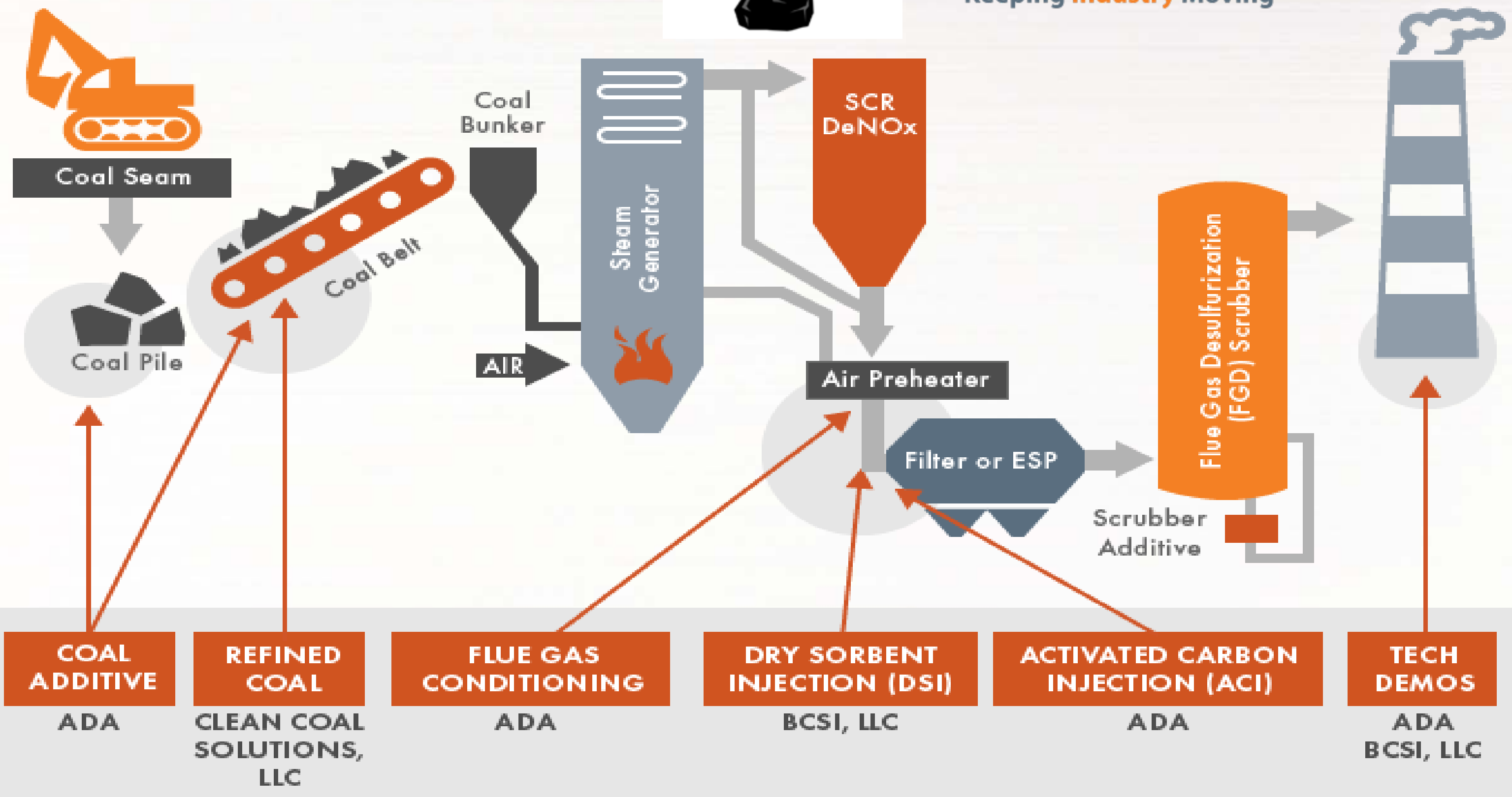
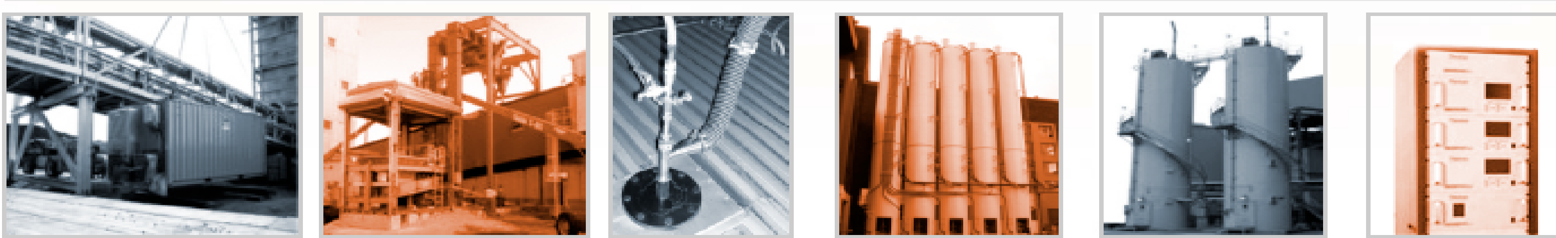
Evaluation of Solid Sorbents as a Retrofit Technology for CO_2 Capture

