PROGRAM facts

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

Hydrogen and Clean Fuels from Coal

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Advanced Materials Corporation
Argonne National Laboratory
Aspen Products Group Inc.
Eltron Research Inc.
Gas Technology Institute (GTI)
GE Global Research
General Electric Company
Headwater Technology Group
ICRC/Syntroleum
Lehigh University
Media & Process Technology, Inc.
Ohio State University
Southwest Research Institute

HYDROGEN AND SYNGAS

Background

The DOE's Hydrogen & Syngas Program was initiated in fiscal year 2004 (FY 2004) to support the President's Hydrogen Fuel Initiative, DOE's goals in the Hydrogen Posture Plan, and the FutureGen project. The mission of the Hydrogen and Syngas Program is to develop advanced energy technologies through joint public and private RD&D. These technologies will facilitate the transition to the hydrogen economy and the use of our nation's abundant coal resources to produce, store, deliver, and utilize affordable hydrogen in an environmentally responsible manner. The Program is implemented by DOE's National Energy Technology Laboratory (NETL).

Research Description

The Hydrogen & Syngas Program is designed to improve current technology and develop new, innovative technology that can deliver affordable hydrogen produced from coal with near-zero emissions. The technologies that comprise the program and those that enable the achievement of the program's goals include activities that are part of the Hydrogen Fuel Initiative as well as associated technologies that are being developed in other coal-based gasification and carbon dioxide sequestration programs.

There are two key hydrogen-production pathways for the program: the central production pathway with gaseous hydrogen and the alternate hydrogen production pathway with hydrogen-rich liquid fuel and substitute natural gas (SNG). In the first pathway, hydrogen is produced from coal at a large, central facility. These facilities may also include co-production of electricity or other products, but capture and ultimately sequester carbon dioxide.

In the second pathway, hydrogen-rich, zero-sulfur liquids and SNG are produced from coal at several small facilities. These liquids and SNG can be transported through the existing petroleum or natural gas pipeline distribution networks and reformed into hydrogen near the end-user. In the interim, the hydrogen-rich liquids may be used as substitutes for petroleum-based liquid transportation fuels.

In conjunction with these two pathways, polygeneration—the production of high-value carbon-based materials or chemicals—will utilize the facilities, products, or intermediate products of a hydrogen, liquid fuels, or SNG production plant that also co-produces electricity. will increase the economic viability of these facilities, making them commercially more attractive.

Program Structure

The Hydrogen & Syngas Program builds on expected successes in associated programs within DOE's Office of Fossil Energy (FE). The research areas within the program together with its interrelationships with other DOE-FE programs are shown in the figure below.

