ILLINOIS INDUSTRIAL CARBON CAPTURE AND STORAGE PROJECT
Project Overview, Lessons, & Future Plans

Carbon Sequestration Leadership Forum
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Acknowledgements

• The Industrial Carbon Capture and Storage (ICCS) project is administered by the U.S. Department of Energy's Office of Fossil Energy and managed by the National Energy Technology Laboratory (award number DE-FE-0001547) and by a cost share agreement with the Archer Daniels Midland Company, University of Illinois through the Illinois State Geological Survey, Schlumberger Carbon Services, and Richland Community College. This ICCS project received DOE funding from the American Recovery and Reinvestment Act of 2009 ($141.4 million).

• The Midwest Geological Sequestration Consortium is funded by the U.S. Department of Energy through the National Energy Technology Laboratory via the Regional Carbon Sequestration Partnership Program (contract number DE-FC26-05NT42588) and by a cost share agreement with the Illinois Department of Commerce and Economic Opportunity, Office of Coal Development through the Illinois Clean Coal Institute.

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

A Global Leader in Renewable Fuels and Products using our Premier Position in Agricultural Processing to Serve Vital Human Needs for Food and Energy by Connecting the Harvest to the Home.
ADM Company Profile

Core Purpose
Connecting the harvest to the home and transforming crops into products that serve vital needs for food and energy.

Financials
• FY 2011 Net Sales: $80 billion
• FY 2011 Net Earnings: $2.0 billion

Processing
• 66,000 MT of corn each day
• 100,000 MT of oilseeds each day
• 28,000 MT of wheat each day
• 3,000 MT of cocoa beans

Logistics
• 26,100 Rail cars
• 1,700 Barges
• 700 Trucks – 1,500 Trailers
• 8 Oceangoing Ships
The ADM Value Chain

CROPS
- Oilseeds
  - Corn
  - Cocoa
  - Wheat

SOURCE
- Microbiology, Chemistry, Engineering, Food and Animal Science

TRANSPORT
- Feedstocks Sourcing and Transportation
  - New Traits
  - New Feedstocks

PROCESS
- Process & Transform
  - Efficiency
  - New Products
  - Sustainability

TRANSFORM
- Value-Added Products

DISTRIBUTE
- Distribute, Market & Sell
  - Product Safety
  - Applications Research
  - Quality

MARKET & SELL
- Food
  - Feed
  - Fuels
  - Industrials

VALUE-ADDED PRODUCTS

Technology Is Key Across the Value Chain

Business Acumen and Financial Strength

Microbiology, Chemistry, Engineering, Food and Animal Science
<table>
<thead>
<tr>
<th>Feed</th>
<th>Food</th>
<th>Industrials</th>
<th>Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soy protein meal</td>
<td>Vegetable oil</td>
<td>Linseed oil</td>
<td>Ethanol</td>
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<tr>
<td>Corn gluten meal</td>
<td>Sweeteners</td>
<td>Soybean oil</td>
<td>Biodiesel</td>
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<tr>
<td>Lysine</td>
<td>Flour</td>
<td>Lactic acid</td>
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<tr>
<td>Threonine</td>
<td>Cocoa</td>
<td>Starch</td>
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<tr>
<td>Other feed ingredients</td>
<td>Soy protein</td>
<td>Polyols</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lecithin</td>
<td>Others</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other specialty food ingredients</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
ADM Research Initiatives

• Biomass Conversion to Fuel Additives
• Integrated Biorefinery: Ethanol & Ethyl Acrylate
• Carbon Capture and Storage
• Membrane Solvent-Extraction: Ethanol
• HTL, Catalytic Pyrolysis, & Hydrogen Research
• Chemical Platform Development: PG/EG
• And Many More.....
Focus of Today’s Presentation

• Provide an Overview and Comparison of the CCS projects underway in Decatur, Illinois
  - Illinois Industrial Carbon Capture and Storage Project (IL-ICCS)
  - Illinois Basin Decatur Project (IBDP)

• Features, Activities, & Impacts of IL-ICCS

• Review Lessoned Learned

• Future Plans for the Facility & Site
DOE - Regional Carbon Storage Partnerships (Phase 3)

Program Objective
Large scale geologic test to inject 1.0 million tons of CO$_2$ over a three year period (1,000 MT/day).

