2.2.5 HYDROGEN USE

Technology Description

In the next 20-30 years, solutions for energy and environmental security may be based on the development of hydrogen systems for stationary power and vehicle applications. Hydrogen is likely to be affordable, safe, domestically produced, and used in all sectors of the economy and in all regions of the country.

Fuel cells are an important enabling technology for the Hydrogen Future. Using hydrogen to power a fuel cell – where hydrogen and oxygen (from air) combine to produce electrical energy, heat, and water – produces no particulates, no carbon dioxide, and no pollution. Even in an early transition strategy using fossil fuels, fuel cells can have near-term environmental benefits through higher-efficiency conversion of chemical energy to electrical energy. The high efficiency of the fuel cell compared to conventional conversion devices results in lower emissions of greenhouse gases and overall reduced fossil fuel use. In addition to fuel cells, turbines and internal combustion engines are being developed or modified to run on hydrogen or hydrogen-blended fuels, with reduced emissions. High-value products, such as uninterruptible power supplies and portable power generators, are likely early-entry markets for hydrogen systems. In the longer-term, hydrogen also is expected to be used in airplanes and in ships to provide carbon-free transportation.

The demand for distributed generation that provides reliable, high-quality efficient power is spurring the development of fuel cells that will provide electricity both to the grid and to on-site consumers. These distributed power systems can achieve even higher efficiencies when waste heat is used on-site for space heating or hot-water systems.

System Concepts and Representative Technologies

- Transportation sector: internal combustion engines or fuel cells to power vehicles with electric power trains, with long-term use as an aviation fuel and in marine applications.
- Industrial sector: ammonia production, reductant in metal production, hydrotreating of crude oils, hydrogenation of oils in the food industry, reducing agent in electronics industry, etc.
- Power sector: fuel cells, gas turbines, generators for distributed power generation.
- Buildings sector: combined heat, power, and fuel applications using fuel cells.

Technology Status/Applications

- The emphasis of current RD&D efforts for transportation applications is on the polymer electrolyte membrane (PEM) fuel cell, which offers simplicity, high-power density, and projected system durability. The low operating temperature of PEM fuel cells allows rapid start-up and makes them attractive for transportation applications, where many start-stop cycles are expected. Industrial participation in PEM system development is booming, with all major automobile manufactures and several fuel cell-specific companies investing in development and deployment activities.
- Emission-reduction requirements are propelling the development of zero-emission vehicles – which, in turn, provide incentives for the growth of hydrogen-powered fuel cell cars, trucks, and buses. Several transit bus fleets are currently incorporating hydrogen and fuel cell technologies into their fleets via limited demonstration projects. Major car manufacturers are developing fuel cell vehicles in response to growing concerns about greenhouse gas and other emissions; and in response to policy drivers, especially for higher efficiencies, significantly lower tailpipe emissions, and reduced oil consumption.
- Current R&D on hydrogen-fueled internal combustion engines (ICEs) is reasonably mature. Several auto manufacturers have developed hydrogen ICEs – Daimler (1975), BMW (1990s), Mazda (1991), Ford

(1999); BMW is currently touring with its 740-series, hydrogen-fueled sedan; and hydrogen-natural gas blends are used for light-duty trucks and transit buses.

- The electrical generator is based on developed internal combustion reciprocating engine technology. It is able to operate on many hydrogen-containing fuels. The efficiency and emissions are comparable to fuel cells (50% fuel to electricity conversion efficiency and essentially zero NO_x). This electrical generator is applicable to stationary power and hybrid vehicles. It allows some markets to use hydrogen economically.

