High Capacity Sorbent and Process for CO_2 Capture

Phase II DOE SBIR/STTR Kick-off

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Presentation Overview

- Project team
- Background on the proposed technology and its scientific/technical merit
- Summary of Phase I results
- Project objectives
- Technical approach/project scope
- Project organization
- Project schedule and associated milestones

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Project Team

- US Department of Energy – NETL
- Envergex LLC
- UND Institute for Energy Studies
- North Dakota Industrial Commission
- Lignite Energy Council
- ALLETE Group
  - Minnesota Power
  - BNI Coal
- SaskPower

Background on the proposed technology and its scientific/technical merit

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Background on the proposed technology and its scientific/technical merit

- The hybrid sorption E-CACHYS ™ process uses a regenerable alkali carbonate-based sorbent for CO_2 capture

- E-CACHYS™ is an improved second generation of the CACHYS™ technology that was originally developed through a DOE SBIR/STTR project and is currently subject of an ongoing DOE bench-scale demonstration project

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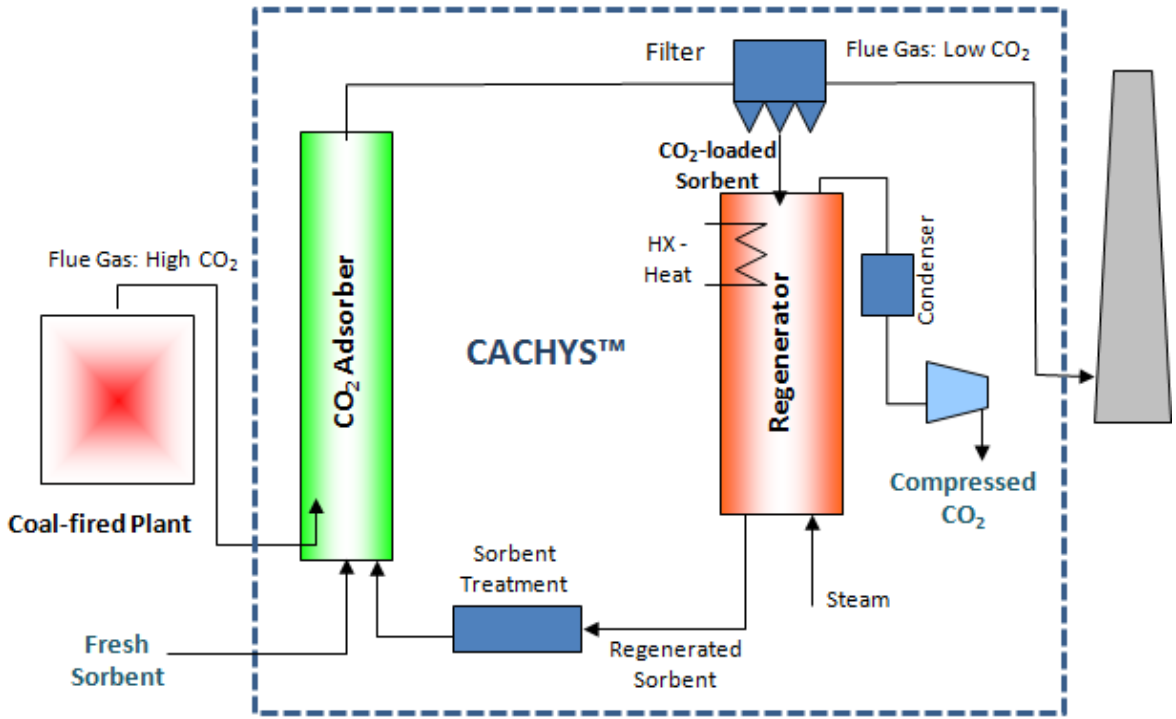
E-CACHYS™ Hybrid Sorption Process



- Key sorbent component–alkali carbonate salt. Reacts with CO_2 to form adduct. Reversible with heat addition.
- 2nd generation sorbent has ~ 2X capacity (12-15% wt % CO_2) compared to 1st generation sorbents
- Additive - enhances adsorption kinetics and reduces regeneration energy
- Design upgraded to increase sorbent lifetime

