Advancing Cleaner Energy

Evaluation of Solid Sorbents as a Retrofit Technology for CO_2 Capture

July 8, 2013
ADA-ES, Inc.

DE-FE0004343

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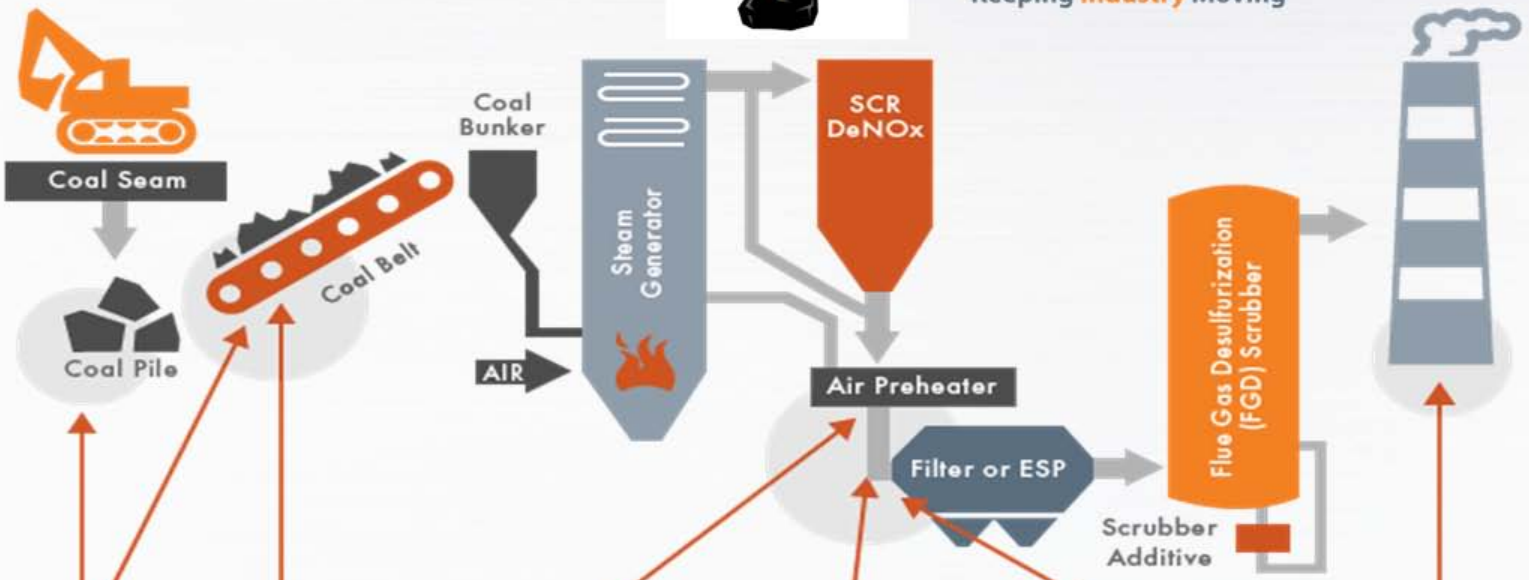
Advanced Emissions Solutions, Inc.

ADA Advancing Cleaner Energy

CLEAN COAL SOLUTIONS LLC.

BCSI Keeping Industry Moving



COAL ADDITIVE	REFINED COAL	FLUE GAS CONDITIONING	DRY SORBENT INJECTION (DSI)	ACTIVATED CARBON INJECTION (ACI)	TECH DEMOS
ADA	CLEAN COAL SOLUTIONS, LLC	ADA	BCSI, LLC	ADA	ADA BCSI, LLC



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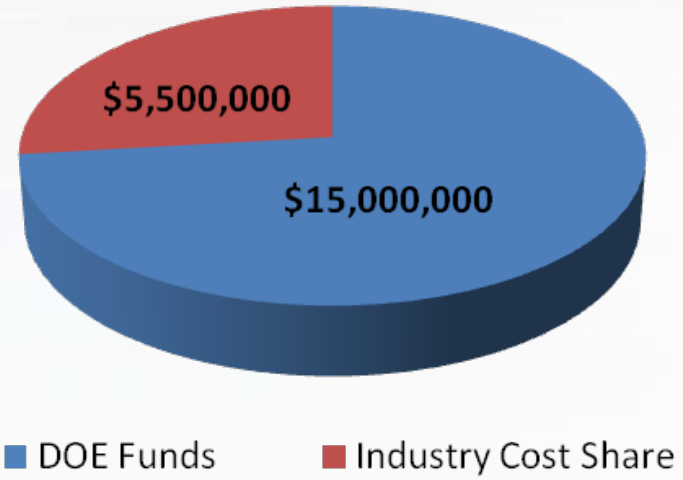
CO_2 Project Funding and Goals

