Monitoring Carbon Storage and Enhanced Gas Recovery Projects in Central Appalachia

A. Kyle Louk
Research Associate - Virginia Center for Coal and Energy Research
Blacksburg, Virginia, USA

2016 Virginia Coal and Energy Alliance PE Seminar
Lebanon, VA, USA
**Research Partners**

- Virginia Center for Coal and Energy Research
- Cardno
- Jerry Hill, Ph.D.
- Southern States Energy Board
- Virginia Department of Mines, Minerals, and Energy
- Geological Survey of Alabama
- Sandia Technologies
- Det Norske Veritas (DNV)
- CONSOL Energy (Research Group)

**Collaborators**

- Schlumberger
- Global Geophysical Services
- Oak Ridge National Laboratories
- British Geological Survey
- University of Nottingham
- University of Tennessee – Knoxville
- University of Virginia
- Southern Illinois University
- Oklahoma State University

**Industrial Partners**

- CONSOL Energy
- Harrison-Wyatt, L.L.C. & Emory River , L.L.C.
- Alpha Natural Resources
- Dominion Energy
- FloCO₂
- Praxair
Financial Assistance for this Project was Provided by:

The U.S. Department of Energy through the National Energy Technology Laboratory’s Program under Contract No. DE-FE0006827
Presentation Outline

• Project Background and Objectives
• \( \text{CO}_2 \) Injection Tests
  • Shale \( \text{CO}_2 \) Injection Test in Morgan County, TN
  • Coalbed Methane \( \text{CO}_2 \) Injection Test in Buchanan County, VA
• Conclusions and Discussion
Motivation

• Geologic sequestration of CO$_2$ can not only mitigate greenhouse gas emissions, but enhance gas recovery in unconventional formations

• Enhancing gas recovery can increase reserves throughout America and Central Appalachia while extending the life of mature fields
**CO₂ Sequestration**

- **Conventional Reservoirs**
  - Permanent Storage
  - Enhanced Oil Recovery

- **Unconventional Reservoirs**
  - CO₂ preferential adsorption
  - Enhance Coalbed Methane Recovery (ECBM)
Unconventional Gas in the U.S.

- U.S. is World leader in Natural Gas Production
  - Eastern U.S. with over 6,000 Tcf of GIP
  - Oakwood and Nora CBM Fields
- Technological Advances in:
  - Horizontal Drilling
  - Hydraulic Fracturing
‘Huff-and-Puff’ Injection Test in a Horizontal Chattanooga Shale Gas Well

- Well Stimulation Permit from TDEC
- Injection Well Converted (March, 2014)
- CO₂ Injected: March 19th – 31st, 2014
- Shut-In: March 31st – July 29th, 2014
- Flowback: July 29th – Present
- Post-Injection Monitoring (Currently Ongoing)
Shale CO$_2$ Injection Test in Morgan County, TN
Monitoring, Verification, and Accounting (MVA)

- **14 Well Program**
  - Injection Well: HW-1003
  - 13 Offset Monitoring Wells
    - 3 Horizontal / 10 Vertical
    - 11 In-Formation / 2 Out-of-Formation
- **Gas and Water Sampling**
- **Perfluorocarbon Tracer Study**
- **Monitoring for:**
  - Injection Phase: % Composition, Tracer Arrival
  - Soaking Phase: % Composition, Pressure, Downhole Liquid Levels
  - Flowback Phase: % Composition, Flowrate, Pressure, Tracers
Shale CO$_2$ Injection Test in Morgan County, TN
Operations Overview
Shale CO₂ Injection Test in Morgan County, TN

Injection Summary

- 510 tons CO₂ injected
- Avg. Flow Rate: 41.5 tons/day
- Avg. Temp.: 48.5º F
- Max Wellhead Press.: ~500 psig
Shale CO₂ Injection Test in Morgan County, TN

Tracer Overview

- Sulfur Hexafluoride (SF₆)
  - 0.574 kg at 50 tons of CO₂
  - Booster Pump and Air Compressor
- Perfluoromethylcyclopentane (PMCP)
  - 0.854 kg at 50 tons of CO₂
  - Syringe Pump
- Perfluoromethylcyclohexane (PMCH)
  - 0.894 kg at 350 tons of CO₂
  - Syringe Pump
Shale CO₂ Injection Test in Morgan County, TN

Results to Date

• Injection Phase
  • No increased concentration of CO₂ at offset wells
  • No detection of tracers at offset wells

• Soaking Phase
  • Wellhead pressure leveled at 260 psig for 3 months
  • No downhole liquids (all gas phase in wellbore)
  • Wellbore composition = +98% CO₂

*Indications of a Closed System
  • Consistent with modeled predictions
  • CO₂ confinement → viable storage option
Flowback Results

Flowback Production vs. Historical Production (zoomed)

Flowback Production vs. Historical Production

Historical
Injection & Soaking
Flowback (with CO2)
Flowback (Hydrocarbons)

Historical Production
Projected
Injection & Soaking
Flowback
Shale CO$_2$ Injection Test in Morgan County, TN

Results to Date
Shale CO₂ Injection Test in Morgan County, TN

Results to Date

- Production of heavy hydrocarbons elevated from baseline values
  - Role of pressure, viscosity, and adsorption/desorption processes
  - Enhanced gas recovery → implication for other shale plays
• Oakwood coalbed methane field
• Stacked coal reservoir. 15-20 seams
• Sandstone and shale confining units
• 20,000 tonne CO₂ injection in three legacy wells over a 1 year period
• CO₂ storage and enhanced gas recovery
• CO₂ Injection: July 3rd – Present
• 8,607 tonnes to date
CBM CO₂ Injection Test in Buchanan County, VA

Site Overview
CBM CO$_2$ Injection Test in Buchanan County, VA
Monitoring, Verification, and Accounting (MVA)

Monitoring Focus Area
- Injection wells
- CBM production wells
- MVA boundaries
CBM CO$_2$ Injection Test in Buchanan County, VA
Monitoring, Verification, and Accounting (MVA)

- Injection wells
- CBM production wells
- MVA boundaries
- Roads
- Monitoring and characterization wells
CBM CO$_2$ Injection Test in Buchanan County, VA
Monitoring, Verification, and Accounting (MVA)

Monitoring Focus Area
- Injection wells
- CBM production wells
- MVA boundaries
- Roads
- Monitoring and characterization wells
- Microseismic array (28 stns)
CBM CO₂ Injection Test in Buchanan County, VA
Monitoring, Verification, and Accounting (MVA)

Monitoring Focus Area
- Injection wells
- CBM production wells
- MVA boundaries
- Roads
- Monitoring and characterization wells
- Microseismic array (28 stns)
- GPS array (20 monuments)
+ InSAR
• Surface and Downhole Pressure and Temperature Gauges
CBM CO$_2$ Injection Test in Buchanan County, VA

MVA Program

¼-mile boundary

TerraSAR-X Satellite
CBM CO₂ Injection Test in Buchanan County, VA

Tracer Program

- Tracer Plan
  - 3 perfluorocarbon tracers (PFTs) in water prior to injection (PMCH, PECH, PMCP)
  - SF₆ in DD-8 gas stream before water is expelled
  - 3 Refrigerants at 15% injection (CF₄, CHF₃, C₃F₈)
  - 3 PFTs at 30-40% injection (PEP, PMP, PDMCH)
Data Analysis

- All gas samples collected and analyzed in-house
- Gas Chromatography
  - 2 GC/MS
  - 2 ECD
  - 1 Portable Natural Gas GC
  - 1 Mine Gas Analyzer
Any Questions?

aklouk@vt.edu