Capture of CO_2 by Hybrid Sorption Process (CACHYS™)

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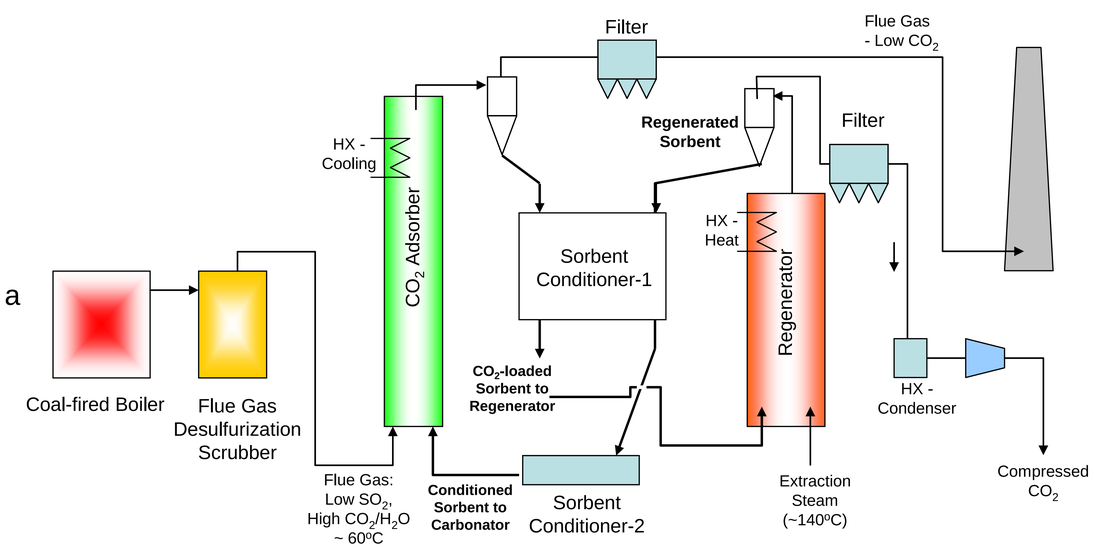
Background and Objectives

- Coal-fired boilers generate 50 percent of electricity in the US (~300 GW_e).
- Coal firing represented 33 percent of the 5.5 billion tons of CO_2 emitted from fossil fuel combustion in 2010.

Objectives

- Develop a process that will efficiently capture CO_2 from flue gas streams and regenerate into a pure CO_2 stream, with a lower operating cost than current methods.
- Goal: 90 percent CO_2 removal at no more than 35 percent increase in the cost of electricity.
- Combine existing technologies to create a new sorbent which will have high CO_2 loading capacity and a process with low regeneration energy penalty.

Hybrid Sorption Process



Example Reactions

$M_xN_y + a.CO_2 + b.H_2O \leftrightarrow$ Product

Product $\leftrightarrow M_xN_y + a.CO_2 + b.H_2O$

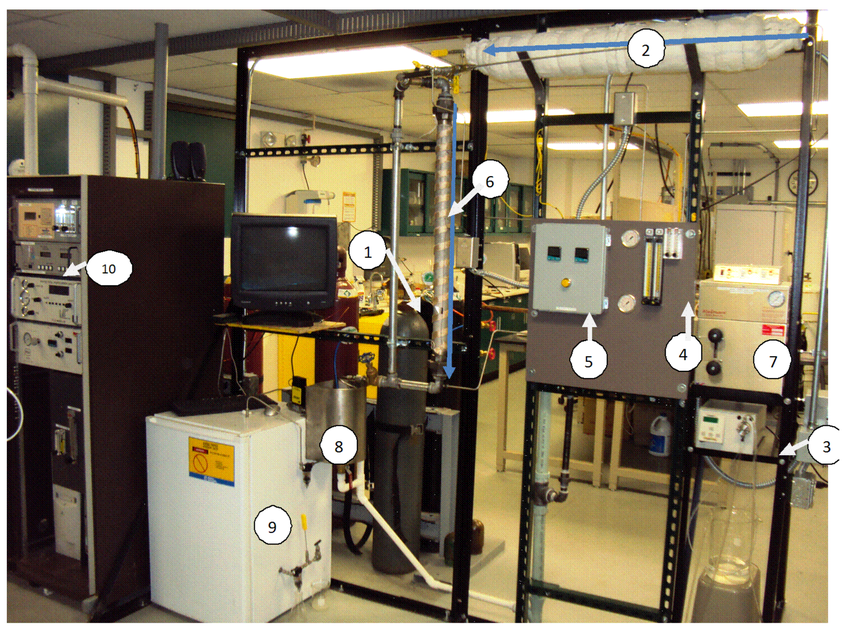
Sorbent

- Proposed process uses impregnated sorbents and hybrid process conditions.
- Sorbents prepared from bulk commodity chemicals/materials – low cost target
- One component – metal carbonate salt. Reacts with CO_2 to form adduct at moderate temperatures. Reversible with the addition of heat.
- Chemicals impregnated on a rigid support material to allow high contacting gas flow; Composition chosen to enhance adsorption kinetics and reduce regeneration energy.