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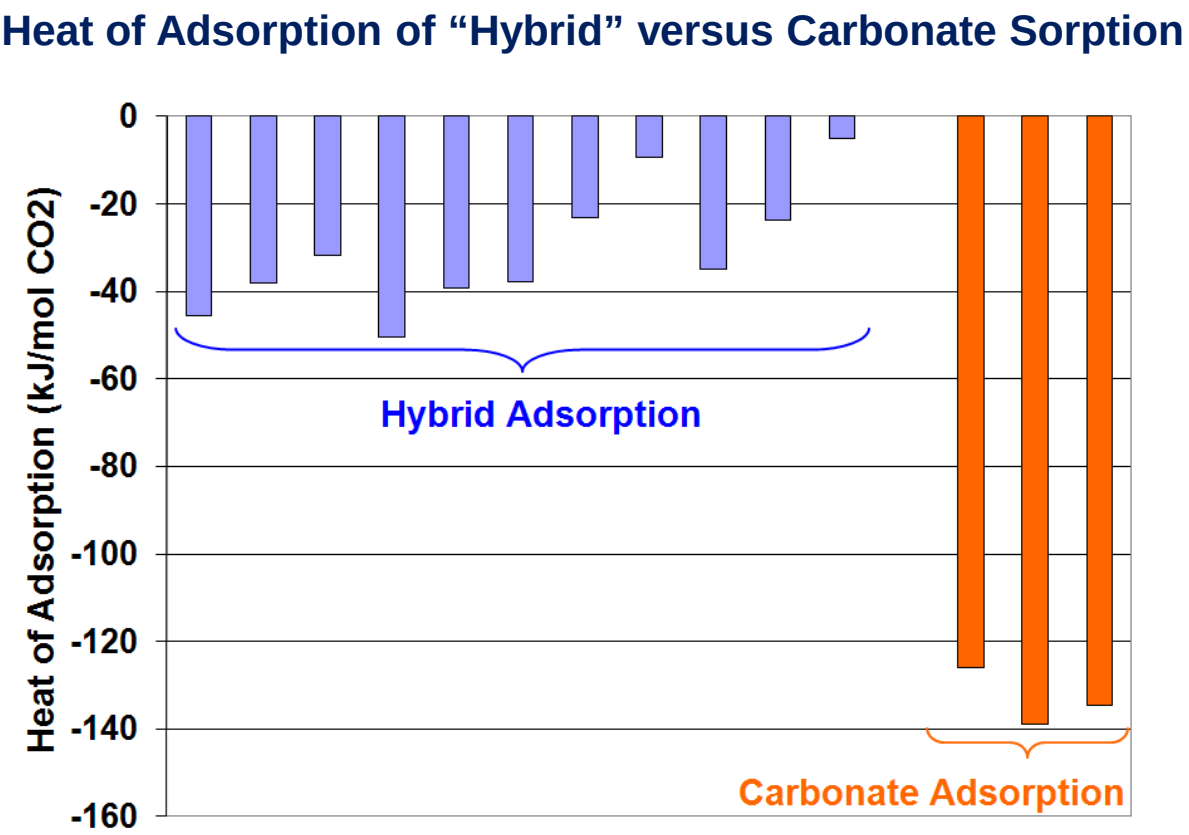
Initial Testing Results



- Initial sorbent screening performed using a thermo-gravimetric and differential thermal analysis (TGA/DTA) system

