Evaluation of Solid Sorbents as a Retrofit Technology for CO_2 Capture from Coal-Fired Power Plants

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Who Is ADA? *(NASDAQ: ADES)*

Technology Development And Services

Mercury Measurement
Mercury Control
Flue Gas Conditioning
Beneficial use of Ash
Clean Coal Additives
CO_2 Capture

Emission Control Systems

Mercury Control (ACI)
Flue Gas Conditioning

Activated Carbon

Interim Processing
Production Facilities
Logistics

*ADA **develops and commercializes innovative technologies** to sustain the viability of coal as a critical national resource.*

Technology Development Approach

Phase I
Viability:
Field Tests
Assess Equip.

Phase II
Pilot-Testing
(1 to 5 MW)

Phase III
Demonstration
(> 30 MW)

Commercial Implementation

Engineering Services

Equipment

Sorbent

DOE NETL CO_2 Project Team

NETL ($2M)

Project Manger: Andrew O'Palko

Cost Share Participants ($1.2M)

- ADA
- AEP
- Ameren
- EPRI
- Luminant
- North American Power
- Southern Company
- Xcel Energy

Key ADA Personnel

- Holly Krutka: Sorbent Assessment
- Tom Campbell: Pre-Pilot Testing
- Cam Martin: Process Engineering

Key Contractors

- Adsorption Research, Inc.
- Stantec
- Jenike & Johansson

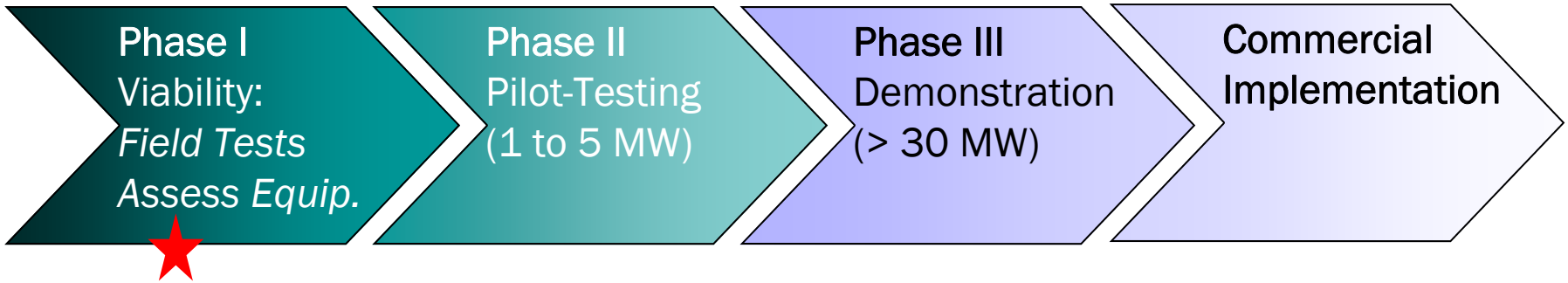
Project Objective

- Assess the viability and accelerate development of solid-sorbent based capture technology for the fleet of coal-fired power plants

Solid Sorbent Development Targets

- Retrofit technology for existing plants
- **High CO_2 removal** (> 90% achievable)
  - Economics of lower targets will be assessed
- **Low Cost** *compared to other options*
  - Maintain costs below $20/ton CO_2
- Produces **high purity CO_2** stream