Project Team Members

Schedule of Activities
- Engineering      Q1 2008 – Q1 2012
- Permitting       Q1 2008 – Q1 2013
- Construction     Q2 2009 – Q3 2011
- Operation        Q4 2011 – Q4 2014
- Monitoring       Q1 2015 – Q4 2016

Knowledge Base
- Site Geological Characterization
- Risk Assessment & Reservoir Modeling
- Engineering Design & MVA

Breaking ground for anthropogenic CO$_2$ storage in a saline reservoir using cutting-edge sequestration technology
Illinois Industrial CCS Project (IL-ICCS)

Project Overview

DOE - Large-Scale CCS from Industrial Sources (Area 1)

Program Objectives
- Target & Demonstrate Advanced CCS Technologies at Industrial Scale Facilities
- Inject and Store One Million Tons of CO₂ Annually (3,000 tons/day)

Project Team Members

Schedule of Activities
- Engineering Q3 2010 – Q1 2012
- Permitting Q3 2011 – Q1 2013
- Construction Q2 2011 – Q2 2013
- Operation Q3 2013 – Q3 2015

Knowledge Base
- Site Geological Characterization
- Risk Assessment & Reservoir Modeling
- Engineering Design & MVA
- Education and Public Outreach

Study the interaction between the CO₂ plumes from two injection wells within the same formation.
Illinois Industrial CCS Project (IL-ICCS)

Project Objectives

- Design, construct, and operate a new CO2 collection, compression, and dehydration facility capable of delivering up to 2,000 metric tons of CO2 per day to the injection site.
- Integrate the new facility with an existing 1,000 metric tons of CO2 per day compression and dehydration facility to achieve a total CO2 injection capacity of 3,000 metric tons per day or one million tons annually.
- Implement deep subsurface and near-surface MVA of the stored CO2.
- Develop and conduct an integrated community outreach, training, and education initiative.

In Q4 2014, the compression equipment from the IBDP project will be incorporated adding 1,000 MT/day of capacity to the ICCS project.
Illinois Industrial CCS Project (IL-ICCS)  
Project Team Members

**Archer Daniels Midland Company**  
- Project Leader  
- Overall Project Execution  
- Facility Owner and Operator  
- Design & Construction of Surface Facilities  
- UIC Class VI Permit Holder

**Schlumberger Carbon Services**  
- Seismic Acquisition & Data Processing  
- Reservoir Modeling  
- Design & Construction of Storage Facility  
- Subsurface Operations  
- Deep MVA CO₂ Monitoring

**Illinois State Geological Survey**  
- Site Characterization  
- MVA Development  
- USDW Monitoring  
- Near-Surface CO₂ Monitoring  
- Outreach and Communication

**Richland Community College**  
- National Sequestration Education Center  
- Community Outreach & CCUS Training  
- New Associate Degree Programs in CCUS

Leveraging Knowledge and Experience
Illinois Industrial CCS Project (IL-ICCS)

Project Schedule

- Site Characterization
- Design and Engineering
- MVA & UIC VI Permit
- Construction
  - Compression & Transmission
  - Well Construction
  - 100 Mw Substation
- Commissioning & Operation

Year:
- 2011
- 2012
- 2013
- 2014
- 2015
Illinois Industrial CCS Project (IL-ICCS)
Project Process Flow Diagram

Notes:
P = psia
M = wt% moisture
MTPD = metric tons per day
D = depth in feet
T = thickness in feet
(all values approximate)
ICCS project site selection benefitted from the information developed through the Regional Carbon Sequestration Partnership Program.