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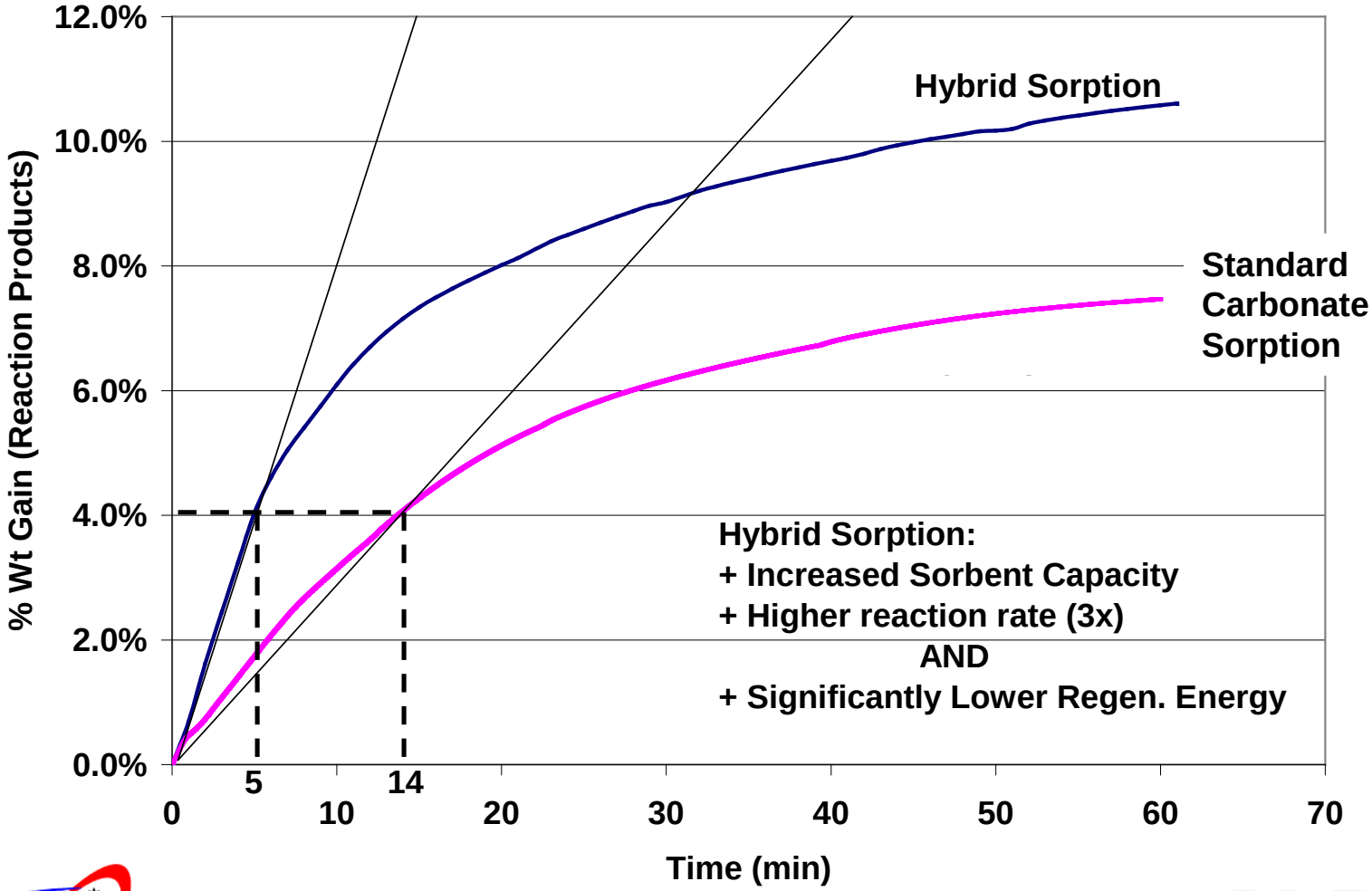
Reaction Rates



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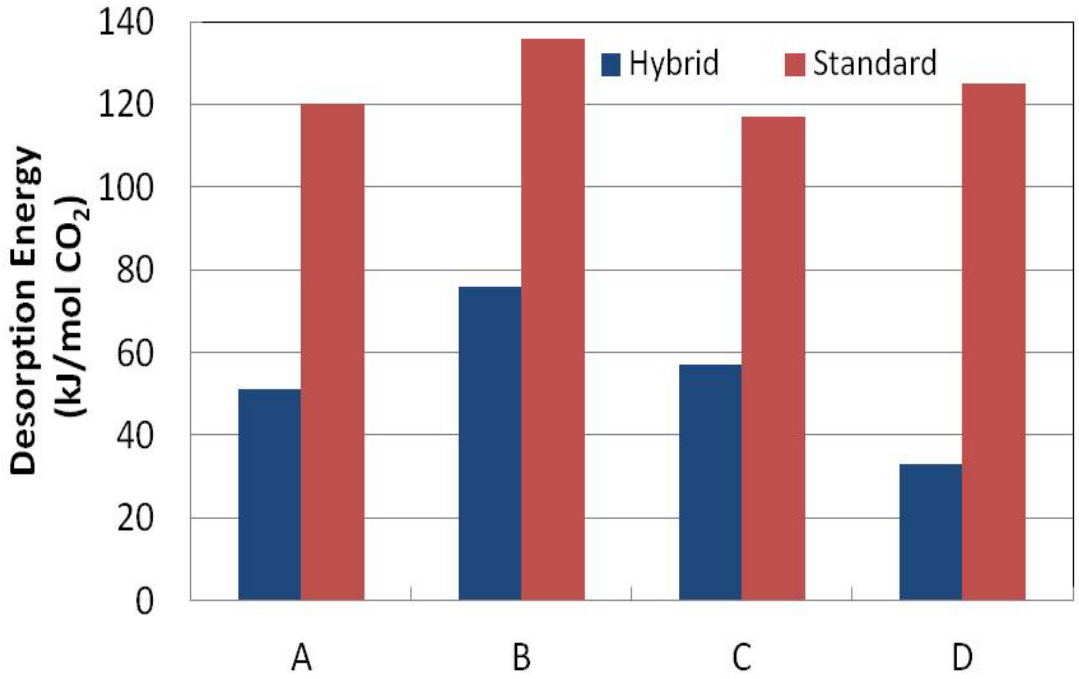
Effect of Hybrid Sorbent Operation on Regeneration Energy