DE-FE0004343

July 29, 2014
ADA-ES, Inc.

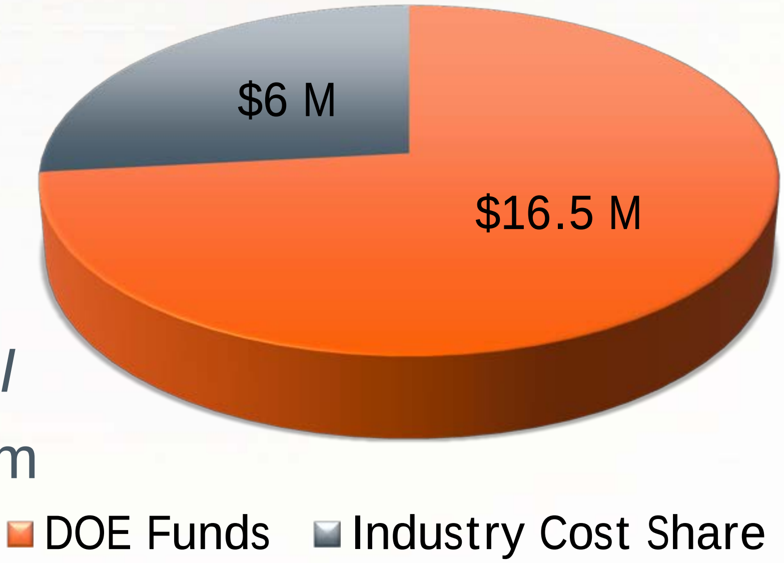
Advanced Emissions Solutions, Inc.





