Advancing Toward Commercialization
Final Stages of the SECARB Early Test
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Early Test Scope

• Monitoring saline and EOR in a commercial EOR project
• “Early” because project was nearly ready to start at time SECARB entered
• 10,000 ft deep Cretaceous Tuscaloosa Formation
Early Test Goals

• Large-scale storage demonstration
  • 1 MMT/year over >1.5 years
  • Periods of high injection rates
    • Result >5 years monitoring with >5 MMT CO$_2$ stored

• Measurement, monitoring and verification
  • Tool testing and optimization approach
  • Deploy as many tools, analysis methods, and models as possible

• Stacked EOR and saline storage
  • Commercial technology transfer
    • Uploaded data to EDX

Current major effort
Early Test Evolution

- Site identification
- Characterization
- Planning monitoring
- Start injection
- Phase II monitoring
- Phase III installation
- Phase III injection
- Phase III monitoring
- End of monitoring
- Data assessment
- Technology transfer

Yearly Timeline:

- 2006
- 2007
- 2008
- 2009
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017
- 2018
- 2019

Key Points:

- Commercial injection continues
Contributions of Early Test

- Early Test Developed monitoring approaches for later commercial projects
  - Stacked storage concept
  - Fluid flow in heterogeneous media
  - ERT for deep CO₂ plume
  - Limitations of 4-D seismic – hydrocarbon interference, signal/noise
  - No induced seismicity > magnitude 0 (with RITE, Japan)
  - Pressure and fluid chemistry monitoring in Above-Zone Monitoring Interval (AZMI)
  - Process-based soil gas method
  - Limitations to effectiveness of groundwater surveillance for documenting storage
Stacked storage EOR and Saline

- Characterization based on long production history
- Balanced flood
  - Fluid withdrawal (oil, water, gas CO₂) = Fluid injection (water, CO₂) during most of the operation
  - Area and magnitude of elevated pressure controlled by production
  - Area occupied by CO₂ controlled by production
- Controlled flood
  - Injection and production patterns
- Active surveillance
  - Production, pressure
  - Other techniques as needed
    - Wireline log, seismic, tracers,
Response of highly heterogeneous reservoir to multi-phase flow

SECARB Time lapse seismic shows fluid change
LLNL Electrical Resistance Tomography - changes in response with saturation

Time-lapse sequence of resistivity changes observed during injection

- 17 Dec 2009: Initial CO₂ breakthrough
- 21 Dec 2009: CO₂ plume growth
- 26 Dec 2009: CO₂ plume growth
- 15 Jan 2010: CO₂ plume grows wider and thicker
- 3 Feb 2010: CO₂ plume growth

C. Carrigan, X Yang, LLNL
D. LaBrecque Multi-Phase Technologies
CFU31F-2, 68 m away from injector

Travel time = 317 h

Inj. rate 2nd SF6 on May 9

Arrive on May 20

Travel time = 319 h

Inj. rate 2nd SF6 on May 9

Arrive on May 18

CFU31F-3, 112 m away from injector

Jiemin Lu, GCCC
Limitations to 4-D seismic

(b) CO$_2$ saturation distribution estimate (Carter [18]) compared to fluid flow simulation
Limitations to 4-D seismic

(a) Acoustic impedance difference (Zhang et al. [17]) compared to fluid flow simulation

Alfi & Hossieni, BEG
No detectable induced seismic response to 1000 psi overpressure, graben faults

Makiko Takagishi, RITE
Magnitude 0.4 horizontal and .07 vertical
Above-Zone Pressure Observations

3,200m

3,060m

68m

31F-2

120m

AZMI

Confining layer

IZ

Pressure [kPa]

Time [day]

Pressure [MPa]

Time [day]

S Hosseini, S. Kim BEG
Groundwater at the Cranfield Site: Sampling

- More than 12 field campaigns since 2008
- ~130 groundwater samples collected for chemical analysis of
  
  Cations: Ag, Al, As, Ba, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Mo, Na, Pb, Se, Zn
  Anions: F\(^-\), Cl\(^-\), SO\(_4\)^{2-}, Br\(^-\), NO\(_3\)^{-}, PO\(_4\)^{3-}
  TOC, TIC, pH, Alkalinity, VOC, \(\delta^{13}\)C

  On-site: pH, temperature, alkalinity, water level

- ~10 samples for noble gases
- ~20 groundwater samples for dissolved CH\(_4\)
- 15 Water wells
Groundwater at the Cranfield Site
Single-Well Push-Pull Test

- Maximum concentrations of trace metals observed, such as and Pb, are much less than the EPA contamination levels;
- Single well push-pull test appears to be a convenient field controlled-release test for assessing potential impacts of CO₂ leakage on drinking groundwater resources;

Results were summarized in the following paper:

