CO$_2$ Injection
Surface Facility Design

MGSC Assessment of Geological Carbon Sequestration Options in the Illinois Basin: Phase III

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Presentation Outline

• Project Overview
• Value Proposition – CO$_2$ for EOR from Ethanol Production Facilities
• Ethanol Production Overview
• Surface Facility Design
  – Design Criteria
  – Equipment Selection
• Current Project Status
Project Overview

• U.S. Department of Energy Phase III Large-scale sequestration demonstration project
• Capture and storage of 1 MM metric tons CO₂ in saline reservoir over 3 years of injection
• Project Participants
  – Midwest Geological Sequestration Consortium (MGSC)
  – Illinois State Geological Survey (ISGS)
  – Archer Daniels Midland Company (ADM)
  – U.S. Department of Energy – Nation Energy Technology Laboratory (DOE / NETL)
  – Schlumberger Carbon Services
  – Trimeric Corporation
• 7 year project / $84 MM (DOE - $66.7 MM)
Overall Project Objectives

- Help evaluate Carbon Capture and Storage as a means of reducing atmospheric CO$_2$ concentrations.
- Capture of CO$_2$ from the ADM Ethanol Plant in Decatur, IL
- Compress, dehydrate and inject of 1 MM metric tons (~20 MMSCFD) of CO$_2$ over 3 years
- Monitor the effectiveness of CO$_2$ storage in a deep saline aquifer including 2 years of post injection monitoring
Project Goal – Injection

- Illinois Basin geology contains multiple seals for carbon dioxide (CO₂) above the Mt. Simon Sandstone
- Monitoring other sandstones above the Mt. Simon Sandstone can provide warning of any problems

Project Goal – Monitoring

MMV Plan to Include atmosphere (saline reservoir only), vadose zone, and groundwater

Source: R. Finley, Phase II Year 1 Update, October 2006
Why is the capture of CO$_2$ from ethanol vents important?

• Many Industrial uses for Carbon Dioxide
  – Food & Beverage Industry
  – Oil Recovery
  – Chemical Industry

• Large domes of naturally occurring CO$_2$
  have finite capacity and limited locations
Anthropogenic Sources of CO$_2$ are abundant and widespread

Examples:

- Coal-fired power plants
- Cement plants
- Coal gasification facilities
- Amine plants
- Refinery vent streams
- Ammonia plants
- Ethanol plants
Value Proposition – CO$_2$ from Ethanol

- High Purity – > 99% CO$_2$
- Low Relative Capture Costs - separation system not required
- Ethanol Production Growth (>30% increase 2006 to 2007)
- Total US Ethanol Production – over 10,400 MMgal/yr*
- Typical 50 MMgal/yr ethanol plant produces ~7 MMSCFD or 370 metric tons / day of recoverable CO$_2$

However…
- Many Ethanol producers are not located near existing CO$_2$ pipelines

*Source: Renewable Fuels Association – December 9, 2008
U.S. Ethanol Biorefinery Location

Source: Renewable Fuels Association, January 2008
Existing CO$_2$ Pipelines

Source: Nicholas School of Environment Duke University
CO$_2$ from Ethanol vs. Existing Pipelines
Ethanol Process Overview

Source: http://www.lincolnlandagrienergy.com/ (The Ethanol Process)
Project CO$_2$ Block Flow Diagram

Fermentation → Water Scrubber → CO$_2$ → Compression → Injection

Injection Surface Facility

Dehydration
Injection Surface Facilities
Design Requirements

• Inject 1 MM metric tons of CO$_2$ over 3 year period of time
  – Must deliver 995 metric tons/day (19 MMSCFD) or greater

• Inlet Pressure ~ 1 psig

• Well head pressure 1350 to 2000 psig

• Dehydrate CO$_2$ - 7 lb of H$_2$O/MMSCF (~ 150 ppmv)
# CO₂ Injection Operational Limits

<table>
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<tr>
<th>Component</th>
<th>Limit</th>
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<tr>
<td>Carbon dioxide</td>
<td>99% (minimum)</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>500 ppmv</td>
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<tr>
<td>Oxygen</td>
<td>100 ppmv</td>
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<tr>
<td>Water</td>
<td>30 lb/MMSCFD / 630 ppmv (maximum)</td>
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Project / Site Specific Factors for Design

• Research Project
  – Minimal sparing
  – Highly instrumented
  – 3 years of injection
  – Cooling water available

• Discharge pressure flexibility needed due to undetermined injection pressure requirements
Compression Equipment Selection

• Comparison of several equipment configurations based on:
  – Equipment Purchase Costs
  – Energy Costs
  – Complexity
  – Space Requirement
  – Lead Time
Equipment Options Matrix

• Case 1 – blower, screw, recip
• Case 2 – blower, screw, recip, pump
• Case 3 – blower, screw, recip, chiller, condenser, pump
• Case 4 – blower, recip
• Case 5 – blower, recip, pump
• Case 6 – blower, recip, chiller, condenser, pump

Each case was evaluated for several discharge pressures ranging from 1400 to 2000 psig
# Equipment Matrix (Simplified)

<table>
<thead>
<tr>
<th>Case #</th>
<th>Booster Blower</th>
<th>Screw</th>
<th>Recip</th>
<th>Chiller &amp; Condenser</th>
<th>Final Stage pump</th>
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Lowest Cost
Selected Equipment

• Blower
  – Single unit or possibly two-50% units
  – Boost vent gas pressure by 10 to 12 psi

• Flooded Screw Compressor
  – Two 50% units in parallel
  – Discharge pressure ~ 275 psig

• Reciprocating Compressor
  – Two Stage
  – Discharge Pressure ~1400 psig

• Triethylene Glycol dehydration unit
  – Fed from outlet of 1st stage reciprocating compressor

• Multi-Stage Centrifugal Pump (if needed)
Process Flow Diagram
Current Project Status

- Major Equipment Bid Process - underway
- Equipment Installation – 4th quarter 2009
- CO₂ Injection – Early 2010
Conclusions

- Minimal sparing results in lower purchased equipment cost
- TEG Dehydration allows for lower cost uninsulated carbon steel pipeline
- Recycle to existing plant vent simplifies flow range capability
- Optional multi-stage centrifugal pump decouples reciprocating compressor specification from injection pressure requirements
- Estimated capture treating cost: $0.90 – 1.1/Mscf
Questions?
Acknowledgement

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