the ENERGY lab

PROJECT FACTS

Advanced Combustion Systems

A Novel Supercritical Carbon Dioxide Power Cycle Utilizing Pressurized Oxy-combustion in Conjunction with Cryogenic Compression

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 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.

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PARTNERS

Thar Energy LLC

PERFORMANCE PERIOD

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

COST

Total Project Value
$1,250,000

DOE/Non-DOE Share
$1,000,000/$250,000

AWARD NUMBER

DE-FE0009395

U.S. DEPARTMENT OF ENERGY

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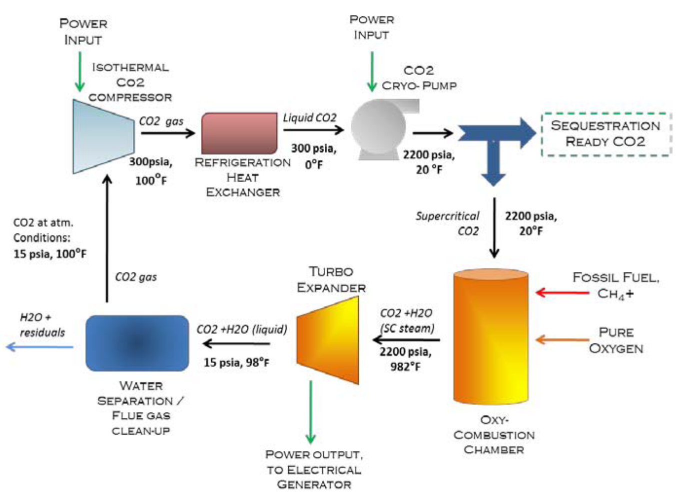
Project Description

The Southwest Research Institute® (SwRI) has teamed with Thar Energy LLC to investigate the technical feasibility and improved economics of a novel supercritical carbon dioxide (sCO_2) power cycle utilizing pressurized oxy-combustion in conjunction with cryogenic compression. The cryogenic pressurized oxy-combustion cycle (CPOC) offers a significant increase in overall system efficiency while producing an output stream of sequestration-ready CO_2 at pipeline pressures. The CPOC is an integrated hybrid Brayton-Rankine cycle in that it has a gas-to-liquid phase change in the compression process but is gaseous (supercritical to subcritical gas) in the expansion process. An advantage of the sCO_2 cycle is relatively high fluid densities when compared to steam, enabling the development of compact power blocks as small as 1/30 the size of a traditional Rankine cycle steam turbine. The CPOC leverages developments in pressurized oxy-combustion technology; a cryogenic CO_2 compression scheme (developed by SwRI under a previous DOE project); and recent developments in supercritical CO_2 power cycles. Initial development of the CPOC by SwRI indicates that the single loop cycle can reach relatively high system efficiencies—above 50 percent net plant efficiency—at modest combustion temperatures (below 1,300°F) but with high operating pressures [about 2,200 pounds per square inch absolute (psia)].



Single loop CPOC cycle

Advantages of the sCO_2 power cycle will be verified through engineering design and economic analysis. System process and economic models will be used to maximize net cycle efficiency while minimizing costs. A sensitivity analysis will be conducted to understand the relative importance of each component on the system cost and the impact of each component on system performance. A technology assessment will be performed for critical cycle components or components that have a significant impact on cycle performance to identify current technology readiness levels (TRL) and development paths required to mature essential technologies into a commercially viable system.

Primary Project Goal

The project goal is to validate the capability of the novel sCO_2 power cycle by utilizing pressurized oxy-combustion in conjunction with cryogenic compression to achieve the DOE goals of 90 percent CO_2 removal at no more than a 35 percent increase in cost of electricity (COE) as well as high overall plant efficiencies with CO_2 compression to 2,200 psia.

Objectives

The objectives of the Phase I effort are to (1) verify the system performance and economic benefit of the CPOC cycle through engineering system and economic analyses, and (2) identify the key technologies that have a significant impact on the cycle performance and require further technological development to reach commercial potential.

Planned Activities

- Develop an engineering analysis model and an economic model for cycle optimization and evaluation.
- Conduct engineering and economic analyses to validate cycle feasibility and to select the final CPOC configuration as the basis for cycle optimization.
- Conduct cycle optimization of the selected CPOC cycle configuration to increase net cycle efficiency while achieving the stated cost goals.
- Identify critical components based on a sensitivity analysis of the engineering and economic analysis models. Review each component to identify current TRL levels and the impact of performance uncertainty on the cycle analysis model.
- Conduct a design review of low TRL components to identify key developments required for commercialization of each component, and document the study in the Technology Gap Analysis Report.

Accomplishments

- Project awarded in September 2012.

Benefits

Further development of the supercritical CO_2 power cycle will result in important progress toward achieving the DOE program cost and performance goals for advanced oxy-combustion technologies. The CPOC offers significant improvements in overall system efficiency, while producing an output stream of sequestration ready CO_2 at pipeline pressures, and the capability of achieving greater than 90 percent CO_2 capture with less than a 35 percent increase in the COE.