- The overall objective of this funding stage is to validate solid sorbent-based post combustion CO_2 capture through slipstream pilot testing.
- Project Goals:
  - Achieve 90% CO_2 Capture
  - Reduce costs of carbon capture
    Progress towards <35% LCOE Goal
  - Generate a high purity CO_2 stream
  - Successfully scale sorbents



Cooperative Agreement (Award No. DEFE0004343)
American Recovery and Reinvestment Act of 2009
Administered by DOE-NETL: Project Manager Bruce Lani

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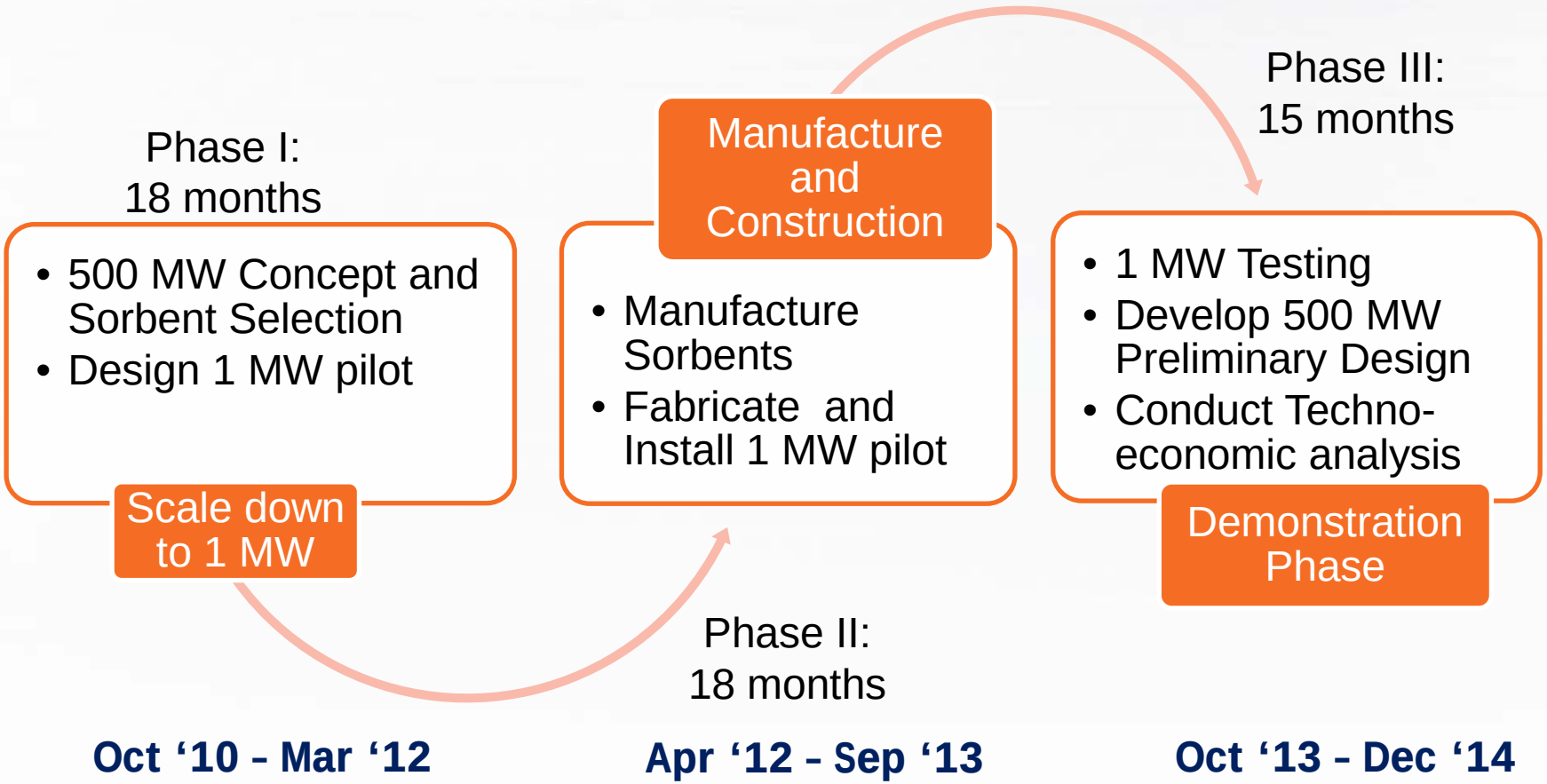
Project Budget Period Overview



