The SECARB Anthropogenic Test: A Small-Scale, Fully Integrated CCS Demonstration Project

Rob Trautz
Principal Technical Leader

2014 SCCS Annual Affiliates Meeting
May 22, 2014
Presentation Outline

• Anthropogenic Test overview
  – Capture
  – Transportation
  – Storage
• Advanced CO₂ monitoring program
  – Fiber optic based distributed sensing
• Challenges and perspective
SECARB Anthropogenic Test Overview

- World’s first and largest integrated CO$_2$ capture, transportation and storage project on a coal-fired power station using advanced amines
- Southern Co. and MHI have captured over 200,000 metric tons of CO$_2$ since June 2011
- SECARB has transported, injected and stored 100,616 metric tons since August 2012
- Injecting CO$_2$ into the Paluxy Formation, which has excellent storage capacity of regional significance
MHI Advanced Amine Process
25 MW Equivalent Capture Plant
• 19 km (12 mile) CO₂ pipeline transports CO₂ from Plant Barry to the Citronelle Dome in Alabama
• Goal is to inject 100,000–300,000 metric tons of CO₂ into the Paluxy Formation (saline)
• Extensive monitoring program: pre-injection (8 months), injection (2 yrs) and post-injection (3 yrs)
• Site closure in 2017
Pipeline Construction Overview

• 4-inch diameter pipeline
  ✓ X52 carbon steel pipe
  ✓ Fusion bonded epoxy coated
• Directional drilled 18 sections under roads, utilities, railroad tracks, tortoise colonies, and wetlands (30 to 60 ft deep)
• Trenched remaining sections
  ✓ Buried average of 5 ft
• Surface re-vegetation and maintenance
• Corrosion protected
### Geologic Overview

- Injecting CO\textsubscript{2} into the Lower Cretaceous Paluxy Formation (9,400–10,500 ft)
- Above the oil reservoir in the Citronelle Oil Field
- Massive 1,100 ft interval of stacked fluvial sands and confining units
- Numerous reservoir seals and confining units above the Paluxy (at least 5)
- Structural dome has proven four-way closure

<table>
<thead>
<tr>
<th>System</th>
<th>Series</th>
<th>Stratigraphic Unit</th>
<th>Major Sub Units</th>
<th>Potential Reservoirs and Confining Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Citronelle Formation</td>
<td>Freshwater Aquifer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Undifferentiated</td>
<td>Freshwater Aquifer</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vicksburg Group</td>
<td>Chickasawhay Fm., Bucatunna Clay</td>
<td>Base of USDW Local Confining Unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jackson Group</td>
<td>Talahatta Fm.</td>
<td>Minor Saline Reservoir</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Claiborne Group</td>
<td>Hatchetigbee Sand, Bash Marl, Salt Mountain LS</td>
<td>Saline Reservoir</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wilcox Group</td>
<td>Porters Creek Clay</td>
<td>Confining Unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Midway Group</td>
<td>Selma Group</td>
<td>Confining Unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eutaw Formation</td>
<td>Minor Saline Reservoir</td>
<td>Minor Saline Reservoir</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tuscaloosa Group</td>
<td>Marine Shale</td>
<td>Confining Unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Washita-Fredericksburg</td>
<td>Dantzler sand, Basal Shale</td>
<td>Saline Reservoir Primary Confining Unit</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Paluxy Formation</td>
<td>&quot;Upper&quot;, &quot;Middle&quot;, &quot;Lower&quot;</td>
<td>Injection Zone</td>
</tr>
<tr>
<td>Lower</td>
<td></td>
<td>Mooringport Formation</td>
<td>Confining Unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ferry Lake Anhydrite</td>
<td>Confining Unit</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Donovan Sand</td>
<td>Upper, &quot;Middle&quot;, &quot;Lower&quot;</td>
<td>Oil Reservoir Minor Saline Reservoir Oil Reservoir</td>
</tr>
</tbody>
</table>
Monitoring, Verification and Accounting
Program Overview

- One Injector (D-9-7 #2)
- Two deep Observation wells (D-9-8 #2 & D-9-9 #2)
- Two in-zone & above zone Monitoring wells (D-4-13 & D-4-14)
- One PNC logging well (D-9-11)
- Twelve soil flux monitoring stations
- Four shallow groundwater monitoring wells
- R&D effort is focused on deployment of the Modular Borehole Monitoring (MBM) System in observation well (D9-8#2)
Advanced Modular Borehole Monitoring (MBM) System

