the ENERGY lab

PROJECT FACTS

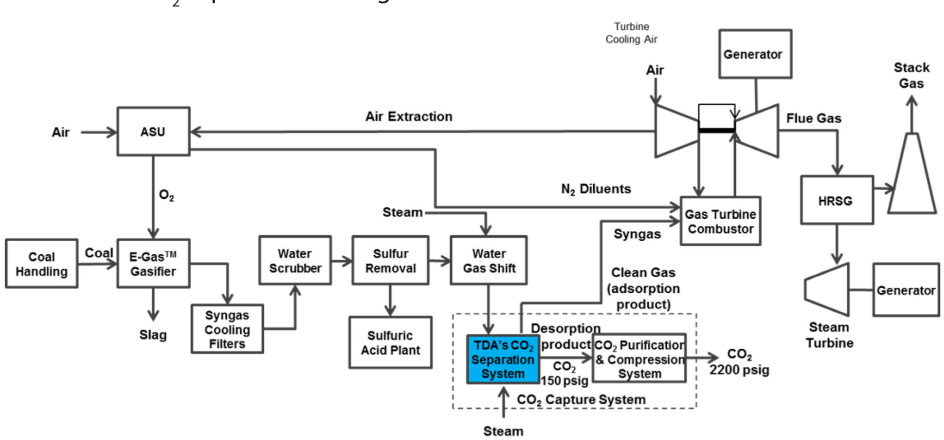
Carbon Capture

Pilot Testing of a Highly Effective Pre-Combustion Sorbent-Based Carbon Capture System

Background

The mission of the U.S. Department of Energy Office of Fossil Energy's (DOE FE) Carbon Capture Research & Development (R&D) Program, implemented through the National Energy Technology Laboratory (NETL), is to develop innovative carbon dioxide (CO_2) emissions control technologies for fossil fuel-based power plants. The Carbon Capture R&D Program portfolio of pre- and post-combustion CO_2 emissions control technologies and related CO_2 compression is focused on advancing technological options for new and existing power plants to enable cost-effective CO_2 capture for beneficial use or storage of CO_2 and ensure that the United States will continue to have access to safe, reliable, and affordable energy from fossil fuels. The DOE FE/NETL goal is to demonstrate second-generation technologies that can capture 90 percent of the CO_2 at less than $40 per metric ton (tonne) in the 2020-2025 timeframe. DOE is also committed to extend R&D support to even more advanced transformational carbon capture technologies that will increase competitiveness of fossil-based energy systems beyond 2035.

Pre-combustion CO_2 capture technologies are applicable to integrated gasification combined cycle (IGCC) power plants, where solid fuel is converted into gaseous components (synthesis gas or syngas) by applying heat under pressure in the presence of steam and oxygen. The carbon is captured from the syngas before combustion and power production occurs. Pre-combustion carbon separation and capture is relatively simple and less expensive compared to post-combustion capture as it has a greater driving force, with the processed syngas at a much lower volume, at a higher pressure, and containing a higher concentration of CO_2. Pilot-scale testing with actual coal-derived syngas is a key step in the continued development of promising sorbent-based pre-combustion CO_2 capture technologies.



TDA's CO_2 separation system integrated with an IGCC power plant.

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PROJECT DURATION

Start Date	**End Date**
10/01/2013	09/30/2017

COST

Total Project Value
$10,000,000

DOE/Non-DOE Share
$8,000,000 / $2,000,000

PROJECT NUMBER

FE0013105

U.S. DEPARTMENT OF ENERGY

Project Description

TDA Research (TDA), along with its partners, will continue to advance development of their novel sorbent-based pre-combustion carbon capture technology through pilot-scale testing. TDA's high-temperature pressure swing adsorption (PSA)-based process uses an advanced physical adsorbent that selectively removes CO_2 from coal-derived syngas at temperatures as high as 300 degrees Celsius, achieving high power-cycle efficiency. The sorbent is a mesoporous carbon grafted with surface functional groups that remove CO_2 via physical adsorption. The sorbent binds CO_2 more strongly than common physical adsorbents, providing the chemical potential needed for the high temperature operation. As CO_2 does not form a true covalent bond with the surface sites (as with chemical absorbents), the sorbent regeneration can be accomplished with a relatively small energy input.

Previous work conducted under DOE/NETL funding (DE-FE0000469) verified the techno-economic viability of the technology through bench-scale and slipstream testing. The sorbent was shown to achieve a very high working capacity, maintain its performance over 11,650 cycles, and withstand the potential impurities in actual syngas. Researchers found that the high-temperature CO_2 removal capability and low regeneration energy requirement resulted in the plant efficiency of the TDA CO_2 capture process exceeding 34 percent higher heating value (HHV), compared to 31.4 percent for the conventional Selexol™ solvent system. The capital cost for an IGCC system with TDA's process was estimated to be 12 percent lower than that of IGCC with the Selexol process. For the current project, the sorbent performance will be evaluated using actual syngas in a fully equipped system at a larger scale and for a longer duration. Researchers will optimize the sorbent reactor design using computational fluid dynamics (CFD). The PSA cycle sequence will be improved through adsorption modeling. Two 0.1 megawatt electric (MWe) tests will be conducted for 9 to 12 months in a fully equipped prototype unit and using actual syngas to prove the viability of the new technology. All results will feed into a techno-economic analysis supported with Aspen Plus® simulations to calculate the impact of the CO_2 capture system on plant efficiency and the cost of electricity.

The first pilot test will be conducted at the Power Systems Demonstration Facility at the National Carbon Capture Center (NCCC) and the second test at Sinopec's IGCC plant in China. These facilities use different types of gasifiers (air-blown transport gasifier vs. oxygen-blown gasifier) and feedstocks (low rank coals vs. petcoke), which will allow researchers to assess process efficacy in very different gas streams.

Primary Project Goal

The primary project goal is to develop a new sorbent-based pre-combustion carbon capture technology for IGCC power plants that will meet the overall DOE Carbon Capture Program performance goals of 90 percent CO_2 capture rate with 95 percent CO_2 purity at a cost of $40 per tonne of CO_2 captured by 2025.

Objectives

The project objectives are to verify the techno-economic viability of the new technology by designing and fabricating a 0.1 MWe pilot-scale unit, conducting long-term pilot-scale tests with actual coal-derived syngas, and performing a high fidelity engineering and cost analysis.

Planned Activities

- Determine the optimal sorbent reactor design using detailed adsorption modeling and CFD analysis, perform detailed process design and modeling using Aspen Plus software, and optimize the PSA cycle and full-scale system design including specifics for both air- and oxygen-blown gasifiers.
- Develop a sorbent manufacturing plan, produce the required amount of sorbent, and complete long-term bench-scale testing of the sorbent (up to 60,000 adsorb/desorb cycles) to assess durability under representative conditions.
- Fabricate the 0.1 MWe testing unit.
- Conduct the two separate field tests at NCCC and Sinopec using the pilot-scale test unit.
- Perform a final techno-economic analysis based on incorporation of the field test results into the simulation model for optimization of IGCC plant performance.
- Perform a final technology environmental, health, and safety assessment.

Accomplishments

Project awarded in September 2013.

Benefits

TDA's high temperature PSA-based CO_2 removal technology holds potential to significantly improve the IGCC process efficiency needed for economically viable production of power from coal and other heavy feedstocks. Higher net plant efficiency and lower capital and operating costs result in a substantial reduction in the cost of electricity for the IGCC plant. Continued development and validation of the process will put it on a path to be ready for first-of-a-kind commercial-size demonstration by 2025.