Phase II Field Demonstration at Plant Smith Generating Station: Assessment of Opportunities for Optimal Reservoir Pressure Control, Plume Management and Produced Water Strategies

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Presentation Outline

▪ Technical Status
  – Project overview
  – Adaptive pressure/plume management
  – Joint inversion
  – Experimental design
  – Well field infrastructure

▪ Accomplishments to Date

▪ Next Steps

▪ Appendix – Supplemental Slides
  – Lessons learned
  – Synergy opportunities
  – Benefits to Program
  – Etc., etc.

Photographs of existing Gulf Power wellfield. Photos clockwise from upper left: Eocene Injection well EIW-4; graveled access road; pump station under construction; cleared and permitted drilling pad location for future well
Phase I Site Screening and Down Selection Resulted in Selection of Plant Smith

- Evaluated existing geologic, geophysical and hydrologic data in the vicinity of each site, including
  - Well records, logs, core data, regional structural and stratigraphic studies and subsurface production/injection data
- Examined existing surface infrastructure at each plant
- Gaged plant commitment to hosting the BEST project
- Selected Plant Smith

Plant Bowen, Euharlee GA
Plant Daniel, Escatawpa MS
Plant Gorgas, near Parrish AL
Plant Miller, near West Jefferson AL
Kemper Co Energy Facility, MS
Plant Smith Overview

- Multiple confining units
- Thick, permeable saline aquifers
  - Eocene Series (870-2,360)
  - Tuscaloosa Group (4,920-7,050 ft)
  - Represent significant CO$_2$ storage targets in the southeast US
- Large Gulf Power Co. waste water injection project under construction (infrastructure)
- Water injection pressures will be managed as a proxy for CO$_2$ injection (~500k-1M gal/day)

No CO$_2$ injection will take place
During Phase I EPRI Conducted a Life-Cycle Analysis of Extracting and Treating Brine, Transmitting Treated Water

- Used Plant Smith waters as the basis for the analysis
- Performed techno-economic assessment of a hypothetical CCS water extraction project
  - Extraction
  - Transportation
  - Pre- and primary-treatment assuming zero liquid discharge
  - Residual waste disposal
- Computed power required over 30 years of operation
- Calculated CapEx/OpEx costs for entire system

**Added cost of water treatment can be significant**
Phase II Field Demonstration Experimental Design—Passive and Active Pressure Management

- Passive pressure relief in conjunction with active pumping can reduce pressure buildup, pumping costs and extraction volume.
- Existing “pressure relief well” and “new” extraction well will be used to validate passive and active pressure management strategies.

Pressure relief well has the potential to reduce extraction volume by 40%
Goals of Subsurface Pressure Management Via Passive + Active Brine Extraction at Plant Smith

- Scenario—Minimize risks for injection-induced seismic events and leakage along hypothetical faults by controlling
  - Pressure buildup
  - Plume migration
- Limit the size of the Area of Review
- Limit the volume extracted
- Develop and test effectiveness of adaptive optimization methods and tools to manage overall reservoir system response
Adaptive Pressure Management will Ensure Proper Control of Pressure and Plume Migration

- The adaptive management workflow integrates modeling + optimization + monitoring + inversion

- The adaptive workflow for optimized management of CO\textsubscript{2} storage projects utilizes the advanced automated optimization algorithms and suitable process models

Why is adaptive management needed?

- Incomplete knowledge of subsurface properties exist, especially during the planning stages of CO\textsubscript{2} projects

- During operations, the subsurface system behavior needs to be monitored continuously, and the models need to be frequently updated
Involves an 18-month injection of ~1,090 m$^3$/d (200 gal/min) of water disposal

Injection into relatively thin and confined layers ensures generation of easily detectable differential pressures

Strong contrast between low salinity injected fluid (~1,200 mg/L) and the Tuscaloosa brine (about 166,000 mg/L on average) enables geophysical plume monitoring

Selected two geological layers located close to the top of the LT domain for injection and extraction in our base case scenario

Caprock and reservoir fracturing unlikely for the targeted injection rate

Pressure and plume control using active and passive extraction wells near a hypothetical fault

Preliminary Hydrogeological Model (Layered)

Using optimization algorithms, optimal extraction rates are calculated to meet the pressure constraints along the faults
Pressure and Salinity Changes for the Base Case Pressure Management Scenario