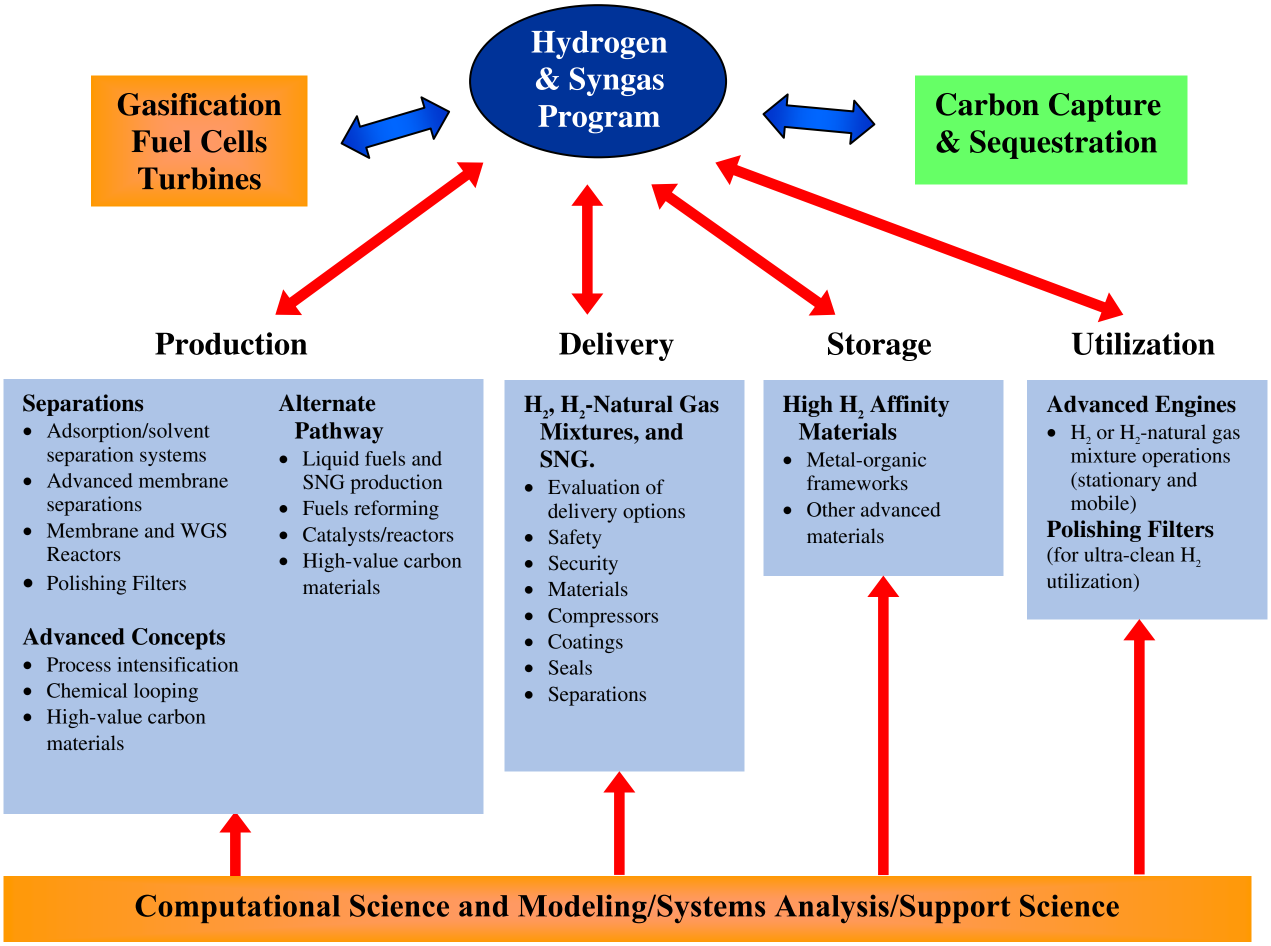


Figure 1

Goals

The Hydrogen & Syngas Program has the following goals:

- **Central Production Pathway:** By 2015, demonstrate a 60 percent efficient, near-zero emissions, coal-fueled hydrogen and power co-production facility that reduces the cost of hydrogen from coal by 25 percent compared to current coal-based technology.
- **Alternate Hydrogen Production Pathway:** By 2013, optimize, integrate and make available an alternative hydrogen production pathway and reforming system to produce decentralized hydrogen from high hydrogen content hydrocarbon liquids and substitute natural gas (SNG) that can be delivered through the existing infrastructure.
- **Polygeneration:** By 2015, enhance coal facility profitability by producing a variety of high-value, coal-derived chemicals and/or carbon materials that can be incorporated into the central or alternate pathway hydrogen production systems.
- **Storage:** By 2009, bring research on hydrogen storage technologies for transportation and stationary applications to an orderly conclusion.
- **Delivery:** By the end of 2009, bring the research on hydrogen, hydrogen-natural gas mixtures, or synthesis gas delivery to an orderly conclusion.
- **Utilization:** By the end of 2015, complete the development of hydrogen and hydrogen-natural gas mixture internal combustion engine modifications and operations.

Program Justification

The United States is becoming increasingly dependent on imported oil for transportation fuels. Increased demand from developing countries for the finite world oil reserves is expected to raise crude oil prices and cause world oil production to peak, possibly over the next 20–30 years. Some analysts believe that this peaking may already be occurring or may occur within the next decade. In contrast, U.S. coal reserves nearly equal the total proven world conventional oil reserves – a 250-year supply of U.S. coal at today's domestic production rates.

The production of hydrogen from coal requires coal gasification, which can produce a clean synthesis gas with virtually zero pollutant emissions. Any carbon dioxide generated during the conversion of synthesis gas to hydrogen can be captured through carbon sequestration technologies and concentrated into stream for use, for example, in enhanced oil recovery. Producing hydrogen and hydrogen-containing fuels from coal therefore represents a clean pathway to a hydrogen-based economy and an alternative pathway to reduce the nation's requirements for imported oil.

Fuel cell technology is available to convert hydrogen into electric power in a clean and efficient manner for both automotive and stationary power applications. The potential emissions for hydrogen produced from coal with sequestration and used in fuel cell vehicles compared to hybrid electric vehicles and internal combustion vehicles is shown on Figure 2.