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Project Team

- DOE – NETL
  - o Project Sponsor
- ADA-ES, Inc.
  - o Project Management
  - o Developed Process Concept
  - o Sorbent Eval & Selection
  - o Process Validation Testing
  - o Techno-Economic Assessment
- Technip Stone and Webster Process Technology
  - o Detailed Engineering Services
    - *Significant Experience with Fluidized Bed Reactor Design*
- Stantec Consulting, Ltd.
  - o Cost Analysis, Plant Integration
    - *Owners Engineer Perspective*
- McAbee Construction
  - Pilot fab and installation
- EPRI
  - o Technical Advisor
  - o Cost Share
  - o Independent Performance Evaluation and Techno-Economic Assessme
- Southern Company
  - o Host Site, Cost Share
- Luminant
  - o Cost Share

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Fundamentals of Adsorption

- Solids functionalized with amines react with CO_2 at "low" temperatures
- Solids are heated to reverse reaction with CO_2
  - *Temperature swing adsorption (TSA)*

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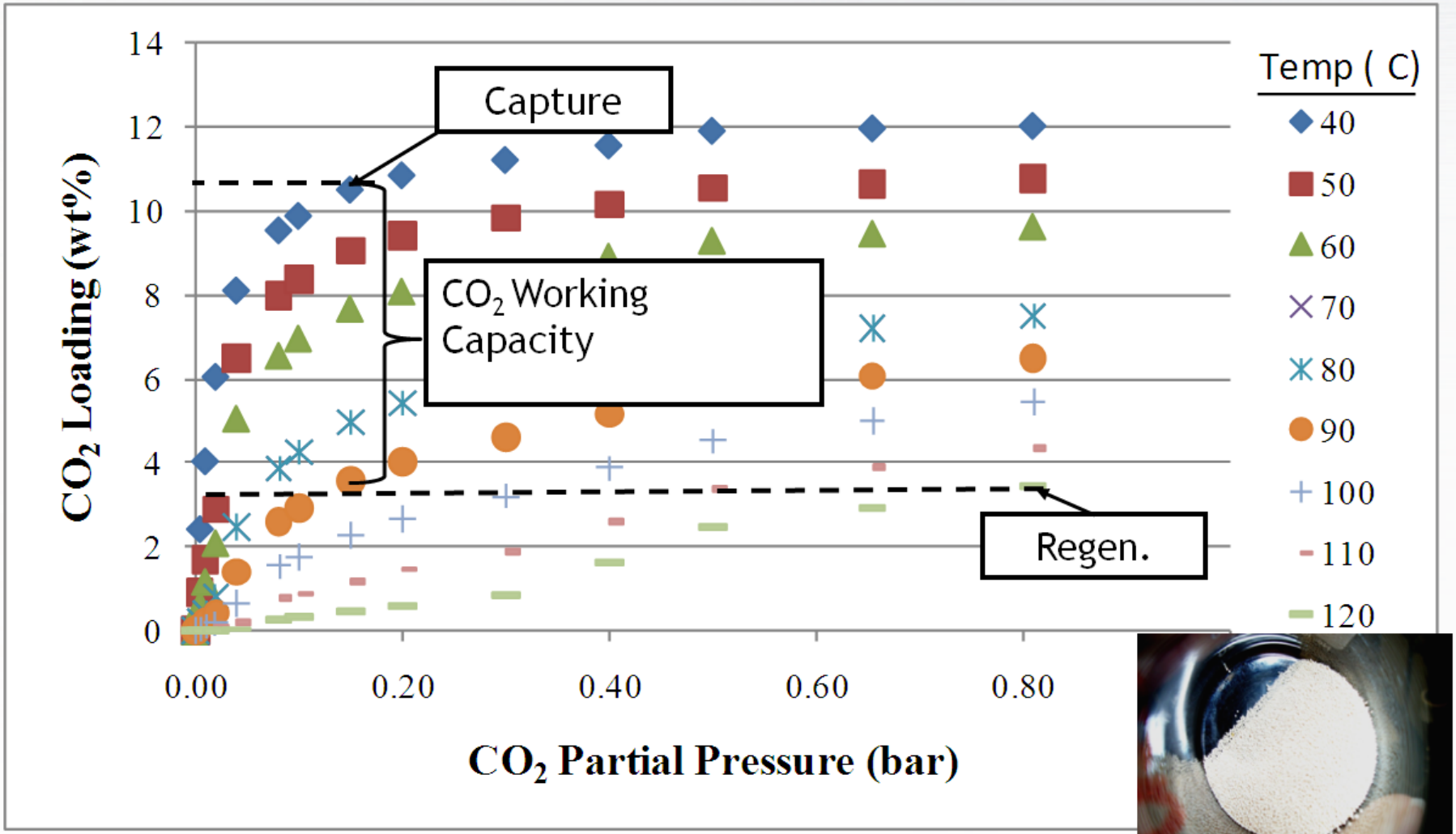
Sorbent Capacity for CO_2