- 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 (2005-2010)**
- 20 injection tests in saline formations, depleted oil, unmineable coal seams, and basalt

**Development Phase (2008-2017+)**
- 9 large scale injections (over 1 million tons each)
- Commercial scale understanding
- Regulatory, liability, ownership issues
Site Selection
Regional Geologic Characterization

- Cratonic basin
- 60,000 square mile area
- Structurally complex to the south with faulting and seismicity

- ADM Decatur facility is located near the center of this geologic formation
- Estimated CO$_2$ storage capacity between 27 to 109 billion metric tons
Site Characterization

Seismic Acquisition

- Receiver lines spaced 640 ft. (N-S lines)
- 18,090 point receivers
- Source lines spaced 720 ft. (E-W lines)
- 2,018 shot points

- Fold coverage is maximized over injection well location
- 40’-by-40’ bin size (horizontal resolution)

- Q-Land Technology with improved signal-to-noise ratio
- More desirable for acquiring seismic data within industrial settings
Site Characterization

Seismic Processing & Geocellular Model Development

- Both projects seismic data sets were merged prior to processing
- Improved resolution and clarity
- Petrophysical properties extrapolated from CCS #1 logs
- Extended coverage over both sites
- Large model dimensions (30-by-30 miles) used to minimize boundary effects
- Yielding more usable data within AoR.

Legacy Data  Merged Data
Site Characterization
Seismic Inversion: Formation Density

• Synthetic wavelet constructed from correlation to wellbore log data
• Seismic data inverted to generate petrophysical properties
• 2D Line 101 inverted to generate image of formation density
• Enhances detailed features and allows interpretation of depositional bodies
The ADM site has excellent features for CO₂ storage:

- High purity source of CO₂
- Thick permeable formation for storage. Porosity <20% and permeability 26 mD
- Formation depth
- Thick seal with no resolvable faulting
- Additional seal formations
- No local penetrations of the primary seal formation
- Low population density
Site Characterization
AoR - Maximum Extent of the Plume or Pressure Front

• The delineation of the AoR is based on the Maximum Extent of the Separate-phase Plume or Pressure-front (MESPOP) methodology, as detailed in the relevant US EPA guidance document (USEPA, 2011).

• The pressure front is defined by the differential pressure needed to allow fluid from the injection zone to flow through a hypothetical open conduit into the overlying lowermost USDW (St. Peter Sandstone).

• Site specific data used to determine the MESPOP and was calculated to be 171 psi.

USEPA Pressure Front Delineation Equation

\[ P_{i,f} = P_u \cdot \frac{\rho_i}{\rho_u} + \rho_i g \cdot (z_u - z_i) \]

Illustration of pressure front delineation calculation based using the St. Peter Sandstone is as the lowermost USDW.
Site Characterization
Updating the Site Model – Matching Operational History

- The site model was calibrated using data obtained during the first four (4) months of the IBDP injection period.
- The IBDP injection rate was input into the simulation to calculate the bottom hole pressures and pressures at five different zones at the verification well.
- Reservoir permeability and skin were the main parameters impacting the injection pressure calibration and were used as fitting parameters.
- Once the injection bottom hole pressure was calibrated, simulated pressures at five different zones at the verification well were fine-tuned calibrating the kv/kh ratio of the tight sections and compressibility of the reservoir rock.
Site Characterization

*Updating the Site Model – Matching Operational History*

- RST Well Logs helped us estimate the location, saturation, and thickness of the CO2 column around the injection and verification wells.
- This information helped us fine tune the end points of relative permeability curves which dominate the CO2 and brine flow in the reservoir.
- Using the calibrated model, a predictive simulation was run to evaluate plume development and pressure perturbation during the course of the injection.
- The project’s planned injection schedule was used for the 52 year simulation.

### Injection Schedule for IBDP (CCS#1) and IL-ICCS (CCS#2) Projects

<table>
<thead>
<tr>
<th>YEAR</th>
<th>IBDP (MT/D)</th>
<th>IBDP (MT/YR)</th>
<th>ICCS (MT/D)</th>
<th>ICCS (MT/YR)</th>
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<td>Total</td>
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<td>4,750,000</td>
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Site Characterization
Modeling Plume Extent and Pressure Front

March 2012 (Year 0.3)
Site Characterization

Modeling Plume Extent and Pressure Front

January 2013 (Year 1.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2014 (Year 2.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2015 (Year 3.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2017  (Year 5.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2019 (Year 7.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2020  (Year 8.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2025 (Year 13.0)
Site Characterization

Modeling Plume Extent and Pressure Front

January 2030  (Year 18.0)
Site Characterization
Modeling Plume Extent and Pressure Front

