Solid Sorbents as a Retrofit CO_2 Capture Technology: Results from 1 kW Pilot Tests

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Luminant: Cliff Clark, George Willis
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Technical Approach

Phase I: Assess Viability

- **Technical**

  >90% CO_2 capture

  Produce high purity CO_2

  Scalable Sorbent

  Scalable Equipment

- **Economic**

  < 35% increase in COE

  - CapEX Drivers

    Size of Equipment

    Materials of Construction

    Process Complexity

  - OpEX Drivers

    Energy to release CO_2

    Energy to compress CO_2

    Sorbent Replacement

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Comparing Solid and Solvents

Parameter	Amine Enriched Sorbents	30% MEA*
Heat Capacity (BTU/lb_{sorb} F)	0.3	0.9
ΔT Regeneration (F)	80	100
Working CO_2 Capacity (%)	13.5	6.5
Regeneration Energy (BTU/lb CO_2)	760	1550
Volume of Material (ft^3/lb CO_2 captured)	0.16	0.27

** Most MEA values are from DOE/NETL*

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Phase I: Dual Focus Viability Assessment

Sorbents

- Lab Screening
- Lab-Scale Field Screening
- 1 kW Pilot Testing

Equipment

- Survey & Assessment
- Costs & Impacts
- Design
  - 500 MW Concept

<u>Objective</u>: *Assess the viability and accelerate development of solid-sorbents for CO_2 capture on the existing fleet of coal-fired power plants*

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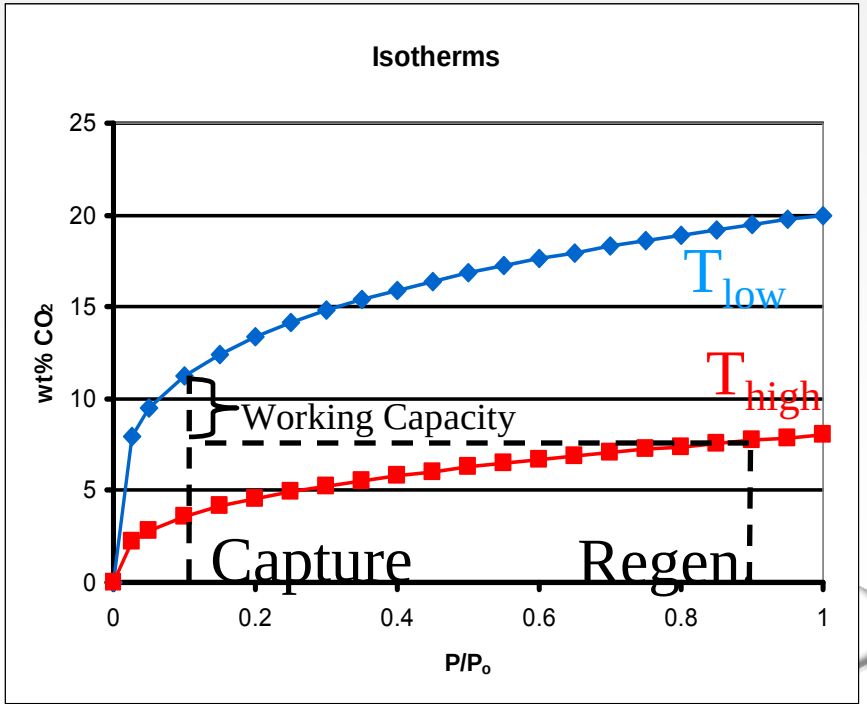
Sorbent Assessment

- Sorbent Families
  - Supported Reactants Chemisorption
    - Amines and Carbonates
  - Non-reacting Adsorbents Physisorption
    - Zeolites and Activated Carbon
- Success Criteria
  - Working capacity
  - Consistent performance
  - Theoretical Regeneration Energy



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Sorbent Selection Focus Areas

Lab-Scale Testing Results

- Effect of Moisture
- Effect of Flue Gas Constituents
- Theoretical Regeneration Energy
  - Theoretical RE : 700 to 40,000 kJ/kg CO_2
  - Working Capacity : up to 14%
  - $\Delta T_{ads.-regen.}$: 25 to 250°F (15 to195°C)
- Cyclic Stability : up to 260 cycles
- Rate of Reaction (qualitative)