- Appropriate process conditions during regeneration (hybrid operation) reduces overall regeneration energy
- Evidence shown in the lab-scale (TGA/DSC) and at the bench-scale test facility

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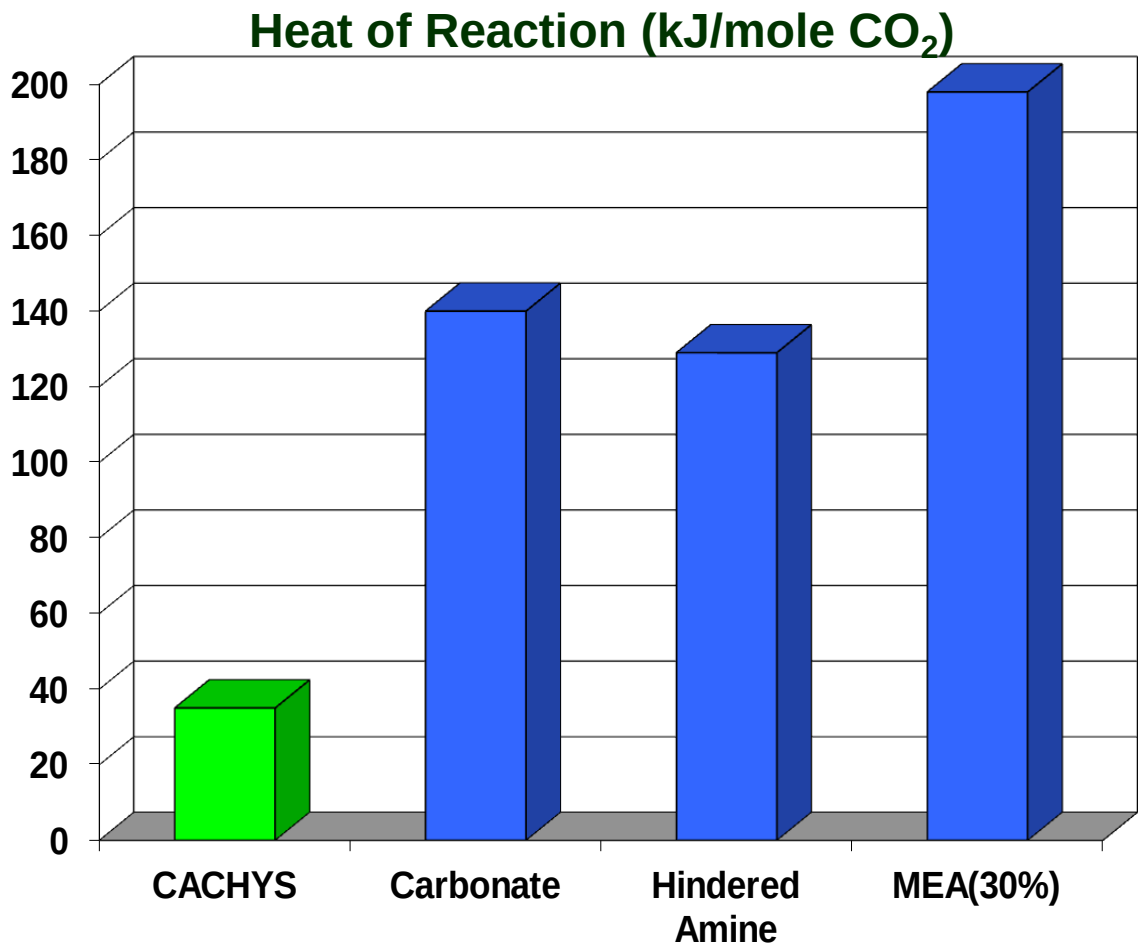
E-CACHYS™ Process Benefits

- ✓ Low heat of reaction ~ 40 kJ/mol CO_2
- ✓ Ultra high sorbent capacity (2x 1st generation sorbents ~ 12-15 wt%)
- ✓ Increased sorption kinetics
- ✓ Use of low cost, abundantly available materials
- ✓ Improved process design that increases sorbent lifetime and reduces the impact of attrition