January 2062 (Year 50.0)
Site Permitting

USEPA: UIC Class VI Permit

1st UIC Class VI Permit Application Reviewed by the US EPA

- UIC Class VI permit application submitted on July 25, 2011.
- US EPA Region V issued a notice of completeness on August 26, 2011.
- EPA issued an information request on December 21, 2012.
- The project team sent a response on January 25, 2012.
- The EPA issued a determination that stated the St. Peter Sandstone formation was the lower most USDW.
- The project team submitted revised permit application using new USDW on May 31, 2012.
- OG-7 application for construction of monitoring well submitted June 4, 2012.
• Collection, Compression, and Dehydration Facility
• CO$_2$ Transmission System
• 100 MW Electrical Substation
• Electrical Distribution System
• Sequestration Site and Monitoring Facility
• National Sequestration Education Center (NSEC)
Engineering Design & Construction
Capital Project Approach Plan

ADM has a stage-gate project plan that is divided into six stages:

• Concept and Feasibility Stage
• Assessment Stage
• Development and Design Stage
• Construction Stage
• Start up and Commissioning Stage
• Final Audit and Closing Stage

Reduce Capital and Technical Risk
Engineering Design & Construction
Modular Design & 3D Computer Aided Design

- Major equipment designed as modular components on self contained skids using 3D CAD
- Combined modules into single model which allowed integration of the mechanical, structure, civil, & electrical design elements
- 3D model allowed rapid evaluation of changes to the mechanical and structural design elements
- All construction drawings were created from the 3D model allowing for precise shop fabrication of 80% of the mechanical, structural & electrical components.

Reducing Installation Cost
Engineering Design & Construction Planning
Construction Scheduling and Equipment Installation

• Designed enclosures with a coordinated/staged construction schedule

• Minimized craft interference and accelerated building erection

• Staggered craft work schedule minimized interference

• The enclosure also facilitate construction during winter or periods of inclement weather

• Refurbished existing equipment and structures to minimize project footprint and costs

• 24 month construction schedule

Reducing Installation Time & Cost
Workshop Summary: Engineering Design & Planning

Storage Site: Major Well Schematics

- Illinois Basin - Industrial Sources Major Well Schematics
- Injection Well Schematic
- In-Zone Monitor Well Schematic
- Geophysical Monitoring Well Schematic
- Detail of the Westbay System

Key Components:
- Pressure gauge
- Packers
- Sample Port
- Perfs
- 31 Sensor Array
- Westbay System 7 Zone Monitoring
- Adapted from the water industry

13 CR Casing

Built to Meet Class VI Standards
Well Construction Management
Storage Site - Lost Circulation Event

- CCS #1 LCM event in the Knox zone conventional LCM were not effective for this zone – Set cement plugs

- MW #1 – bypassed LCM and set cement plugs. 70% cost reduction vs. CCS #1

- Using of 3D seismic and modeling techniques to predict location and severity of lost returns.

- Developed drilling protocol to maximize drill time during LC event (drill thru the formation) and set cement plug.
Environmental Monitoring (MVA)
Conceptual Framework

<table>
<thead>
<tr>
<th>Near Surface</th>
<th>Deep Subsurface</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil and Vadose Zone</td>
<td>Above Seal</td>
</tr>
<tr>
<td>Aerial Imagery</td>
<td>Geophysical Surveys</td>
</tr>
<tr>
<td>Soil CO₂ Flux</td>
<td>Seismic Monitoring</td>
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<td>P Monitoring</td>
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<tr>
<td></td>
<td>Geophysical Surveys</td>
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<td>Geochemical sampling</td>
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<tr>
<td>Ground Water</td>
<td>Injection Zone</td>
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<tr>
<td>Geochemical Sampling</td>
<td>P/T Monitoring</td>
</tr>
<tr>
<td>P/T Monitoring</td>
<td>P/T Monitoring</td>
</tr>
</tbody>
</table>
Environmental Monitoring
Near Surface Monitoring

• Near infrared aerial imagery will be used to evaluate plant stress
• Soil resistivity characterized shallow depths for identification of optimum GWM locations
• GWM for baseline conditions and operational surveillance
• Surface soil CO₂ flux monitoring
Environmental Monitoring
Deep Subsurface Monitoring

