

Fuel Cells and Microturbines



FUEL CELLS ARE ON THE CUTTING EDGE OF FUTURE TECHNOLOGIES and have the potential to reshape our energy future. They use an electrochemical process to turn hydrogen and oxygen into pollution-free electricity and heat. Fuel cells have the potential to make the U.S. an energy independent nation, transforming our economy from one based on imported fossil fuels to a “hydrogen economy” fueled by hydrogen generated with local renewable

resources. Fuel cells offer an opportunity for communities interested in pursuing renewable energy demonstration projects as the technology is still under development and all aspects of the technology and the supporting infrastructure are in need of pilot trials.

FUEL CELLS

Although the first fuel cell prototype was made in England in 1838, the modern version of fuel cell technology was developed as part of the Apollo moon program. NASA has demonstrated the commercial viability of fuel cells by continuing to use them to power space flights. Fuel cells can replace internal combustion engines in vehicles, batteries in all sorts of portable devices like cell phones and watches, and can generate electricity and heat for buildings and homes. Fuel cells are modular and can be small enough to fit in a watch or big enough to power large buildings.



The most immediate future applications for fuel cells will be in vehicles and replacing batteries in phones

and other mobile electronics. All of the major auto manufacturers have fuel cell vehicles under development and Honda and Toyota began leasing fuel cell cars on a small scale in 2003. Fuel cells are also being used in pilot trials at schools and in city buses in Iceland, the U.S. and European cities. Stationary applications in buildings for heating and electricity will likely follow close behind.

The market potential for fuel cells is estimated at \$1.7 trillion by 2020. The private sector is investing \$3 billion annually, and investment is

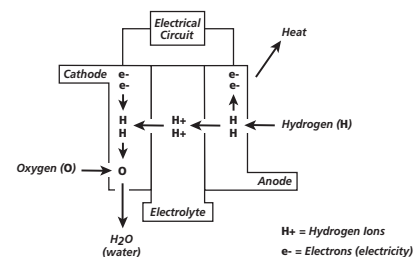
Fuel cells have the potential to make the U.S. an energy independent nation.

How Fuel Cells Work¹

A fuel cell is an electrochemical energy-conversion device like a battery. Fuel cells produce electricity via a chemical reaction, harnessing the chemical attraction between hydrogen and oxygen. The oxygen is taken from the air, and hydrogen fuel can come from water via electrolysis or from fossil fuels like gasoline or methanol. A catalyst pries hydrogen atoms apart into a positive ion and an electron. The positive ions pass through a membrane to bond with the oxygen; the electron travels around the membrane and through a circuit, generating an electrical current. On the other side of the membrane, the oxygen, hydrogen ions and electrons recombine to form water.

There are a number of different fuel cell technologies under development to serve different needs. Different types of conductive materials or electrolytes are used. Proton exchange membrane (PEM) fuel cells are most common in vehicles and in small devices. Other types are alkali, molten carbonate, phosphoric acid, and solid oxide fuel cells.

The basic hydrogen fuel cell





CASE STUDY:

Iceland: A Demonstration of the Coming Hydrogen Economy

ICELANDIC NEW ENERGY, LTD. is a group made up of government, business, and academic institutions facilitating Iceland's transition from a fossil fuel based economy to a hydrogen economy. Chemistry professor Bragi Arnason originally proposed the idea of transforming Iceland into the world's first hydrogen economy. His idea, with the backing of Vistorka, an Iceland consortium, and three multinationals, Shell Hydrogen, Daimler-Chrysler, and Norsk Hydro (all part of Icelandic New Energy, Ltd.) is now becoming a reality.

Iceland will be the launching ground for testing hydrogen-powered vehicles and building a hydrogen-fueling infrastructure. All of the hydrogen will be produced using electricity from local renewable energy resources.

The world's first public access, hydrogen fuel station opened in April of 2003. The fueling station is the first of its kind to allow public access, and this demonstration is expected to yield critical information necessary toward establishing a hydrogen delivery infrastructure. Three hydrogen-fuel city buses, provided by Daimler-Chrysler, will be put in use in Summer 2003 and begin a two year pilot program.