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E-CACHYS™ Sorbent Characteristics

Desired ultra-sorbent characteristics:

1. High capacity(~ 12-15 g CO_2/100 g sorbent)-high active ingredient content
2. Low energetics (30-80 kJ/mol CO_2)
3. Improved reaction rate (kinetics, mass transfer)
4. Easy to handle (minimal agglomeration or equipment fouling)
5. Sustainable long-term performance (reuse-reformulation)
6. Safe; minimal environmental hazard
7. Low cost manufacturing/reformulation
8. Abundant and low cost raw materials, compatible with reformulation
9. Use in commercially available equipment designs

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Phase I – Summary of Results

- Task 1 – Preparation of Advanced Sorbents for CO_2 Capture
  - Manufactured ~ 15 - 20 advanced substrate materials necessary for formulation of advanced sorbent

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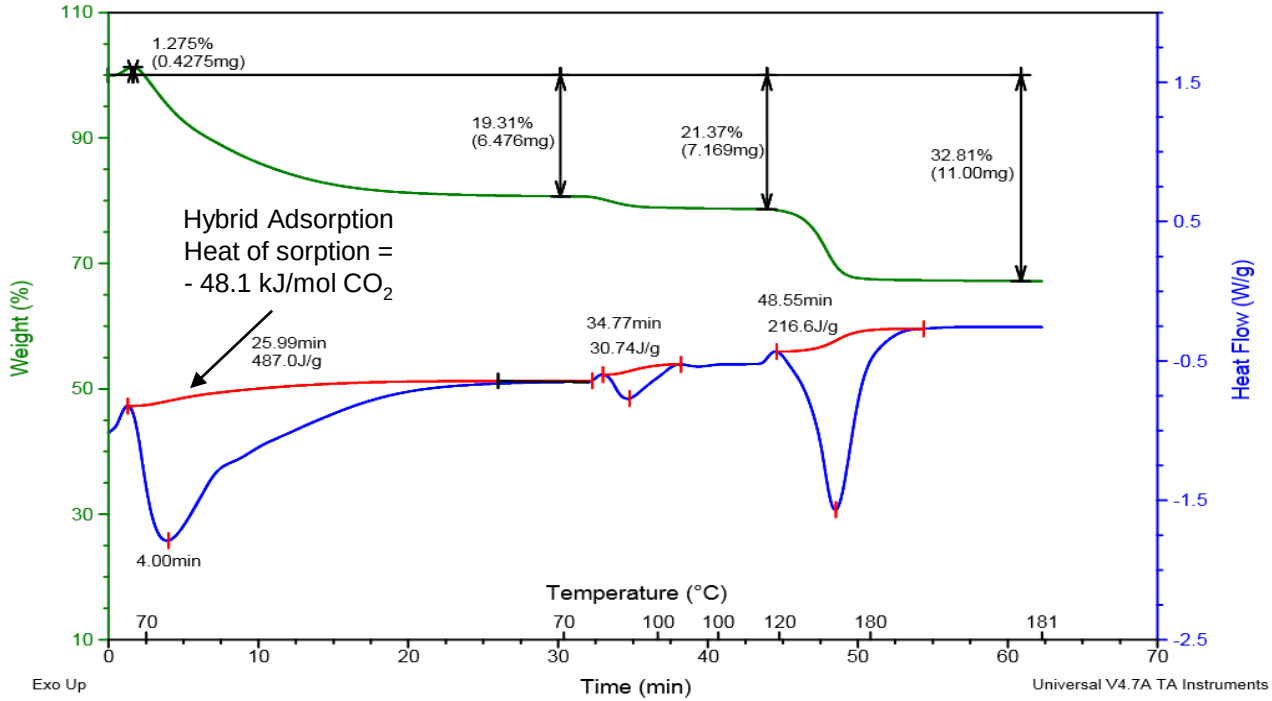
Phase I – Summary of Results

- Task 2 – Hybrid Sorbent Screening Using TGA/DSC
  - TGA/DSC was used to ensure that the ultra-high capacity sorbents maintained the same low heat of reaction characteristics as 1st generation sorbents
  - Results are within the established range of 40-80 kJ/mol CO_2 for hybrid sorption



