoring
- Recycled
RCSP program goal: Evaluate protocols to demonstrate that it is probable that 99% of CO₂ is retained

Permanence of geologic system well understood prior to test.

• Assessment of leakage risk.
  – Well performance is highest uncertainty and focus of monitoring research

• Conformance of flood in the injection zone
  – Pressure
  – Plume confined by 4-way closure.
    • Uncertainty – amount of radial flow (down dip/out of pattern)

• Measure changes above the injection zone
  – along well
  – above zone monitoring interval (AZMI)
  – Seismic response
  – at surface over long times
Evaluation of available Cement Bond Logs

Risk Assessment result – greatest leakage risk in unknown well rock-casing annulus bond
In-zone and AZMI pressure monitoring
In Zone Continuous pressure data from dedicated monitoring well

- Large perturbations obvious
- Even small perturbations observable (100’s tons/day flux from 1 km)
- Fault observed to be sealing

Incremental Delta Pressure - injection zone (psi) in the monitoring well EGL#7

Meckel and Zeidouni
Stratal slices: there is no sign of leaking!

Cross-section flattened
Velocity difference

Fault

Velocity difference above zone

Initial result: Hongliu Zeng
New analysis: Leakage not occurring along this well – integrated pressure-thermal analysis - Qing Tao UT PGE
Continuous data series 3 years

Maximum sustained pressure differential ~1,200 psi / 80 bar / 8 MPa
RCSP program goal:
Predict storage capacities within +/- 30%

• Capacity and injectivity well known at project start.
  – Open boundary conditions predicted during characterization are demonstrated by good model match.
  – CO₂ moved radially from injectors at the scale of the test (density contrast did not dominate)
• Advance understanding of efficiency of pore-volume occupancy (E factor)
  – Measure saturation during multiphase plume evolution
  Increase predictive capabilities (underway through modeling)
  – The plume continued to thicken over time, increasing capacity
DAS Simulation
Role of the mudrock during CO₂ injection

- Pressure propagation is governed by ratios of mudrock/sandstone permeability and storativity

- Permeable and compressible surrounding rock reduces pressure propagation within a reservoir

Kyungwon Chang UT DoGS
Continued...

- **Area of Review (Area of pressure increase):**
  - Compressible/permeable mudrock may reduce the radius of review
  - The uncertainty in mudrock properties leads to large variance in radius of review

Kyungwon Chang UT DoGS
Residual methane effect on AOR and plume size

, U-tube-team; Seyyed Hosseini,
Significance of Methane Outgassing

Simon Matthias, Univ. Durham; Seyyed Hosseini, BEG
Effect of residual methane in analytical solution

- Reduction of relative permeability

\[
P - P_0 = \frac{M_0}{4\pi r^2 H k} \left\{ \begin{array}{ll}
\frac{\mu_c}{k_{rs}} \ln \left( \frac{z_T}{z} \right) + \mu_g q_D^2 F_3(z_T) + \mu_m q_D^3 F_2(z_L) + \frac{\mu_b q_D^3}{k_{rb0}} F_1(z_G), & 0 \leq z < z_T \\
\mu_g q_D^2 F_3(z) + \mu_m q_D^3 F_2(z_L) + \frac{\mu_b q_D^3}{k_{rb0}} F_1(z_G), & z_T \leq z \leq z_L \\
\mu_m q_D^3 F_1(z), & z_L < z \leq z_G \\
\mu_b q_D^3 F_1(z), & z > z_G
\end{array} \right.
\]

(49)

\[
\alpha = \frac{M_0 \mu_b (c_r + (1 - S_{g3}) c_b + S_{g3} c_m)}{4\pi r_p k}, \quad z_E = \frac{\pi \rho c_H r_p^2}{M_0 f}
\]

(53)

Simon Matthias, Univ. Durham; Seyyed Hosseini, BEG

- Increase of compressibility
At higher methane residual saturations it can:

1. Reduce the injectivity
2. Reduce the far-field pressure
3. Increase the plume size by 30%

Simon Matthias, Univ. Durham; Seyyed Hosseini, BEG
Knowledge Sharing

- UT Energy Forum
- UT Law School Continuing Education
- CSLF – Recognition of SECARB Early Test
- 10th Annual CCS conference (Pittsburg)
- IEA Monitoring network
- Trondheim CCS Conference
- Pew Center Accounting Framework
- Canadian Standards Association (CSA) carbon sequestration standards development
- CO2CARE – EU post-closure research
- BIG CCS – Norwegian University Research program
- CCP Contingency Workshop
- EPA/LBNL Geologic Sequestration and Water workshop
- AEP Mountaineer – Geologic Expert Team
- Review EPA guidance documents
- UT CCS1
- STORE and SECARB-Ed training
- 29 Publications [www.gulfcoastcarbon.org](http://www.gulfcoastcarbon.org) bookshelf
- Thesis and dissertations: 2 completed; 3 underway
Future work

• Long-term monitoring- AZMI, groundwater, soil gas
• Complete cross-tool comparison
• Support other experiments
  – LBNL - CO2 geothermal
  – RITE - microseismic
  – Schlumberger cement analysis
  – Univ. Edinburgh noble gas study
  – SIM-SEQ
• Possible CCUS activities
Document storage permanence

### Storage only saline green field
- Prove-up capacity
- Prove-up confinement
- Simple fluid – low solubility
- Few wells
- Historical uses?
- Evolving regulatory and legal framework
- Unknown public acceptance

### CCUS – EOR in brownfield
- Well-known capacity
- Well-demonstrated confinement
- Complex fluids, high solubility
- Many wells
- Complex history
  - Perturbation from past practices
- Mature regulatory and legal framework
- Good public acceptance
Role of Dissolution in Plume and Pressure Evolution CCS/CCUS

CO₂ injected into brine:
Minor dissolution: volume displaced 4% less than volume injected

CO₂ injected into oil:
Complete dissolution: volume displaced as much as 40% less than volume injected

Less space occupied = enhanced security and lower pressure.
Is it always true that traps and seals that held oil will hold CO$_2$?

- How will fault-seals respond to changes in pressure and fluid chemistry?
- If injection occurs much more rapidly than charge, will it fill the trap the same way?
- How much CO$_2$ escapes from pattern floods?