Over 100 materials from 22 different sources tested at ADA

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Sorbent Selection

	Amines	Carbon	Zeolites	Carbonates
• Effect of Moisture			X	
• Effect of Flue Gas Constituents	X	X		X
• Theoretical Regeneration Energy				
– Theoretical RE			X	X
– Working Capacity	X	X		X
– $\Delta T_{ads.-regen.}$				
• Cyclic Stability		X		
• Rate of Reaction (qualitative)				

Promising Materials: Supported Amines and Activated Carbon

Five supported amine materials indicate initial promise.
Two produced in 600 lb quantities for 1 kW pilot testing.

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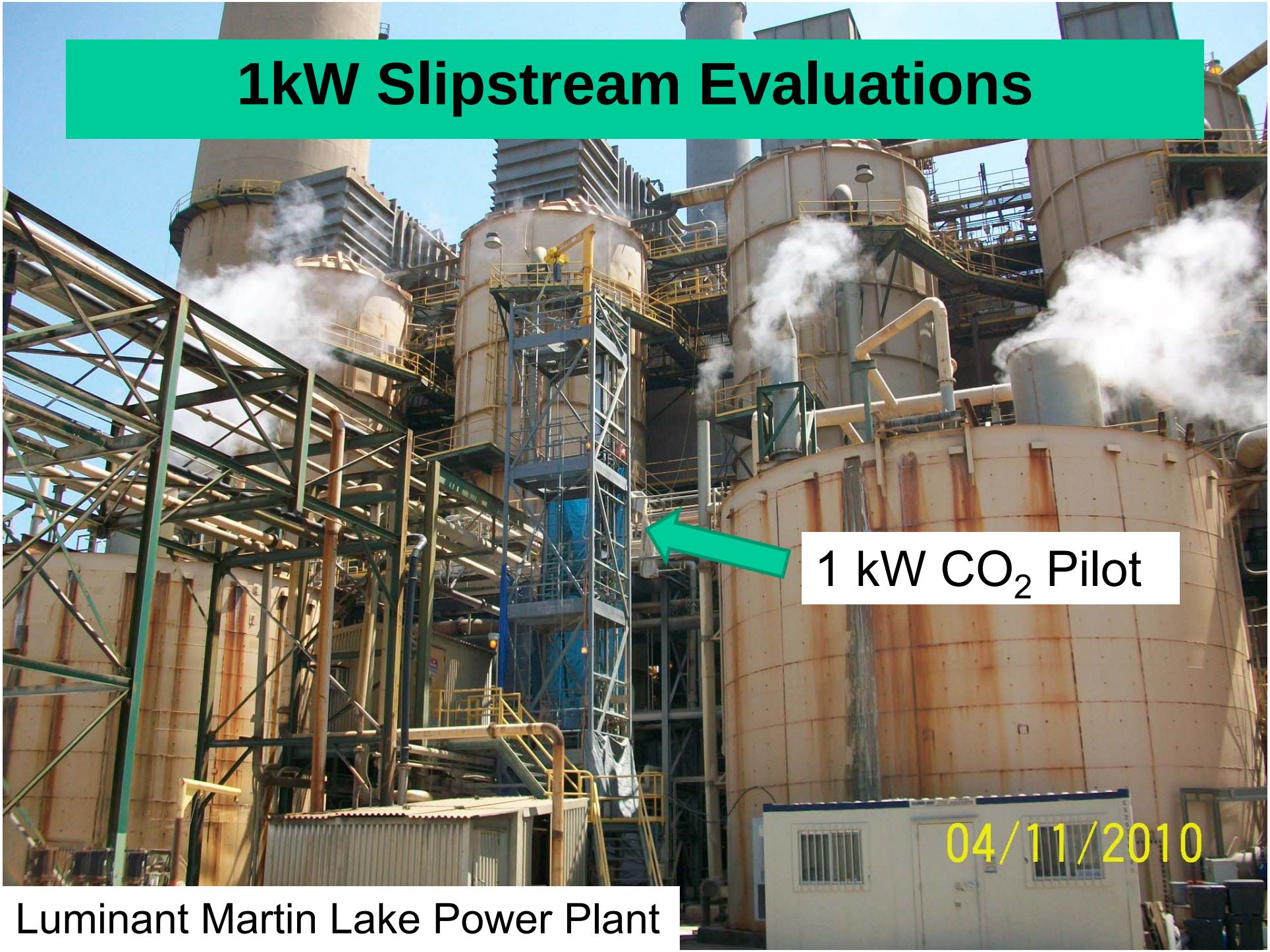
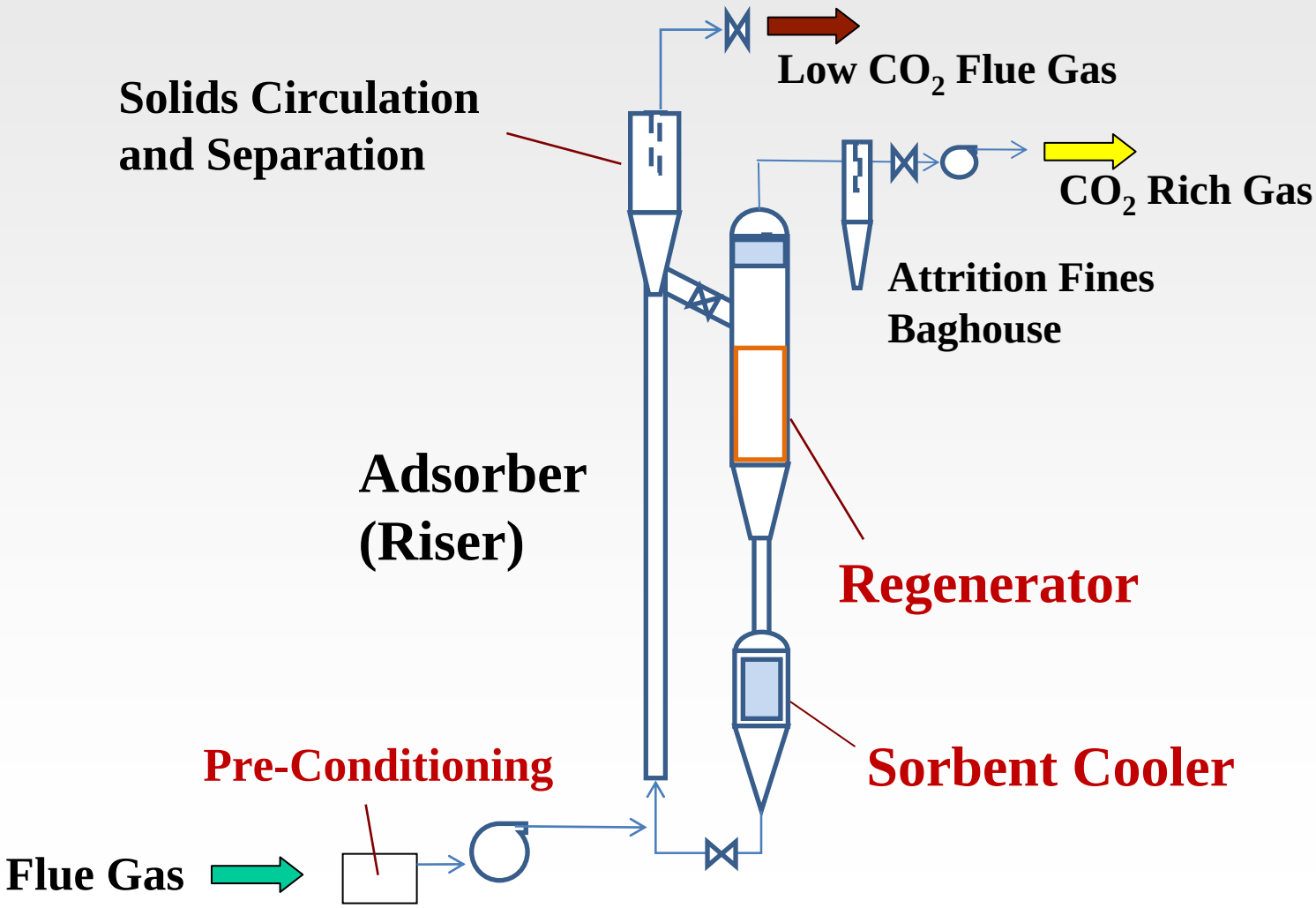
1kW Slipstream Evaluations