Development Approach



We Are Here

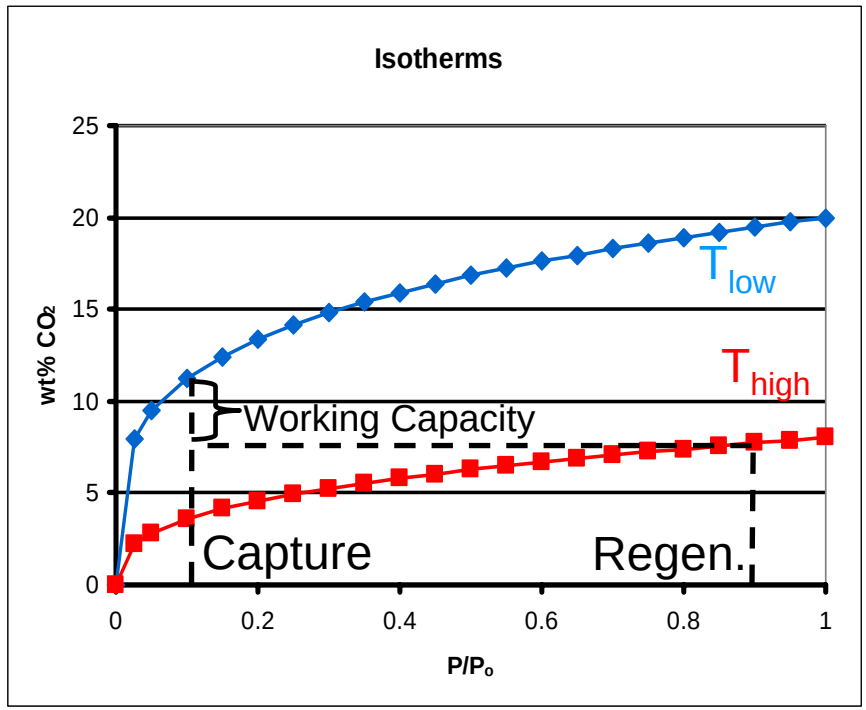
Phase I: Viability Assessment for Temperature Swing Adsorption

- Screen existing and developmental sorbents
- Evaluate promising materials at field sites:
  Phase I scale: ~1 Ton CO_2/day
- Conceptual equipment design and initial economics for 500MW plant

Temperature Swing Adsorption (TSA)

Sorbent Success Criteria:

- Working capacity
- Reaction Energy
- Theoretical Regeneration Energy
- Consistent performance
- Reaction Kinetics
- Durability
- Cost



Theoretical Regeneration Energy

*

$$\frac{Q}{m_c} = \frac{m_e}{m_c} C_e \Delta T + \frac{B}{L} C_s \Delta T + C_{p.c} T_2 - C_s T_1 + \frac{Q_r}{m_c}$$

Energy To Heat Equipment	Energy To Heat Sorbent	CO_2 Phase Change	Rxn

Chemisorbents — Dominant

Physisorbents — Dominant

*Hoffman, J.S., Richards, G.A., Pennline, H.W., Fischer, D., Keller, G, (2008) *Factors in Reactor Design for Carbon Dioxide Capture with Solid, Regenerable Sorbents*, Clearwater Coal Conference, Clearwater, FL.

Project Approach: Phase I

Dual Focus

Sorbents

1st Gen Screening. → 2nd Gen Screening → Pre-Pilot Testing

Phase I Viability Assessment

Equipment

Survey & Assessment. → Costs & Impacts → Design:
500 MW Concept
1 MW Pilot

Sorbent Assessment Task

- **Screening** at lab-scale (< 3g sorbent) on simulated and actual flue gas (20 to 30 materials)
- Supplemental sorbent characterization tests in lab (Scale-up candidates)
- **Parametric testing** at pre-pilot-scale (~ 1000 lbs sorbent)
  3 test sites:
  - *Xcel Energy Sherco: scrubbed PRB,*
  - *Alabama Power Gaston: scrubbed bituminous,*
  - *Luminant Martin Lake: scrubbed lignite*

  Is ≥ 90% CO_2 capture continuously achievable ??

Update: Sorbent Assessment

28 sorbents tested to-date at lab-scale

Success Criteria	**Results**
Working capacity	0 to >13.5 wt%
Consistent Performance	up to 60 cycles tested
$\Delta T_{capture\text{-}regen}$ Required	15-195^{o}C tested
Theoretical Regeneration Energy	700 to 40,000 kJ/kg CO_2