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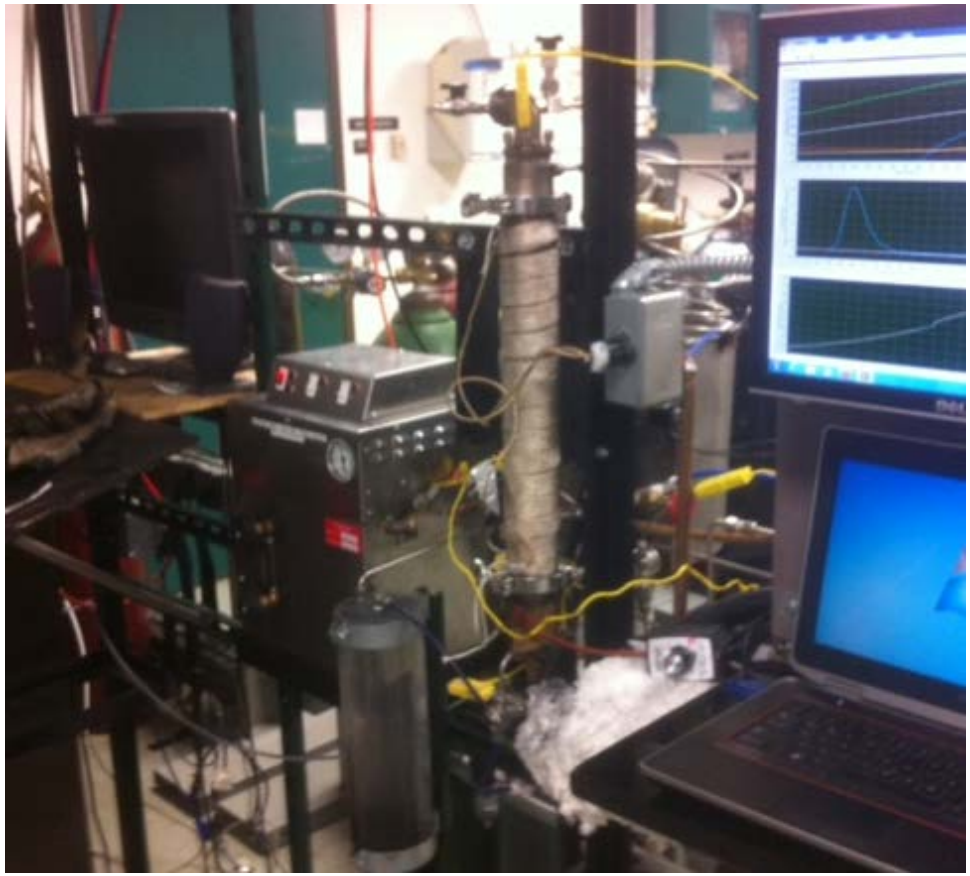
Phase I – Summary of Results

- Task 3 – Laboratory-scale Fixed/Bubbling Bed System Testing

- Produced and purchased sorbents were evaluated for CO_2 capture and regeneration performance
- Determined optimum process conditions with simulated flue gas
- Specific emphasis placed on conditions necessary to maximize sorbent CO_2 working capacity
- Performed 75-cycle test to determine longer-term integrity and performance of the sorbent
- Down-selected a single sorbent type for evaluation in Phase II



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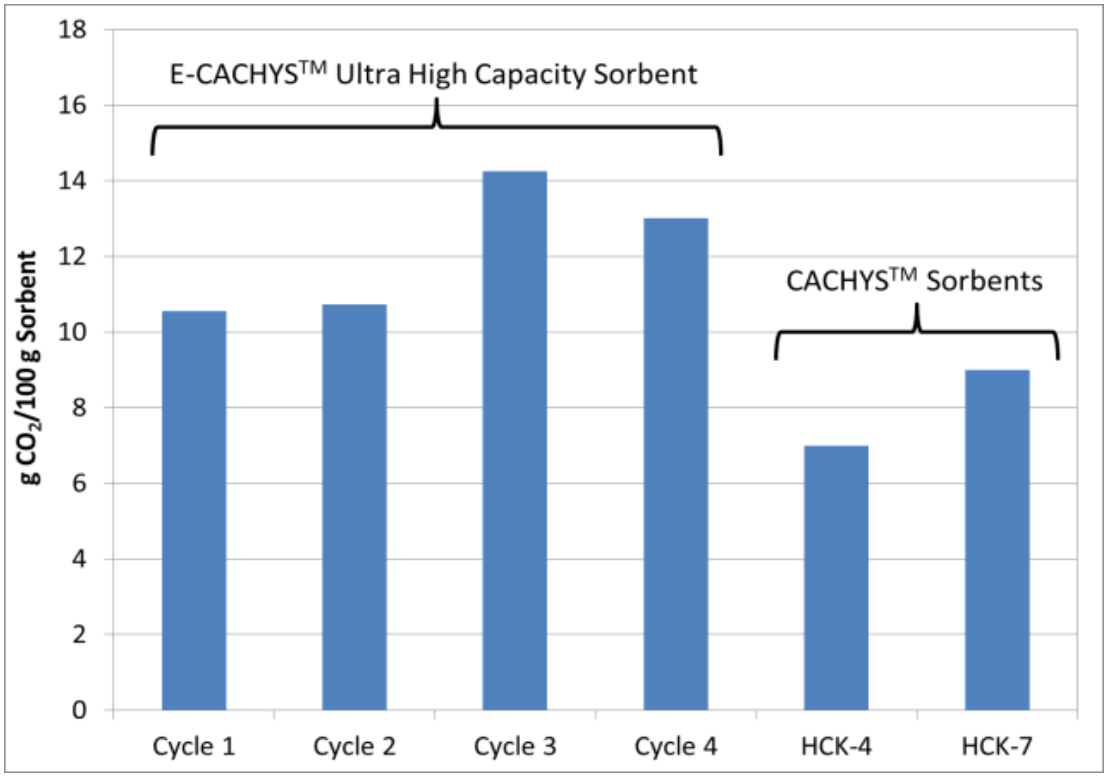
Phase I – Summary of Results (Task 3)