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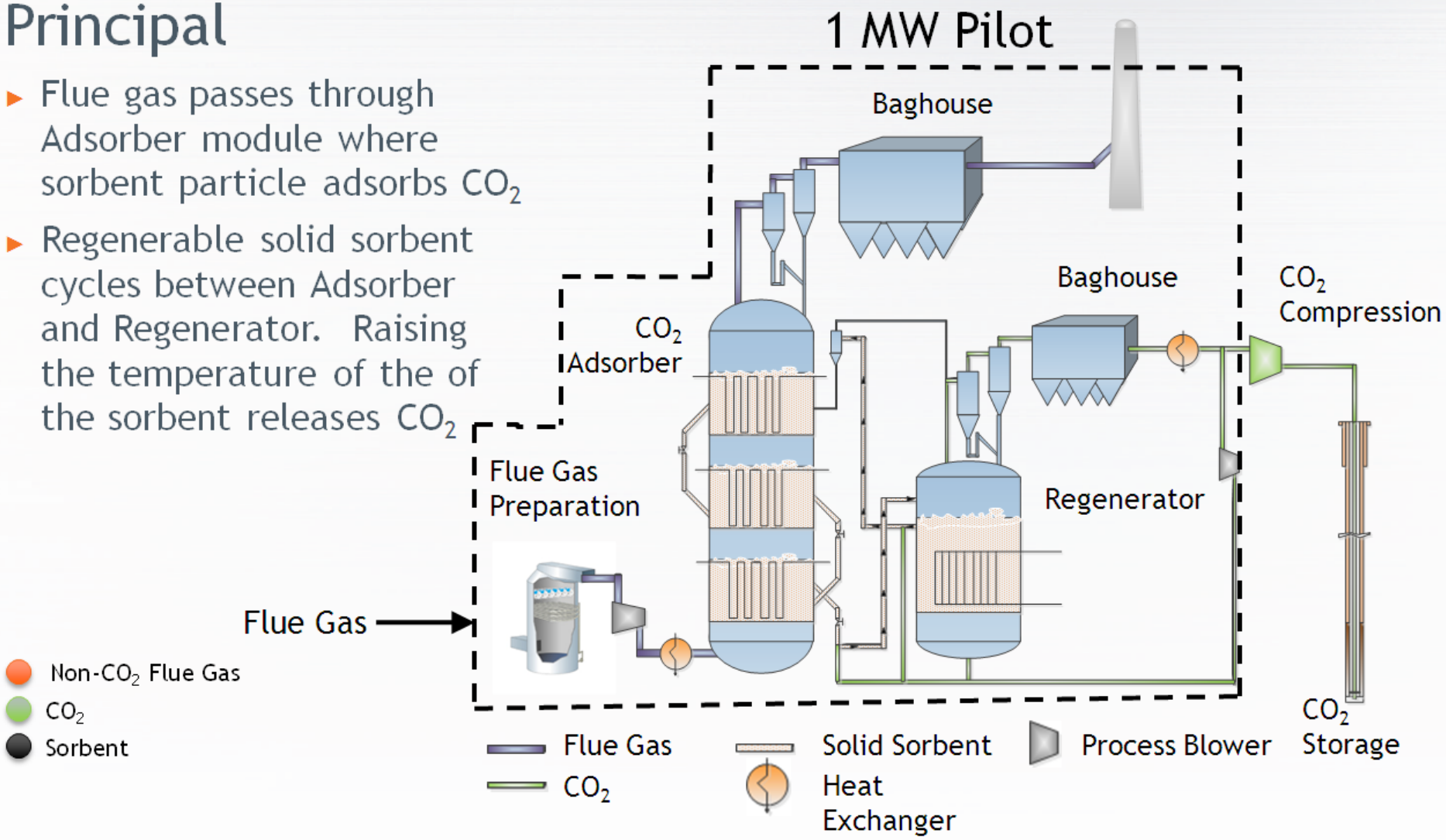
ADAsorb™ Process Conceptual Design