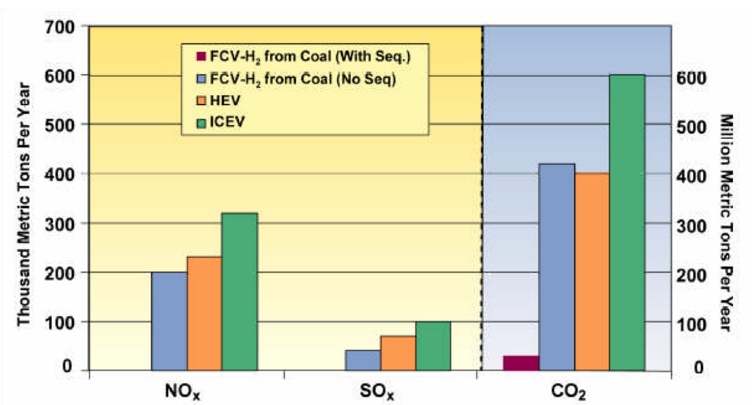


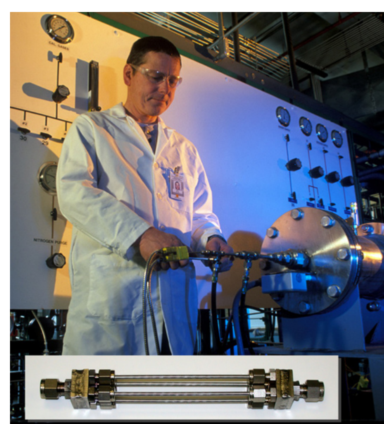
Figure 2

Accomplishments

- Commercially-ready micro porous membranes
- Novel metal alloys and cermet membranes
- Specialized membrane seals and brazing techniques
- Bench-scale membrane reactors
- Computational models to develop and predict membrane performance

Benefits

- Achieve energy security and a sustainable hydrogen economy by economically producing hydrogen from coal.
- Reduce environmental concerns associated with energy use in automotive and stationary power applications through the clean production of hydrogen from coal in tandem with carbon sequestration.
- Ensure the availability of a major primary energy resource that can be used for the production of hydrogen in volumes sufficient to provide the fuel which will be needed for the future fuel cell-powered vehicle market.



NETL Hydrogen Membrane Test Unit (inset shows membrane reactor)

Major Project Accomplishments

- Scaled up a hydrogen separation ceramic membrane for FutureGen and selected a membrane system configuration. Demonstrated a selectivity > 99.999 percent at a 1000 psi pressure differential and 270 psi permeate pressure. Demonstrated large-scale wafer flux of 100 $ft^3/hr/ft^2$ at 100 psi at 420 °C. Began the design and construction of 1.3 lb/day H_2 separation facility to obtain engineering data ***(Eltron Research, Inc).***

PROJECT PARTNERS (cont.)

United Technologies Corp.

University of California, Davis

University of Michigan

University of Wyoming – Western Research Institute

Wright-Patterson Air Force Base

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For more information about the Hydrogen & Syngas Program visit the NETL website **www.netl.doe.gov**

From sidebar at left, select "Technologies" and then "Hydrogen and Clean Fuels."

- Verified the performance of an Eltron membrane at 400 °C for ~ 30 hours in a high pressure hydrogen test facility. Permeability was 10 times that of pure Pd. ***(NETL – Office of Research & Development).***
- Completed the fabrication of self-supported Cu and Pd-Cu alloy membranes in the range of 1-10 µm in thickness by depositing samples onto polymeric substrates of ~20 sq. in. in area. Obtained a hydrogen flux of 242 $ft^3/hr/ft^2$ at 20 psi at 400 °C for 2.5 micrometer thick, 2.6 cm^2 membrane. ***(Southwest Research Institute).***
- Completed construction of a permeation unit capable of operations up to 10 atm. by pressing commercially available CaO powders to obtain crack-free green disks. The disks were then sintered in the temperature range of 1300 to 1400 °C for 4 hours to obtain membranes with the capability to handle H_2S-containing gas streams. Conducted initial permeation test on a tubular, supported calcium membrane tube in the range of 600-700 °C. ***(Gas Technology Institute).***
- Completed pilot-scale fabrication tests for one-meter-long hydrogen membranes and completed single gas tests with these membranes ***(Oak Ridge National Laboratory).***
- Prepared a carbon molecular sieve (CMS) membrane and tested its hydrogen and nitrogen single-component permeances over the temperature range 25-300 °C as the first step toward characterizing the hydrogen separation efficiency of the membrane ***(Media & Process Technology).***
- Developed procedures to coat and heat-treat Ta tubes with Pd/Cu coatings on the outer and inside surfaces of the tubes. Measured hydrogen permeability through a series of membranes at different conditions and identified appropriate operating procedures and conditions ***(Aspen Group, Inc).***

Planned Projects

- Produce barrel quantities of coal-derived liquids using iron-based Fischer-Tropsch FT synthesis in Process Development Unit (PDU)-scale reactor. Investigate primary and secondary wax/catalyst separation, hydro-treating and hydrocracking of neat FT liquid products, and hydrogen yield from product reforming ***(Headwaters Technology Innovation Group).***
- Evaluate a cobalt-based Fischer-Tropsch (FT) catalyst for converting coal-derived synthesis gas to high-hydrogen content liquids. Produce gallon quantities of FT liquids to be further processed into No. 2 diesel for small-scale testing as ultra-clean transportation fuel, evaluated as fuel for specialized vehicles for the military, and tested as feed to a reformer to produce hydrogen ***(ICRC).***
- Alternative Hydrogen Production Pathways and Hydrogen Utilization Solicitation (to be awarded Sep. 2006).
  - High H_2 Content Liquids & Reforming
  - Hydrogen in Internal Combustion Engines
- Central Hydrogen Production (to be awarded Dec. 2006).
  - Process Intensification
  - Polishing Technology

New Projects in FY-06

Selections made in three topics:

- Co-Production of hydrogen and electricity
- Synthetic Natural Gas (SNG)
- High-Value Products