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

Project Overview

Period 1:
21 months

- 500 MW Concept and Sorbent Selection
- Design 1 MW pilot

Scale down to 1 MW

Oct '10 - June '12

Manufacture and Construction

- Manufacture Sorbents
- Fabricate and Install 1 MW pilot

Period 2:
18 months

July '12 - Sep '14

Period 3:
10 months

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

Demonstration Phase

Oct '14 - July '15

Project Team

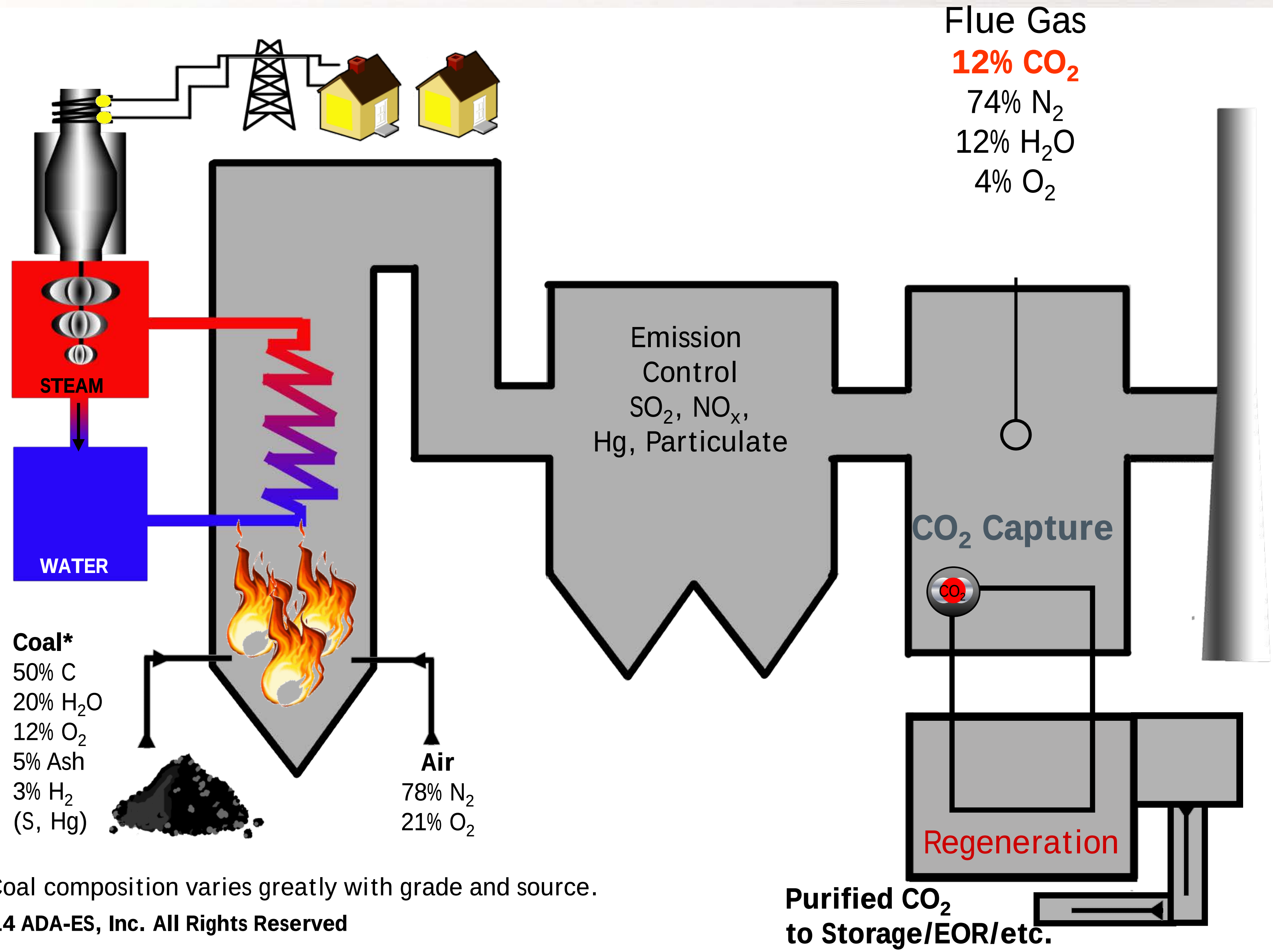
- DOE – NETL
  - o Project Sponsor
- ADA-ES, Inc.
  - o Project Management
  - o Developed Process Concept
  - o Sorbent Eval & Selection
  - o Process Validation Testing
  - o Techno-Economic Assessment
- Technip Stone and Webster Process Technology
  - o Detailed Engineering Services