Sorbent Testing

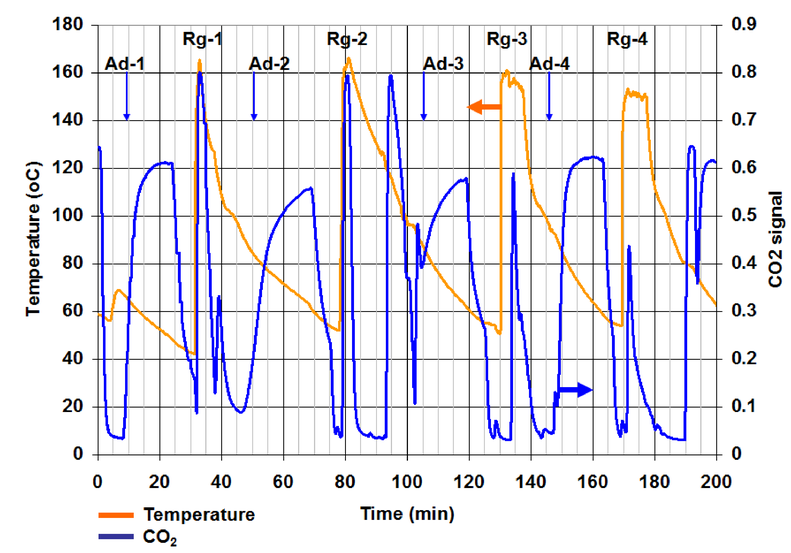
- Initial sorbent screening performed by thermo-gravimetric and differential thermal analysis (TGA/DTA) and differential scanning calorimetry (DSC).
- A laboratory fixed bed apparatus (~ 1kg sorbent) is being used to determine sorbent loading capacity, breakthrough curves, optimal regeneration operation and practical energy requirements.

Experimental Setup



1. Gas tanks to simulate flue gas composition
2. Gas pre-heater to heat flue gas to desired temperature
3. Low flow water pump to add humidity to simulated flue gas
4. Meters to control and meter inlet gas flow and composition
5. Panel to control pre-heater and packed bed temperature
6. Packed bed to hold and test selected sorbents
7. Steam/hot gas generator to regenerate sorbent
8. Cool water condenser to knock out majority of stream energy
9. Refrigerator to condense water vapor for collection
10. Online carbon dioxide gas analyzer

Results



- **Multi-Cycle CO_2 Adsorption and Release and Temperature Profiles During Fixed Bed Testing**

