Midwest Regional Carbon Sequestration Partnership

David Ball  
MRCSP Project Manager

Neeraj Gupta, Ph.D.  
Leader, Geologic Sequestration

Battelle Energy Technology

7th Annual Carbon Capture and Sequestration Conference, May 7, 2008 Technical Session
MRCSP’s mission: be the premier resource for sequestration knowledge in its region

Developing a Regional Model of the Economics of Sequestration

Characterization, Phase I, 2003 - 2005

Quantifying CO₂ sources, demographics and economics in the region

Terrestrial:
- Potential for 20% annual offset for large point sources

Geologic:
- 100s of years of capacity for large point sources in deep saline alone

Validation, Phase II, 2005 - 2009

Reaching Out To and Educating Stakeholders

Implementation

www.mrcsp.org
Terrestrial Sequestration –
Three field projects being pursued

Croplands

Reclaimed Minelands

Wetlands
Croplands test sites (Ohio State Univ.)

OH

# 59 Sandusky

# 139 Cuyahoga, Geauga, Lake

# 124 (Pike, Scioto, Jackson)

# 139 Crawford, Mercer

PA

KY

# 121 Scott, Harrison

# 122 Adair, Brusel

# 125 Clay, Leslie, Knox

# 140 Bradford, Wyoming

# 148 York, Lancaster

# 147 Fulton, Huntington
Mineland Reclamation (Univ. of WV)

Mylan Park site.

Sample Acquisition.

New Hill site (sampling points).

Sampling Plan.

<table>
<thead>
<tr>
<th>Year</th>
<th>Depth</th>
<th>Dent's Run</th>
<th>Mylan Park</th>
<th>New Hill</th>
<th>Skousen</th>
</tr>
</thead>
<tbody>
<tr>
<td>2006</td>
<td>0 – 6 cm</td>
<td>53</td>
<td>54</td>
<td>52</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>6 – 12 cm</td>
<td>39</td>
<td>60</td>
<td>44</td>
<td>26</td>
</tr>
<tr>
<td>2007</td>
<td>0 – 6 cm</td>
<td>Soon</td>
<td>65</td>
<td>54</td>
<td>Soon</td>
</tr>
<tr>
<td></td>
<td>6 – 12 cm</td>
<td>Soon</td>
<td>11</td>
<td>36</td>
<td>Soon</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>92</td>
<td>190</td>
<td>186</td>
<td>56</td>
</tr>
</tbody>
</table>
Reclaimed Marshlands (Univ. of Md)

- Two tidal marsh cells
  - One newly created 2.7-acre cell (2003)
  - One natural marsh cell
  - 2008: adding newly restored cell pending restoration
MRCSP Phase II Geologic Tests

Michigan Basin

Ohio Strat Well

Cincinnati Arch

Appalachian Basin
RE Burger Power Plant (FirstEnergy)

R. E. Burger Power Plant

Drill Rig (Jan 2007)

Seismic Survey, July 2006

8000 Foot Test Well
Site Characterization - Example for R.E. Burger Plant

• 10-mile seismic survey completed in August 2006
• Additional 1-mile of “quasi-3D” to investigate reservoirs and 3D options
Detailed Seismic Interpretation
Example from Appalachian Basin

• The Oriskany Sandstone (between the Onondaga and Helderberg) is right at the resolution limit of this data

• The White Clinton is much easier to see and post injection changes may be detectable

*Initial Results
Site Infrastructure, Burger

Temporary CO₂ Storage

Pump and flow control equipment

Photos Courtesy of Praxair and BOC

Well Structure
East Bend Station (Duke Energy)

Injection Target, Mt. Simon Formation

Seismic Survey
October, 2006

East Bend Station

Test Well Design
Geology at East Bend

- Preliminary geologic site assessment has been completed.
- Results indicate a thick Mt. Simon sandstone formation at 3200-3500 ft.
- Seismic survey completed in October 2006 – No significant faulting or concerns for injection

Thickness Map of Mt. Simon sandstone for Cincinnati Arch Site
East Bend Site: Addressing Regulatory Issues and Protocols – Area of Review

- AOR based on STOMPCO\textsubscript{2} sims or other methods based on volumetric storage
- AOR to be validated with monitoring

**STOMPCO\textsubscript{2} Simulations**

Area of Review Map (East Bend)
The Michigan site has key infrastructure needed to support CO\textsubscript{2} injection

DTE’s Turtle Lake Gas Processing Plant

Core Energy’s Compression Plant and CO\textsubscript{2} Pipeline

Pure CO\textsubscript{2} Being vented at gas processing plant

6” Diameter CO\textsubscript{2} pipeline leaving compression plant

The lessons learned in operating this system will carry over directly to Phase III
At our Michigan site we completed injection of 10,000+ tonnes of CO\textsubscript{2} in March ‘08.

