FUEL CELL FACT SHEET

EESI

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February 2000

THE MOST IMPORTANT ENVIRONMENTAL TECHNOLOGY?

Millions of Americans continue to live with unhealthy air. Climate change is forcing the United States and other nations to reconsider their energy use policies. American energy demand continues to rise, with a record-high dependence on foreign oil. As a result, research, development and deployment of clean and renewable energy technologies that provide a permanent solution is urgently needed.

There is an energy technology that can eliminate both air pollution and foreign oil imports — a device that is quiet, compact, flexible, highly efficient and exceptionally clean. It's called the fuel cell. This nonpolluting power source is unique in its potential applications: it can provide energy for sources as large as a utility power station and as small as a smoke detector. It is perhaps the most important anti-pollution technology in our history.

> "The work going on [in fuel cell development]...is unbelievable." Jack Smith, Chairman, General Motors

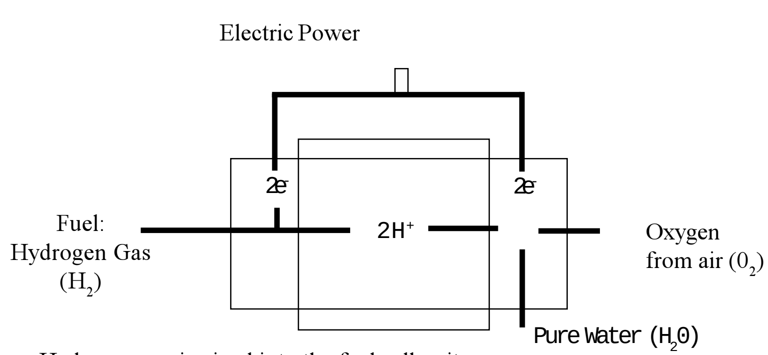
Fuel cells also can curb emissions of the greenhouse gas carbon dioxide. For this reason, commercialization of fuel cells is a priority under the administration's Climate Change Action Plan. The president's National Critical Technology Panel included fuel cells as one of the 22 technologies considered essential for the United States to develop to achieve economic progress and maintain national security. Furthermore, fuel cell development is expected to provide a substantial economic opportunity for export.

What are fuel cells? How do they work? Why are they so important? What are the next steps for development of this crucial technology? This short and simple fact sheet answers these basic questions.

HOW DOES A FUEL CELL WORK?

A fuel cell is a mini power plant that produces electricity without combustion. Chemical energy is converted directly into electrical energy and heat when hydrogen fuel is combined with oxygen from the air. Water is the only by-product. No pollutants are produced if pure hydrogen is used. Hydrogen can be produced from water using renewable solar, wind, hydro or geothermal energy. Hydrogen also can be extracted from anything that contains hydrocarbons, including gasoline, natural gas, biomass, landfill gas, methanol, ethanol, methane and coal-based gas.

Hydrogen Fuel Cell



Hydrogen gas is piped into the fuel cell unit.
Encouraged by a catalyst, hydrogen atoms are split, giving off a stream of electrons (2e-) for electricity, and positively charged hydrogen atoms (2H+).
The electrons pass through an anode and cathode creating an electrical current.
Oxygen (O_2) is piped into the other end of the fuel cell and combines with the charged hydrogen atoms (2H+) to form water.

A fuel cell is much more efficient than conventional energy sources because it converts the chemical energy of the fuel *directly* into electricity without going through an intermediate combustion step. This is why a fuel cell is cleaner than any carbon fuel even when using the carbon fuel as its hydrogen source. Moreover, the heat produced in the conversion process can be used for space and water heating.

Each fuel cell provides a very small voltage. Individual fuel cells are arranged in "stacks" to generate a useful level of voltage for practical applications from smoke detectors to power plants.

WHY ARE FUEL CELLS IMPORTANT?

Fuel cells can play a leading role in meeting national goals of clean air, climate protection and energy security. Fuel cell systems can meet the toughest of air pollution standards. Fuel cells are so clean that California clean-air regulators allow fuel cell power plants to bypass traditional permit requirements even when the hydrogen comes from fossil fuels.

Fuel cells also can significantly reduce carbon dioxide emissions compared to traditional energy sources. Fuel cells can obtain more than 80 percent efficiency when both heat and electricity are used. Additionally, since hydrogen is the most abundant element, sources of hydrogen fuel are everywhere: landfill gas, biomass, ethanol, methanol, natural gas and propane, to name a few.

The chart at right shows how minuscule the emissions are from a 200 kilowatt (kW) fuel cell system fueled by natural gas, compared to federal New Source Performance Standards (NSPS) and emissions from new gas-fired boilers and combined-cycle gas turbines.