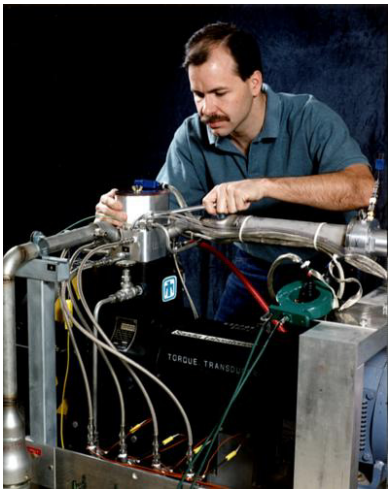
Current Research, Development, and Demonstration

RD&D Goals

- By 2005: (1) demonstrate PEM fuel cells and hydrogen ICEs in a small number of vehicles; (2) demonstrate uninterruptible power supplies and hydrogen applications in power parks.
- By 2010: (1) demonstrate a solid oxide fuel cell with projected capital costs of $400/kW for coal-fueled fuel cell/turbine hybrids; (2) demonstrate hydrogen-fueled PEM fuel cells in automobile application with a 60% peak efficiency, 220 W/liter energy density, 325 W/kg specific power, at a projected cost of $45/kW; (3) demonstrate hydrogen PEM fuel cell vehicles with 2,000 hours of durability at multiple sites.
- By 2015: (1) demonstrate PEM fuel cells for automotive applications at a projected cost of $30/kW; (2) demonstrate a fuel cell/turbine hybrid operating on coal with a system efficiency of 70% with carbon sequestration and capital costs of $400/kW.

RD&D Challenges

- Efforts to reduce costs and improve reliability of high-temperature and reversible fuel cells for stationary applications are needed.
- New high-temperature, anhydrous fast-proton-conducting membranes for use in new high-performance fuel cells need to be further developed. These new nanoengineered glass-ceramic proton conducting membranes are expected to yield high proton conductivities between 100° and 300°C, excellent thermal stability up to 300°C, superior electrochemical and chemical stability, and zero fuel crossover diffusion.



- Increased hydrogen content in natural gas-hydrogen blends needs to be tested in gas turbines to establish hydrogen's impact on reducing NO_x emissions. Development of a detailed understanding of the effect of hydrogen addition to gas turbines (kinetics, fluid dynamics, flame structure) is needed, working with industrial partners to implement hydrogen-natural gas turbines as distributed and centralized generation devices.

RD&D Activities

- DOE's HFC&IT Program is carried out by national laboratories, universities, and the private sector, including CRADA collaborations between industry and the national labs, and cost-shared industry-led efforts.
- The overall strategy of the HFC&IT Program is to conduct a comprehensive and balanced program that includes mid- and long-term research and development of hydrogen production, storage, and utilization technologies; integrated systems and technology validation with close industry collaboration that develops, demonstrates, and deploys critical technologies emerging from research and development; and an analysis element that helps to determine the performance and cost targets that technologies must meet to achieve the overall goals of the HFC&IT Program, as well as the specific project objectives determined by peer review.

Recent Progress

- Air-Breather fuel cells were developed that are exceedingly simple and most effective for small power demands such as pocket-sized portable devices.
- A gasoline ICE scooter was converted to run on hydrogen, with an onboard metal hydride storage system. Because the foreign market for scooters is very large (compared to the U.S. market), this represents a large export opportunity.

• A retrofit strategy for light- and medium-duty vehicles was developed and implemented to convert them to operate on mixtures of hydrogen and natural gas. The vehicles achieve equal vehicle range and reduced exhaust emissions, and are more powerful than the same vehicle operating on natural gas alone.
Commercialization and Deployment Activities
• Major industrial companies are pursuing R&D in fuel cells with a mid-term (5-10 years) timeframe for deployment of these technologies for both stationary and vehicular applications. These companies include General Motors, Ford, Daimler-Chrysler, Toyota, Honda, United Technology Corporation Fuel Cells, Xcellsis, and Ballard. • Several auto manufacturers have developed hydrogen ICEs – Daimler (1975), BMW (1990s), Mazda (1991), Ford (1999); BMW is currently touring with its 740-series hydrogen-fueled sedan; and hydrogen-natural gas blends are used for light-duty trucks and transit buses. • The program has launched a technology vision and roadmapping effort with industry to develop a framework for public-private partnerships to develop and deploy a national hydrogen infrastructure.