Are Solid Sorbents a Viable Option for Post-Combustion CO_2 Capture?

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DE-NT0005649

PROJECT OBJECTIVE

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

APPROACH

- **Sorbents**
  - Evaluate candidate sorbents at
    - Lab-scale (fixed bed) and pre-pilot scale (fluidized bed)
    - Simulated and actual flue gas
  - Variables:
    - Adsorption temperature
    - Regeneration temperature
    - Moisture level
    - SO_2 concentration
  - Key sorbent characteristics
    - CO_2 capture
    - Stability
    - Handling properties
    - Cost
    - Scale-up manufacturing
- **Equipment**
  - Survey and evaluated equipment options for
    - Adsorption
    - Regeneration
    - Heat transfer
    - Materials handling
  - Scale-up engineering for 1MW pilot and 500MW plant

SUCCESS CRITERIA

- > 90% CO_2 removal achievable
- Total cost of CCS results in <35% increase in cost of electricity
- Process can produce a high purity CO2 stream adequate for sequestration

INTRODUCTION

Carbon capture and sequestration (CCS) can be an important component of reducing worldwide CO_2 emissions from stationary point sources, such as coal-fired power plants. Aqueous amines and ammonia are being demonstrated for CO_2 capture in a temperature swing cyclic process. Solid sorbents can also be used in a similar process, but have the potential to drastically reduce the energy required to release the CO_2 during material regeneration. However, the majority of solid sorbent research is being conducted on lab-scale samples without significant consideration of process and/or equipment design.

ADA Environmental Solutions is currently evaluating the viability of solid sorbents in a temperature swing process as a retrofit option for the existing fleet of coal-fired plants. Activities include collecting and testing currently available sorbents, assessing process requirements, and evaluating process equipment options to project the performance, capital, and operating costs associates with technology option. ADA is working closely with sorbent developers, equipment vendors, and plant operators during this effort. This work is being conducted through a U.S. DOE Cooperative Agreement with supplemental funding from ADA, EPRI, and industry.

SELECT PRELIMINARY RESULTS

Lab-Scale Materials Characterization

Reducing the energy penalty required for regeneration is one of the most important criteria to lowering the cost for commercial-scale CCS. Equation 1 is an energy balance used to calculate the theoretical energy for regeneration (TRE).

$$\frac{Q}{m_c} = \frac{m_e}{m_c} C_e \Delta T + \frac{B}{L} C_s \Delta T + C_{p,c} T_2 - C_s T_1 + \frac{Q_r}{m_c} \qquad (1)^{1}$$

Lab-Scale Preliminary Results: 28 sorbents tested

Success Criteria	Results
Working capacity	0 to >13.5 wt%
Consistent Performance	up to 165 cycles tested
$\Delta T_{capture-regen}$ Required	15-195°C tested
Theoretical Regeneration Energy*	700 to 40,000 kJ/kg CO_2

**Benchmark: Aqueous MEA 3600 kJ/kg CO_2 (1550 BTU/ lb CO_2)[2]*

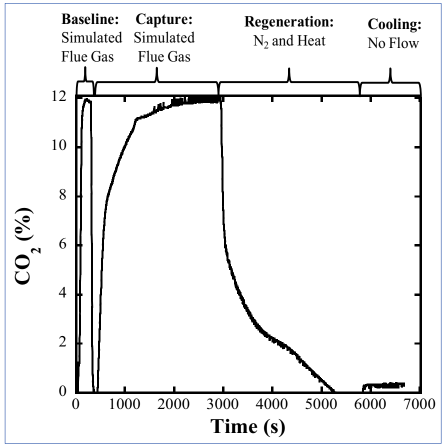


Figure 1. Complete cycle profile for sorbent R on simulated flue gas

Note that sorbent R was able to remove all the CO_2 in the simulated flue for several seconds. This level of performance was observed for several supported amine materials.

	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*

Figure 2. Summary of sorbent performance

Note that the conclusions presented in Figure 2 are based ONLY on the materials tested thus far in the program.

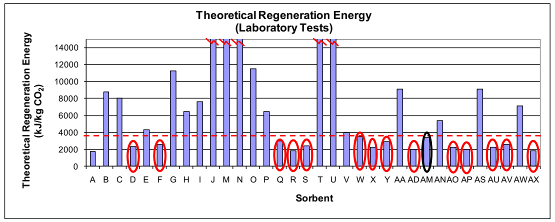


Figure 3. Theoretical regeneration energy for most materials tested

Note that the TRE for aqueous MEA is included as the dashed red line on Figure 5.[2] Several sorbents have a theoretical regeneration energy lower than the benchmark value.

Pre-Pilot Parametric Testing

- Temperature swing regeneration
- Circulating fluidized bed
- 5 cfm flue gas (scrubbed)
- Between 100 and 300 lbs of sorbent
- Up to one week of testing per sorbent

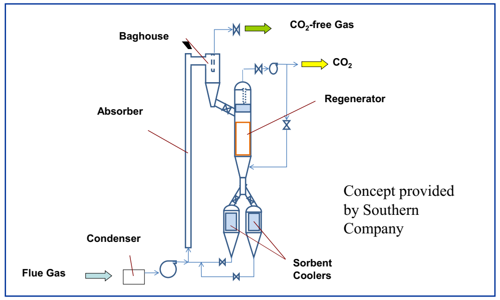


Figure 4. Conceptual schematic of pre-pilot equipment

CONCLUSIONS

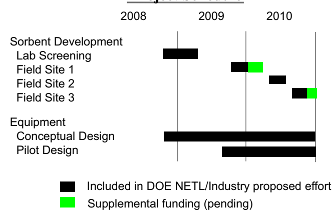
Preliminary results based on lab-scale sorbent screening are promising. One of the most important considerations for a commercial-scale CO_2 capture system is the energy required to release the CO_2 during regeneration. Thus far, several materials have shown the potential to drastically reduce this energy below the current benchmark value. However, an optimal temperature swing process and the related equipment must be developed. The pre-pilot evaluations will represent a significant advancement in process evaluation.

FUTURE WORK

All of the pre-pilot scale testing has yet to be completed. Upcoming work in this project includes:

- **Sorbent Assessment**
  - Lab-scale
    - Simulated flue gas
      - Continue to screen materials for >100 capture/regeneration cycles
      - More fully assess the effect from SO_2
    - Actual flue gas – 2 additional field tests
  - Pre-pilot
    - Multiple sites
    - Vary SO_2
    - Vary temperature
    - Vary moisture
- **Equipment Survey and Evaluation**
  - Continue to collect information on applicable systems and components
  - Selectively down-scale equipment based on a developed Kepner-Tregoe screening criteria list
  - 500 MW conceptual design
  - 1 MW pilot detailed design

Project Schedule



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2. Ramezan M., Skone T.J., Nsakala N., Liljedahl G.N., "Carbon Dioxide Capture from Existing Coal-Fired Power Plants", Final Report DOE/NETL-401/110907, December, 2007.

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