

# ADVANCING UTILIZATION OF MANURE METHANE DIGESTER

## Fuel Cells

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.

### Background

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 space 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 are available.

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 growing each year. The high cost of fuel cells still remains a barrier for widespread commercial uses, 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 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 can 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 streams generated by 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.

### Basics

All fuel cells create electricity through an electrochemical reaction of hydrogen and oxygen. The only by-products of a hydrogen-fueled fuel cell are pure water and heat. Although each type of fuel cell will run a bit differently, they have similar components. All fuel cells have a central electrolyte. An electrolyte is a material that conducts either a positive or a negatively charged atom or molecule (called an ion) from one side of itself to the other. This electrolyte is sandwiched between two electrodes. Like a car battery, a fuel cell has two electrodes: a positive electrode (the cathode) and a negative electrode (the anode). Unlike a car

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Minnesota Office of Environmental Assistance, *Common Types of Fuel Cells*, October, 2003

Clean Energy Resource Teams, *Designing a Clean Energy Future: A Resource Manual*, July, 2003

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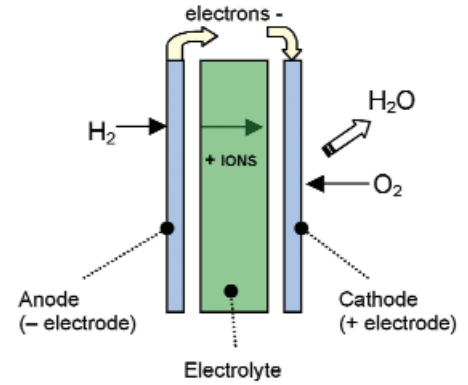
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battery, however, the electrodes in the fuel cell contain special metals called “catalysts” that speed the rate of the electrochemical reaction. *Types of fuel cells vary by the different materials used to make the electrolyte and these catalyst electrodes.*

In a fuel cell, when hydrogen (H) and oxygen (O) atoms come together to form water (H<sub>2</sub>O) two electrons are released and are made available to power an external circuit. Although types of fuel cells may differ in the molecular form of the hydrogen and oxygen used to accomplish it this, basic, natural reaction is used in all fuel cells to make water and electricity. As shown in the diagram, hydrogen, (either pure or from some hydrocarbon fuel) and oxygen (from air) enter opposite sides of a fuel cell. An electrochemical reaction occurs at each electrode (at either the anode or the cathode,

depending on the type). At the anode, the hydrogen atom loses an electron and its proton (or ion) goes into the electrolyte. The electrolyte is specifically made to conduct ions to the other pole of the fuel cell but not electrons. At the cathode, when two ions enter it from the circuit, these join with an oxygen atom and create a water molecule.

Electrons, directed to flow through a wire from one electrode to the other, power an electrical circuit for use.



### Definitions

**anode** — the negatively charged electrode through which electrons leave a fuel cell

**catalyst** — a substance, usually a metal present in small amounts, that increases the speed of the reaction in a fuel cell without being consumed in the process.

**cathode** — the positively charged electrode through which electrons return to a fuel cell.

**electrode** — the conducting material, or pole, through which an electric current leaves or enters an electrolyte.

**electrolyte** — the material that conducts ions (positive or negatively charged ions) across the inside of a fuel cell from one of its electrodes to its opposite.

| TYPE OF FUEL CELL  | EFFICIENCY                  | OPERATING TEMPERATURE | USE   |
|--|-----------------------------|-----------------------|---|
| Proton Exchange Membrane (PEM) or Polymer Electrolyte Membrane (PEMFC) | 40% (80%) with cogeneration | 175° F                | <i>Transportation</i> – cars, buses, boats, trains, scooters, bikes, wheelchairs, forklifts<br><br><i>Residential</i> – household electrical power needs<br><i>Portable</i> – laptop computers, cell phone, medical equipment, robots |
| Direct Methanol (DMFC)   | 40%                         | 120 – 150° F          | <i>Portable</i> – cell phone, laptop computers, vacuum cleaners, highway road signs   |
| Alkali (AFC)   | 60% (80%) with cogeneration | 250 – 500° F          | <i>NASA space program</i> – space vehicles  |
| Phosphoric Acid (PAFC)   | 40% (80% with cogeneration) | 300 – 400° F          | <i>Landfill/wastewater treatment facilities</i> – to generate power from methane gas  |
| Solid Oxide (SOFC)   | 55% (85% with cogeneration) | 1,800° F              | <i>Commercial</i> – utility power plants, airport terminals, public and commercial office buildings, hotels, hospitals  |
| Molten Carbonate (MCFC)  | 55% (85% with cogeneration) | 1,200° F              | <i>Commercial</i> – utility power plants, airport terminals, schools, office buildings, hotels, hospitals   |