- Sorbent capacities of ultra-high capacity E-CACHYS™ sorbent – ~ 1.5-2X current CACHYS™ sorbent

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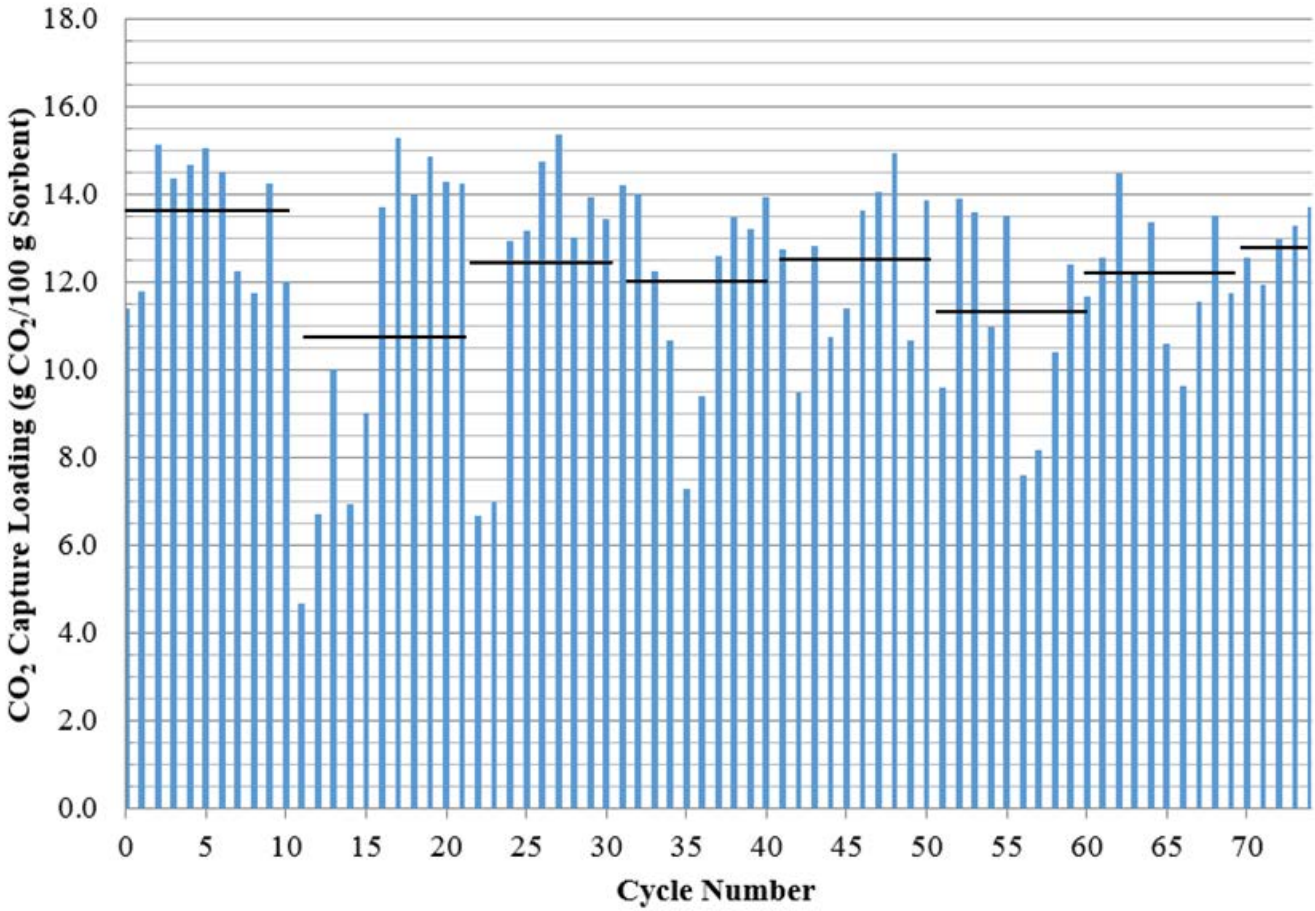
Phase I – Summary of Results (Task 3)



