CARBON MANAGEMENT
AT
THE VIRGINIA CENTER FOR COAL AND ENERGY RESEARCH

ELLEN GILLILAND – VIRGINIA TECH

VCEA Annual Meeting
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VCCER CARBON MANAGEMENT PROJECTS

Sponsored by U.S. Department of Energy, National Energy Technology Laboratory (NETL)

In collaboration with Southern States Energy Board (SSEB) and Southeast Carbon Sequestration Partnership (SECARB)

Also in collaboration with newly-formed SECARB-Offshore Partnership

SECARB-Offshore Study Area for Evaluation of Deep Saline Storage Resources
Task 2: Two ECBM Field Validation Projects:
- 1,000-ton test in Russell County, VA
- 252-ton test in the Black Warrior Basin, AL.


SECARB Phase II
Task 2: Two ECBM Field Validation Projects: 1,000-ton test in Russell County, VA and 252-ton test in the Black Warrior Basin, AL.

Small-Scale Injection
Two Small-scale injection projects:
- 510-ton CO₂ injection in a horizontal shale well in Morgan County, TN
- 14,000-ton CO₂ injection in three coalbed methane wells in Buchanan County, VA.

SECARB-Ed
Training of the existing CCS workforce and the development of new professionals.

SOSRA
“Southeast Offshore Storage Resource Assessment (SOSRA)” will assess prospective geologic storage resources for carbon dioxide (CO₂) in the State and Federal waters of the Mid-Atlantic, South Atlantic and eastern Gulf of Mexico planning areas.

ESUP
“Field Laboratory for Emerging Stacked Unconventional Plays (ESUP)” will investigate and characterize the resource potential for multi-play production of emerging unconventional reservoirs in Central Appalachia.

ESUP Goals:
- Goal 1: Drill and selectively core a deep vertical stratigraphic test well up to 15,000 feet to basement through the Conasauga-Rome Petroleum System
- Goal 2: Drill at least one multi-stage lateral well in the Lower Huron Shale for completion using non-aqueous fracturing techniques, such as CO₂

ECO₂S
“Establishing an Early CO₂ Storage Complex in Kemper County, Mississippi (ECO₂S)” will perform the initial characterization and will establish the complex’s feasibility for commercial storage including modeling induced seismicity and ground deformation response.
MOTIVATION:
UNCONVENTIONALS (COALBED METHANE/SHALE) FIELD TESTS

• Microporous texture ➔
  - High storage capacity

• Preferential adsorption ➔
  - Higher for CO$_2$ vs. CH$_4$
  - Chemical storage mechanism
  - Enhanced Recovery (ECBM/EGR)

Micro-CT image of natural fractures in coal
SECARB PHASE II:
FIELD VALIDATION TEST IN RUSSELL COUNTY, VA
 Legacy vertical CBM Well on 60-acre spacing, permitted under EPA Class V (Experimental)

- 1,000 tons of CO₂ injected for “huff and puff” test
  - Injection period: January 5 – February 3, 2009 (30 days)
  - Shut-in period: Feb. 4 – June 30, 2009 (~5 months)
  - Flowback period: July 1, 2009 - present (~9.5 years)

- Current status: post-injection monitoring
**Objective:** evaluate suitability of CBM reservoir for CCUS operations
Tracer Study

- Perfluorocarbon tracer
- Detected at 10 offset wells
- No CO₂ breakthrough at offsets
- Evidence of reservoir connectivity, adsorption
Enhanced Gas Production

- Estimated Ultimate Recovery (EUR) of gas for test well has increased by 85%
- CO₂ in flowback is ~35% over 10 years
SMALL-SCALE INJECTION TESTS:
MORGAN COUNTY, TN, AND BUCHANAN COUNTY, VA
Legacy horizontal production well in Chattanooga Shale formation, permitted under TDEC

- 510 tons of CO2 injected for “huff and puff” test
  - Injection period: March 18-31, 2014 (14 days)
  - Shut-in period: March 31- July 29, 2014 (~4 months)
  - Flowback period: July 29, 2014- present (~4.5 years)