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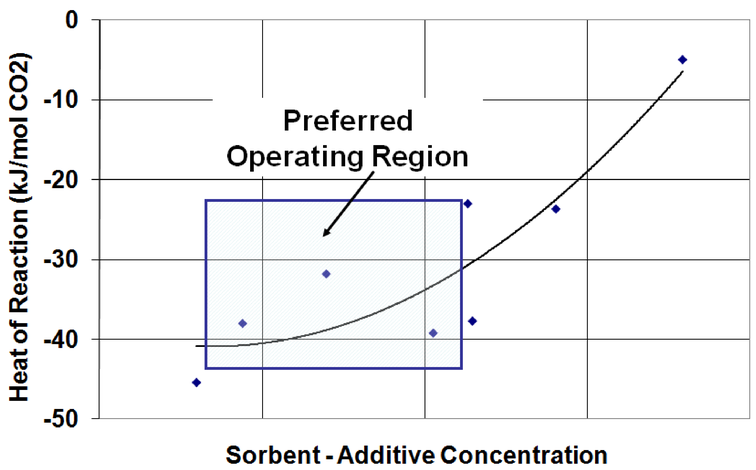
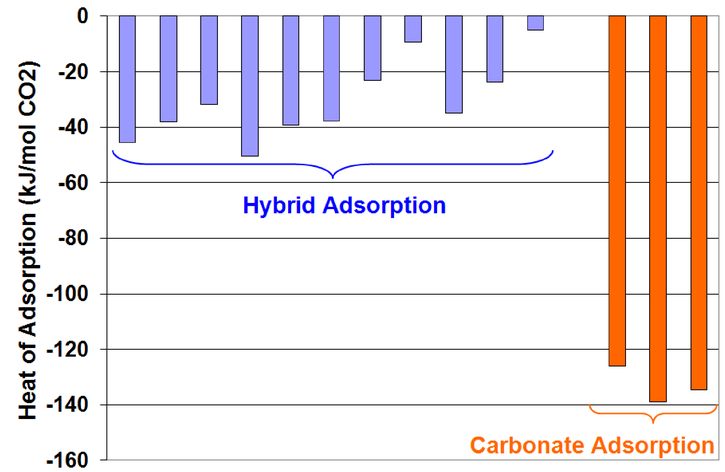
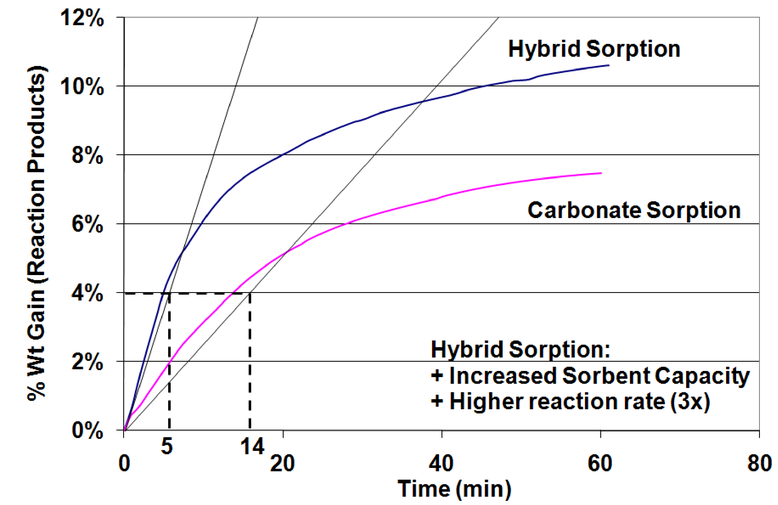
Results



❑ Effect of Sorbent Additive Content on Heat of Reaction



❑ Heat of Adsorption of "Hybrid" versus Carbonate Sorption



❑ Effect of Hybrid Sorption on Reaction Rates

ASPEN Simulation Results

❑ Major CACHYS process components comprise:
- Adsorber
- Sorbent Heat Exchanger
- Sorbent Regenerator
- Vapor Recompression System
- CO_2 Compression Unit

Power Plant Rating [MW_e]	100
60°C Flue Gas Flow [lbmol/hr]	36,294
Sorbent Flow [lbmol/hr]	98,484
Total Regeneration Heat Duty Requirements [kJ/mol CO_2]	-57.4
Sorbent Heat Exchange Couple [MMBTU/hr]	71
Parasitic Power Consumption Due to Carbon Capture and Compression	16.5%

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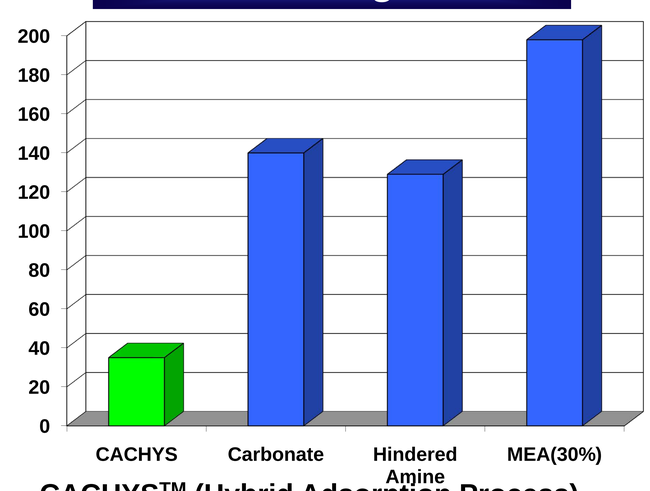
Advantages



CACHYS™ (Hybrid Adsorption Process)

- ✓ Heat of reaction ~ 40 kJ/mole CO_2
- ✓ Low heat of regeneration
- ✓ High sorbent capacity
- ✓ Increased sorption kinetics
- ✓ Low cost, abundantly available materials
- ✓ Exceeded DOE's goal of 90% CO_2 capture at less than 35% increase in cost of electricity

Future Work

❑ Using the information from the sorbent testing, the feasibility of this method will be evaluated for an industrial sized system.

❑ With promising bench-scale testing, we are proposing to install a sub-pilot test unit on a slipstream at UND's coal-fired steam plant .

Funding and Partnerships

❑ This project was funded by the Department of Energy through their Small Business Technology Transfer (STTR) Program.

❑ Soliciting commercialization partners and sponsors for further development

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