Luminant Martin Lake Power Plant

1kW Pilot System



Process concept provided by Southern Company

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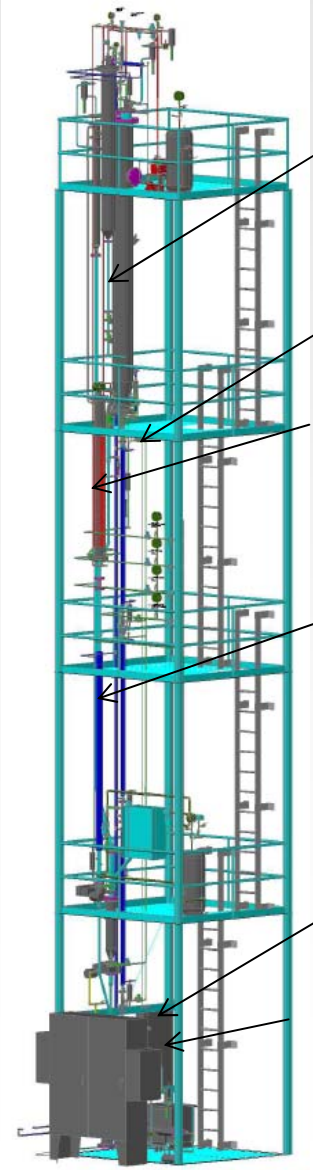
1 kW Pilot

Physical Dimensions:

- Footprint: 8’ x 10’
- Overall Height: ~60’
- Gas Flow: ~ 5 acfm



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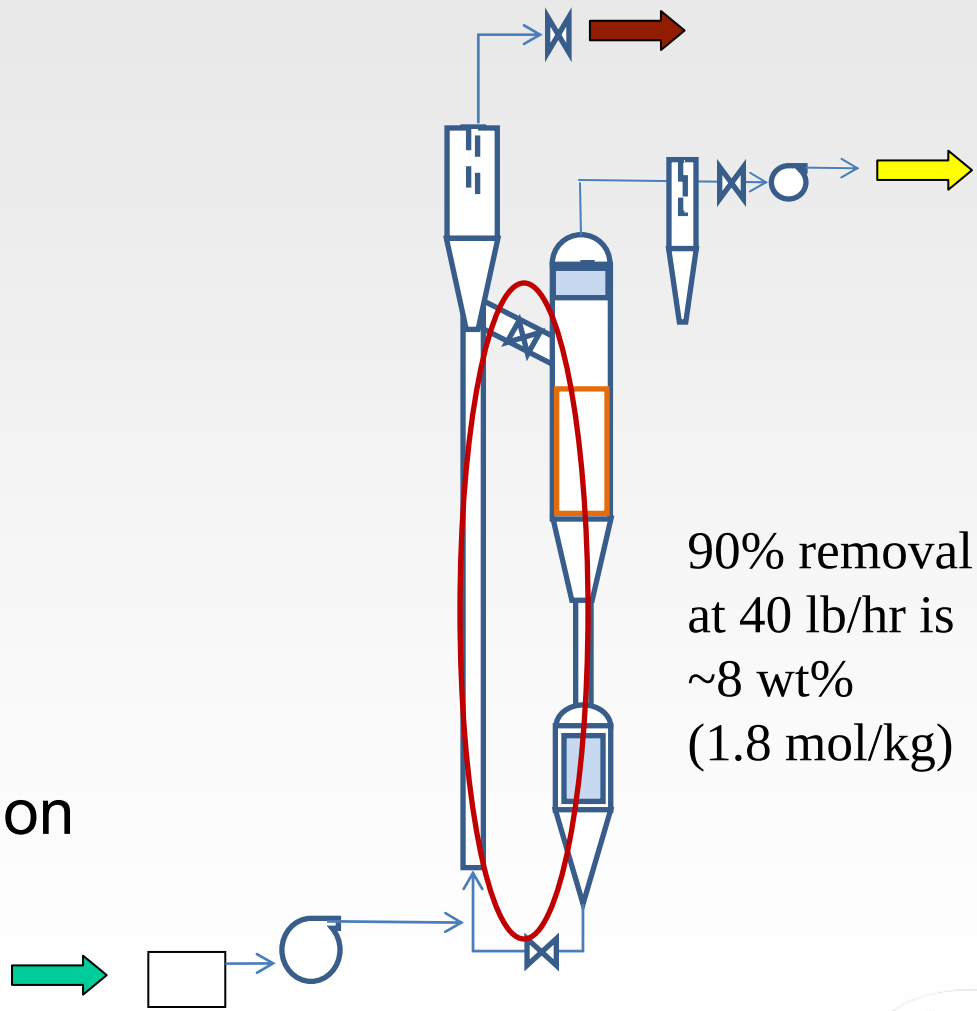
System Operation

