Fuel Cell & Hydrogen Energy Association
TRANSFORMING THE ENERGY NETWORK
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FACT SHEET

Hydrogen Production From Coal

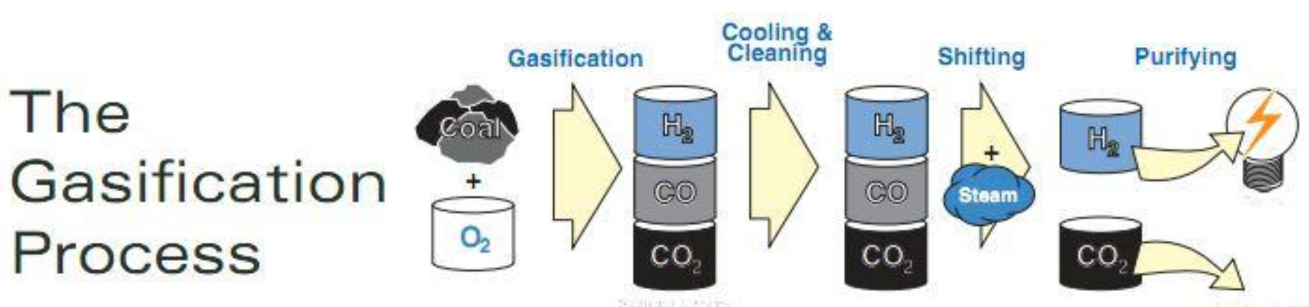
Hydrogen holds great promise for meeting our future energy and fuel needs. One of hydrogen's greatest strengths is its ability to be produced from a wide variety of resources. One of these resources is coal. Hydrogen production from coal, with carbon capture technology, can provide a low cost, low emission, high volume stream of hydrogen to provide clean energy to everything from buildings and laptop computers to cars and buses. Hydrogen is not yet produced commercially from coal, but the technology needed is well-known.

The abundance and low cost of coal as a raw material make it an important player in developing a hydrogen future. With 273 billion tons, the U.S. has the largest estimated recoverable reserves of coal, possessing 27% of the world's reserves. In 2005, according to the U.S. Energy Information Administration, coal cost $1.54 per million Btu, compared to $7.59 for petroleum and $8.21 for natural gas (*Source: Electric Power Monthly, November 2006*).

Hydrogen Production Using Coal Gasification

The process most likely to be used for turning coal into hydrogen is called gasification. Coal gasification dates back to the mid-19th century when it was used to make "town gas" for local cooking, heating, and lighting—many of the uses that natural gas meets today. Gasification works by mixing coal with oxygen, air, or steam at very high temperatures without letting combustion occur (partial oxidation). Most of today's pulverized coal power plants burn coal (combustion) to generate steam for use in a turbine. Currently, only two commercially operated power plants are using the more efficient and cleaner gasification technology.

Coal gasification plants in general have better emissions profiles than conventional pulverized coal power plants for different types of emissions. Higher operating efficiencies in the gasification plants allow for significant reductions in pollutants. Carbon dioxide emissions, for one, are reduced roughly 20%. This can be further reduced to almost zero by adding carbon capture and sequestration technologies (see The Gasification Process diagram below and the text box on page 3).



The Process

Step 1: Gasification

Gasification turns coal into a very hot (up to 1800°C) synthesis gas, or syngas, which is composed of carbon monoxide, hydrogen and carbon dioxide, as well as small amounts of other gases and particles. This is accomplished by mixing pulverized coal with an oxidant, usually steam, air or oxygen.

Step 2: Cooling and Cleaning

Next, the syngas is cooled and cleaned to remove the other gases and particles, leaving only carbon monoxide, carbon dioxide and hydrogen. Syngas is easier to clean than the emissions from a pulverized coal power plant. During syngas cleaning, mercury, sulfur, trace contaminants, and particulate matter are removed.

Step 3: Shifting

Next, the syngas is sent to a "shift reactor." During the shift reaction, the carbon monoxide is converted into more hydrogen and carbon dioxide by mixing it with steam. Afterwards, the syngas consists mostly of hydrogen and carbon dioxide.

Step 4: Purification

Once the syngas has been shifted, it is separated into streams of hydrogen and carbon dioxide. The hydrogen, once cleaned, is ready for use. The carbon dioxide is captured and sent off for sequestration (see text box on Page 3).

Step 5: Usage

There is now a stream of pure hydrogen ready for a variety of uses. It can be burned in a gas turbine for electricity generation, converted to electricity in a fuel cell, used as a fuel for an internal combustion engine or as a chemical for making fertilizer, semiconductors and many other products.

