Transformational Sorbent System for Post-Combustion Carbon Capture

primary project goal

TDA Research, partnered with University of Alberta, University of California Irvine, and the Wyoming Integrated Test Center (ITC), is developing a transformational sorbent system for post-combustion carbon dioxide (CO_2) capture capable of capturing more than 90% of the CO_2 emissions from a coal-fired power plant and recovering CO_2 at 95% purity with a cost of electricity 30% lower than an amine-based system. TDA's system uses a novel, highly stable, high-capacity CO_2 sorbent in a vacuum/concentration swing adsorption (VCSA) process that uses a single-stage vacuum pump with low auxiliary load. The sorbent regeneration comprises two steps: (1) a vacuum to recover the CO_2 and (2) a purge using boiler air intake, subsequently feeding the CO_2-laden air to the boiler. The technology provides a cost-effective solution for controlling CO_2 emissions from existing coal-fired power plants. The low heat of adsorption of CO_2 and the use of a VCSA process that eliminates any steam purge results in reduced energy input for sorbent regeneration. The radial outflow sorbent reactor beds can be constructed into modules that can be added together, allowing for easy scale-up.

technical goals

- Optimize the sorbent formulation.
- Assess impact of flue gas contaminants (sulfur dioxide [SO_2], nitrogen oxide [NO_x], hydrogen chloride [HCl]).
- Scale-up sorbent production.
- Complete long-term sorbent cycling experiments at bench scale using simulated flue gas.
- Design and construct a prototype system with fixed-bed radial flow reactors.
- Design the VCSA cycle sequence.
- Perform field-testing in a prototype test unit using actual flue gas for a minimum of 4,000 hours.
- Prepare a high-fidelity techno-economic analysis (TEA) and environmental, health, and safety (EH&S) assessment.

technical content

TDA Research is developing a high-capacity sorbent for CO_2 capture in a system that uses a novel adsorption cycle scheme. TDA's metal organic framework (MOF) sorbent has very high CO_2 uptake, high CO_2 selectivity over nitrogen (N_2), and a relatively low energy requirement for regeneration. The process, shown in Figure 1, includes sorbent that operates at approximately 50°C during adsorption under mild vacuum (~0.2–0.3 atmosphere [atm]). The regeneration occurs in a two-step process, using vacuum to recover the CO_2 and a purge using the boiler intake air, which then feeds the CO_2-laden air back to the boiler. This approach generates a flue gas that is rich in CO_2, thereby benefiting the adsorption of the CO_2 on the sorbent while allowing use of a practical, single-stage vacuum pump with a low auxiliary load.

program area:
Point Source Carbon Capture

ending scale:
Bench Scale

application:
Post-Combustion Power Generation PSC

key technology:
Sorbents

project focus:
Metal Organic Framework-Based Sorbent System

participant:
TDA Research Inc.

project number:
FE0031734

predecessor projects:
N/A

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partners:
University of California Irvine; University of Alberta; Wyoming Integrated Test Center

start date:
06.01.2019

percent complete:
67%

The project team is designing a fixed-bed radial flow reactor-based test unit for field-testing at a project partner host site with actual coal-derived flue gas to show the performance of their CO_2 capture system. TDA's radial flow contactor increases the viability of using sorbents in fixed beds for post-combustion capture by reducing the pressure drop through the beds and allowing for rapid regeneration of the sorbent. The radial flow reactor configuration allows for use of multiple modular beds for ease of scale-up to large-scale processes.

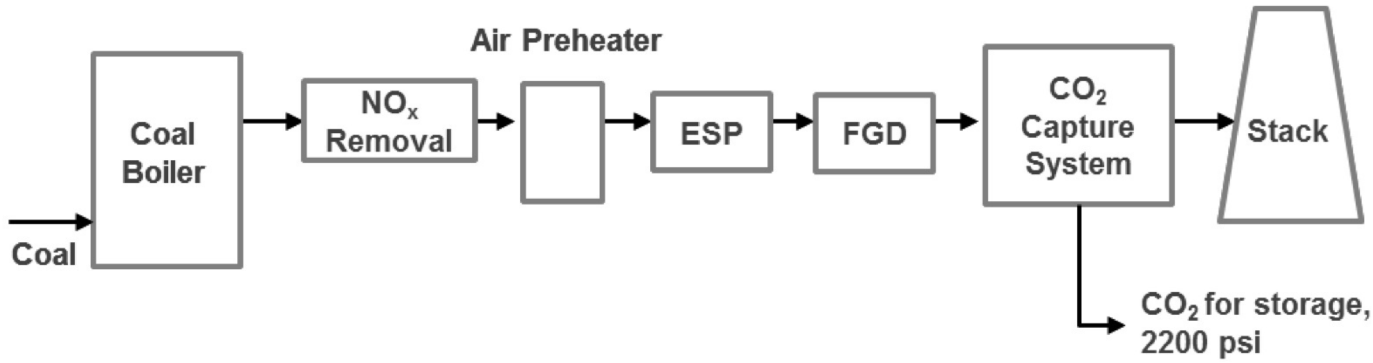

Figure 1: Schematic of TDA's CO_2 capture system.