For more information contact:

World Business Council for Sustainable Development

"DaimlerChrysler, Shell, and Norsk Hydro: The Iceland Experiment", a case study of Iceland and the Hydrogen Economy

www.wbcsd.ch



Completed hydrogen fueling station in Iceland

-  Improves the environment
-  Works well with agriculture
-  Helps with reliability concerns
-  Recycles waste materials and waste heat
-  Offers community economic development
-  Improves energy independence, local control, and energy security
-  Promotes learning about energy

growing each year. The high cost of fuel cells, however, still remains a barrier for widespread commercial use, but expectations are that they will be cost competitive with other technologies by the end of this decade.

Fuel cells can operate at conversion efficiencies as high as 80% for fuel cells running on hydrogen. Fuel cells running on methanol or gasoline are only 40% efficient, but all fuel cells have the added advantage of producing thermal hot water that can be integrated into a combined heat and power system. This makes them an efficient energy source that can evolve to serve multiple needs.

Fuel cells also provide the added benefit of providing a “clean” source of energy. Because the energy is generated by a chemical reaction, the electron stream generated from fuel cells is cleaner than that normally generated using conventional power plants. For many industries the quality of their power is not of extreme importance, but for some niche applications, such as computer chips, power quality is crucial.

HYDROGEN FUEL

Fuel cells have the potential to be pollution-free and to make the U.S. energy independent. Whether or not they live up to that promise depends on how the hydrogen fuel is generated. Hydrogen is all around us. Water is made of hydrogen and oxygen and hydrogen is in all living things, but it is rarely in the elemental form needed for fuel. It takes energy of some kind to generate pure hydrogen. Hydrogen can be produced via three primary mechanisms.



Electrolysis generates hydrogen by splitting the water molecule into its two components, hydrogen and oxygen, by passing an electrical current through the water and then capturing the hydrogen. The question is how to generate the electricity to do it. Will it be coal, nuclear power, or electricity from renewables?

The cleanest and most environmentally friendly way of generating hydrogen is to use renewable energy resources, like wind, biomass, or solar, to generate the electricity to perform the electrolysis. This choice has the additional benefit of bringing economic development opportunities to Minnesota. Using wind and solar power to generate hydrogen makes these intermittent resources more valuable. They can be used when available to produce hydrogen, solving the dilemma of their intermittent nature.

Bio-chemical Conversion of Biomass The plant material all around us contains hydrogen. Demonstration projects are showing that hydrogen fuels can be made from plant waste materials using enzymes, fermentation, catalysts, and algae. Many communities have wastes from sugar beet plants, food processing plants, ethanol and biodiesel facilities, and even sewage treatment plants that may in the future be used to generate hydrogen fuels.

Reforming of Fossil and Bio Fuels requires pre-treatment of the fuel, which could be crude oil, methanol, ethanol, natural gas, or even gasoline or diesel fuel, in a “fuel reformer” that extracts the hydrogen for use in a fuel cell. The drawback to this method is that except for ethanol and methanol, it still requires the use of imported fossil fuels and still produces air pollution and greenhouse gases. On the other hand, reforming fossil fuels is a more efficient mechanism of using these fuels because it involves a chemical reaction rather than thermal production and results in more miles per gallon.



CASE STUDY:

Top Deck Holstein Dairy Farm's Microturbine



TOP DECK HOLSTEIN DIARY FARM, located in Westgate, Iowa, took a bold step in 2002 when it started using methane

from its anaerobic digester to fuel a 30 kW Capstone microturbine and a 100 kW Waukesha engine. The digester converts manure from 700 cows into methane that is used to generate 130 kW of renewable energy, demonstrating the fuel versatility of microturbines and their on-farm applicability. The project generates electricity and puts waste heat to use while reducing manure odor and converting the manure into other usable byproducts. All of the electricity is sold to the grid as the generators are of the induction type. The heat produced from the engines is used to heat the digester to maintain mesophilic temperatures and in a heat loop to the milking parlor for preheating water and heating the milking parlor in the winter.

Top Deck Holstein Dairy Farm's project is supported through a partnership between farm owner Roger Decker, Alliant Energy, the Iowa DNR, and Iowa State University Extension.