- 18 Level, tubing deployed, clamping geophone array
- Two in-zone quartz pressure/temperature gauges for reservoir diagnostics
- U-tube for high frequency, in-zone fluid sampling (tube-in-tube design)
- Fiber optic cable for distributed temperature and acoustic measurements
  - Heat-pulse monitoring for CO₂ leak detection
  - Acoustic array for CO₂
- 2 7/8” production tubing open for logging
Pressure/Temperature Measurements

Quartz pressure/temperature transducers

Fiber optic based Distributed Temperature Sensing (DTS)

Rat Hole
Citronelle Offers a Unique Opportunity to Compare Seismic Methods to Monitor CO₂ Plume Location

• Seismic surveys deployed at Citronelle include:
  – Cross-well seismic surveys
  – Offset vertical seismic profile (VSP) surveys using
  – Walk away VSPs
• Seismic Sources and Receivers
  – 80-level (long) geophone array deployed in the injector (D9-7#2) and observation well (D9-8#2)
  – 18-level (short) geophone MBM array in D9-8#2
  – Fiber-optic distributed acoustic sensor (DAS) array with over 3,100 DAS “receivers”

VSP source offset locations (stars), receiver locations (D9-7#2 and D9-8#2), and walk-away lines (blue and red lines)
Baseline Seismic Surveys

Semi-permanent short MBM geophone array

Temporary long string geophone array

Cross-well (baseline Jan. 2012)
Time Lapse Comparison of Baseline (5-2012) to May and August 2013 VSP Surveys using MBM

Seismic processing by SR2020

Slight change in amplitude at target depth
Distributed Acoustic Sensing (DAS)

- Light emitted into a fiber is reflected throughout the fiber’s length by Rayleigh scattering
- DAS system measures the modulation of the backscattered light
- An acoustic field around the fiber exerts tiny pressure/strain changes on the fiber, resulting in changes to the backscattered light
- The DAS measures these changes by generating a repeated light pulse every 100 μs and continuously processing the returned optical signal, thus interrogating each meter of fiber up to 10 km in length at a 10 kHz sample rate
- Unlike other methods, the system records the full acoustic signal, including amplitude, phase and frequency

A 10 km single mode fiber becomes a high density acoustic array with 10,000 linear sensors with 1 m spatial resolution!
VSP Walkaway Surveys Were Performed in June 2012 and August 2013

- Walkaway surveys provide detailed coverage between the injection & observation wells
- Source: vibroseis truck
  - ~60 shot points
  - 4–6 sweeps/sht MBM
  - Up to 128 sweeps/sht DAS
  - Sweep duration: 16 s, recording 4 s
  - Sweep frequency range: 10–160 Hz
- Simultaneous recording of receivers:
  - 18-level MBM geophone array in D9-8#2
  - DAS in D9-8#2

Map showing position of the individual shot points (red dots) for walkaway VSP 2012
Seismic energy was recorded by DAS but the signal-to-noise ratio (SNR) was not sufficient to observe P-waves below approximately 1600 m (i.e., 2.7 km/s event)

SP 2054 located ~100 ft offset from the D-9-8 sensor borehole. Observed two tube waves.

SP 2021 located ~700 ft offset from the D-9-8 sensor borehole. Estimated wave speeds for two events (red and blue lines) are labeled in km/s.
Acquisition of stacked source sweeps improved DAS data signal to noise ratio, producing traces that match those from more sensitive geophones.
Challenges and Perspective

• Reliable, robust sub-surface monitoring equipment and methods are still needed that will last for decades
  – Five out of 18 geophone levels have been killed to date at Citronelle
  – Conventional pressure transducers are experiencing higher noise floor and/or drift
  – FO distributed sensing is innovative and may fill the long-term monitoring gap, but unproven
  – Instrument/method redundancy will be an important component of any monitoring program

• The SECARB Anthropogenic Test represents the largest integrated post-combustion CO$_2$ capture, transportation and storage project performed to date on a coal fired unit (equiv. to 155,000 t/yr)
Perspective

- Proposed EPA New Source Performance Standards will require EGU to meet 1,100 lb/MW gross emission limit
  - 40% capture on new coal-fired power stations
  - Modest 1,640 MW plant will need to store 5.1 million metric tons/yr for 40 yrs (>200 Mt total!)
  - Compliance with Subpart RR may push utilities into saline storage prematurely eliminating economic incentive associated with CO$_2$-EOR

- Full scale global saline storage project experience to date is limited to ≤ 1Mt/yr (Sleipner, Snohvit, In Salah)

- Lack of available data on saline reservoirs creates large economic uncertainty

- EPA rules for existing EGUs to be issued in June 2014 (??)
Together…Shaping the Future of Electricity