International Journal of Greenhouse Gas Control
Single-well push-pull test for assessing potential impacts of CO₂ leakage on groundwater quality in a shallow Gulf Coast aquifer in Cranfield, Mississippi
C. Yang, BEG
Groundwater Monitoring Network Efficiency

\[ ME = \frac{W_d}{W_T} \]

- \( 20/151=0.13 \) by 4 years
- \( 50/151=0.33 \) by 15 years
- \( 58/151=0.38 \) by 35 years

\( M_M = W_W \)

\( W_T \)

CO\(_2\) leakage from a P&A well is detected by a monitoring network if change in DIC, dissolved CO\(_2\), or pH in any one of wells of the monitoring network is higher than one standard deviation of the groundwater chemistry data collected in the shallow aquifer over the last 6 years.

Changbing Yang
Process-Based Soil Gas Monitoring

- No need for years of background measurements.
- Promptly identifies leakage signal over background noise.
- Uses simple gas ratios 
  \[(\text{CO}_2, \text{CH}_4, \text{N}_2, \text{O}_2)\]
- Can discern many \(\text{CO}_2\) sources and sinks
  - Biologic respiration
  - \(\text{CO}_2\) dissolution
  - Oxidation of \(\text{CH}_4\) into \(\text{CO}_2\) (Important at CCUS sites)
  - Influx air into sediments
  - \(\text{CO}_2\) leakage
Publications, Workshops, Presentations

• 108 Early test-derived publications (EDX upload)
• Presentations
  • http://www.beg.utexas.edu/gccc/news/2019

Katherine Romanak was a panelist and co-organizer of the only CCS-dedicated side event at the 24th Conference of the Parties to the UNFCCC (COP24) in Katowice Poland. Photo by Malgosia Rybak
# Commercialization of Monitoring

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Commercial Down-selection of monitoring tools

You can’t have everything! Example limitations:

• Tool interference
  
  e.g. “jewelry” on casing interferes with log response
  Perforated well – geochemical and geophysical tool deployment interference

• Tool limitations – cost, cost of analysis
  
  Papers on cost/value

Sensitivity of time until detection of leakage on number of wells installed, Bolhassani (2017.)
Methods for down-selection of monitoring tools

- Optimized tool selection (Assessment of low probability material impact: ALPMI)

- Risk assessment method as usual
- Quantify risks to define material impact
- Specify magnitude, duration, location, rate of material impact
- Model material impact scenarios
- Identify signals in the earth system that indicate or preferably precede material impact
- Select monitoring tools that can detect these signals at required sensitivity
- Deploy tools; collect and analyze data
- Report if material impact did/did not occur

- Explicitly model unacceptable outcomes showing leakage cases.

- Approaches like those normally used for seismic survey design should be deployed for all modeling tools.

- ALPMI uses models differently than the typical history matching the expected performance.

- Avoid subjective terms like safe and effective.
  - E.g.: Specify mass of leakage at identified horizon or magnitude of seismicity.
  - Specify certainty with which assurance is needed.

- Method down selects only signals that indicate material impact may occur or may be occurring.

- Forward modeling tool response is essential to developing the expected negative finding: “No material impact was detected by a system that could detect this impact.”

- This activity as traditionally conducted. Include all the expected components, such as attribution, updating as needed, feedback, etc.

- Via this ALPMI process can a finding that the material impact did not occur be robustly documented.
Moving CCS toward Commercialization – technical data to inform policy

- SECARB-based work on:
  - Review and comment on Draft CCS Protocol of the California Air Board Low Carbon Fuel Standards
  - Assist with preparation of Society of Petroleum Engineers CO₂ Storage Resources System Management document and guidance
  - Completed serving on International Standards Organization working group on accounting for storage associated with CO₂ EOR
Commercialization of learnings at SECARB Early Test
Accomplishments to Date

Cranfield Project Deployed
Project Planned or proposed

Air Products
Petra Nova
Technology transfer from SECARB early test to other projects

SECARB Early test learning
- New time-lapse AZMI pressure technique
- Air Products-Hastings Commercial EOR project
  - Process-based soil gas, attribution approach methods monitoring
  - Gas breakthrough observations
- Methane exsolution issue for EOR (offshore focus)

Romanak work in Queensland
- AZMI pressure
- ALPMI down-select technique
- Process-based soil gas, attribution approach methods to groundwater monitoring

Petra Nova-West Ranch Commercial EOR project
- Methane exsolution issue for EOR (offshore focus)
Next Steps after RCSP

• Beyond Carbon SAFE storage prospects
  • Confidence and cost
• Monitoring linked to policy e.g. 45Q, CA LCSF and evolving policy
• Life cycle for EOR options, link to DAC and BECS
• Education of stakeholders, business, finance and local and national public, students
  • Realistic risk/benefit/feasibility
• Lower risk-- lower cost site closure-- technical input