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Farm tour of the Top Deck Holstein Dairy Farm's Microturbine



Digester pump (foreground) and gas house, which stores the engines

-  Improves the environment
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Minnesota has much to gain from the growth and development of fuel cells. There are a number of Minnesota businesses working on various aspects of fuel cell technology and the University of Minnesota has opened a new center for renewable energy research and development. Perhaps the greatest opportunity, however, is in the area of hydrogen fuel made using renewable power or biomass. Using wind, biomass, and solar power to make hydrogen fuel will increase the flexibility and reliability of these intermittent renewable resources, creating a larger market for the power.

MICROTURBINES: ON SITE GENERATION

Microturbines are small single-staged combustion turbines that generate between 25 kW and 500 kW of power, although their size varies. Microturbines are usually powered by natural gas, but can also be powered by biogas, hydrogen, propane or diesel. They are a renewable energy technology, if powered by biogas or hydrogen generated from renewables.

They produce electricity efficiently while keeping emissions low. Like fuel cells, micro-turbines can be paired with heat recovery systems to achieve efficiencies of up to 80%.

A joint United States Department of Agriculture (USDA) and U.S. Department of Energy demonstration project announced in July 2002 will capitalize on the renewable potential by generating biogas, using anaerobic digestion of cow manure, as a microturbine fuel. Additionally, a small dairy farm in Iowa, Top Deck Holstein Dairy Farm (see case study), started using a 30 kW microturbine fueled by biogas in May 2002.

Microturbine designs evolved from automotive and truck turbochargers, auxiliary power units for airplanes, and small jet airplanes. A 30 kW microturbines is about the size of a small refrigerator, making them ideal applications for businesses with limited space. In addition to their small size, they offer benefits including: low initial costs, low maintenance costs, ability to put several together to build a reliable and independent system, few moving parts, light-weight, low emissions, high efficiency, and low electricity costs.

Microturbines are composed of a compressor, combustor, turbine, alternator, recuperator, and generator but have only one moving part. The turbine, compressor, and generator are all located on a single shaft. Microturbines use air bearings that do not require lubricating oil. Microturbines cost in the range of \$1000/kW.

Further research on microturbine technology is underway to develop new “flex-microturbines” that can produce more electricity using low-energy, low-pressure biogas.

END NOTES

¹Leo, Alan, *There's a Power Revolution Coming, and It Will Run on Hydrogen*. February 2002. Retrieved June 23, 2002 from: http://www.technologyreview.com/articles/wo_leo020502.asp.

PHOTOGRAPHS

page 75 – *Toyota.com* (upper), *National Renewable Energy Laboratory* (lower left), *Schatz Energy Research Center* (lower right); page 76– <http://www.athygli.is/myndir.html>; page 77 – *National Renewable Energy Laboratory*; page 78 – *Alliant Energy*; 79 – *Jon Heer/CenterPoint Energy*



Microturbine installation at a Minnegasco Facility



HELPFUL RESOURCES FOR COMMUNITIES

All web links listed here are available (and updated if necessary) at www.mnproject.org (click on “publications”)

Fuel Cells 2000: the Online Fuel Cell Information Center Website. A nonprofit organization providing extensive information on fuel cell technologies, including a listing of fuel cell vendors. (www.fuelcells.org)

How Stuff Works Website. Has general information about hydrogen and fuel cells. (www.howstuffworks.com/fuel-cell.htm) (www.howstuffworks.com/hydrogen-economy.htm.)

Minnesota Office of Environmental Assistance. Website has several fact sheets including, “Fuel Cells – Power Where It’s Needed” and “Hydrogen – The New Fuel of Choice.” (www.moea.state.mn.us)

National Fuel Cell Research Center. Information on how fuel cells work, lists manufacturers and researches, and provides detailed information on research projects. (www.nfcrc.uci.edu)

MIT Enterprise Technology Review. Technical descriptions about how fuel cells work. (http://www.technologyreview.com/articles/wo_leo020502.asp)

World Business Council for Sustainable Development. “DaimlerChrysler, Shell, and Norsk Hydro: The Iceland Experiment” a case study of Iceland and the Hydrogen Economy. (www.wbcscd.ch)

U.S. Department of Energy Hydrogen Information Network. (www.eren.doe.gov/hydrogen/features.html)

Distributed Energy Resources. Information on the DOE microturbine program can be found at: (www.eren.doe.gov/der/microturbines/microturbines.html)