5000 Foot Deep Test Well Drilled in November 2006

Injection Operations

Starting Injection

180 feet of core taken

Confining Layer: Amherstburg Limestone

Injection Target: Bass Islands Dolomite

Well Column

Gas Processing Plant
Injection Test Well
Antrim Gas Well
CO\textsubscript{2} Pipeline
Niagara EOR Wells

Target Storage Formation
CO₂ Mechanical Integrity Testing – Example from MRCSP MI Site

• Initial step-rate test and shut-in test completed with CO₂ prior to sustained injection as part of UIC mechanical integrity testing, February 7-13, 2008.

• Testing provides data on hydraulic behavior of the reservoir system.
CO₂ Injection Testing – MRCSP MI Site

- 10,241 metric tons CO₂ injected from February 18-March 8, 2008 (including initial mechanical integrity test volume).
- Injection Rate increased from 400 to 600 metric tons/day after 1 week (some fluctuations in injection rate due to compression facility).
- Injection well was shut-in for 1 month after injection to track reservoir pressures decline and allow stabilization.
**CO₂ Injection Testing – MRCSP MI**

**Injection Over 18 Days**

- Bottom-hole pressures 2000-2020 psi during injection with some fluctuations due to supply variations at compression station.
- Overall, testing shows 600 metric tons/day or higher may be sustained in this formation.
The Michigan monitoring suite has worked well under adverse winter conditions.
Results from Michigan have already allowed us to take our models to the next step.

- Preliminary Modeling Based on Regional Data
- Site Drilling and Testing
- Site Specific Modeling
- Post-Injection Calibration/Validation

Conceptualize ➔ Design ➔ Calibrate ➔ Validate
Characterize ➔ Monitor ➔ Communicate
MRCSP Phase III proposed sites

**Primary site**
- Host: TAME, a joint venture of The Andersons and Marathon Petroleum
- Injection start: FY2010
- Scale: 1 million tonnes of CO$_2$ over a four-year period
- Target: Mt. Simon at ~3500 ft.

**Optional site**
- Host: Duke Energy
- Plant operational: FY 2012
- Possible injection start: FY 2012
- Scale: Possible 2 million tonnes over four-year injection period
- Target: Mt. Simon at ~8000 ft.
  - Multiple injection zones and caprock layers
Candidate site plan for ethanol site

- The TAME Ethanol plant sits on about 80 acres
- Candidate location for compression plant and injection well site
- A CO$_2$ transfer line will be needed to move the raw CO$_2$ from the vent stack to the compression plant.
Ethanol site infrastructure requirements

Current spec for compressor plant calls for four 5 to 6-stage reciprocating intercooled units at 1250 hp each (similar to Ariel units shown)

- Pressure rise: ambient to ~1,500 psig
- Total flow: ~800 tonnes CO₂ per day

Flow control strategy is expected to be via throttled bypass loop

A glycol dehydration system integrated with intercooler package is anticipated for moisture control

Raw CO₂ from ethanol plant vent stack will be transported to compressor plant via low pressure transfer line

- Shown is 600 tonne per day line
Phase III — Geologic Framework

- Thick sequence of paleozoic age sedimentary rocks is present in the project area.
- Mt. Simon is the only target deep enough for storage consideration.
- The area has a low seismic hazard as delineated by USGS.
UIC Regulatory process anticipated for Phase III ethanol plant site

- NEPA assessment and several other permits will also be needed
Potential Monitoring Techniques

- System Monitoring
- Cross-well or 3D Seismic
- Wireline, Coring and Mechanical Integrity
- Surface Flux and Soil Gas Probes
- Borehole Tiltmeters
- Multi-level Monitoring
- Brine Chemistry and Fluid Sampling

Not Shown:
- Wellhead Monitoring
- Acoustic Emissions
Phase III Progress—
Public outreach is a key component

• We have already begun outreach activities at the Phase III TAME site by meeting with the Mayor of Greenville and about 12 community leaders

• In Phase III we plan to continue to build upon our outreach methodology developed in Phases I and II:
  – A detailed, interactive, and up to date website with pictures and updates of our field activities
  – Fact sheets on sequestration, the MRCSP, and specific field activities.
  – Meetings with employees at the test site to make sure they understand the technology and reason for the test
  – Public information meetings in the vicinity of the test sites
  – Collaboration with educators and other stakeholders in the region

This outreach methodology has worked extremely well in allowing us to proceed to field implementation on all three of our Phase II sites.
Outreach and public education is an important part of our overall program.

Open house at one of our geologic test sites
MRCSP membership

U.S. Department of Energy/NETL

CEED®
CENTER FOR ENERGY AND ECONOMIC DEVELOPMENT

CONSOL ENERGY

PRAXAIR

CEC
Chicago Climate Exchange

FirstEnergy

OUCC
Indiana Office of Utility Consumer Counsellor

Duke Energy

OHIOMC
Ohio Soybean Council

AMP OHIO

RWE

AEP

Core Energy, LLC

New York State Museum
Thank You

The sight and sound of 600 tonnes/day of CO\textsubscript{2} being injected at 3,500 ft in Northern Michigan