- Developed a preliminary reservoir model based on the existing data and simulated density and viscosity-dependent brine flow
  - Injection = 200 gal/min
  - Max. Extraction Rate ~20 gal/min
  - Starting at time = 6 months
- Passive extraction may reduce the total volume extracted up to 40%, according to the base case scenario
Optimization Algorithms Provide Minimum Extraction Rates as a Function of Time to Satisfy the Constraints for the Given Reservoir Conditions

Adaptive optimization algorithm

1. Optimization With Existing Model(s)
2. Monitoring/Model Testing
3. Model Calibration

Initial estimation of the projected extraction rates with uncertainty in reservoir properties

Error bars indicate potential variability in extraction rates
Monitoring – Inversion for Pressure & Salinity

• **Borehole** - Continuous and time-lapse (discrete) borehole measurements of fluid pressure, flow rate, temperature, and electrical conductivity will be used to provide high-resolution, ground-truth, direct measurements at discrete locations (1D).

• **EM** - Time-lapse crosswell and borehole-to-surface EM will provide indirect measurements of the higher resistivity injected ash pond water with spatial resolutions in 2D and 3D approaching several meters to tens of meters, respectively.

• **InSAR** - InSAR will be used to map surface deformations resulting from subsurface pressure increases over 16 day intervals.

• **Joint Inversion** - We will use LBNL’s powerful inverse modeling and parameter estimation tool iTOUGH (in its parallel version MPiTOUGH2) for the automated joint inversion of hydrological, large-scale geophysical (EM) data, and surface deformation data.
Crosswell Electromagnetic (EM) Method

Receiver well

Transmitter well (Injection Well)

261m

Magnetic Source:
- moves from \( z = -50 \) to 250m
- 5m intervals

Magnetic Receiver:
- moves from \( z = -50 \) to 250m
- 2.5m intervals

Primary sensing volume for shown source-receiver pair

Plume
Crosswell EM Measurements Before and After Injection

Before Injection

365 Days

Resistivity

Anomalous Magnetic Fields
Preliminary Results: Crosswell EM Measurements Before and After Injection (600 Days)
New EM Borehole Transmitter: Design and Manufacture

- Existing transmitter does not have sufficient power to be effective at Plant Smith
- SNR expected to be 2 at 10 Hz, we need at least 5
- Designed a new, more powerful and resilient transmitter
  - Core is transformer steel
  - Length is 4.5 m, diameter 8.5 cm
  - Number of wire turns about 8000
  - Moment 4000-8000
  - Weight ~100 kg (heavy!)
  - Pressure rating 2 km, temp 125 C.
  - Operation design 5-500 Hz
- Well separation max ~ 1 km
- Will (soon) have downhole signal generation

- Manufacture nearing completion
- First field test planned for Oct. 2018
Well Field Infrastructure

- Developed detailed technical specifications for:
  - Well pads
  - Extraction well
  - Injection well including four casing/tubing options
  - Flowline
  - Submersible pump
  - Power requirements

- Plant Smith site visit and pre-bid meeting with perspective drillers
  - Four drilling firms attended
  - Only two Florida-based firms responded with bids
  - Large disparity between prices

BEST project infrastructure layout showing the proposed location of the extraction well (TEMW-A), injection well (TIW-2) and flowline, and the existing passive-relief well (TIW-1)
Drilling of Injection Well TIW-2 is Underway

A. Completed drill pad

B. Drill pad monitoring well installation

C. Conductor casing for TIW-2

D. Conductor casing installation
Water Treatment User Facility Design

- Preliminary design provides different water qualities for testing by DOE researchers and commercial water treatment vendors
  - High salinity (166,000 mg/L TDS) Tuscaloosa water only
  - Low salinity fresh or waste water (30-1,000 mg/L TDS) from Plant Smith
  - Intermediate salinity (30-166,000 mg/L TDS) by mixing in a blending tank
Accomplishments to Date

✓ Permitting
  – Submitted minor modification to existing permit (May 2017)
  – Permit modification approved (Oct. 2017)

✓ Experimental Design
  – Scoped extraction rates to select submersible pump size
  – Design and build of new EM transmitter

✓ Well field infrastructure design
  – Developed well design and technical specifications
  – Selected qualified Florida certified driller (July 2017)
  – Drilling of TIW-2 started (July 2018)

✓ Water treatment user facility design
  – Preliminary design and costs completed
  – Users are being solicited for pre-treatment requirements
Next Steps

