Alstom’s Chemical Looping Combustion Technology with CO₂ Capture for New and Existing Coal-Fired Power Plants

Background

The Advanced Combustion Systems (ACS) Program of the U.S. Department of Energy/National Energy Technology Laboratory (DOE/NETL) is aiming to develop advanced oxy-combustion systems that have the potential to improve the efficiency and environmental impact of coal-based power generation systems. Currently available carbon dioxide (CO₂) capture and storage technologies significantly reduce the efficiency of the power cycle. The ACS Program is focused on developing advanced oxy-combustion systems capable of achieving power plant efficiencies approaching those of air-fired systems without CO₂ capture. Additionally, the program looks to accomplish this while maintaining near zero emissions of other flue gas pollutants.

Oxy-combustion systems use high purity oxygen to combust coal and produce a highly concentrated CO₂ stream that can be more easily separated out of the flue gas. First-generation oxy-combustion systems utilize oxygen from a cryogenic air separation unit (ASU) integrated with a boiler system that represents current state-of-the-art air-fired boiler design. These first-generation oxy-combustion systems have demonstrated technology viability; however, further research is needed to develop advanced oxy-combustion systems to meet the DOE carbon capture goals.

Oxy-combustion system performance can be improved either by lowering the cost of oxygen supplied to the system or by increasing the overall system efficiency. NETL targets both of these possible improvements through sponsored cost-shared research into pressurized oxy-combustion and chemical looping combustion (CLC). Chemical looping combustion conducts the oxidation and reduction reactions in separate reactors, allowing the capture of concentrated CO₂ and requiring no ASU. Through the two-phase Advanced Oxy-combustion Technology Development and Scale-up for New and Existing Coal-fired Power Plants Funding Opportunity Announcement, eight projects were recently chosen to begin Phase I. Under the 12 month Phase I effort, validation of the proposed pressurized oxy-combustion or CLC process will be accomplished through engineering system and economic analyses. Phase I projects will be eligible to apply for Phase II awards to develop and test the novel process components at the laboratory or bench scale.

Project Description

Alstom Power, Inc. (Alstom) will investigate improvements to a unique CLC system previously developed for CO₂ capture and separation. Alstom’s Limestone Chemical Looping Combustion (LCL-C™) technology has progressed through research conducted in the past 10 years under previous DOE/NETL projects. The LCL-C technology is
applicable for use in new plants or retrofit to existing pulverized coal-fired (PC) and circulating fluidized bed (CFB) power plants. This technology has the potential to remove over 90 percent of the CO₂ produced from coal combustion with less than 20 percent increase in the cost of electricity (COE). Alstom will conduct techno-economic studies, engineering studies for process and equipment improvements, and supporting bench-scale testing.

Phase I work will include economic evaluations of four LCL-C plant configurations. The base case for the study will be a previously developed basic CLC plant that will be updated to a current DOE economic basis. It will be used for comparison against other alternatives for the techno-economic studies in this project. A second case will determine the effect of designing the reducer reactor using standard CFB gas velocities. A third case will investigate the effect of using a pressurized reducer reactor, which reduces the reactor size and the amount of compression required for the CO₂ outlet gas stream. A fourth case will investigate the use of an advanced ultra-supercritical (USC) steam cycle for the chemical looping system. The advanced USC steam cycle should increase overall plant efficiency and lower the cost of electricity. Mass and energy balances will be performed for each case. The four LCL-C cases will be compared against a base case study of a supercritical PC plant without CO₂ capture.

In conjunction with the economic evaluations, Alstom will conduct a series of engineering studies focusing on equipment performance and selection for pressurized reducer operation as well as investigating several potential areas for process improvement. Specific systems targeted include solids and fuel management with a pressurized reactor and methods for accommodating a high pressure differential between two connected reactors under steady state and load change conditions. Areas of study for process improvement include the sensitivity of the plant efficiency to reducer pressure, the effect of reducer pressure on reaction kinetics, impact and methods for maximizing carbon retention in the reducer, and enhanced oxygen carrier performance. Bench-scale testing and computational fluid dynamics (CFD) analysis will be performed in support of these engineering studies.

**Primary Project Goal**

The primary project goal is to progress the development of an advanced CLC system for coal-fired power generation that removes greater than 90 percent of the CO₂ with less than 20 percent increase in the COE.

**Objectives**

Specific objectives supporting the project goal are to (1) perform engineering and economic analyses on the effects of operating pressure to determine the most practical, cost-effective configuration, (2) perform engineering analyses to determine practical methods and limitations of achieving pressurized operation, (3) perform engineering analyses and bench-scale testing to investigate possible process improvements, and (4) identify data/technology gaps and required process/equipment improvements.

**Planned Activities**

- A Thermoflow (thermal engineering software) model will be developed for the reference supercritical PC plant without carbon capture based on the net 550 MWe Case 11 from the U.S. DOE's Cost and Performance Baseline for Fossil Energy Plants Volume 1, November 2010.

- Thermoflow models will be developed for each of the four LCL-C plant configurations and used to produce detailed mass and energy balances, along with predicted performance.

- A limited amount of bench-scale testing will be done in support of the engineering and system studies.

- Economic analyses will be conducted to estimate the economic performance for each case using NETL’s Power System Financial Model Version 6.6.

- Engineering studies will be conducted to focus on equipment performance and selection for pressurized reducer operation as well as to investigate several potential areas for process improvement.

- A technology gap analysis will be conducted for the five cases investigated.

**Accomplishments**

- Project awarded in September 2012.

**Benefits**

The techno-economic results of this project are expected to show that the LCL-C technology can meet the DOE goals for coal-based power generation CO₂ abatement and COE, and potentially be the lowest cost method for CO₂ removal. It is anticipated that pressurizing the reducer will show (1) a reduction in CO₂ compression costs, (2) a reduction in the overall cost of electricity, and (3) that the advanced steam cycle will increase these advantages.