Principal

- Flue gas passes through Adsorber module where sorbent particle adsorbs CO_2
- Regenerable solid sorbent cycles between Adsorber and Regenerator. Raising the temperature of the of the sorbent releases CO_2



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Advantages of Solid Sorbents

- Energy Penalty -Sensible heat* and latent heat of evaporation are lower
- Non-corrosive - Less expensive materials of construction, no corrosion inhibitors required
- Low volatility - Reduced emissions of amines
- Water savings - Less cooling water required, minimal liquid waste, no process makeup requirements
- Process Flexibility and Operability
  - Can be applied to cycling plant "load following"
  - No risk of foaming or other solvent-related challenges
- Reactions with SO_2 may be reversible

**Heat recovery developed for liquid systems*

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ADAsorb™ CO_2 Capture Process

Advantages

- Heat transfer
  Isothermal operation
- Mass transfer favorable
- Proven at the industrial scale
- Approaches counter-current gas/solids contacting

Challenges

- Pressure drop
- Solids circulation
- Sorbent attrition
- Water adsorption
- Heat recovery

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Project Status

BP1

- Detailed characterization of sorbent
- 500 MW concept completed
- Design of 1 MW pilot completed

BP2

- Sorbent has been manufactured
- Detailed engineering of pilot completed
- Fabrication of pilot is underway

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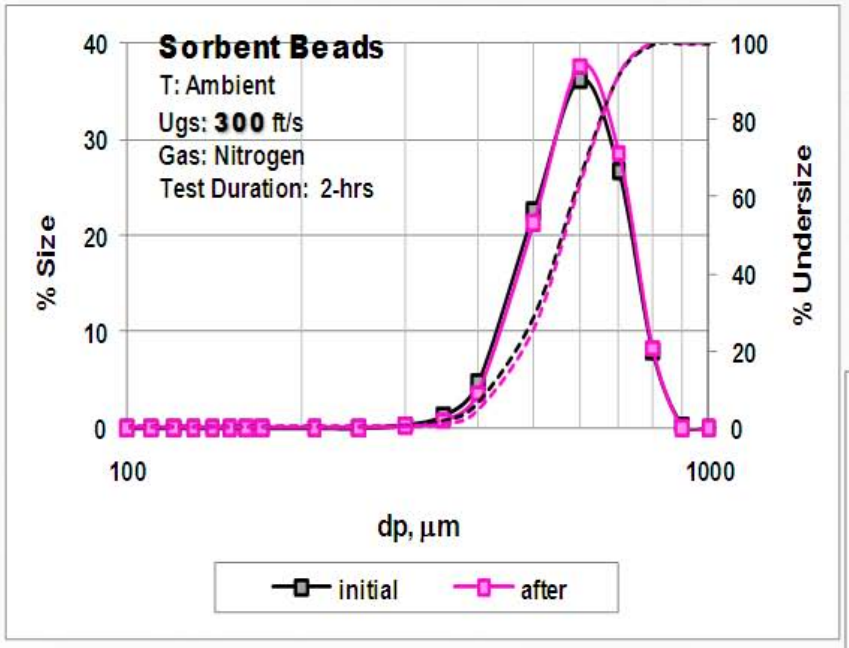
BP1 Pre-Engineering Activities - Examples

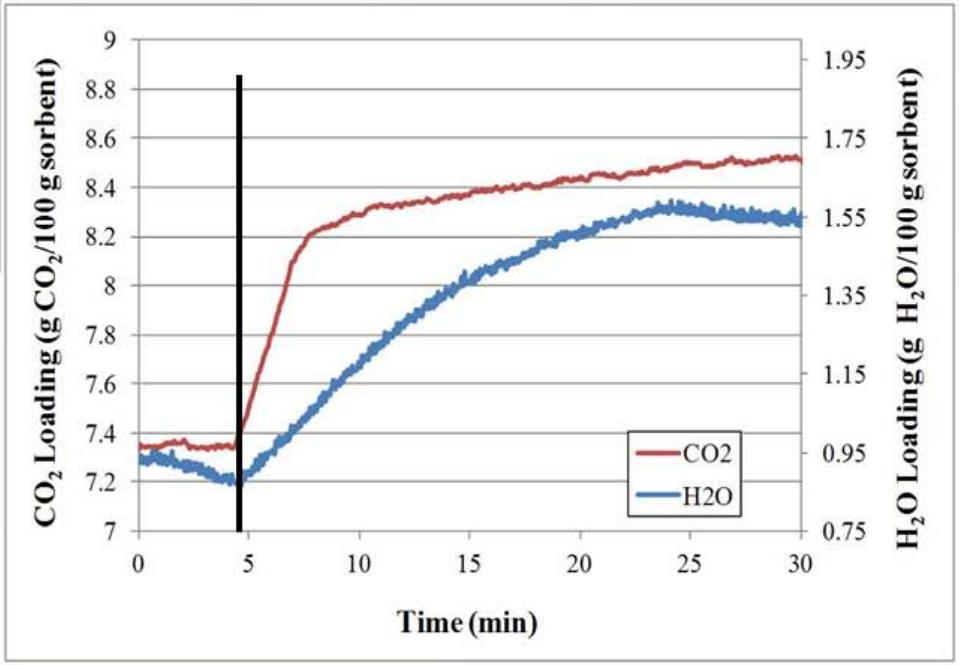
- CO_2 uptake
- H_2O uptake
- Specific heat capacity
- ΔH_{rxn}
- Cyclic Stability
- Attrition
- Heat transfer coefficient
- Hydrodynamics