    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

Post-Combustion CO_2 Capture



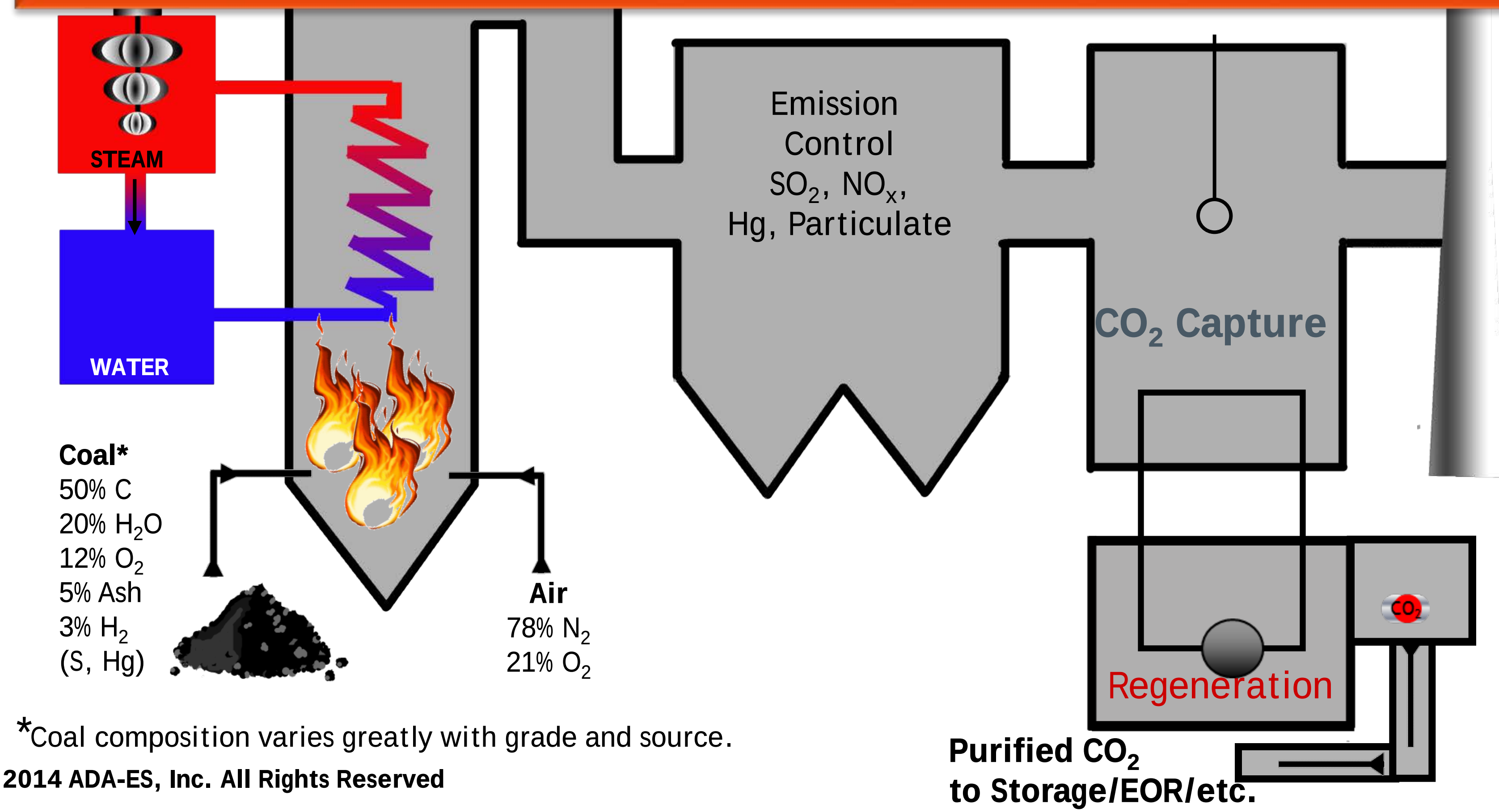
*Coal composition varies greatly with grade and source.

