Evaluation of Solid Sorbents as a Retrofit Technology for CO$_2$ Capture

Project Update: July 10, 2012

ADA Environmental Solutions creates and delivers cutting edge technical and chemical solutions to reduce emissions from coal-fired power plants, Portland cement kilns and industrial boilers, helping customers meet environmental goals while balancing their business needs.
Presentation Outline

• Background
  – Participants
  – Project Goals
  – Project Overview

• 1 MW Pilot
  – Sorbent Characteristics
  – Contactor Design Selection
  – Host Site Information
  – Project Accomplishments
  – Future Plans

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ADA CO₂ Capture Program

• Phase I – Viability Assessment
  – Cooperative Agreement: DE-NT0005649
    • Dual Focus: Sorbents & Process
    • 1 kWₑ Test Device
• Phase II – FEED & Pilot Testing
  – Cooperative Agreement: DE-FE0004343
    • Sorbent Selection & Reactor Design
    • Full-Scale Conceptual Design
    • 1 MWₑ Pilot Unit
    • Techno-Economic Assessment
• Phase III (Demonstration)
  – Full-Scale Preliminary Design
  – Validate Design (>25 MWₑ)
Project Goals

The overall objective of this funding stage is to validate solid sorbent-based post combustion CO₂ capture through slipstream pilot testing.

Project Goals:
- Achieve 90% CO₂ Capture
- LCOE increase less than <35%
- Generate a high purity CO₂ stream
- Successfully scale sorbents

Federal Funding provided by the DOE National Energy Technology Laboratory’s Innovations for Existing Plants Program
Project Objectives

- Reduction in energy penalty and costs associated with post-combustion CO₂ capture
- Reduction in overall environmental impacts versus other CO₂ capture options
- Reliable operation
- Applicable to retrofit and new builds
- Period of Performance:
  - October 1, 2010 – December 31, 2014
Project Participants

• DOE – NETL
  o Project Sponsor
• ADA-ES, Inc.
  o Project Management
  o Sorbent Evaluation & Selection
  o Conceptual Process Design
  o Techno-Economic Assessment
• Shaw Energy & Chemicals, Inc.
  o Detailed Engineering Services
  o Significant Experience with Fluidized Bed Reactor Design
  o Isothermal and Adiabatic Reactors
  o Single & Multibed Reactors
• Stantec Consulting Ltd.
  o Cost Analysis
  o Plant Integration
  o Owners Engineer Perspective
• EPRI
  o Industry Cost Share
  o Independent Performance Evaluation and Techno-Economic Assessment
• Southern Company
  o Host Site
  o Cost Share
• Luminant
  o Cost Share
Project Budget Period Overview

Phase I: 18 months
- Refine 500 MW Conceptual Design and Sorbent Selection
- Design 1 MW pilot
- Scale down to 1 MW

Phase II: 18 months
- Manufacture and Construction
  - Manufacture Sorbents
  - Fabricate and Install 1 MW pilot

Demonstration Phase
- 1 MW Testing
- Develop 500 MW Preliminary Design
- Conduct Techno-economic analysis

Phase III: 15 months
Potential Benefits of Solid Sorbents

• Energy Penalty
  o Sensible heat requirement is less – although heat recovery should be considered
  o Latent heat of evaporation
• Corrosion
  o Less expensive materials of construction
  o No corrosion inhibitors required
• Air
  o Reduced emissions of amines
• Water
  o Less cooling water required
  o Minimal liquid waste
• Process Flexibility and Operability
  o Can be applied to cycling plant “load following”
  o No risk of foaming or other solvent-related challenges
Sorbent Properties
Sorbent Selection

• Selection Criteria
  o Kinetics
  o Higher working CO₂ delta loading
  o Stability
  o Part of a commercial process
  o Experience with changing particle size
  o Potential regeneration after the formation of heat stable salts

• 1MW Pilot Capacity
  o Approximately 5 tons (dry basis) required for operation
  o Batches will have same specifications
  o QC checks through lab scale testing
Sorbent Kinetics

Temperature change from 50 °C to 40 °C

Graph showing the change in CO₂ and H₂O loading with time for CO₂ and H₂O.

- CO₂ Loading (g CO₂/100 g sorbent)
- H₂O Loading (g H₂O/100 g sorbent)
- Time (min)
1 MW Pilot Design
Design Considerations

- Capital costs
- Gas/solids contacting
- Heat transfer
- Sorbent attrition
- Pressure drop
- Maintenance requirements
- Footprint
Designs Considered

**Comparison**

- **Similar**
  - Capital costs
  - Footprint
- **Advantage TDR**
  - Pressure drop
  - Attrition
- **Advantage SFB**
  - Gas/solids contacting
  - Heat transfer
  - Commercial design
Fluidization Characterization

- **Variables**
  - Sorbent particle size
  - Gas velocity: (1-5 ft/s)

- **Measurements**
  - Fluidization regime
  - Pressure drop (average and fluctuations)
  - Heat transfer coefficient
  - Entrainment rate

- **Results**
  - Optimized particle size distribution
  - Bed density: 15-30 lb/ft³
  - Heat transfer coefficient: 65-105 Btu/hr·ft²·F
  - Entrainment flux: provided operation limits
Mechanical Attrition Test Results

- Temperature (T): Ambient
- Gas: Nitrogen
- Ugs: 300 ft/s
- Test Duration: 2-hrs

The graph shows the percentage size (% Size) against % Undersize with dp (µm) on the x-axis. The data points represent the initial and after conditions of the sorbent beads.
Principal

- Flue gas passes through Adsorber module where sorbent particle adsorbs CO₂.
- Regenerable solid sorbent cycles between Adsorber and Regenerator. Raising the temperature of the sorbent releases CO₂.

Next Steps: Heat Integration & Optimization
Host Site

- **Host Site:** Southern Company – Alabama Power Co. Plant Miller
  - 4 EGUs (~2,640 MW<sub>e</sub>)
  - Flagship Plant
  - PRB Coal
  - WFGD
  - Pilot Located near WFGD on Unit 1
1 MW Pilot Location
# 1 MW Pilot Project Schedule

<table>
<thead>
<tr>
<th>Milestone Description</th>
<th>Date</th>
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<tbody>
<tr>
<td>Start site work for 1 MW pilot</td>
<td>4Q12</td>
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<tr>
<td>Substantial completion of mechanical installation SOW</td>
<td>3Q13</td>
</tr>
<tr>
<td>Substantial completion of electrical SOW</td>
<td>4Q13</td>
</tr>
<tr>
<td>Demonstrate pilot operation</td>
<td>1Q14</td>
</tr>
<tr>
<td>Begin continuous performance testing</td>
<td>1Q14</td>
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<tr>
<td>Complete field testing</td>
<td>2Q14</td>
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Budget Period 2 Scope

- Procure and Manufacture Sorbents
- Procure and Fabricate Pilot-Scale Equipment
  - Procure Pilot Scale Equipment
  - Finalize Fabrication and Construction Work Packages
  - Equipment and Module Fabrication
- Installation and Startup
  - Host-site Preparation
  - Mechanical Installation
  - Electrical Installation
  - Commissioning/Startup Activities
Budget Period 3 Scope

- Pilot Scale Operation and Evaluation
  - Parametric Testing
  - 60 Day Continuous Performance Test
- Define and Collect Compression and Sequestration Information
- Prepare Commercial Design Specifications
  - Refine Full-Scale Design Specifications
  - Full-Scale Conceptual Engineering Design
  - Conduct Full-Scale System Economic Evaluation
  - Heat Recovery Information
Creating a Future with Cleaner Coal

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