The Importance of Carbon Capture

The U.S. Department of Energy is researching a large slate of new and upgraded technology for many of the processes used to transform coal to hydrogen. With these technologies and others, carbon dioxide emissions from coal to hydrogen production can be brought down to near zero. For example, while a conventional 500 MW pulverized coal plant might emit 444 tons of CO_2 an hour, a similarly sized coal to hydrogen plant with carbon capture and sequestration would emit

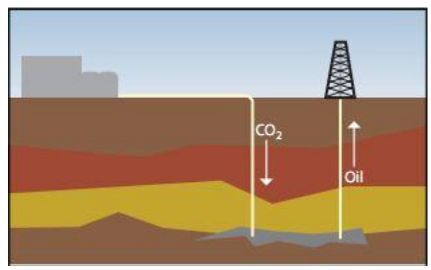
FutureGen

Through FutureGen, a government and industry partnership, efforts are already underway to design, build and operate a low-emission, 275-megawatt coal-fi red electric generation and hydrogen production plant using coal gasification and carbon sequestration technologies. This high-efficiency, near-zero emission, plant would coproduce hydrogen and electricity, becoming operational by 2015. FutureGen will use this prototype plant as a large scale engineering laboratory for testing clean power, carbon capture and coal-to-hydrogen technologies. This is a large step toward a DOE goal to reduce the cost of cleanly produced hydrogen from coal.

36 tons of CO_2 per hour of operation—a reduction of over 90%. These carbon capture technologies can also be used with electric power plants.

In 2004, the combustion of coal for electric power generation in the U.S. produced over 1.5 billion tons of carbon dioxide, accounting for one-quarter of all carbon dioxide emitted from U.S. fuel sources. Using gasification to turn coal into hydrogen produces fewer carbon emissions than burning coal, and it can help make carbon capture technology economically viable. Although coal is cheap compared to most other fuels, without the ability to capture carbon emissions and address health, safety, and infrastructure concerns, hydrogen production from coal may not be an environmentally or economically viable option.

Keeping Carbon Emissions Out of Our Air: What is Carbon Capture and Storage?



Geologic carbon sequestration: CO_2 from a power plant is injected into an oil well, removing the CO_2 from the air, and resulting in Enhanced Oil Recovery (EOR).

The phrase "Carbon capture and storage" covers a variety of methods for capturing and permanently storing gaseous carbon dioxide that would otherwise be released into the atmosphere and contribute to global climate change. These methods can be used to reduce atmospheric emissions of carbon dioxide from many industrial processes, not just hydrogen production.

Carbon is stored naturally in the earth's terrestrial biosphere (in forests, soil, and plants) and ocean reservoirs (via the ocean carbon cycle), from which it is cyclically released and absorbed. Carbon can also be stored in geologic formations such as oil and gas deposits, saline aquifers, and coal seams. It is possible to use natural carbon cycles with manmade processes to separate, store and/or otherwise utilize carbon dioxide in a manner that will reduce its concentration in the atmosphere. Man-made sequestration methods have been demonstrated in geological formations in the North Sea (salt brines) and Saskatchewan, Canada where carbon dioxide is piped from a coal gasification plant in North Dakota and injected into a mature oil field. Injecting carbon dioxide is a form of Enhanced Oil Recovery (EOR) which both increases the efficiency of extraction and keeps carbon emissions out of the air. While carbon dioxide injection is an established and cost effective technology in the U.S., research must still be done to make sure there are enough underground reservoirs for the volume of CO_2 we might want to store, and to make sure the gases are not escaping through the ground into the air over time.

Over the past few years, considerable research has been conducted to refine carbon dioxide capture concepts, develop the appropriate technologies, and reduce the associated capital costs. Carbon sequestration is essential to the successful implementation of hydrogen production from coal and other fossil fuels. The current cost of sequestering carbon dioxide is between $30 and $100 per ton of carbon sequestered. Using this technology increases the cost to produce hydrogen from coal by 20 to 30 percent while capturing about 90% of the carbon emissions. One U.S. DOE goal is to reduce the cost of carbon sequestration to $10 per net ton of avoided emissions by 2015.

Some carbon sequestration concepts and technologies are relatively new and there is limited data on the long term effectiveness of these approaches. Continued research and well instrumented pilot and field projects are necessary to determine the impacts on the environment and the long term performance of carbon sequestration.