Development of a 1-Million Tonne Demonstration of Carbon Sequestration from a Biofuel Source: The Illinois Basin - Decatur Project

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• The Midwest Geological Sequestration Consortium (MGSC) is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky.

• Landmark Graphics software via University Donation Program and Petrel software via Schlumberger Carbon Services.
DOE Regional Carbon Sequestration Partnerships
Developing the Infrastructure for Wide Scale Deployment

Seven Regional Partnerships
400+ distinct organizations, 43 states, 4 Canadian Provinces

- Engage regional, state, and local governments
- Determine regional sequestration benefits
- Baseline region for sources and sinks
- Establish monitoring and verification protocols
- Address regulatory, environmental, and outreach issues
- Validate sequestration technology and infrastructure

Characterization Phase (2003-2005)
Search of potential storage locations and CO₂ sources
Found potential for 100’s of years of storage

Validation Phase (2005-2011+)
19 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

Development Phase (2008-2018+)
Large scale injections
Commercial scale understanding
Regulatory, liability, ownership issues
A collaboration of the Midwest Geological Sequestration Consortium, the Archer Daniels Midland Company (ADM), Schlumberger Carbon Services, and other subcontractors to inject 1 million metric tons of anthropogenic carbon dioxide at a depth of 7,000 +/- ft (2,000 +/- m) to test geological carbon sequestration in a saline reservoir at a site in Decatur, Illinois.
Who: Illinois Basin-Decatur Project Organization

Schlumberger Carbon Services
Subcontractors for oilfield services, geophysics, and reservoir simulation

Archer Daniels Midland Company
UIC permit holder, CO2 source, site, injection operations and control

Trimeric Corporation
Compression & dehydration facility and pipeline (with ADM)

10 Other Subcontractors and Cooperators
Core analysis, basin structure, well test analysis, geophysics, etc.
When: Illinois Basin - Decatur Project

Major Project Elements  MGSC Phase III

• UIC permitting: January 2008-ongoing
  • Application, hearing, minor modification, major modification
• Injection well drilled: February-May 2009
• Geophone well drilled: September-November 2009
• Baseline 3D seismic survey completed: January 2010
• Compression/dehy/pipeline facility: design, procure, construct, test: February 2009-October 2011
• Monitoring well drilled, completed: September-November 2010, March-June 2011
• Authorization to inject: November 2, 2011
• Operational: November 17, 2011
Operational Injection:
17 November 2011

- IBDP fully operational 24/7
- IBDP is the first 1 million tonne carbon capture and storage project from a biofuel facility in the US
- Injection through fall 2014
- Intensive post-injection monitoring under MGSC through fall 2017

Cumulative Injection (7 June 2012): 175,528 tonnes
Key Points to Remember about the IBDP

- IBDP is the first demonstration-scale (1 million tonne) US project to use carbon dioxide (CO\textsubscript{2}) from an industrial source within the DOE Regional Carbon Sequestration Partnership (RCSP) program.

- IBDP is a fully integrated demonstration, from a compression-dehydration facility and a pipeline to delivery of supercritical CO\textsubscript{2} to a three-well injection and observation system on an intensely monitored site.

- IBDP is the product of four years of effort, from date of funding to CO\textsubscript{2} in the reservoir, including site characterization, permitting, 5,424 m (17,900 ft) of drilling, reservoir geology, engineering, and geophysics, risk assessment, outreach, and baseline monitoring.
Illinois Basin Stratigraphic Column

Pennsylvanian coal seams

Mississippian sandstone and carbonate oil reservoirs

New Albany Shale

back-up seals

Maquoketa Shale

St. Peter Sandstone

Eau Claire Shale

Mt. Simon Sandstone

reservoir

seal
Project Description: Geology Brahmaputra River System

Nemec, 1992
MGSC
Illinois Basin- Decatur Project (IBDP) Site

MGSC monitoring well

MGSC Injection and geophone wells

0.5 mile

photo by Illinois Dept. of Transportation, 8 November 2010
Illinois Basin-Decatur Project Site
(on ADM industrial site)

- A Dehydration/compression facility location
- B Pipeline route (1.9 km)
- C Injection well site
- D Verification/monitoring well site
- E Geophone well
Monitoring, Verification and Accounting

Example Environmental Monitoring Framework

Near Surface

- Atmospheric
  - Atmos. monitoring

- Soil and vadose zone
  - Eddy covariance
  - Aerial imagery

- Shallow groundwater
  - Soil gas
  - Geophysical surveys
  - Geochemical sampling
  - P/T monitoring

Deep Subsurface

- Above seal
  - Geophysical surveys
  - Geochemical sampling
  - P/T monitoring

- Injection zone
  - Geophysical surveys
  - Geochemical sampling
  - P/T monitoring
Surface
Environmental Monitoring

Soil flux

Groundwater

Eddy Covariance
Logged March 1, 2012 with ~75,000 tonnes metric tons injected from Schlumberger Carbon Services
Geophone in special carrier strapped to 3.5 inch (8.9 cm) tubing

- 3,500 ft (1,060 m) well with 31 geophones cemented into uncased hole on tubing string

Injection Well

Geophone Well Completed November 2009
Shown above in the left two panels is a west-east image section. Rightmost panel is the difference of the two. The input to migration is the processed and cross-equalized, notch filtered upgoing data.
Time-lapse 3D VSPs: NRMS Maps with 50 x 50 ft Bin

NRMS computed between 5000-5500 ft (1524-1677 m) depth

NRMS computed between 6950-7100 ft (2119-2165 m) depth

VSP well
Injection well
Verification well

Preliminary Analysis from Schlumberger Carbon Services
Schlumberger Westbay* System First-in-the-World Deployment at 2,200 m+ for Eleven Sampling Levels

