the ENERGY lab

PROJECT FACTS

Carbon Capture

Evaluation of Dry Sorbent Technology for Pre-Combustion CO_2 Capture

Background

An important component of the Department of Energy (DOE) Carbon Capture Program is the development of carbon capture technologies for power systems. Capturing carbon dioxide (CO_2) from mixed-gas streams is a first and critical step in carbon sequestration. To be technically and economically viable, a successful separation method must be applicable to industrially relevant gas streams at realistic temperatures and practical CO_2 loading volumes. Current technologies that are effective at separating CO_2 from typical CO_2-containing gas mixtures, such as coal-derived shifted synthesis gas (syngas), are both capital and energy intensive. Research and development is being conducted to identify technologies that will provide improved economics and efficiencies over the current state-of-the-art.

In alignment with DOE Carbon Capture Program goals, the National Energy Technology Laboratory (NETL) has teamed with URS Group (URS) to test and validate a dry sorbent technology for CO_2 capture from synthesis gas streams prior to being combusted in a gas turbine. This pre-combustion capture technology, called Sorbent Enhanced Water-Gas Shift (SEWGS), is envisioned for coal gasification processes that would utilize high hydrogen content fuel gas with either a fuel cell or an H-class turbine to generate power.

Project Description

URS and the University of Illinois at Urbana-Champaign (UIUC) are investigating a dry sorbent process configured to combine the water-gas-shift (WGS) reaction with CO_2 removal for coal gasification systems. A combination of process simulation modeling and sorbent molecular and thermodynamic analyses will be performed to predict optimal sorbent properties and identify optimal operating temperature and pressure ranges required to maximize the energy efficiency of the combined WGS and CO_2 capture processes. Results from the computational study will be used to identify suitable sorbents, either commercially available or under development. In addition, the project team will use these results as a guide to synthesize a number of sorbent materials made from multiple precursor materials and custom-designed to exhibit properties for superior CO_2 sorption. A laboratory program will be conducted using high-temperature and -pressure reactors (HTPRs) to evaluate the sorbents at conditions simulating coal-derived syngas entering a WGS reactor. The tests will determine optimal process conditions for CO_2 removal and regeneration for different sorbent types and impacts of key syngas impurities. Results will be used as the basis of an analysis to evaluate the technical and economic feasibility of the dry sorbent technology as a pre-combustion CO_2 mitigation process.

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PARTNERS

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PROJECT DURATION

Start Date
01/01/2010

End Date
03/31/2013

COST

Total Project Value
$2,684,396

DOE/Non-DOE Share
$1,999,934 / $684,462

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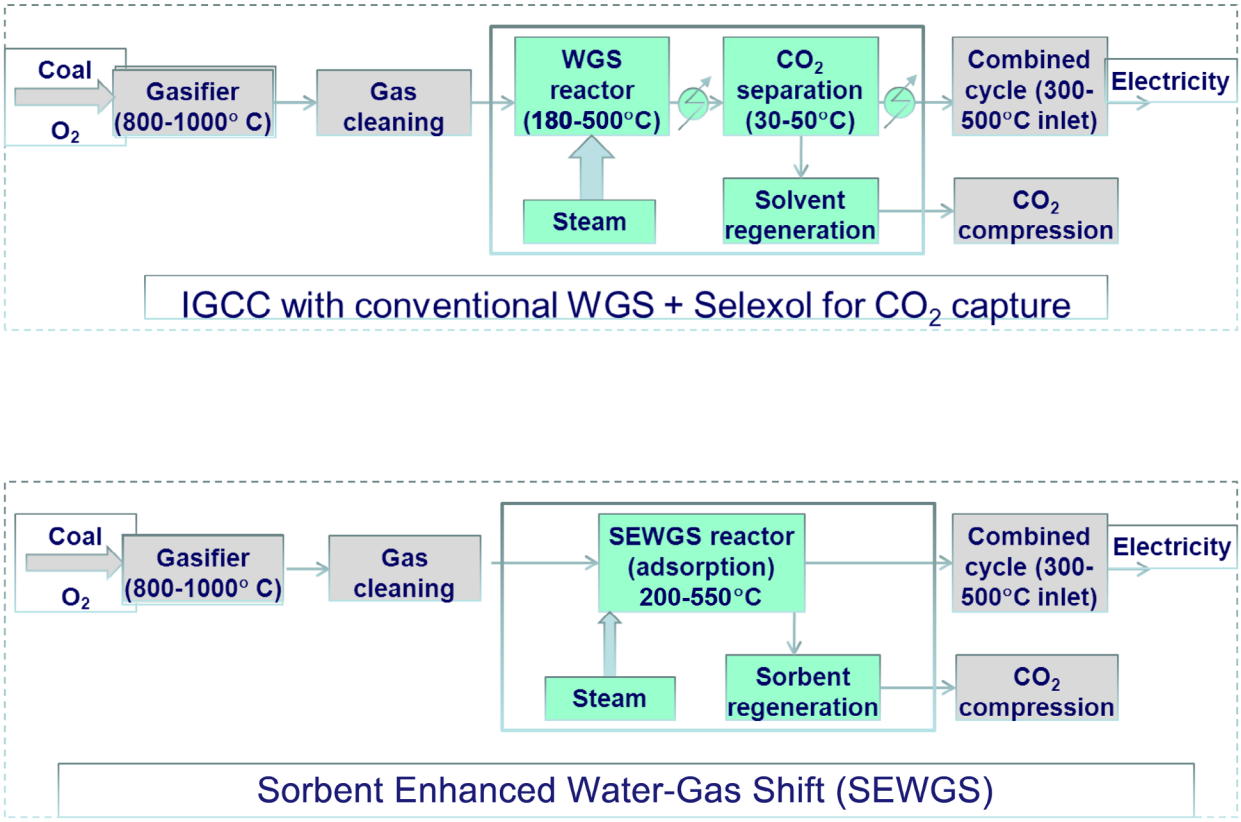
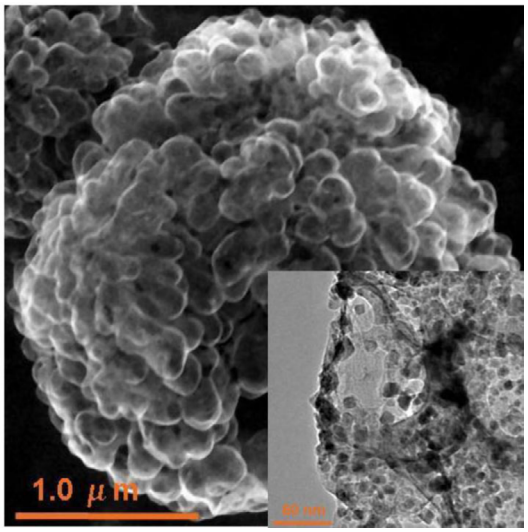