Post-Combustion CO_2 Capture

Solids functionalized with amines react with CO_2 at "low" temperatures

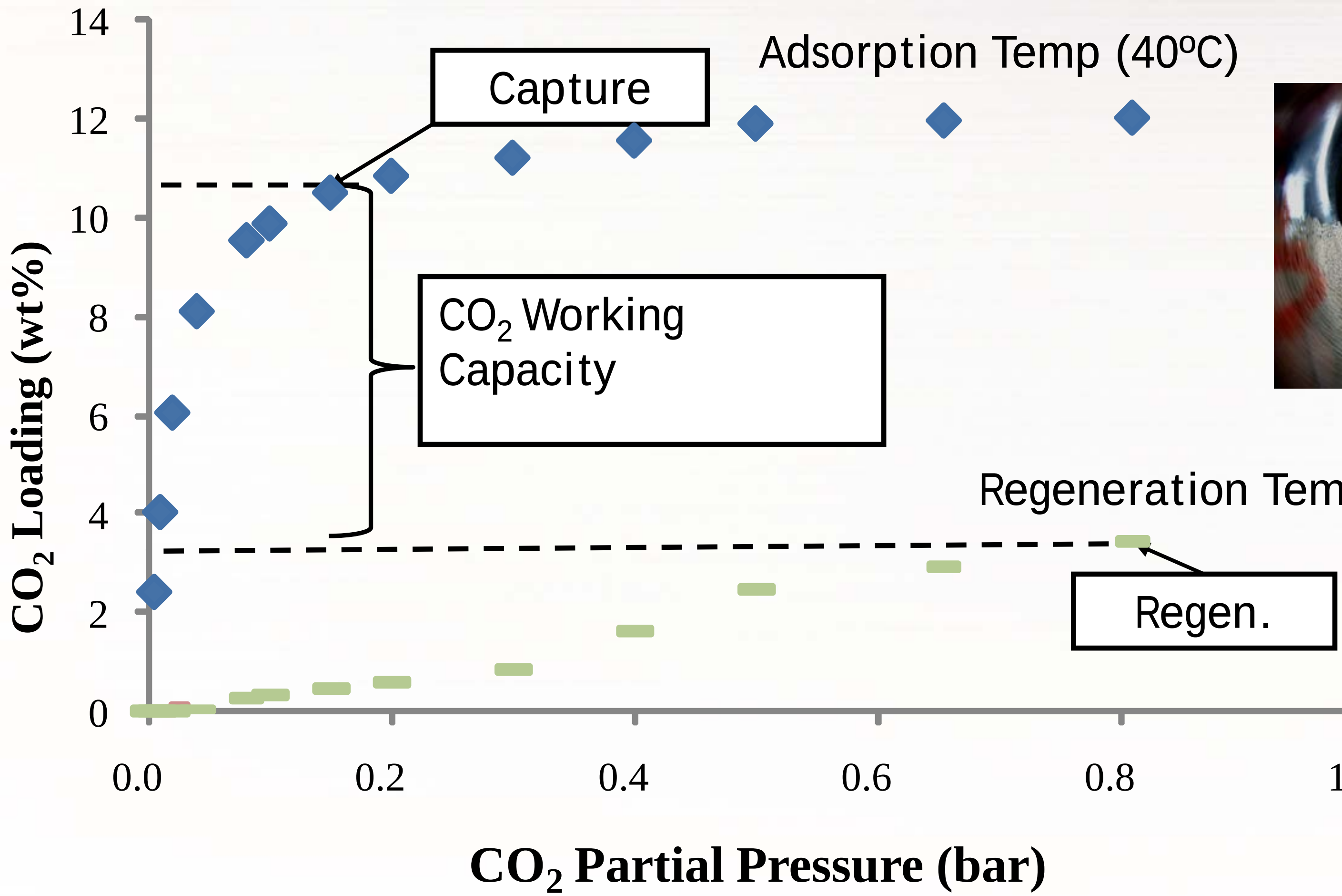
Solids are heated to reverse reaction with CO_2

Temperature swing adsorption (TSA)



*Coal composition varies greatly with grade and source.