BP1: Lab Characterization - Results



Attrition Resistant

Slow kinetics for H_2O



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Pilot Construction Activities

- Pilot designed in “modules”
- Off-site fabrication

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Construction Status

- Engineering design complete
- Major procurement complete
- Module Fabrication

  Module Fabrication ~ 50% complete
- Site Preparation

  Steam Line 70% complete, foundation work started

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Project Schedule Forecast

Task	Date
Modules Installed	Sept ’13
Substantial Completion of Mechanical and Electrical Installation	Dec ’13
Field Testing	2014

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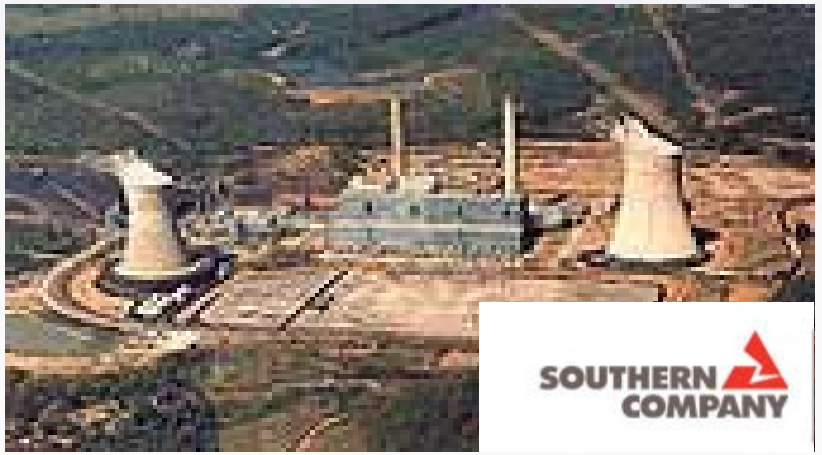
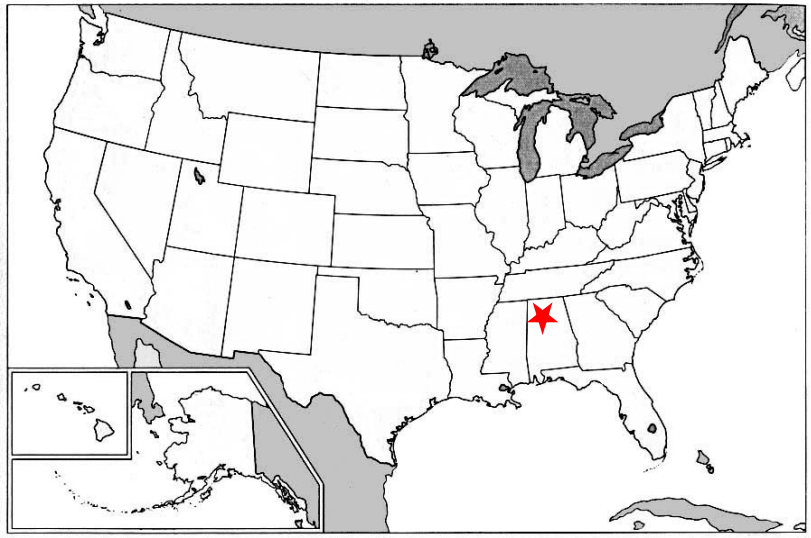
Process Validation Pilot Testing