- CCS#2 T/P monitoring
- Distributed Temp Sensor
- VM#2 Westbay system
- Multi-level sampling ports reservoir fluid collection and T/P monitoring
- GM#2 has 31 sensor array
- Pressure sensor to monitor above the seal
- Allow offset or walkaway Vertical Seismic Profile (VSP)
- Well logging (RST)
ICCS Outreach and Education
Building on Current Regional CCS Activities

- Trusted Information Source
- Local, Regional, National, and International Events
  - Decatur Public Events
  - AAPG Short Courses
  - IEA GHG Summer School 2011
- Providing Information
  - Invited presentations
  - Technical presentations
  - Model presentations
  - Teacher workshops
  - Coordination with STEM.
- Education Development
  - STELA Learning Environment
  - Undergraduate CCUS course

Working with local programs to leverage program dollars.
National Sequestration Education Center

- Innovative Educational Spaces
- Academic Curricula
- Community & Industry Workshops
- Workforce Training Activities
- Visitor Center
- K-12, Community & Regional Outreach
- Sequestration Training & Learning Array (STELA)

Project Groundbreaking Ceremony: August 24, 2011
Richland Community College

Richland is developing two new degree programs with an emphasis on CCUS:

• Associate of Applied Science Engineering Technology- Sequestration Specialty (Starts in fall 2012)
• Associate of Science - Sequestration Concentration

Several universities in Illinois have already reviewed and accepted Richland CCUS courses as electives in their degree program(s).

This recognition allows the students obtaining their 2-year degree from Richland to receive credits for the CCUS courses when they transfer to a 4-year degree program at these universities.
Environmental and Cost Benefits
GHG Reduction & Fuel LCA

- Significant CO₂ site emission reductions.
- Injected CO₂ has a reduction of 94% GHG emissions based on using Midwest electricity (coal).
- CCS will significantly reduce the carbon footprint of fuel ethanol.
- The operational expense is significantly lower than post combustion capture.
- 15 billion gallons annually, represents about 40 million metric tons of CO₂.
Estimated Jobs Creation & Retention

• 900+ Jobs
• 400+ Local Jobs
• 6-8 Permanent Jobs
• Professional and Construction Trades
Local Area Businesses

$30,000,000 will flow down to local area businesses through consumer spending.

Future Commercial Potential

- Enhanced Oil Recovery
- Product Development
  - CO₂ Liquids
  - Carbonates
  - Fertilizer
- Process Development
  - SC Extraction
  - Solvent Applications
- Carbon Management
  - Storage
  - Trading & Risk Management

(1) BASIN ORIENTED STRATEGIES FOR CO₂ ENHANCED OIL RECOVERY: ILLINOIS AND MICHIGAN BASIN OF ILLINOIS, INDIANA, KENTUCKY AND MICHIGAN; Advanced Resources International, February 2006
Project Construction
Progress Photographs
Project Construction
*Progress Photographs*
Project Construction
Progress Photographs
IL-ICCS: Project Benefits Review

Public Benefits

• Recovery Act funding creating jobs for economic recovery
• Mitigating risks for the industry to demonstrate the largest integrated, saline storage project in the U.S.
• Community Outreach - CCUS technologies
• Collected CO$_2$ is produced from biologic fermentation, a significant feature of the Illinois ICCS project is its “negative carbon footprint.”
• Validate the Mt. Simon Sandstone saline reservoir site for commercial-scale, long-term geologic storage of CO2. Collect crucial scientific and engineering data in advance of carbon capture requirements

Project Outcomes

• Demonstrates cost advantages/economic viability of CCS at ethanol plants
• Facilitates exploration of long-term CO2 utilization options- EOR Illinois Basin Develops a market for utilization of U.S. geologic saline storage capacity that ranges from 1,700 to 20,000 billion metric tons (2010 Carbon Sequestration Atlas, NETL)
Thank You!

Industrial Carbon Capture and Storage Project:
• U.S. Department of Energy Award No. DE-FE-0001547
• Administered by the DOE’s Office of Fossil Energy
• Managed by the National Energy Technology Laboratory
• DOE cost share from American Recovery and Reinvestment Act of 2009

Cost Share Agreements:
• Archer Daniels Midland Company
• University of Illinois through the Illinois State Geological Survey
• Schlumberger Carbon Services
• Richland Community College

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