Nine Sampling Levels In the Mount Simon Sandstone

Two Sampling Levels Above the Eau Claire Shale

Two Fluid Sample Sets Collected Preinjection

November 2010

*Mark of Schlumberger
Westbay Installation and Sampling

June-August 2011
## Water Quality Comparison

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Shallow Groundwater</th>
<th>Ironton-Galesville</th>
<th>Mt. Simon (injection formation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductivity (mS/cm)</td>
<td>1.5</td>
<td>80</td>
<td>170</td>
</tr>
<tr>
<td>TDS (mg/L)</td>
<td>1,000</td>
<td>65,600</td>
<td>190,000</td>
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<tr>
<td>Cl⁻ (mg/L)</td>
<td>170</td>
<td>36,900</td>
<td>120,000</td>
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<tr>
<td>Br⁻ (mg/L)</td>
<td>1</td>
<td>180</td>
<td>680</td>
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<tr>
<td>Alkalinity (mg/L)</td>
<td>380</td>
<td>130</td>
<td>80</td>
</tr>
<tr>
<td>Na⁺ (mg/L)</td>
<td>140</td>
<td>17,200</td>
<td>50,000</td>
</tr>
<tr>
<td>Ca²⁺ (mg/L)</td>
<td>100</td>
<td>5,200</td>
<td>19,000</td>
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<tr>
<td>K⁺ (mg/L)</td>
<td>1</td>
<td>520</td>
<td>1,700</td>
</tr>
<tr>
<td>Mg²⁺ (mg/L)</td>
<td>50</td>
<td>950</td>
<td>1,800</td>
</tr>
<tr>
<td>pH (units)</td>
<td>7.2</td>
<td>6.9</td>
<td>5.9</td>
</tr>
</tbody>
</table>

- **Shallow groundwater** (16 well average)
- **Ironton-Galesville** (2 zone average; swab only)
- **Mt. Simon** (9 zone average)
Westbay System Response 300 m from Injector

Illinois Basin Decatur Project
Pressure data as observed in Verification Well #1 (VW1)
VW1 is 1000 ft from Injection Well CCS#1

1.21 MPa (175 psi) increase at level of perforations
33 m above perforations
100 m above perforations

from Schlumberger Carbon Services multilevel groundwater characterization and monitoring system
CO\textsubscript{2} in Annulus

CO\textsubscript{2} in Reservoir

Non-CO\textsubscript{2} Fluid Movement

Westbay Zones

Westbay Zones 2 and 3 equivalent to lower and upper perforations, respectively

from Schlumberger Carbon Services
Baseline 3D Geophysical Survey
Completed January 2010
Topography on the Unconformity Impacts CO₂ Distribution
Precambrian Topography Deflects CO$_2$
Mount Simon Sandstone Deposition on Pre-existing Topography
(4.3 m [14 ft] depth steps)
Two of the 4-Component geophones are within the Mt. Simon, the third is positioned above the caprock (Eau Claire Shale).

24 levels of the 3-Component geophones are collecting microseismic data. Active Levels are 8 to 31. Inactive, are levels 1 to 7, not shown.

From Schlumberger Carbon Services

~ 675 ft msl

Perforation Zone Within the Mt. Simon

Granite Wash (Base of the Mt. Simon)

St. Peter Sandstone

Top of the Mt. Simon Sandstone

Geophysical Well #1

ADM CCS #1 (Injection well) With PS3 OYO 4C geophones

Verification Well #1 With OYO 3C geophones

TD= 7236 feet MD
Multicomponent Geophones¹ Installed on Tubing String in Injection Well

¹Schlumberger PS³ System
Microseismic Magnitude vs. Distance from Injection Well

Min -3.85
Max -1.73
Diff 2.12
Avg. -3.213465784
STD 0.348842139 ft

from Schlumberger Carbon Services
Microseismic Events Recorded NW of Verification Well

Preliminary Analysis

Injection Well with Sensors
Reservoir Model:

- Eclipse 2011.2
- 20 × 20 mile coverage
- ~ 3M Cells, 143 × 143 × 148
- Cell Horizontal Dimensions are from 5 ft and 50 ft at wells to 1500 ft at the model boundaries
- Cell Vertical Dimensions from 3 ft to 30 ft
- Infinite acting boundary conditions

from Schlumberger Carbon Services
IBDP - CO$_2$ Plume & Pressure Pulse Evolution

March 2012

from Schlumberger Carbon Services
IBDP - CO₂ Plume & Pressure Pulse Evolution

2013

from Schlumberger Carbon Services
IBDP - CO₂ Plume & Pressure Pulse Evolution

2014

from Schlumberger Carbon Services
Dual 550 TPD Reciprocating Compressors with Glycol Dehydration

- Shell and tube heat exchangers
- Cooling water
- Supply & return
- Dehydration unit contactor
- Dehy inlet separator
- Discharge separator
- Motor
- Compressor
- Blower
- Blower aftercooler
- Suction scrubber
- Pipeline to wellhead
Data Collection System

courtesy Schlumberger Carbon Services
Industrial Carbon Capture and Storage (ICCS) Wells Currently in UIC Class VI Permit Process
Illinois Industrial Carbon Capture and Storage (IL ICCS) Project will Prove CCS at Scale

- Commercial scale operations of one million metric tons per year will be achieved
- Will build on the leading-edge technology of the Illinois Basin - Decatur Project by expanding injected volumes
- Will add an education and training component through Richland Community College, National Sequestration Education Center
- IBDP and IL ICCS will be a first in the world to assess two injected carbon dioxide plumes in the same reservoir that resemble volumes derived from a commercial coal-fired power plant
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Photo credits: Daniel Byers