- **Host Site:** Southern Company
  Alabama Power Co. Plant Miller
  - Flagship Plant
  - 4 EGUs (~2,640 MW_e)
  - PRB Coal
  - WFGD
- Pilot Designed for
  - 90% CO_2 Capture
  - ~2,100 lb CO_2/hr
  - Flue Gas Flow Rate
    ~ 3,500 ACFM





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Barge Access Area at Miller

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Module Arrival and Routing

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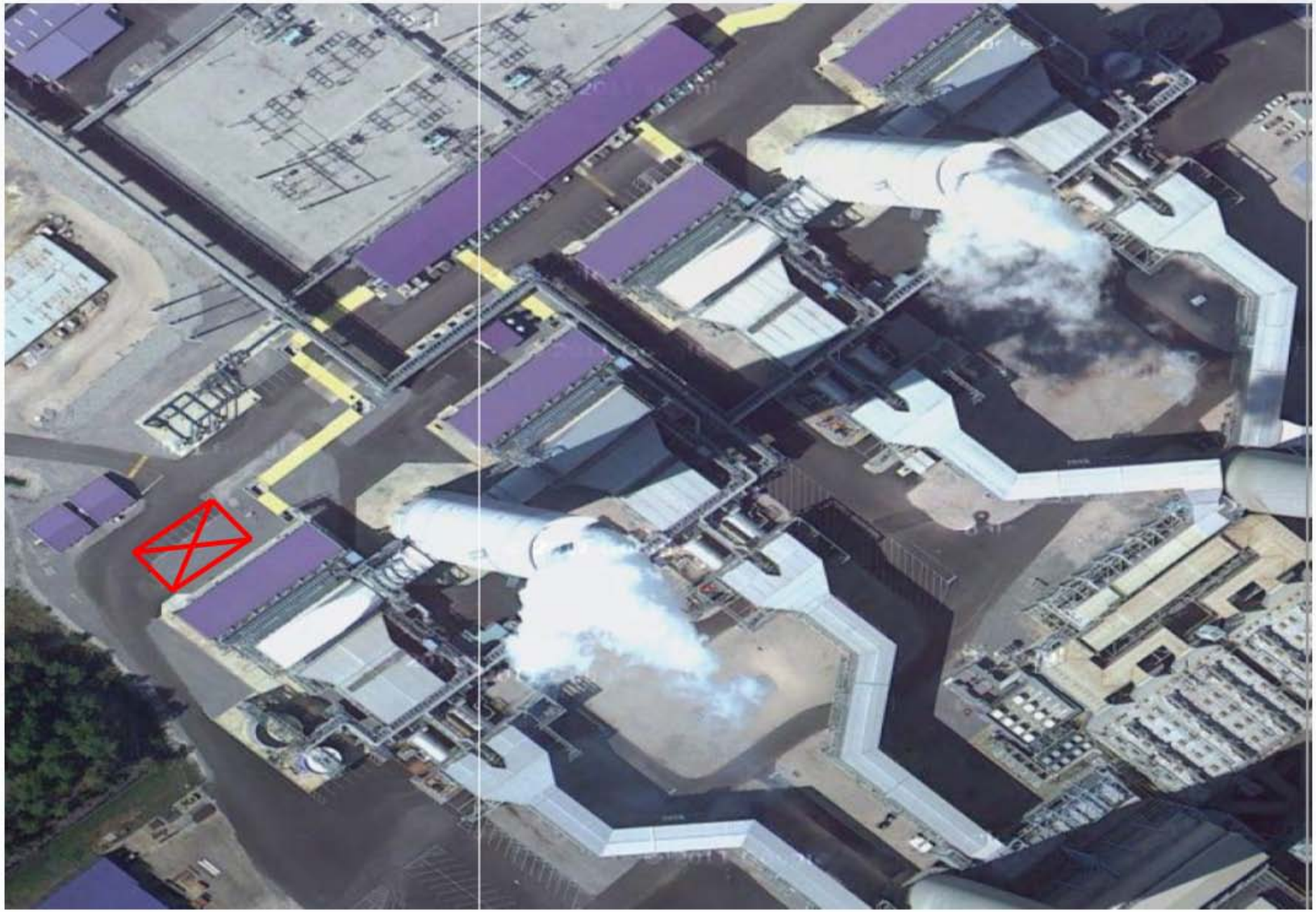
1 MW Pilot Location