- Continuous
  - Adsorption and regeneration simultaneously
- Batch
  - Adsorption and regeneration are separate
  - Increase regeneration time



90% removal at 40 lb/hr is ~8 wt% (1.8 mol/kg)

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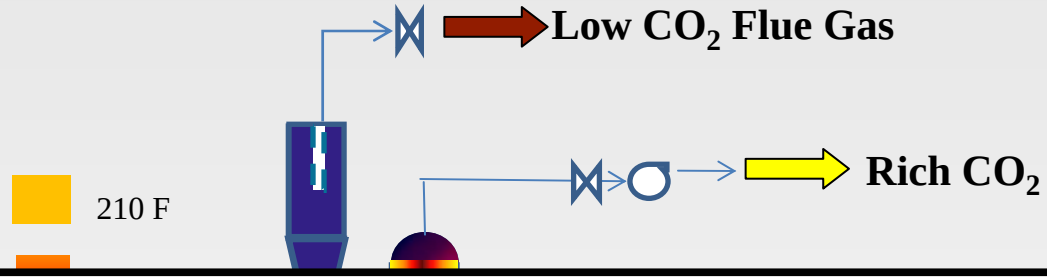
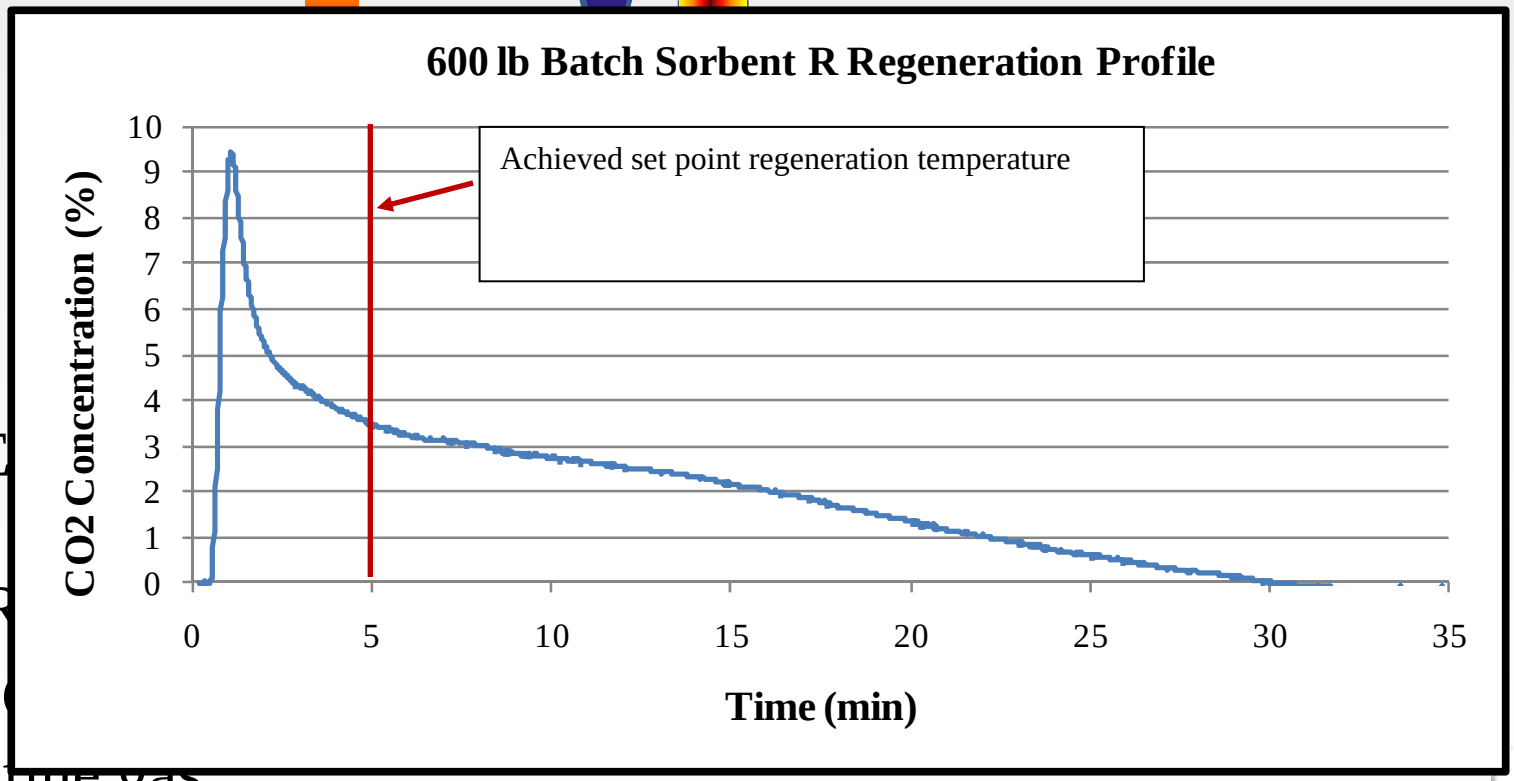
1 kW Pilot with Sorbent R





