the ENERGY lab

PROJECT FACTS

Existing Plants, Emissions & Capture

Bench-scale Development of an Advanced Solid Sorbent-based CO_2 Capture Process for Coal-fired Power Plants

Background

The mission of the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) Existing Plants, Emissions, & Capture (EPEC) Research & Development (R&D) Program is to develop innovative environmental control technologies to enable full use of the nation's vast coal reserves, while at the same time allowing the current fleet of coal-fired power plants to comply with existing and emerging environmental regulations. The EPEC R&D Program portfolio of post- and oxy-combustion carbon dioxide (CO_2) emissions control technologies and CO_2 compression is focused on advancing technological options for the existing fleet of coal-fired power plants in the event of carbon constraints.

Pulverized coal (PC) plants burn coal in air to produce steam and comprise 99 percent of all coal-fired power plants in the United States. Carbon dioxide is exhausted in the flue gas at atmospheric pressure and a concentration of 10–15 percent by volume. Post-combustion separation and capture of CO_2 is a challenging application due to the low pressure and dilute concentration of CO_2 in the waste stream, trace impurities in the flue gas that affect removal processes, and the parasitic energy cost associated with CO_2 capture, recovery, and compression. Sorbent-based technologies, which adsorb CO_2 onto a solid sorbent, have the potential to effectively reduce the energy penalties and costs associated with post-combustion CO_2 capture for both new and existing PC-fired power plants.

Project Description

Research Triangle Institute (RTI), in collaboration with its partners, will develop and evaluate an advanced solid sorbent-based CO_2 capture process that has the potential to substantially reduce the parasitic energy requirement and costs associated with capturing CO_2 from coal-fired flue gas compared to conventional aqueous amine CO_2 scrubbing. A promising molecular basket sorbent (MBS) from Pennsylvania State University (PSU) will be combined with RTI's circulating, fluidized, moving-bed reactor (FMBR) process design concept and thoroughly evaluated at bench scale on actual coal-fired flue gas to demonstrate feasibility of the process concept.

Developed through previous DOE projects, PSU's MBS exhibited many of the desired performance characteristics for use in the RTI CO_2 capture process. The MBS comprises a CO_2-philicpolymer, polyethyleneimine (PEI), loaded onto high surface area nano-porous materials. The sorbent has demonstrated high CO_2 loading capacity and thermal properties that could greatly reduce parasitic power requirements for CO_2 capture. In the current project, researchers will transition the existing MBS material from a highly-

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PARTNERS

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PROJECT DURATION

Start Date	**End Date**
10/01/2011	09/30/2014

COST

Total Project Value
$3,847,161

DOE/Non-DOE Share
$2,997,038 / $850,123

AWARD NUMBER

FE0007707

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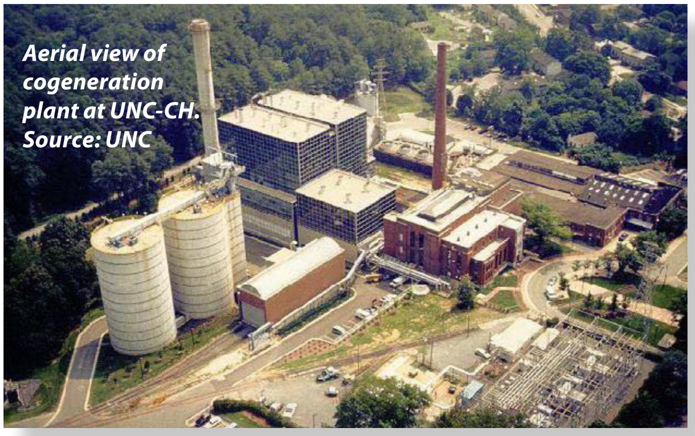
promising, laboratory-scale fixed-bed adsorbent to a fluidizable, attrition-resistant CO_2 adsorbent that can be effectively utilized in the proposed capture process.

In a previous DOE project, RTI developed a cyclic, thermal-swing process design based on continuous sorbent circulation through dual FMBRs for CO_2 adsorption and sorbent regeneration. In the current project, the FMBR design will be evaluated under CO_2 capture and sorbent regeneration conditions to prove that it is an optimal solid sorbent-based process design. It is anticipated that this effort will demonstrate the FMBR's exceptional heat transfer characteristics, its potential for reducing process pressure drop, and the advantages for sorbent circulation versus multi-vessel, gas-switching approaches.

The advanced sorbent will initially be tested in a single laboratory-scale fluidized bed column. The results will be used to design and fabricate a continuous-flow bench-scale system based on RTI's two-column CO_2 removal process concept. After the completed bench-scale system is fabricated and tested in the lab, it will be tested on flue gas from a coal-fired boiler at the University of North Carolina at Chapel Hill (UNC-CH). This field testing will demonstrate long-term thermal, chemical, and physical stability and the CO_2 capture and sorbent regeneration performance of the MBS sorbent and FMBR process technologies. The data obtained during the field test will be used to prepare a design for a full-scale unit and to conduct technical, economic, and environmental analyses.



Aerial view of cogeneration plant at UNC-CH. Source: UNC

Primary Project Goal

The primary project goal is to conduct a bench-scale demonstration of RTI's CO_2 capture concept using novel MBS materials, coupled with preliminary design, optimization, and economic analysis of a full-scale system, to show the potential for this technology to meet the DOE goals of capturing at least 90 percent of the plant CO_2 while increasing the cost of electricity by less than 35 percent.

Objectives

Project objectives are the (1) optimization and production scale-up of advanced MBS materials in fluidizable form, and development of associated fluidized-bed process technology; (2) collection of critical process engineering data using single-stage testing equipment to allow for detailed design of a bench-scale CO_2 capture prototype based on MBS materials; (3) bench-scale demonstration of effective and continuous CO_2 capture from coal-fired flue gas using a MBS-based process system; and (4) demonstration of the technical and economic feasibility of a commercial embodiment of the MBS-based CO_2 capture process through a detailed technology feasibility study.

Planned Activities

- Complete a preliminary technology feasibility analysis of a full-scale, MBS-based CO_2 capture process.
- Improve the thermal and chemical stability of base PEI reactant while transitioning fixed-bed MBS material to a fluidizable form.
- Develop computational fluid dynamics models of the MBS-based fluidized-bed process.
- Design and fabricate a bench-scale, single-stage FMBR.
- Conduct baseline experiments to characterize the performance of the single-stage system using second generation fluidized-bed MBS material.
- Design and construct a bench-scale, continuous-flow FMBR CO_2 capture process based on laboratory data.
- Produce an advanced, third generation, fluidized bed MBS material.
- Perform shakedown testing and commissioning of the continuous-flow bench-scale prototype at RTI's Central Utility Plant facility.
- Install the continuous-flow bench-scale prototype to operate on a small slipstream of flue gas at the UNC-CH's Energy Services Department's coal-fired cogeneration plant.
- Conduct parametric field testing for at least 1,000 hours to investigate the effect of actual, coal-derived flue gas on long-term sorbent and process performance and reliability.
- Produce an updated technology feasibility study using information collected during the bench-scale field tests.

Accomplishments

- Kick-off Meeting conducted in December 2011.

Benefits

The advanced, MBS-based CO_2 capture process is anticipated to have reduced parasitic loads and lower capital and operating costs for CO_2 capture from coal-fired power plants than conventional technologies, and holds potential to meet the cost and performance goals set by DOE. The development of the MBS-based process also advances the solid sorbent CO_2 capture field, and the process engineering and design work will represent important advancements for most solids-based CO_2 capture systems.