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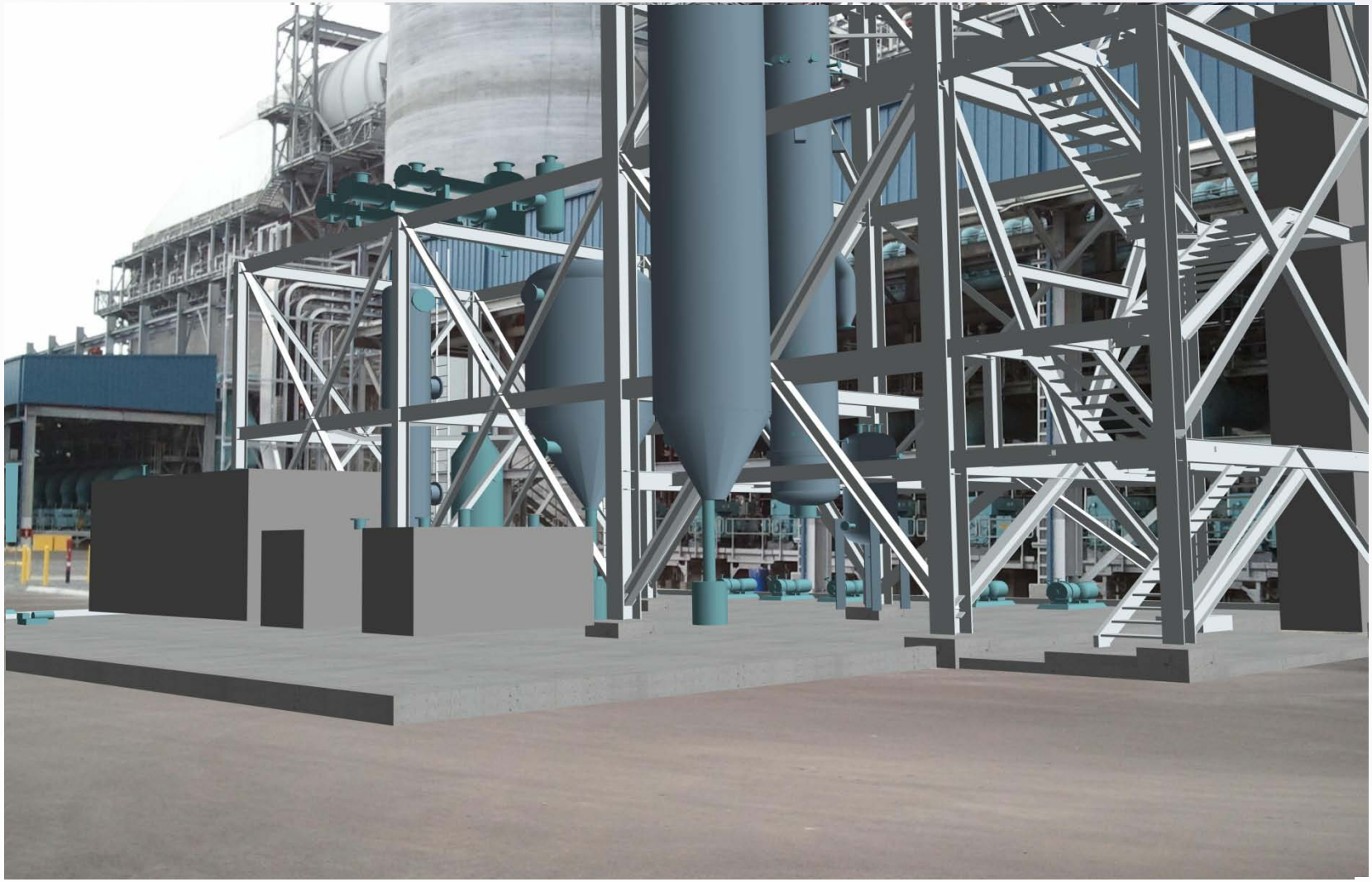
1 MW Pilot Location



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Upcoming Activities

- Complete construction, installation, and start-up of pilot
- Operate 1 MW_e pilot continuously for 60 days
- Use data from 1 MW_e pilot to update 500 MW design and complete a techno-economic analysis
- Provide a roadmap of future technology improvements based on sorbents and process

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Key Areas for Improvement

- Process
  - Heat Recovery
  - Heat Integration
- Sorbent
  - Fast Kinetics
  - Larger CO_2 Working Capacities
  - Higher Heat Transfer Coefficient
  - Improved Heat Tolerance
  - Lower Specific Heat Capacity
  - Lower Water Uptake
  - Lower Cost (*including replacement*)

- *Use pilot to evaluate process improvements*
- *Use pilot to test advanced sorbents*
- *Scale-up technology*

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Questions?

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