E

R

flue gas

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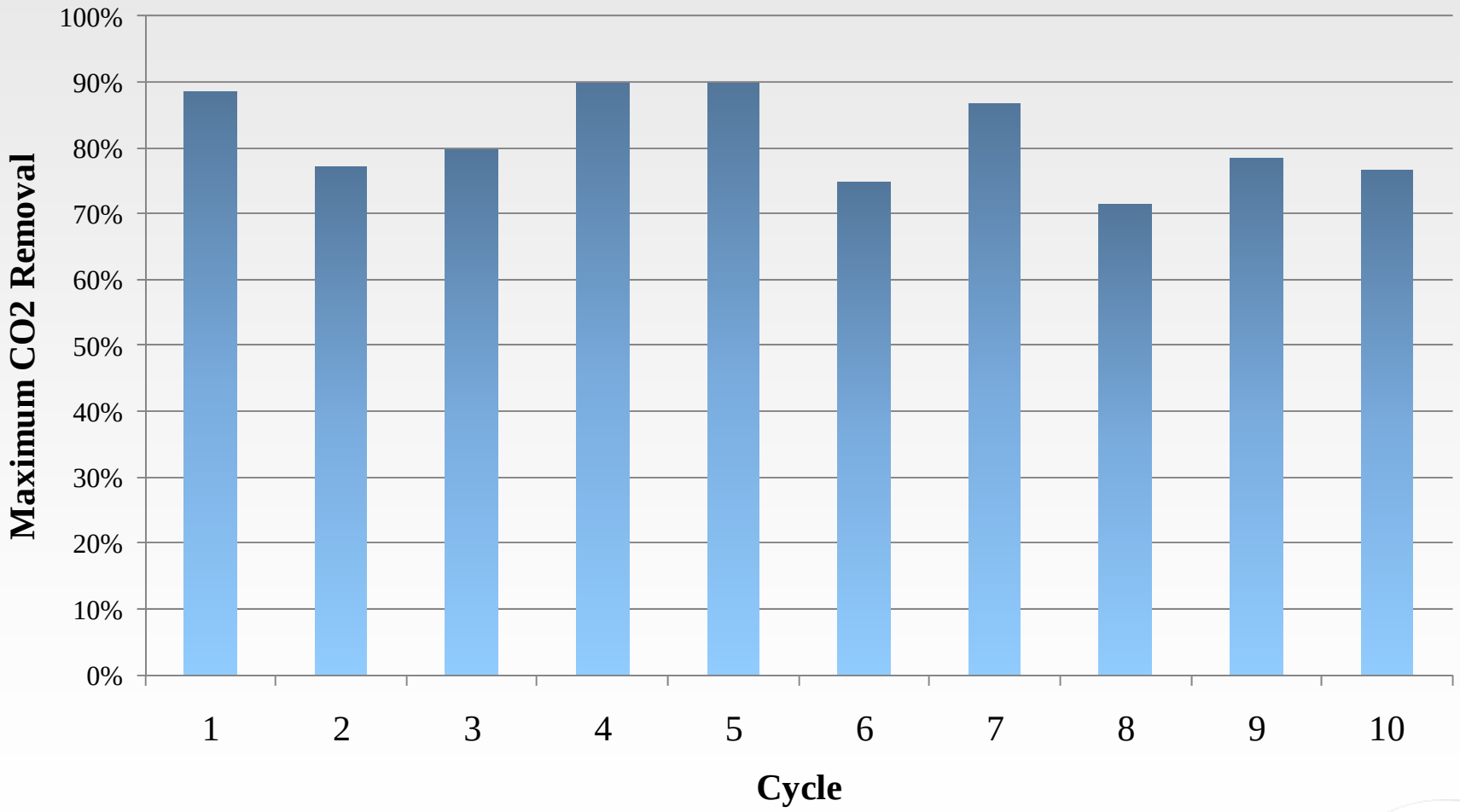
Batch Test Summary
Sorbent R



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1 kW Summary of Results

- ✓ > 90% capture achieved
- ✓ Fast adsorption reaction
  - ➢ Significant removal at < 1 sec. residence time
- ✓ Pressure drop: 2.5 – 3 in H2O (includes ICFB) at 40 lb/hr circulation
- ☒ Slow regeneration with test sorbent (R)
  - ➢ Batch operation required to characterize performance in this pilot

Successful sorbents must regenerate quickly and/or in the presence of increased CO_2 concentrations.