Benefits

Fuel cells are the only technology that can provide pollution-free energy for both transportation and electric utilities.

Fuel cells are quiet, reliable, easy to maintain and safe.

Fuel cells are modular, allowing units to be installed as energy demand warrants.

Regulated air pollutants such as sulfur and nitrogen oxides, carbon monoxide, and unburned hydrocarbons are nearly absent. The Department of Energy (DOE) has estimated that more than 1 million tons of these pollutants would be avoided each year with only a 10 percent penetration of fuel cells into the car and light truck market.

With 10 percent market penetration, carbon dioxide emissions — the major greenhouse gas — would be reduced by 60 million tons a year. Fuel cells emit 40 percent to 60 percent less carbon dioxide than conventional power generation systems when hydrogen is derived from carbon-based fuels. Carbon dioxide emissions can be completely eliminated when hydrogen is produced using solar or wind power.

Use of fuel cells can reduce U.S. dependence on foreign oil. If just 20 percent of cars used fuel cells, the U.S. could cut oil imports by 1.5 million barrels everyday.

The development of fuel cell technology will bring about significant economic opportunities in the market.

Fuel cells can be fabricated in a wide range of sizes without sacrificing either efficiency or environmental performance. This flexibility allows fuel cells to generate power in a clean, efficient manner for automobiles, utilities and buildings.

Benefits for Utilities and Buildings

Fuel cell modules can be installed as needed on sites without investing in large, remote power plants and new high voltage lines. The power generating capacity of stationary sources can be readily increased by adding more fuel cell modules. Fuel cells have been installed in hotels, hospitals, offices and other buildings to provide their electricity, and space and water heating needs.

Types of Fuel Cells

Different types of fuel cells are named according to the type of medium used to separate the hydrogen and the oxygen:

Alkaline fuel cells: used in space applications since the 1960s.

Phosphoric acid fuel cells (PAFCs): This is the most commercially developed type of fuel cell. It is already being used in applications such as hospitals, schools and airports.

Proton exchange membrane fuel cells (PEMs): user-friendly technology, used today in transportation demonstrations and small-power applications.

Molten carbonate fuel cells (MCFCs): now entering the demonstration phase for baseload power.

Solid oxide fuel cells (SOFCs): U.S.-developed, small-scale demonstration unit now operating in Japan.

Direct methanol fuel cells (DMFC): new member of the fuel cell family, draws the hydrogen from the liquid methanol, eliminating the need for a fuel reformer.

There will be major opportunities in the international market for fuel cells. Power can be supplied hundreds of kilowatts at a time, rather than hundreds of megawatts. This modular flexibility, grid-independent operation and on-site energy production is ideal for rural areas and developing countries that lack power grids, which are extremely expensive to build and maintain.

Benefits for Transportation

Fuel cell powered cars can meet California's current Zero Emission Vehicle (ZEV) standard if hydrogen is stored on board the vehicle.

Even using methanol fuel and an on-board reformer, a fuel cell automobile is 100 times cleaner than the "Ultra-Low Emission Vehicle" (ULEV) nitrogen oxide tailpipe standard.

Because fuel cell systems have no moving parts, they are more reliable and require less maintenance than internal combustion engines.

WHAT IS THE STATUS OF FUEL CELLS?

For more than a century — since their development by British chemist Sir William Grove — fuel cells were little more than a laboratory curiosity. In the mid-1950s, some U.S. companies began experimenting with them. But it was the U.S. space program that pulled fuel cells out of the laboratory and into the mainstream of modern technology.

Three decades later, automakers have made dramatic progress in development of fuel cell vehicles. Several major automakers have said they will have commercially-available fuel cell cars for sale in 2004. Many prototypes are already on the road. A DOE-sponsored consortium has built three prototype phosphoric acid fuel cell (PAFC)-powered buses. A Department of Transportation (DOT)-sponsored consortium has built one proton exchange membrane fuel cells (PEM) powered bus and one PAFC powered bus. Fuel cell buses are being demonstrated "in service" in Chicago and Vancouver.

Stationary applications are advancing as well. There are nearly 50 megawatts of fuel cell demonstrations underway or planned in Japan, the United States, and Europe. More than 200 cogeneration units have been installed and interest is steadily increasing. PAFCs are in the initial commercial stage. On-site systems ranging from 200 kilowatts have operated at installations across the country, ranging from prisons to hospitals, providing more than two million KWh of electricity.

