PROJECT facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Advanced Research

08/2007

FUTUREGEN TECHNOLOGIES

Background

FutureGen — a federally supported initiative announced in January 2003 by President George W. Bush — has as its goal the creation of the world's first coal-based, zero-emission, prototype power plant producing both electricity and hydrogen. A key part of the FutureGen concept is to support the production of hydrogen to fuel a "hydrogen economy," with the use of clean burning hydrogen in power-producing fuel cells, as well as for use as a transportation fuel. The main challenge is to use coal — the nation's most abundant fossil fuel — cost-effectively in ways that produce essentially zero emissions, which includes the separation and capture of carbon dioxide (CO_2), the leading greenhouse gas, coupled with CO_2 sequestration (long-term storage). Significant research and development (R&D) is required in order to make FutureGen a practical reality and to prove the new technologies employed so that they can be transferred for use in commercially operated facilities.

A FutureGen-type plant is designed around Integrated Gasification Combined-Cycle (IGCC) technology. This technology relies on coal gasification, integrated with combined-cycle electricity generation that employs both gas and steam turbines. The primary technical hurdles to be addressed to support the FutureGen concept can be categorized in these broad areas:

1) Reliable, efficient coal and biomass gasification technologies with flexibility for maximizing hydrogen production and increasing the efficiency of combined-cycle power generation

2) Innovative advances in combustion technology that minimize emissions to allow for carbon sequestration

3) Cost-effective gas cleanup and separation technologies

4) Cost-effective methods for carbon sequestration

5) Hydrogen transportation and storage

Figure 1. FutureGen conceptual illustration

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PROJECT DURATION

04/01/04 to 03/31/06

COST

Total Project Value
$295,000

DOE/Non-DOE Share
$295,000 / $0

ADDRESS

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Objectives

Under the sponsorship of the Office of Fossil Energy of the U.S. Department of Energy (DOE-FE), the University of North Dakota Energy and Environmental Research Center (EERC) has supported the FutureGen concept with R&D dedicated to addressing some of the key technical barriers to FutureGen deployment. Research focused on promoting future energy conversion and distribution technologies that use both fossil and alternative fuels with zero or near-zero emissions of pollutants. Four main activities were involved:

1) Demonstrating at a fundamental level that the combustion of coal in an oxygen-water vapor (O_2-H_2O) atmosphere is feasible, by comparing burning rates, nitrogen oxides (NO_X) produced, and effects on particulates to those in a conventional excess air combustion system;

2) Developing a feed system for a low-rank coal and carbon dioxide slurry that could be injected into an energy conversion system, allowing for more efficient gas separation and lower toxic air emissions;

3) Pilot-scale testing to optimize hydrogen production in an integrated fluidized-bed gasifier, coupled with a steam reforming system; and

4) Demonstrating the use of alloy hydrides for hydrogen storage, with a focus on the effects of engineered nanostructures.

Accomplishments

Significant results were achieved in each of the project areas.

Coal Combustion — Thermogravimetric analysis (TGA) testing indicated that combustion in an O_2-H_2O atmosphere is feasible and results in decreased NO_X. Production of NO_X was substantially reduced for both subbituminous and bituminous coals at a 1:1 flow rate. Less carbon monoxide was also produced in the O2-H2O atmosphere compared to air. It was concluded that some partial gasification might have occurred in the O_2-H_2O atmosphere, with up to 1,000 ppm hydrogen being observed. Some differences in combustion behavior suggested that partial gasification might be occurring along with oxidation.

Gasifier Feed System — A combination viscometer/autoclave system was successfully designed, installed, and operated for measuring viscosity of fuel slurries produced with liquid CO_2 and coal. The slurries demonstrated rapid settling of the solid fuel compared to settling rates in aqueous-fuel slurries. Residual moisture content of the tested fuel appeared to have little effect on viscosity of the liquid CO_2-based slurries.

Hydrogen Production Testing — Shift catalyst performance with commercially available catalysts was successfully measured. TGA testing was coupled with a slipstream arrangement in which a 4-lb/hr continuous fluidized-bed reactor was integrated with a small catalyst test reactor. The system fired Wyoming subbituminous coal. TGA showed that sulfidation occurred over a range between 150 °C and 300 °C, and a water-gas shift reaction also occurred over the same range.

Hydrogen Storage — A magnesium-based organometallic compound was successfully impregnated into a porous carbon support and then decomposed in situ to allow placement of magnesium in the pores. The resulting sorbent initially showed good performance for adsorbing and releasing hydrogen, but the chemistry behind the performance was not fully determined, and the results were not precisely repeatable at low temperatures. Hydrogen storage that was observed may not have been the result of hydrogen being converted to carbon-supported magnesium hydride, but rather more of a physical packing.