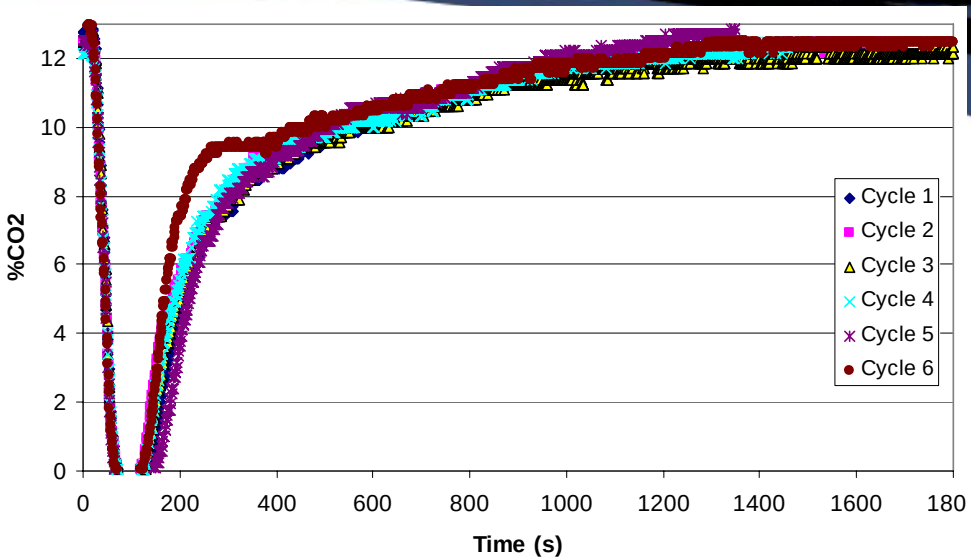
Benchmark: Aqueous MEA 4530 kJ/kg CO_2 (1930 BTU/ lb CO_2) [*]

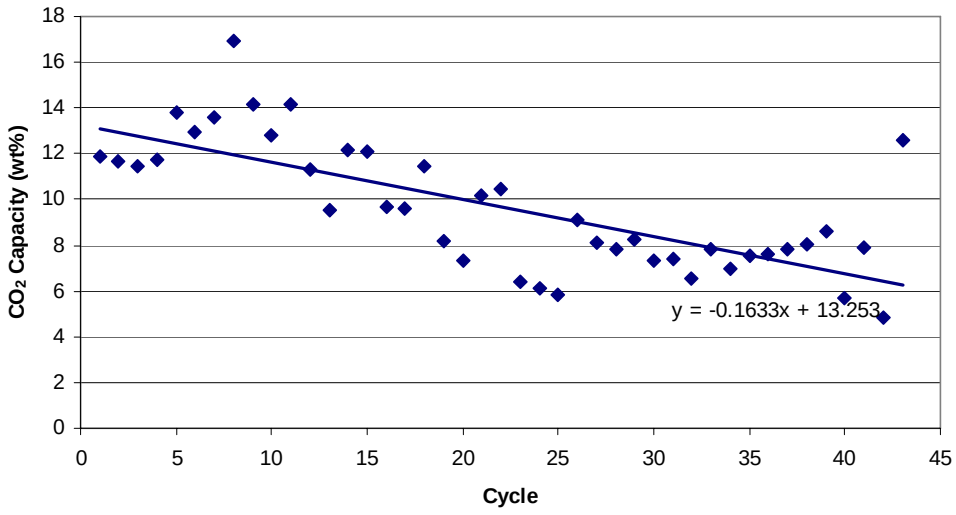
[*] Tarka, T.J., Ciferno, J.P., Gray, M.L., Fauth, D. (2006) *CO2 Capture Systems Using Amine Enhanced Solid Sorbents*. 5th Annual Conference on Carbon Capture & Sequestration, Pittsburg, PA.