Sorbent Isotherms

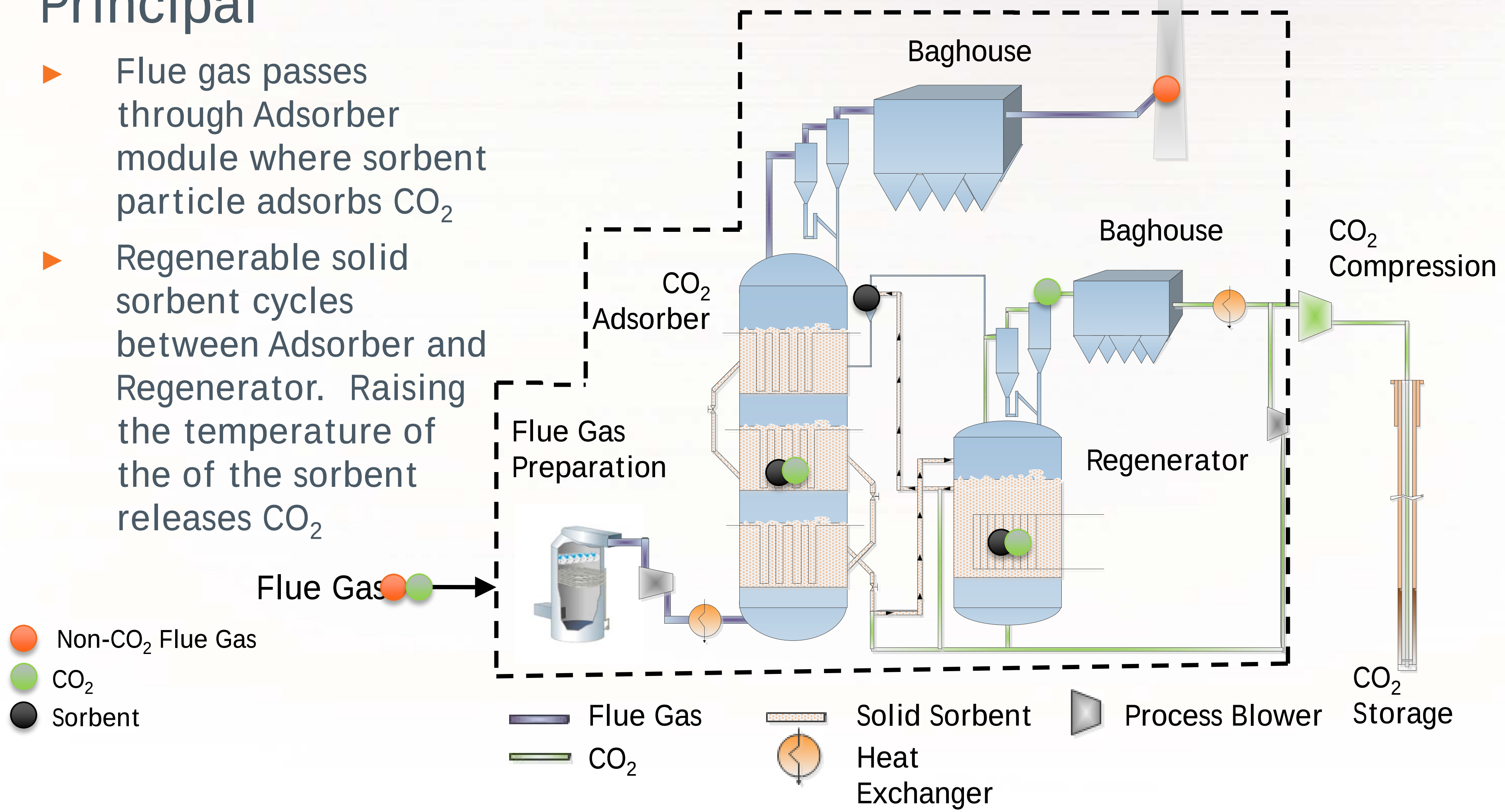


Process Conceptual Design

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

1 MW Process Validation Unit



Development Approach

Phase I: Concept → **Phase II: Pilot Testing (1 MW)** → **Phase III: Demonstration (> 25 MW)** → **Commercial Implementation**

- Begin with the end in mind
- Identify cost drivers
- Focus R&D and execute work schedule with commercialization goal in mind

2008 - 2011
Phase I

2011 - 2014
Phase II (1 MW Pilot)

2015 - 2019
Phase III (>25 MW Demonstration)

