the ENERGY lab

PROJECT FACTS

Advanced Combustion Systems

Commercialization of the Iron-Based Coal Direct Chemical Looping Process for Power Production with In Situ CO_2 Capture

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 (CO_2) 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 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 (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 CO_2 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

The Babcock & Wilcox Power Generation Group (B&W), in collaboration with Ohio State University (OSU) and Clear Skies Consulting, will further development of an advanced iron-based coal direct chemical looping (CDCL) process. Over the past 10 years, OSU

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PARTNERS

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PERFORMANCE PERIOD

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

COST

Total Project Value
$1,400,000

DOE/Non-DOE Share
$761,600/$638,400

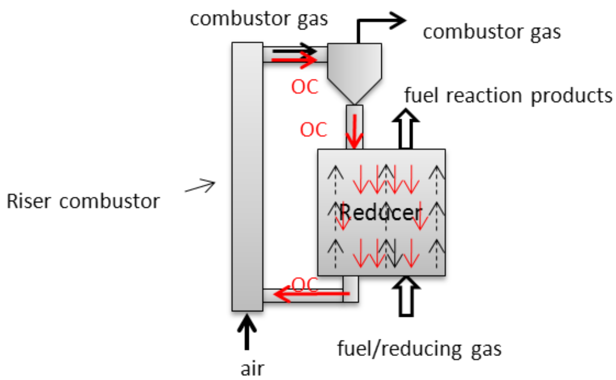
AWARD NUMBER

DE-FE0009761

U.S. DEPARTMENT OF ENERGY

has developed a proprietary iron oxide (Fe_2O_3)-based composite oxygen carrier particle that is ten times more reactive than pure Fe_2O_3 and is recyclable for more than 100 reduction-oxidation cycles without loss in reactivity. The CDCL process developed at OSU evolved from a novel concept to an integrated sub-pilot [25 kilowatt thermal (kWth)]-scale system with over 200 hours of successful operation studying various kinds of coal.

The CDCL process consists of a unique moving bed reduction reactor where pulverized coal reacts with the iron-based oxygen carrier particles to form normal combustion products, predominantly CO_2 and H_2O, while reducing the oxygen carrier particles from iron (III) oxide (Fe_2O_3) to a mixture of iron (II) oxide (FeO) and iron (Fe). The reduced oxygen carrier particles are then sent to a combustor and oxidized back to Fe_2O_3 with air. The oxygen carrier particle oxidation reaction (particle regeneration) releases large amounts of heat used for electricity generation via a steam turbine. The CO_2 produced in the reducer is cooled, cleaned, and compressed for sequestration. The unique reactor design and reaction pathway of the CDCL process allows for retrofit, repowering, and/or greenfield installation. A preliminary techno-economic analysis indicated the CDCL process has the potential to achieve greater than 96 percent CO_2 capture with an increase in the cost of electricity (COE) of about 33 percent.



Chemical looping combustion moving bed reducer operation

In Phase I the project will validate the advanced CDCL process for power generation through a techno-economic analysis and development of a commercial-scale plant design. By leveraging laboratory and previous sub-pilot work, the project team will collect data regarding oxygen carrier particle and process performance. A conceptual 550 megawatt electric plant design will be developed, including two configurations for the reducer reactor. A previously developed Aspen Plus® process model will be updated to incorporate the commercial CDCL process parameters and utilized in the optimization of the commercial design. Based on process simulation results and a detailed plant cost estimate, a comprehensive economic analysis of the commercial CDCL plant will be conducted and the COE will be determined. A sensitivity analysis will be performed to evaluate the effects of changes to key process parameters on the project economics. A detailed process analysis will identify and quantify critical technology gaps requiring closure to establish the viability of the commercial CDCL plant.

Primary Project Goal

The project goal is to validate the iron-based CDCL process and evaluate its potential as a cost-effective CO_2 capture technology for electric power generation.

Objectives

Specific Phase I objectives are to (1) develop the concept of a commercial plant design, (2) perform a techno-economic evaluation of the commercial design, (3) identify technology gaps, and (4) develop a preliminary design and budget estimate for a suitable pilot facility that will address the technology gaps and provide additional information to advance its technology readiness level.

Planned Activities

- Conduct limited laboratory analyses to support the design of a full-scale system.
- Update the Aspen Plus model and utilize it to optimize the commercial CDCL plant design.
- Develop a proposal-level cost for the commercial CDCL plant design and complete a comprehensive economic analysis of the plant.
- Determine the corresponding COE for the proposed commercial design and compare to the DOE target.
- Determine the technical gaps separating the current CDCL technology and a commercial product that meets DOE goals.

Accomplishments

- Project awarded in September 2012.

Benefits

The iron-based CDCL process has the potential for lower capital and operating costs as compared to first generation carbon capture technologies and the capability to meet the DOE target of less than 35 percent increase in COE with greater than 90 percent carbon capture. This is made possible by the elimination of the ASU. Successful completion of the project will assist in developing an advanced CDCL process for industrial power generation by resolving uncertainties associated with commercial-scale operations. The CDCL technology is applicable to both new and existing power plants. The process can be applied for repowering of existing plants as the CDCL process requires no modification of the existing steam turbine cycle.

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