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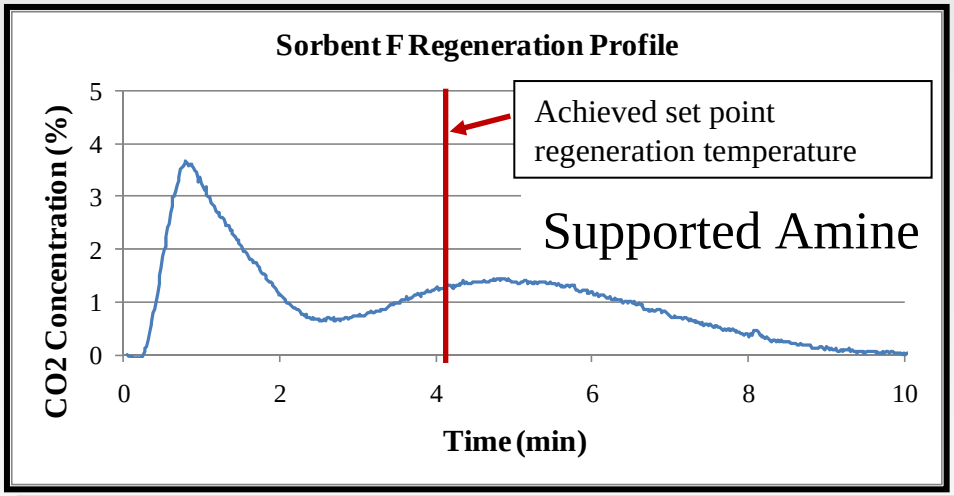
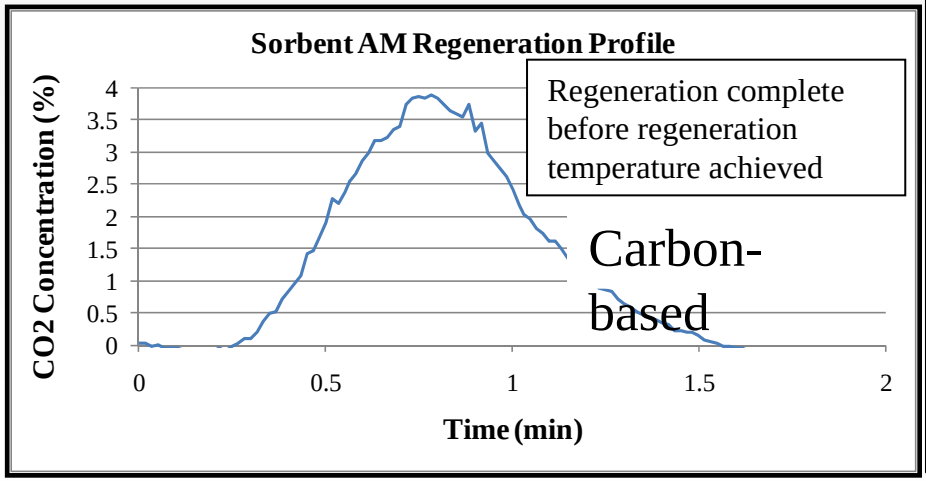
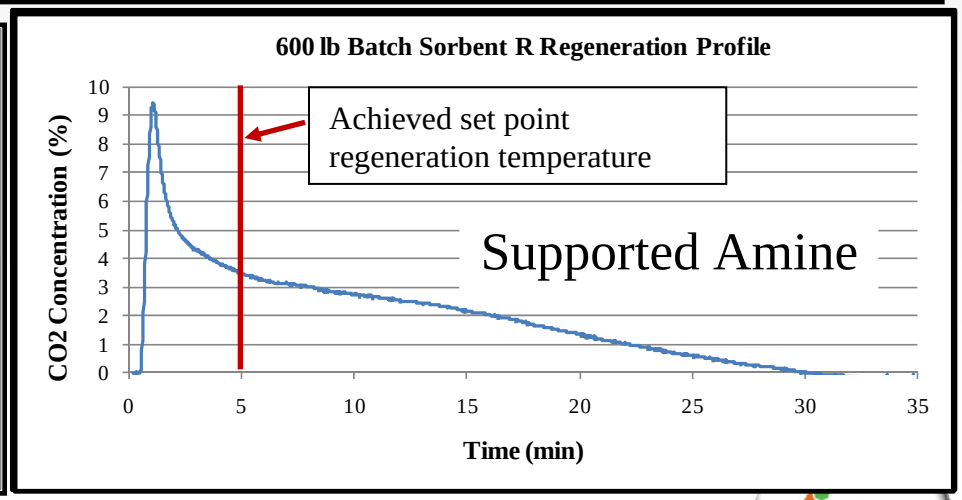
Lab Results: Reaction Rate

- Significant variation in the time required to reach equilibrium
- Lab-scale reaction times can provide clues about 1 kW operating procedure as well as commercial scale capital costs







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Summary of Sorbent Assessment

- Modeling and results to-date indicate that solid sorbents are a promising option for CO_2 capture.
- Alternative sorbents must be demonstrated at the 1 kW scale.

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Project Next Steps

- Test two alternative supported amine materials and one activated carbon sorbent in 1 kW system at Xcel Energy Sherco Station
- Install 1kW at NCCC for additional testing
- Complete concept design and economics for 500 MW

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Next Steps for Solid Sorbents

- New NETL project funded for additional development of 500MW design supported through 1 MW pilot testing

Seeking additional project partners

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Phase I Project Team

DOE NETL Team Members

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

Additional EPRI Member Participation and Support

- TVA
- FirstEnergy
- DTE

Key Contractors:

Stantec, Pressure Chemical

DOE Cooperative Agreement: DE-NT0005649

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