Example: Supported Amine

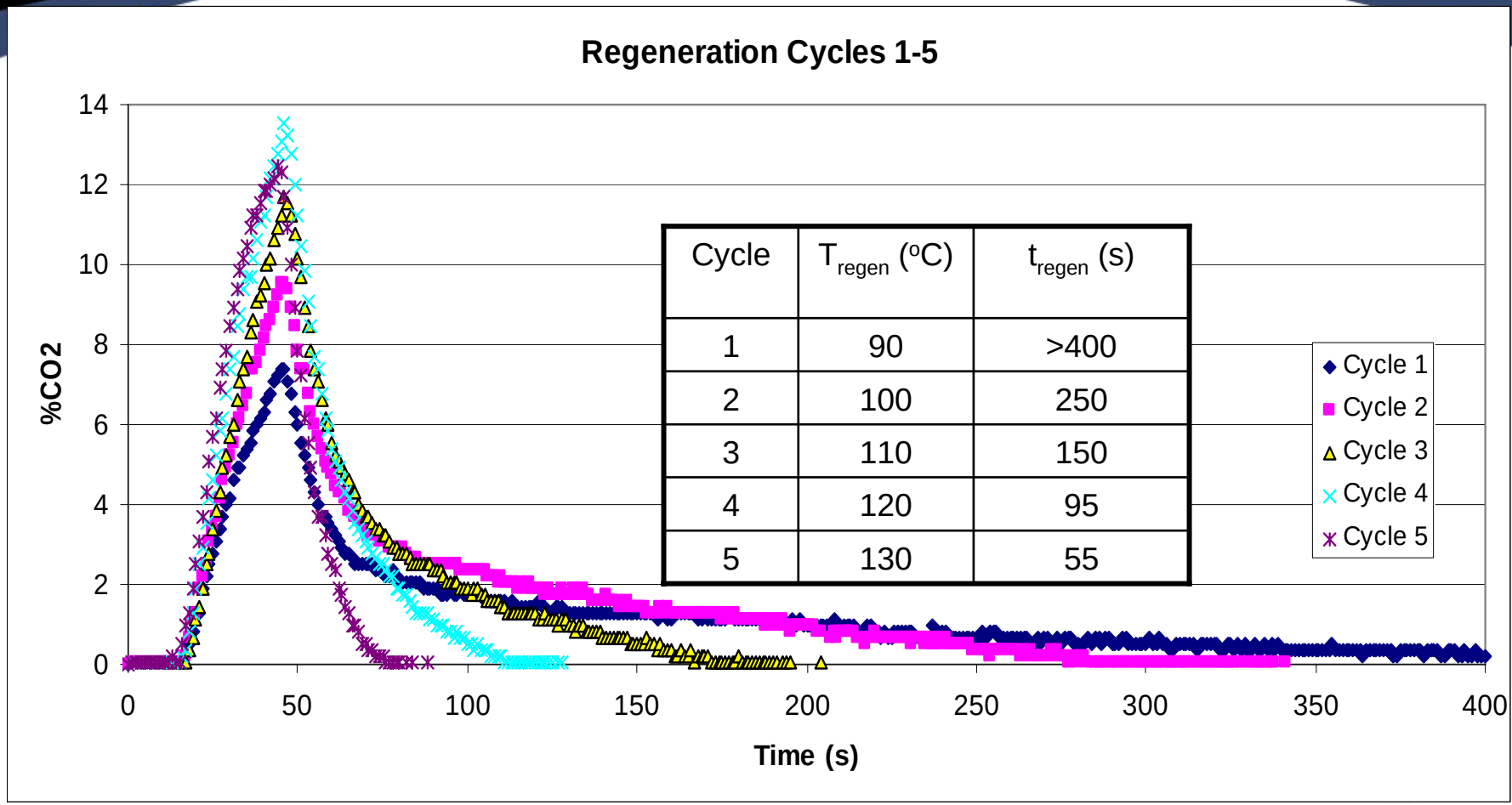
- 2.5 g tested
- Laboratory (6 cycles)
  - Fast, complete regeneration
  - Regeneration: 80-100ºC
  - Working Capacity ~13wt%
- Field (43 cycles)
  - Regeneration at 100ºC
  - Decreasing capacity
- TRE: 1700 kJ/kg CO_2 (740 BTU/lb CO_2)

