the ENERGY lab

PROJECT FACTS

Advanced Combustion Systems

Staged, High-Pressure Oxy-Combustion Technology: Development and Scale-up

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 CO_2 capture and storage significantly reduces efficiency of the power cycle. The aim of the ACS program is to develop advanced oxy-combustion systems capable of achieving power plant efficiencies approaching those of air-fired systems without CO_2 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 CO_2 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 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). 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

Washington University in St. Louis has teamed with Burns & McDonnell, the Electric Power Research Institute, and Ameren to investigate the technical feasibility and improved economics of a unique pressurized oxy-combustion system incorporating a staged combustion approach. Staged combustion permits control over temperature and heat transfer, allowing for elimination of other temperature control processes such as flue gas recycle or water injection. The potential advantages of this process are higher efficiency, reduced process gas volume, increased radiative heat transfer, reduced oxygen demands, reduced capital equipment costs, increased CO_2 purity entering the carbon compression and purification unit, and reduced auxiliary power demands. These benefits are expected to yield a lower cost of electricity (COE) than alternative approaches to pressurized oxy-combustion.

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PARTNERS

Burns & McDonnell
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PERFORMANCE PERIOD

Start Date	End Date
10/01/2012	09/30/2013

COST

Total Project Value
$1,044,965

DOE/Non-DOE Share
$835,973 / $208,992

AWARD NUMBER

DE-FE0009702

U.S. DEPARTMENT OF ENERGY

Researchers will complete an engineering system analysis, including application of Aspen Plus® and FLUENT modeling software, to design and optimize the novel staged high-pressure oxy-combustion system. As the concept of utilizing staged combustion of coal in nearly pure oxygen without flue gas recycle or other temperature controls has not been proven experimentally, Washington University will conduct some preliminary testing with an existing laboratory-scale oxy-combustion test furnace located at the Laboratory for Advanced Combustion & Energy Research. This experiment will also be simulated using FLUENT software, and the experimental results will be fed back into the model of the pressurized system and used to validate portions of the FLUENT model. An economic analysis will be conducted based on the modeling results. The technical and economic analyses will adhere to DOE requirements and guidelines.

Primary Project Goal

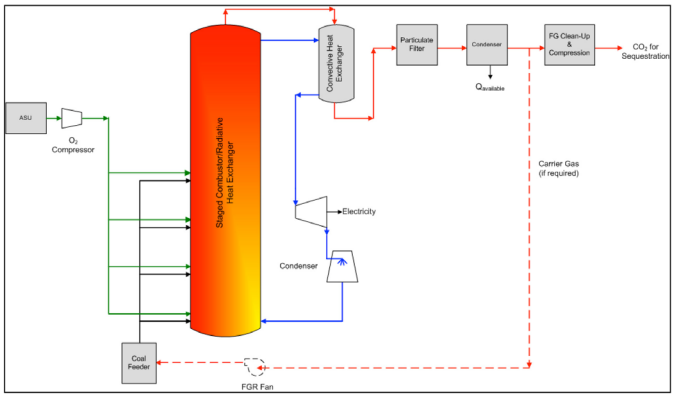
The goal of this one-year project is to perform a techno-economic analysis of a staged high-pressure oxy-combustion system for a pulverized-coal (PC) power plant designed for carbon capture utilization and storage. The project aims to show that staged pressurized oxy-combustion is a viable method of capturing CO_2 and can achieve at least 90 percent CO_2 removal at no more than a 35 percent increase in COE.

Objectives

The specific objectives are to obtain new knowledge regarding the benefits of a staged, pressurized oxy-combustion system by conducting a plant-wide technical and economic simulation; optimize the system utilizing the ASPEN Plus modeling tool; conduct computational fluid dynamic (CFD)-aided design of a novel staged combustion vessel and radiative heat exchanger; and perform laboratory-scale experiments of staged combustion without flue gas recycle.

Planned Activities

- Complete a Design Basis Report to describe the study's assumptions including plant location and ambient conditions, plant capacity factor, labor types, choice of fuel type(s), and technology selections for key components.



Simplified process flow diagram of a staged pressurized oxy-combustion plant.

- Utilize ASPEN Plus modeling software to develop and optimize the design variables, such as the temperature, pressure, flow rates, and gas composition at various stages, and the system pressure drops.
- Use FLUENT CFD modeling capabilities to model and optimize a staged combustion process in a cylindrical vessel, at elevated pressure, to determine the radiative and convective heat transfer profiles necessary to estimate the size of the radiant boiler. Additional specifications determined by modeling are the optimum distance between stages, optimum placement of excess oxygen in the first stage, and the thermal input at each stage.
- Conduct limited preliminary testing with the laboratory-scale oxy-combustion test furnace.
- Complete balance-of-plant equipment specifications.
- Estimate plant capital costs and operation and maintenance costs.
- Determine the COE and the increase in COE over an equivalent new PC power plant without carbon capture to compare to the DOE goals.
- Calculate the cost per ton CO_2 captured, cost per ton CO_2 avoided, and dispatch cost, and compare them to other baseline cases with carbon capture.

Accomplishments

Project awarded in September 2012.

Benefits

Research is required to completely evaluate pressurized oxy-combustion technologies to determine the technical barriers that exist between these concepts and commercialization. Pressurized oxy-combustion systems have the potential to increase overall power plant efficiency while maintaining combustion efficiencies and performance similar to those of air-fired combustion. This staged pressurized oxy-combustion project will provide key technical and economic information to validate this technology. The project results will clarify the advantages of pressurized combustion systems and further technology development.