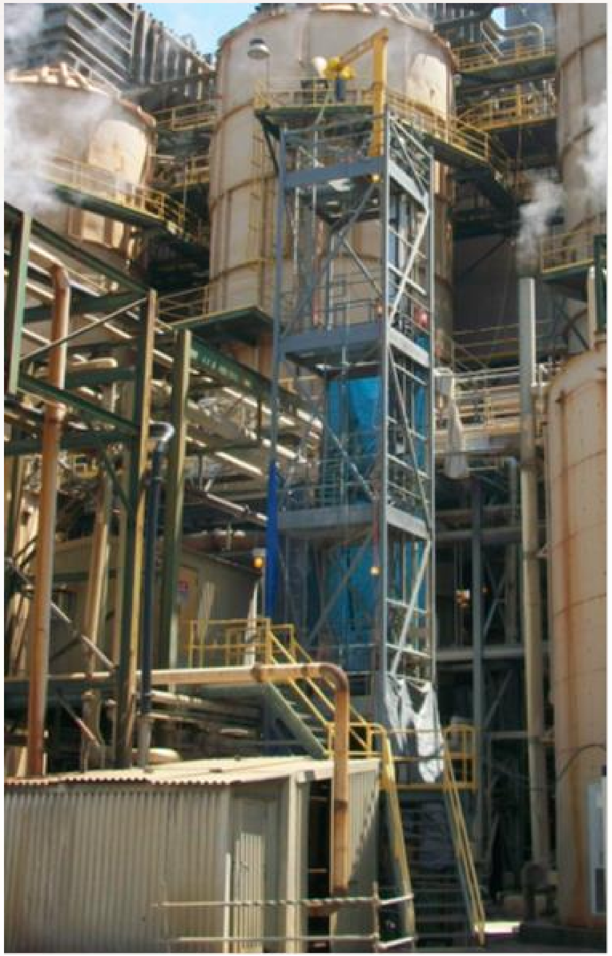
DE-FE0004343

2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019

Advancing Cleaner Energy

Phase I: Viability Assessment

- ✓ Evaluated over 250 candidate sorbents
- ✓ Refined sorbent properties
- ✓ Designed, built, and tested a 1kW entrained flow reactor
- ✓ Developed full-scale concept for initial cost estimate



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
- No risk of foaming or other solvent-related challenges
- Reactions with SO_2 may be reversible

**Heat recovery developed for liquid systems*

ADAsorb™ CO_2 Capture Process

Advantages

- Heat transfer
  Isothermal operation
- Mass transfer favorable
- Proven at the industrial scale
- Approaches counter-current gas/solids contacting
- Process Flexibility
  Can be applied to cycling plant "load following"

Challenges

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

Project Status

BP1

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

✓

BP2

- Detailed engineering of pilot complete
- Sorbent has been manufactured
- Fabrication of pilot is complete
- Installation of pilot is complete
- Commissioning of pilot has begun