Benchmark: 4530 kJ/kg CO_2



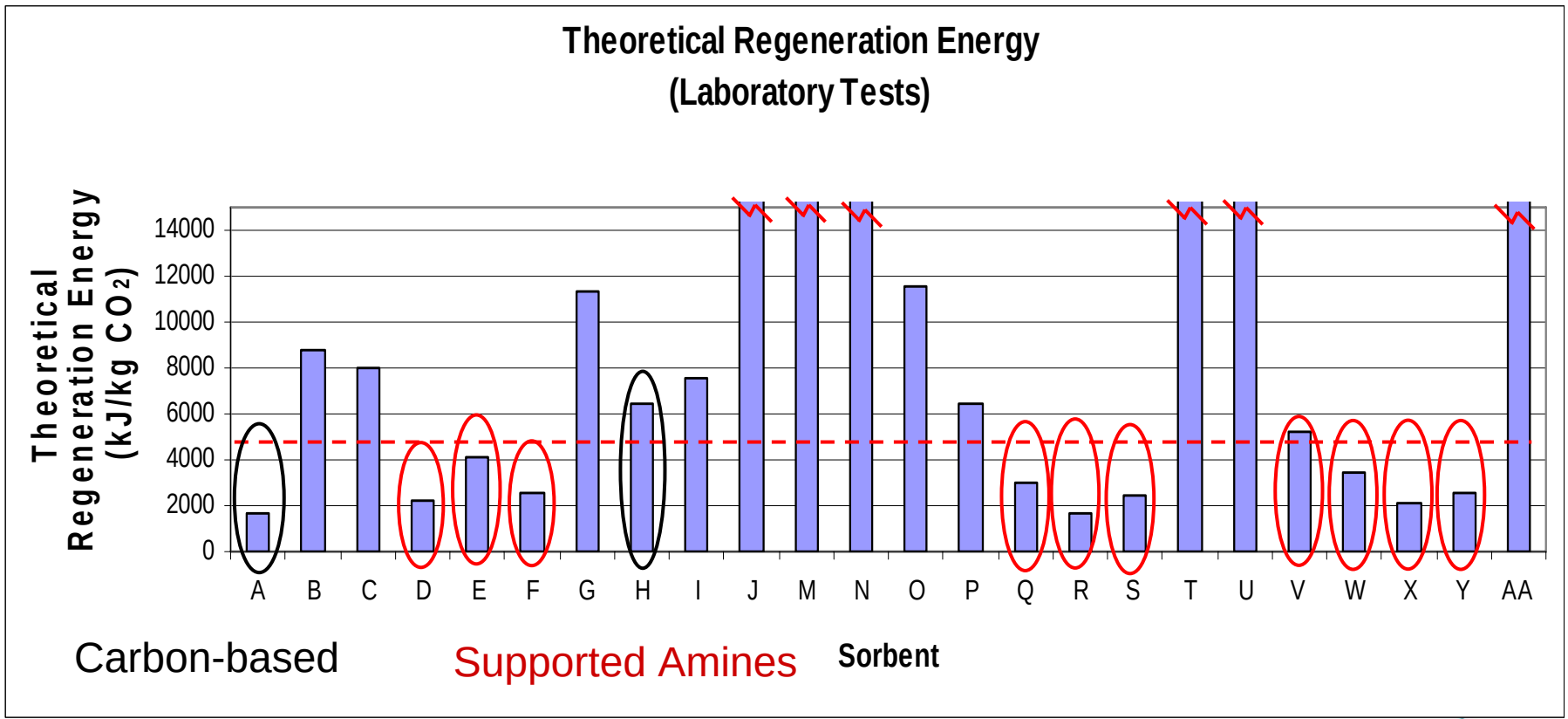


Example: Carbon Nanotube Regeneration



Cycle	T_{regen} (°C)	t_{regen} (s)
1	90	>400
2	100	250
3	110	150
4	120	95
5	130	55

Laboratory Screening Results



Sorbents A through J tested through EPRI contract

Screening Results: Summary

	Supported Amines	Carbonates	Carbon	Zeolites
Working Capacity	High	High	Low	Low
Thermal Stability	Low	High	High	High
TRE* *(vs aq. MEA)*	Lower	Higher	Similar	Higher
Issues	SO_2	SO_2		Moisture

** Theoretical Regeneration Energy*

What Can We Learn from Lab-Scale Testing

Fixed-Bed Screening

- **CO_2 Capture Effectiveness**
  - Working Capacity
  - Selectivity (CO_2, SO_2, NO_x, Hg and moisture)
  - Effect of SO_2, moisture, temperature, and regeneration cycles