TDA Research is optimizing sorbent performance through lab-scale experiments and using computational modeling to show the technical merit of both the sorbent and the capture process. The impacts of flue gas contaminants, including SO_2, NO_X, and HCl, on sorbent performance are being evaluated. The project team will also design and construct the prototype system, design the VCSA cycle, optimize the process design, and complete a detailed cost analysis to compare this process technology against amines. Evaluations using the prototype test unit will be completed first with simulated flue gas in the lab and then at the Wyoming ITC with actual coal-based flue gas, followed by optimization of the cycle design, finalization of the process design, and completion of an engineering analysis to fully assess the techno-economic viability of the process.

technology advantages

- Very high CO_2 uptake (2–3 mmol/g) at 0.15–0.20 bar CO_2 partial pressure.
- High CO_2 selectivity over N_2.
- Relatively low energy input requirement for sorbent regeneration.

R&D challenges

- Minimizing the loss in adsorption capacity due to the sorbent pelletization process.
- Designing the sorbent to maintain stability and life in the presence of moisture.
- Maintaining the low vacuum and purge requirements for the process upon scale-up.

status

TDA Research MOF synthesis improvements have produced space yield improvements of 10–15X and time yield improvements of 5–8X. The reactor was equipped to perform MOF synthesis, filtration/rinsing, and drying/devolatilization, all sequentially in the same reactor. A classified area is designed and built to handle the equipment and solvents required for MOF processing. TDA employed multiple fixed-bed adsorption systems to carry out adsorption breakthrough and adsorption/desorption cycle tests. Scale-up testing from 1–22 L flask and to 180 L Hastelloy reactor will occur in Budget Period 2 (BP2). TDA Research demonstrated a high working capacity in excess of 5 wt%. CO_2 at approximately 15 vol%. CO_2 and approximately 2.5 wt% CO_2 at 4 vol% CO_2. TDA Research also demonstrated how temperature and humidity levels have limited impact on sorbent's working capacity. Higher temperatures resulted in lower working capacity. There was no significant impact in the presence of humidity up to 65%. Stable working capacity was also demonstrated in the presence of flue gas contaminants such as NO_X and sulfur oxide (SO_X). The TEA indicated the total cost of the CO_2 capture system, including flue gas treatment, is $207.8 Million ($378/kW), and the cost of CO_2 capture is approximately

$37/tonne, which meets the U.S. Department of Energy's (DOE) current target of less than $40/tonne at less than $450 Million.

available reports/technical papers/presentations

Alptekin, G., et al. "Transformational Sorbent System for Post Combustion Carbon Capture," 2021 NETL Carbon Management Research Project Review Meeting, Pittsburgh, PA, August 2021. *https://netl.doe.gov/sites/default/files/netl-file/21CMOG_PSC_Alptekin_TDA.pdf*.

Alptekin, G., et al. "Transformational Sorbent System for Post Combustion Carbon Capture," Budget Period 1 Review Meeting, Pittsburgh, PA, January 2021. *https://netl.doe.gov/projects/plp-download.aspx?id=10759&filename=Transformational+Sorbent+System+for+Post-Combustion+Carbon+Capture.pdf*.

Alptekin, G., et al. "Transformational Sorbent System for Post Combustion Carbon Capture," 2019 Carbon Capture, Utilization, Storage, and Oil & Gas Technologies Integrated Review Meeting, Pittsburgh, PA, August 2019. *https://netl.doe.gov/sites/default/files/netl-file/G-Alptekin-TDA-Next-Gen-Sorbent.pdf*.

Alptekin, G., et al. "Transformational Sorbent System for Post Combustion Carbon Capture," Kickoff Presentation, Pittsburgh, PA, August 2019. *https://netl.doe.gov/projects/plp-download.aspx?id=10758&filename=Transformational+Sorbent+System+for+Post-Combustion+Carbon+Capture.pdf*.