✓

BP3

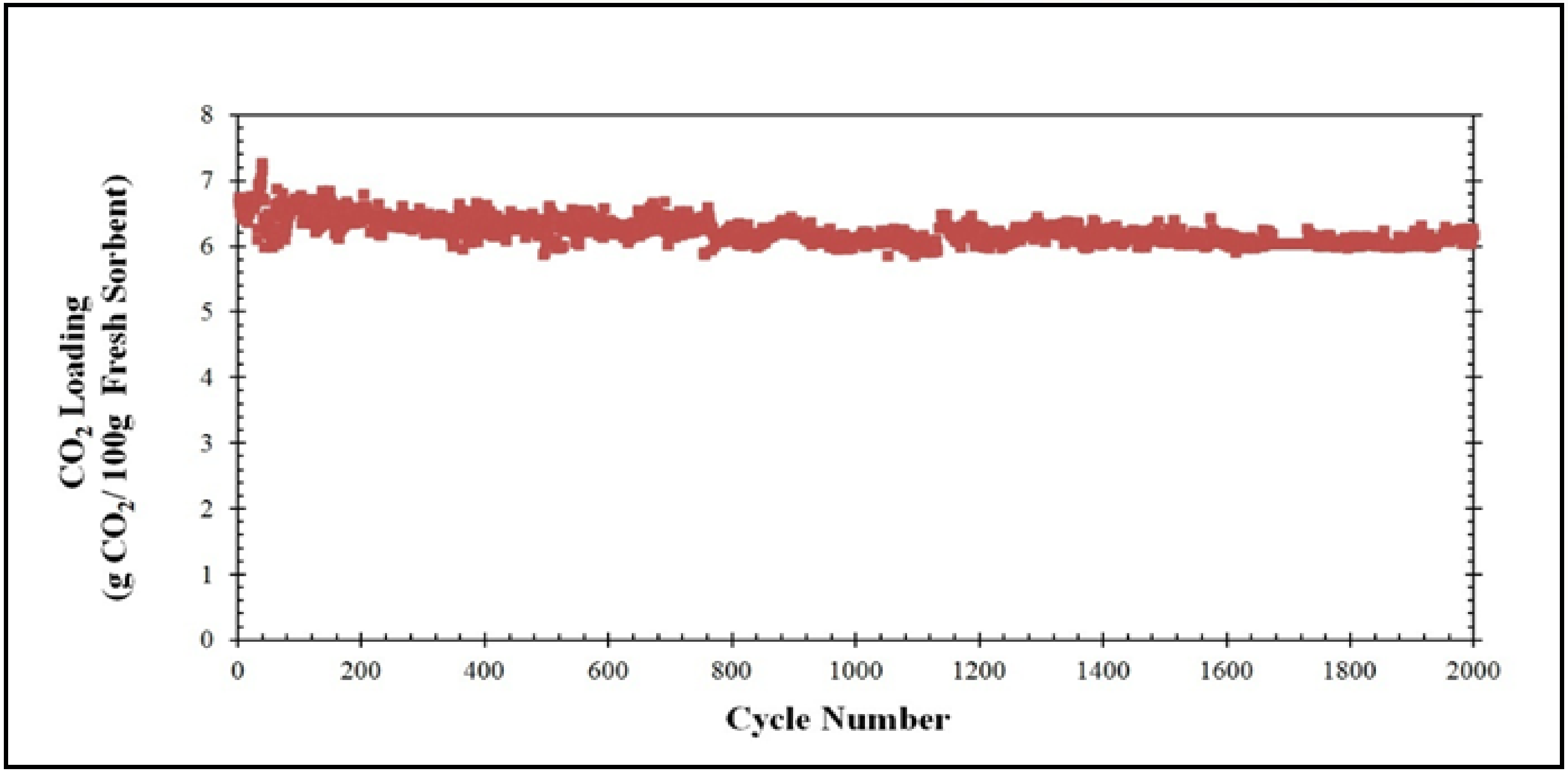
- 1 MW Testing
- Develop 500 MW Preliminary Design
- Conduct Techno-economic analysis

BP 2: Process Investigations

- Design and build Cold Flow Model to investigate fluidization behavior
- Determine requisite particle size distribution
- Investigate attrition
- Measure heat transfer coefficient

BP2: Sorbent Stability

- Sorbents must be able to maintain working capacity over thousands of cycles:



BP 2: Sorbent Stability

- Possible destruction mechanisms that must be avoided:
  - Amine functional group oxidation
  - Breakage of amine-substrate bond
  - Formation of heat stable salt with amine functional group (e.g. SO_2 poisoning)

Pilot Fabrication Activities

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

Pilot Module Transport

Pilot Installation

Project Schedule Forecast

Task	Date
Commissioning/Dry Startup	Aug-Sept ’14
Sorbent Circulation	Sept ’14
Field Testing	Oct-Nov ‘14

Pilot Testing: Host Site

- Southern Company Plant
  - PRB Coal
  - WFGD
- Pilot Designed for
  - 90% CO_2 Capture
  - ~2,100 lb CO_2/hr
  - Flue Gas Flow Rate ~ 3,500 ACFM

Pilot Testing: Focus Areas

- Sorbent attrition physical & chemical
- Volatile emissions
- Validate regeneration energy requirement
- Measure actual adsorption temperatures to maintain 90% CO_2 capture
- CO_2 purity
- Sorbent regeneration time
- Process effects from flue gas constituents
- Determine rate limiting steps
- Optimize process variables
  - Temperatures
  - Sorbent circulation rates

Next Steps

- Pilot Testing: Fall 2014
- Techno-economic analysis: 2015
- Continue evaluating options for post-pilot scale-up
  - Regulatory drivers alone do not justify continued investment
  - Will final regulations and oil prices support use of fossil-generated CO_2?

Advancing Cleaner Energy

Questions?

Sharon Sjostrom
Chief Technology Officer
sharons@adaes.com

Jayson Denney
Project Manager
Jayson.Denney@adaes.com