Other Tests

- **CO_2 Capture Effectiveness**
  - CO_2 Isotherms
  - Reaction Kinetics
- **Physical Properties**
  - Particle Size, Surface Area
  - Density
  - Mechanical Strength
  - Attrition Potential
  - Cohesivity
- **Energy Requirements**
  - Heat of Adsorption/Reaction

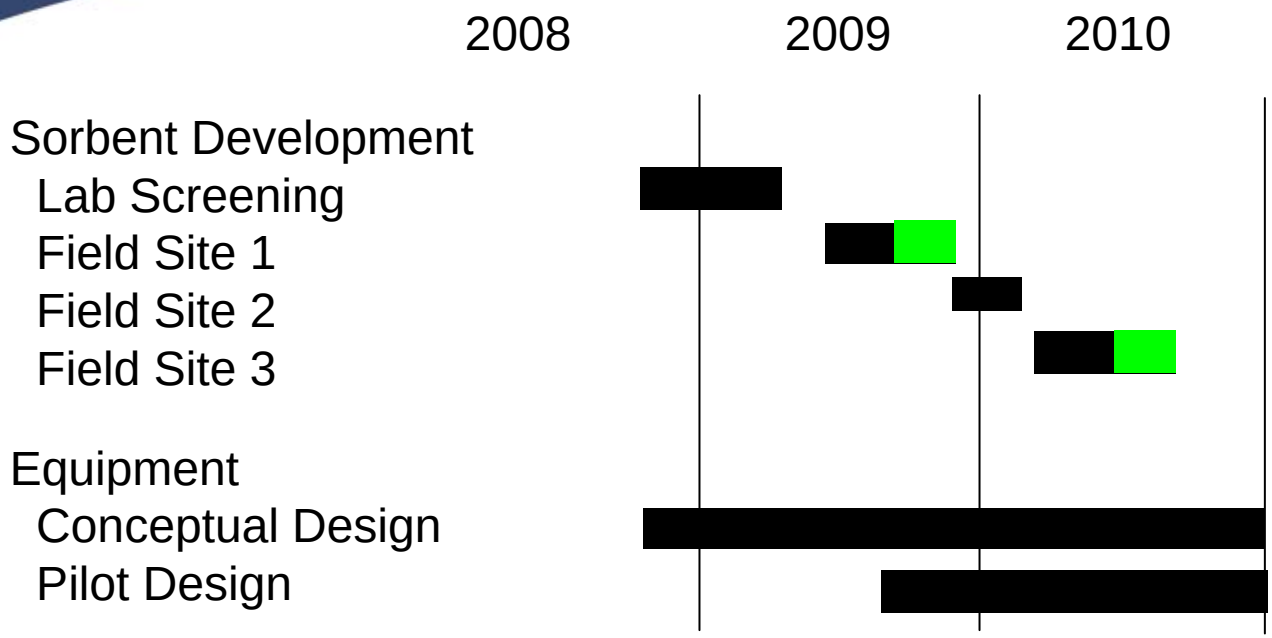
Update: Pre-Pilot Test Preparations

- Sorbent Scale-up:
  - Discussions with sorbent manufacturers underway *(Approximately 1000 lbs per sorbent required)*
- Phase I Contactor Activities:
  - Completed evaluation of pre-pilot contactor options
    - Fixed-bed
    - Moving-bed
    - ✓ Fluidized-bed
  - Preliminary Design should be completed 2Q09
    - Working with Southern Company Engineers who have developed the design concept and will support engineering efforts
  - Construction scheduled to begin immediately after completing design

Commercial Equipment: Technology Survey and Assessment

- Technology Survey – Gathering Info
  - Adsorption Technologies
  - Heat Transfer Technologies
  - Materials Handling Technologies
  - Desorption Technologies
- Develop Screening/Scoring Criteria
  - Modified Kepner-Tregoe
    Must-Wants Approach for each category
- Determine best 3 technology combinations for detailed analyses
  - Meet w/vendors, get budget quotes
  - Perform K-T on combined groups

Phase I Project Schedule



Included in DOE NETL/Industry proposed effort

Supplemental funding (pending)

Next Steps

- If results and economic projections are favorable, progress to Phase II – Pilot testing (1 to 5 MW)

Thank You