- **BP3 (2018-2020) plans include:**
  - Installation of the well field infrastructure
  - Site characterization
  - Final design and installation of the water treatment user facility
  - Equipment commissioning
  - 6 months of injection followed by 12 months of injection and extraction

- **BP4 (2020-2021) plans include:**
  - Site restoration
  - Final reporting

Newly constructed drill pad at Plant Smith for injection well TIW-2
Appendix

Supplemental Slides
Lessons Learned

- Project cost drivers
  - Each state has unique UIC regulatory requirements and guidelines that can impact well construction and project costs
  - Florida drilling market for waste-water injection wells is not very competitive as shown by the large disparity in bids ($6.9M vs. $11.0M)
  - Cost of small diameter extraction well drilled to 5,400 ft with 5-inch production casing is $2.8M. Much higher than expected!!!!

Project anticipated high injection well costs but not for the extraction well
Synergy Opportunities

- EPRI and EERC are developing water treatment user facilities to test and validate water desalination technologies
- EERC and EPRI jointly developed a technology screening questionnaire and selection criteria for hosting the water treatment technologies at the BEST project sites
- EERC hosted the IEA-GHG risk and monitoring network meeting in June 2018
  - Tech transfer and cross-fertilization of approaches and ideas
  - Provide project updates, technology transfer, lessons learned and experiences
Benefit to the Program

- **Program Goals**
  - Develop cost effective pressure control, plume management and produced water strategies that can be used to improve reservoir storage efficiency and capacity, and demonstrate safe, reliable containment of CO$_2$ in deep geologic formations with CO$_2$ permanence of 99% or better.

- **Benefit Statement**
  The project will...
  - Use optimization methods and smart search algorithms coupled with reservoir models and advanced well completion and monitoring technologies to develop strategies that allocate flow and control pressure in the subsurface.
  - Address the technical, economic and logistical challenges that CO$_2$ storage operators will face when implementing a pressure control and plume management program at a power station and increase our knowledge of potential storage opportunities in the southeast region of the U.S.
  - Contribute to the development cost effective pressure control, plume management and produced water strategies that can be used to improve reservoir storage efficiency and capacity, and demonstrate safe, reliable containment of CO$_2$ in deep geologic formations with CO$_2$ permanence of 99% or better.
  - And the operational experiences of fielding a water management project at a power station can be incorporated into DOE best practice manuals, if appropriate.
Project Overview—Goals and Objectives

- Objective: Develop cost effective pressure control, plume management and produced water strategies for: 1) Managing subsurface pressure; 2) Validating treatment technologies for high salinity brines

Pressure management practices are needed to avoid these potential risks. Brine extraction is a possible remedy for reducing or mitigating risk.
### Phase II Project Schedule

<table>
<thead>
<tr>
<th>Description</th>
<th>Start Date</th>
<th>End Date</th>
<th>Dur. (Mos)</th>
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<td><strong>Task 1: Project Management and Planning</strong></td>
<td>8/1/2016</td>
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<td>Sub-recipient &amp; vendor contracting</td>
<td>8/1/2016</td>
<td>3/31/2017</td>
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<td>Revise Project Management Plan and Project Data Factsheet</td>
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<td><strong>Task 2: Permit Development and Compliance Reporting</strong></td>
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<td>Prepare, submit and receive approved NEPA, UIC and other permits</td>
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<td>2/26/2021</td>
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<td>UIC Compliance reporting</td>
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<td><strong>Task 3: Well Field Infrastructure Development, O&amp;M and Closure</strong></td>
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<td>Prepare final design/specs/bids for wells and surface infrastructure</td>
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<td>7/31/2017</td>
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<td>Install wells and infrastructure</td>
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<td>7/14/2019</td>
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<td>Inject water, operate and maintain infrastructure</td>
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<td>Reclaim site</td>
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<td>Prepare final design/specs/bids for treatment infrastructure</td>
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<td>Treat saline water, validation sampling, operate and maintain infrastructure</td>
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<td>Reclaim treatment facility</td>
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<td><strong>Task 5: Pressure Optimization and Produced Water Strategies</strong></td>
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<td>Update Static Geologic Model</td>
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<td>Final design of the field demonstration test</td>
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<td>Development of adaptive management methods</td>
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<td>Implementation and testing of adaptive pressure management method</td>
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<td>Compile, analyze and interpret data</td>
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<td>Evaluate performance of optimization and reservoir models</td>
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<td>Final report</td>
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Bibliography

Together…Shaping the Future of Electricity