- Current status: post-injection monitoring
Objective: evaluate suitability of shale reservoir for CCUS operations
SMALL-SCALE INJECTION TEST: MORGAN COUNTY, TN

CO2 Injection Operations at Morgan County Test Site
SMALL-SCALE INJECTION TEST: MORGAN COUNTY, TN

Hydrocarbon composition during flowback

Production of heavy hydrocarbons elevated from baseline values
SMALL-SCALE INJECTION TEST: BUCHANAN COUNTY, VA

- Three legacy vertical CBM wells, permitted under EPA Class II UIC permit
- 14,000 tons of CO₂ injected over two phases:
  - Injection phase I: July 2, 2015 – April 15, 2016 (~9 months)
  - Injection phase II: December 14, 2016 – January 30, 2017 (6 weeks)
  - Shut-in period: January 30, 2017 - January 9, 2018 (~1 year)
  - Flowback period: January 9, 2018 - present (16 months)
- Current status: post-injection monitoring
Objective: evaluate CO₂ storage potential and ECBM potential of CBM reservoir

Significant scale-up from validation test in Russell County, VA
GEOLOGIC CHARACTERIZATION

- Coal reservoir consists of 15-20 thin, stacked coal seams with an average thickness of 1.0 ft. distributed from 1,000-2,000 ft. deep
- Pennsylvanian-aged Pocahontas and Lee formations
CO₂ Injection simulations used to define Area of Review (AOR) for monitoring program

18-layer reservoir model
SMALL-SCALE INJECTION TEST:
BUCHANAN COUNTY, VA

MVA Focus Area
- Injection wells
- CBM production wells
- MVA boundaries
- Roads
- Monitoring and characterization wells
- Microseismic array (28 stns)
- GPS array (20 monuments)
SMALL-SCALE INJECTION TEST: BUCHANAN COUNTY, VA

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SMALL-SCALE INJECTION TEST: BUCHANAN COUNTY, VA
Reservoir Injectivity

- Wellhead pressures build during injection, decrease and are restored after both injection phases
- Indicates potential for repeated, cyclic injection
• SF₆ detected at five offset wells
• PMCP detected at three offset wells
• Detection extent coincides with the extents of the ¼-mile MVA boundary (predicted CO₂ plume extents)
• Potential influence of overlapping pressure fronts of the injected CO₂
CO2 BREAKTHROUGH AT DD-8A

• Initial CO2 detection at DD-8A (4 months)
• CO2 reached maximum concentration of 12.9% at end of Phase I
• Shortly after the start of Phase II, CO2 concentration increased; reached maximum of 4.5% by the end of Phase II
• Confirms reservoir modeling
Microseismic Monitoring Results
From SET + Geostatistical Analysis

- Higher activity on western margin
- Reorganization of energy during injection
- Hotspots near DD7

Persistence of High Energy Over Time

Count (days)
Microseismic Monitoring Results
From SET + Geostatistical Analysis

- Shift to higher energy during injection, especially in deep reservoir interval

- Correlates with decreasing water level, measured with echometer

- Interpreted as signal of water evacuating DD7 wellbore during first days of CO₂ injection

- Geomechanical heterogeneity
FIELD LABORATORY FOR EMERGING STACKED UNCONVENTIONAL PLAYS (ESUP)
Schematic Overview of ESUP Field Lab

Deep Characterization Well
Target depth: 15,000 ft

20-stage Completion Lateral Gas Production Well
Lower Huron Shale
FIELD LABORATORY FOR EMERGING STACKED UNCONVENTIONAL PLAYS (ESUP)

ESUP
Field Laboratory for Emerging Stacked Unconventional Plays

The goal of ESUP is to investigate and characterize the resource potential for multi-play production of emerging unconventional gas reservoirs in Central Appalachia.
CONCLUSIONS:
REGIONAL PERSPECTIVE

• Unique opportunities in Central Appalachia:
  • CCUS Advantages of unconventionals
  • Variation in reservoir/storage properties
  • Stacked production, storage
  • Optimize production vs. surface impact
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- Ellen Gilliland, Virginia Tech
  - elleng@vt.edu

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