The Department of Defense (DOD) has installed fuel cells at military bases around the country. A fuel cell at Vandenberg Air Force Base in California has replaced polluting diesel generators as a backup source of electricity. The government is studying other fuel cell applications ranging from multi-megawatt power plants, to buses, passenger vehicles, locomotives, surface ships, submarines and mobile military equipment.

> "Automakers...unveiled plans to produce highly advanced hybrid and fuel cell vehicles—at least twice as efficient as current vehicles. These steps will protect the health of millions of Americans."
>
> Vice President Al Gore

Molten carbonate fuel cell developers are testing full-scale prototypes. Within three years, the solid oxide fuel cell also should make its commercial debut. The goal of these technologies will be to offer higher efficiencies, greater compactness and potentially lower cost.

Market Barriers

U.S. developers are already marketing residential and industrial stationary units and hope to commercialize fuel cells for transportation applications by 2004. Fuel cell research and development is being conducted by firms in 35 states. However, fuel cells must overcome a number of challenges to succeed in the commercial marketplace.

Cost: Current fuel cell cogeneration power plants cost about $3,000/kW. For broad market competitiveness, this price must be reduced to $1,500/kW or less for the utility and commercial on-site markets.

"Chicken and Egg" Problem: Investments in mass production capabilities can bring down costs, but such investments are impractical until sufficient orders are received. Yet, that won't happen until costs come down.

Transportation Needs: The size and weight of current PEM fuel cell designs presents a considerable challenge for light-duty vehicle applications. New materials and improved designs are required. Also, fuel cell systems that operate on fuels other than hydrogen do not yet provide the rapid start-up times necessary for light-duty vehicles. Finally, the infrastructure for supplying the hydrogen fuel is not yet available. Development of fuel processor technology that can convert conventional and alternative fuels to hydrogen is under way.

Restricted R&D: Federal policies have restricted R&D on technologies that have reached the commercialization stage. However, since 1995, the Climate Change Fuel Cell Program has provided more than $18 million in assistance for the purchase and installation of more than 90 fuel cell power plants.

Environmental Externalities: Energy prices do not include a full accounting of environmental costs. In addition, gasoline prices are at a historic low and do not reflect the true cost to the environment or national security.

WHAT ARE THE NEXT STEPS FOR THE UNITED STATES?

Fuel cell technology has not yet reached its potential level of commercial success due to a combination of factors, including material costs and a market that does not fully price pollution or national security risk. The actual use of this clean, efficient technology for various commercial applications can be encouraged by direct increases in fuel cell R&D, commercialization investments and measures to increase demand for fuel cell technology.

For fiscal year 2000 (FY00), Congress provided a total of $117 million in fuel cell funding through the Departments of Energy, Defense, Transportation and the Environmental Protection Agency. This year the Administration has requested $112.2 million for the same agencies and there is an additional $5.85 million that is authorized through the Transportation Equity Act for the 21st Century (TEA-21), bringing the total to just over $118 million for fiscal year 2001 (FY01).

The majority of funding goes to the Department of Energy through the Interior and Energy/Water Appropriations bills. In FY00, the Interior Appropriations provided $37 million for transportation, $37.6 million for stationary sources, and $3.55 million for buildings. The Energy/Water Appropriations provided $28 million for hydrogen research. For FY01, the Administration has requested $41.5 million for transportation, $42.2 million for stationary sources, $5.5 million for buildings, and $23 million for hydrogen.

Congress provided two separate funding sources for air quality and clean fuel programs in TEA-21. These programs are the Congestion Mitigation and Air Quality Improvement (CMAQ) program, funded at approximately $1.5 billion annually, and the Clean Fuels Formula Grant program funded at $100-200 million annually. CMAQ funded three fuel cell buses in Chicago. The Clean Fuels program identifies fuel cell vehicle projects as eligible for funding. However, Congressional Appropriations committees have not made any of this guaranteed clean fuels funding available.

Recommendations from Fuel Cell Manufacturers

Develop programs such as the DOE's proposed "buy down" program that would help pay for the initial cost of fuel cells purchased by private industry.

Encourage the use of fuel cells by government agencies and federal facilities. Continue federal "buy" programs such as the one funded for DOD in past years.

Continue and expand federal pilot programs for mobile (light and heavy duty) and stationary uses of fuel cells.

Fund research and development programs to overcome technical barriers to fuel cell commercialization such as cost of materials, size and weight, and fuel choices.

Include fuel cells in potential tax incentive programs for climate change.

Require prices of polluting energy sources to reflect the full cost of environmental and public health impacts, as well as national security risks.

Implement TEA-21's Clean Fuels program.

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This fact sheet was made possible through the generous support of The Energy Foundation