SECARB (Citronelle) Phase III

Prepared For:
2019 Carbon Capture, Utilization, Storage, and Oil and Gas Technologies Integrated Review Meeting

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Citronelle Phase III Project

Baseline
1 year
APR 2011 to AUG 2012

Injection
2 years
SEPT 2012 to SEPT 2014

Post
3 years
OCT 2014 to SEPT 2017

Anthropogenic Test
Capture: Alabama Power’s Plant Barry, Bucks, Alabama
Transportation: Denbury
Geo Storage: Denbury’s Citronelle Field, Citronelle, Alabama
1. Understand the coordination required to successfully integrate all four components (capture, transport, injection and monitoring) of the project;
2. Document the permitting process for all aspects of a CCS project;
3. Test the CO₂ flow, trapping and storage mechanisms of the Paluxy Formation, a regionally extensive Gulf Coast saline formation;
4. Demonstrate how a saline reservoir’s architecture can be used to maximize CO₂ storage and minimize the areal extent of the CO₂ plume;
5. Test the adaptation of commercially available oil field tools and techniques for monitoring CO₂ storage (e.g., VSP, cross-well seismic, cased-hole neutron logs, tracers, pressure, etc.);
6. Test experimental CO₂ monitoring activities, where such technologies hold promise for future commercialization; and
7. Support the United States’ largest commercial prototype CO₂ capture and transportation demonstration with injection, monitoring and storage activities.
1. Project Coordination

Capture

- Southern Company
  - Permitting
  - Plant Integration & Construction
  - Site Host

- Mitsubishi Heavy Industries
  - Technology Provider
  - Advanced Amines

- EPRI
  - Design
  - Technology Provider
  - Advanced Amines
  - Economic Evaluation
  - Knowledge Transfer
  - 3rd Party Evaluation

Transport

- Southern States Energy Board
  - NEPA Preparation

Storage

- DOE/NETL
  - Site Prep/Drilling Contractors
  - Site Host

- EPRI
  - Field Operations
  - Geologic Modeling

- Southern Natural Gas
  - El Paso Company
  - Pipeline Design
  - Pipeline Permitting & Construction
  - Field Operations

- Advanced Resources International
  - Public education/outreach
  - UIC Permitting

- DENISON
  - Field Operations
  - Site Prep/Drilling Contractors

- Southern States Energy Board
  - Risk Workshop Facilitation/Assessment

- MMA
  - Site Host

- UIC
  - Reservoir Modeling

- NEPA
  - Site Prep/Drilling Contractors

Denbury Onshore

Denbury
2. CCS Permitting Process

Select References

A. Oudinot et al. GHGT-14 (2018)  
- Details UIC Class V permit application process, requirements and permit closure

D. Riestenberg et al. CMTC (2015)  
- Details UIC Class V permit details including: injection well permit and CO₂ sequestration well standards

- Details capture facility permitting, transportation permitting and storage permitting
3. Test the CO$_2$ Flow, Trapping and Storage Mechanisms of the Paluxy

Baseline Reservoir Characterization:
- Analysis of over 80 existing oilfield well logs for porosity, thickness and depositional
- Sand mapping to determine “open” or “closed” sand units.

Collected new geologic data on the Paluxy reservoir and confining unit with the drilling of the project’s three new wells:
- 210 feet of whole core and 70 percussion sidewall cores
- Full set of open hole logs on all three wells (quad combo, MRI, spectral gamma, mineralogical evaluation, waveform sonic, cement quality, pulsed neutron capture)
- Baseline vertical seismic profiles and crosswell seismic collected in Feb 2012
Geologic Characterization Results

- Sandstone and mudstone units are continuous at this scale
- $\text{CO}_2$ dispersion vertically
- Multiple stacked plumes
The estimated radius of the CO₂ plume 30 years after cessation of injection is approximately 1000 ft. (305m), which is less than the project’s initial AoR of 1,700 ft.
4. Utilizing Reservoir Architecture

- Limiting the extent of the CO₂ plume by not completing high permeability sand layers
- By shutting in the high permeability sand layer, the plume radius was decreased by ~200 ft
5. Commercial Monitoring Protocols

- Replacement of brine with CO₂ caused a decrease in velocity through the storage geologic unit.
- Time-lapse survey during injection in June 2014.

⇒ Results of the PNC logs demonstrate confinement in the injection zone.

Crosswell Seismic

- No significant negative velocity anomalies.
- Decrease in velocity (negative anomaly).

Pressure Gauges

Well D 9-8 - Pressure Gauge Data

Pressure (psi)

Date


⇒ Results of the PNC logs demonstrate confinement in the injection zone.
### Spinner Surveys

#### Sand Unit Properties (ft)

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<th>Sand Unit</th>
<th>Bottom</th>
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<th>Aug 2013 Flow %</th>
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</table>

A software program was used to measure the average velocity decreases (in percent) of total flow as the CO2 injection exited the well bore at the indicated intervals.
6. Experimental Monitoring: MBM

- 18 Level, tubing deployed, clamping geophone array (6,000-6,850 ft)
- 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 cables** for distributed temperature (DTS) and acoustic measurements (DAS)
  - Heat-pulse monitoring for CO$_2$ leak detection
  - **Acoustic array for seismic** (equivalent to 3m spacing)
- 2 7/8” production tubing open for logging
2014 DAS-VSP Survey Results

- Migrated image
  - Observed strong reflectors
  - Good tie to formation logs (e.g., Selma Chalk)
- No “bright” spot observed where CO₂ was injected

2014 DAS-Cross Well Survey Results

DAS Data at 9,340 ft – Only See Random Noise, Except Some Coherent Noise Not related to sweep
1. Injected, stored, and monitored 114 kt for the largest (at the time) integrated commercial prototype CCTS project at a coal-fired power plant.

2. First time CO₂ transfer of custody occurred between an anthropogenic source and a transport/storage operator.

3. First with Class VI elements in their CO₂ injection permit.

4. Demonstrated non-endangerment (Class VI protocols) and closed permit (first).

7. Support the United States’ Largest Commercial Prototype CO₂ Capture and Transportation Demonstration
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