Schematic of CO_2 capture integrated with the water gas shift process.

Goals and Objectives

The project will pursue development of a dry sorbent material and process that supports the integration of a WGS system with CO_2 removal from coal gasification systems. Sorbent development will target 90 percent (%) CO_2 removal, and will operate at the high temperatures and pressures typically encountered upstream of a WGS reactor. If successful, the sorbents developed in this program will augment or replace the carbon monoxide (CO) conversion catalysts currently used in WGS reactors and improve overall WGS thermal efficiency. The process also enables CO_2 capture and regeneration at high temperature and pressure, thus minimizing energy efficiency penalties on the integrated gasification combined cycle (IGCC) plant.

The goal of the project is to identify a sorbent process that can efficiently capture CO_2 from a gas stream containing CO_2, carbon monoxide (CO), hydrogen (H_2) at temperatures ranging from 200 to 550 degrees Celsius (°C) and CO_2 partial pressures of 200 to 600 psi. After capturing the CO_2, the sorbents will be regenerated using steam or other condensable purge vapors.



Scanning Electron Microsopy (SEM) and Transmission Electron Miscroscopy (TEM) images of a multi-functional sorbent synthesized by a novel method.

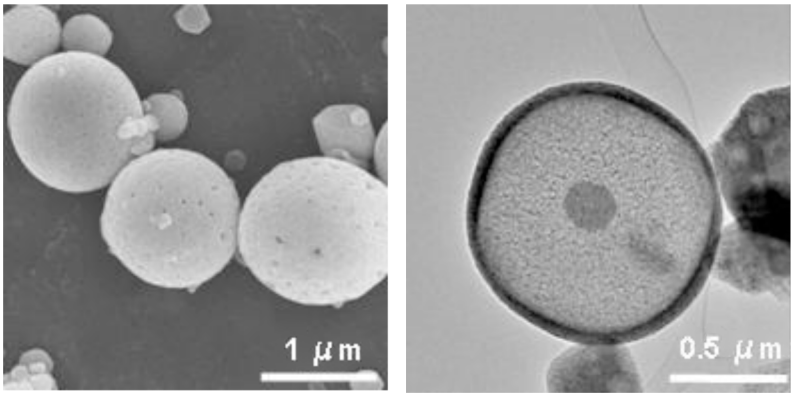
Accomplishments

The research team evaluated 10 initially identified or prepared sorbent materials capable of removing CO_2 at expected WGS reactor temperatures and pressures. A promising sorbent, zirconium (Zr) doped calcium carbonate ($CaCO_3$), was selected, synthesized using both modified ultrasonic spray pyrolysis (USP) and flame spray pyrolysis (FSP), and characterized using various methods such as transmission electron microscopy, scanning transmission electron microscopy, and energy dispersive spectroscopy. Sintering and the role of dopants were investigated using molecular simulations. Thermodynamic simulations of the WGS reaction coupled with CO_2 adsorption were completed. Progress was made in evaluating how gas components and operating conditions impact sorbent performance. Long term performance and economic assessment of the sorbents and associated processes will be completed by March 2013 to conclude whether the sorbent-enhanced WGS process for CO_2 capture is technically and economically viable.

Installation of the URS HTPR and system shakedown has been completed. Researchers at URS and UIUC will continue to conduct testing on the HTPRs using simulated syngas streams with applicable impurities. Research will also be ongoing to investigate the impacts of experimental conditions (pyrolysis temperature, precursor type and concentration, gas flow rate, etc.) on the physical properties and CO_2 adsorption performance of salt-assisted and other USP and FSP sorbents. Synthesis of WGS catalyst/CO_2 sorbent hybrid materials will also be explored to improve the WGS and CO_2 capture performances.

Benefits

The commitment to low-CO_2-emission coal power will effectively meet the challenge of satisfying the nation's dynamic electricity supply requirements while simultaneously decreasing the contribution of coal-based electrical power to atmospheric CO_2 emissions. If demonstrated successfully, this SEWGS process offers the potential to significantly reduce the energy penalty and cost associated with CO_2 separation and capture when compared to conventional technologies.



SEM and TEM images of a hollow, high BET surface Calcium-based sorbent synthesized by a ultrasonic spray pyrolysis method.

High-temperature, high-pressure reactor (HTPR).

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