- Sustainable working capacity of 12-14 wt%

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Phase I – Summary of Results

- Task 4 – Process Design and Economics
  - Aspen Plus simulation comparing E-CACHYS™ sorbent to 1st generation sorbent

Alkali/Carbon Ratio	Low (CACHYS™)	High (E-CACHYS™)
Sorbent conveying power, kW	11,285	6,428
Preheater duty, kW	87,335	48,356
Indirect Heat to Regenerator, kW	196,357	183,169
Sorbent Heat Loss, kW	181,704	137,157

- Estimated reduction in cost compared to CACHYS™ technology:
  - Capital Cost Savings: $65 Million (~10% reduction)
  - Steam Usage Savings: 45 MW_{th} (~15% reduction)
  - Sorbent Replacement Minimization: $15 Million/yr (~50% reduction)
  - Parasitic Power Usage Savings: 8 MW_e (~20% reduction)

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Phase II Project Objectives

- Develop an improved process that will efficiently capture CO_2 from flue gas streams and regenerate into a pure CO_2 stream, with a lower cost than current methods
- Goal: Progress towards cost of $40/ton of CO_2 captured
- Demonstrate improvements over the 1st generation sorbent and process

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Technical Approach and Project Scope

- Scope of work includes eight main tasks:
- Year 1
  - Task 1: Project Management and Planning
  - Task 2: Lab-scale development of enhanced sorbent manufacturing
  - Task 3: Lab-scale development of sorbent reuse methodology
  - Task 4: Lab-scale evaluation of sorbent performance
  - Task 5: Modification of existing slipstream bench-scale facility
- Year 2
  - Task 6: Production of sorbent for bench-scale testing
  - Task 7: Bench-scale testing
  - Task 8: Economic analysis and development of commercial methodologies

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Project Organization

Organization Chart

US Department of Energy
NETL

Principal Investigators
Srivats Srinivasachar – Envergex LLC
Steven A. Benson – IES, UND

Project Co-Sponsors
North Dakota Industrial Commission
ALLETE – Minnesota Power, BNI Coal
SaskPower

Shanna Corbett
Resource Manager, IES

Task 1 – Project Management and Planning

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Laboratory-scale

Task 2 – Sorbent manufacturing
Task 3 – Sorbent reuse
Task 4 – Sorbent Performance

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Task 5 – Modification of bench-scale facility
Task 6 – Bench-scale sorbent production
Task 7 – Bench-scale testing

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Task 8 – Economic analysis and development of commercial methodologies

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Progress Reports
Budget Period 1 and 2

Description	Planned Date
Required Reports	
Project Progress Report (4-month)	12/23/14
Continuation Application and Project Progress Report (9-month)	5/27/15
Phase II Final Report	9/26/16
Additional Reports	
Monthly updates	1st week of following month
Interim reports (approx. quarterly)	3/31/15 12/23/16 3/31/16 06/30/16

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Schedule and Milestones
Budget Period 1

Task	Title/Description	Planned Completion Date
2	Selection of optimum sorbent manufacturing methodology	1/31/15
5	Completion of bench-scale design	2/28/15
3	Selection of optimum sorbent reuse methodology	5/31/15
4	Identification of optimum sorbent characteristics	8/30/15
5	Completion of installation of bench-scale design modifications	8/30/15

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Schedule and Milestones
Budget Period 2

Task	Title/Description	Planned Completion Date
6	Complete manufacturing of sorbent for bench-scale testing	11/30/15
7	Complete shakedown testing and necessary equipment modifications	2/28/16
7	Complete bench-scale parametric testing	5/31/16
7	Complete bench-scale continuous testing	7/31/16
8	Complete final process assessment and process economics evaluation	9/30/16

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