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Biofuels for Fuel Cells

Making energy from nutshells, and other tales | By Myrna E. Watanabe

Photo: Courtesy of Lee Petersen

Researchers from Ascent Power Systems examine a large-area fuel cell component.

Could the world's waste--peanut shells from Georgia, coconut shells from the Philippines, pig-farm waste from China, or even left-over gas from Japanese-beer kegs--be the answer to the next energy crisis? Probably not, but a number of companies and individuals are touting the benefits in a variety of ways. Talk abounds about fuel cells and the "hydrogen economy," spurred by recent announcements that cars running on fuel cells will soon reach the market.

"The first fuel-cell cars will be out in the road in six months," says **Kelvin Hecht**, a consultant for United Technologies Co. (UTC) Fuel Cells in South Windsor, Conn., and chair of the national and international committees for writing safety standards for fuel cells. Although fuel cells are touted as major future sources of energy, powering everything from homes and schools to portable electrical devices, Hecht notes, "The huge market will be the automobile."

Unlike internal combustion engines, fuel cells run on hydrogen or other electron donors, producing an electric current through movement of electrons across a thin wire. The electrons then react with an electron acceptor--oxygen in this case--which, in turn, will attach to the hydrogen ions that have migrated through the fuel cell via an electrolyte. The end result is water as a waste product and heat.

Obviously, fuel cells are much more complex than this, and the electrolyte determines the reaction temperatures. Today's commercial stationary fuel cells are phosphoric acid fuel cells (PAFC), which run at relatively low temperatures of 150-200°C. UTC has been the primary source of such fuel cells. The next generation of stationary, automotive, and residential power will be proton-exchange membrane (PEM) fuel cells. PEM cells work at what are considered to be low temperatures (80-100°C) and need a clean fuel source. Higher temperature fuel cells,

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such as molten carbonate (MCFC), which run at about 800°C, and solid oxide (SOFC), which run at 800-1,000°C, are less fussy about contaminants in their fuel sources. "What's holding up PEM technology is [that] you have to separate the hydrogen from the carbon; any carbon gets inside a PEM fuel cell, actually, it will just shut the fuel cell down," says **Lee Petersen**, vice president, business development, Ascent Power Systems in Littleton, Colo.

THE TOTAL BIOREFINERY CONCEPT "There's a lot of talk right now about the hydrogen economy," says **Francis Kocum**, vice president for technology at HydrogenSource, a joint project of UTC Fuel Cells and Shell Oil Co. "I talk about where the hydrogen comes from," he continues. **Mark Finkelstein**, manager of the biotechnology division for fuels and chemicals, National Bioenergy Center, National Renewable Energy Laboratory (NREL), Golden, Colo., thinks it would be more appropriate to look at a total biorefinery concept, rather than just a hydrogen economy. "Ethanol can be the flywheel of it," he says. But Finkelstein is not referring to ethanol from just any source. He's referring to *bio*ethanol. "Agricultural residues, forestry thinnings, sawdust, municipal solid wastes [largely newspaper and cardboard], in addition to cornstarch, would be making electricity, heat, power fuels, chemicals, and other biobased products," he prognosticates.

According to Hecht, there is presently a niche market for stationary fuel cells--fuel cells about the size of a one-car garage --with 300 200-kilowatt fuel-cell power plants operating around the world. (Two hundred kW "would be enough power for 50 homes," says Hecht.) "What's happening is a few prototypes [are] being sold," says **Helena Chum**, director of chemistry for bioenergy systems division, NREL. But the true innovations in fuel cells are occurring when testing these machines using biobased fuel sources. Unfortunately, raw biobased materials cannot be thrown into a fuel cell, because they currently require preliminary processing. Biological waste materials may be anaerobically digested, subjected to pyrolysis, or otherwise pretreated to release hydrogen.

Photo: Courtesy of Bill Baker/Baker Communications Group

Hansraj Maru

UTC Fuel Cells, according to company spokesperson **Peter Dalpe**, has sold eight units to the New York Power Authority to run off the methane from the wastewater in wastewater treatment plants. Such units are expected to power the plant. Although both UTC and a nearby competitor, FuelCell Energy of Danbury, Conn., have supplied stationary fuel cells to run off landfill gas, it is more difficult to use PEM fuel cells in those situations. "The landfills have all kinds of things dumped in there--metals, organic materials--so the quality of the gas and the contaminant level is highly variable," says **Hansraj Maru**, FuelCell Energy's chief technology officer. Landfill gas varies in quantity, too, depending on seasonal temperature. Maru sees this as a usable source of energy, which may require supplementation from the electrical power grid. UTC is also producing energy for Asahi and Sapporo beer companies in Japan, by using fermentation gas left in beer kegs after they've been emptied. In Guangzhou, China, UTC is installing a fuel cell that will work off waste from a pig farm. Surplus power generated will be exported back to the farm.

There are more unique avenues of research. Scientists from several universities in Georgia, a carbon company, and an environmental company supported by NREL, which is a US Department of Energy laboratory, have been working on a project to convert peanut shells to energy. The shells first are pretreated via pyrolysis, and the hydrocarbons and steam are then reformed. This method makes two products: energy and activated charcoal, notes NREL's Chum. The charcoal can be used in nitrogenous fertilizer. Some of the important goals of this work says Chum, other than energy production, include sequestering carbon so that it is not released into the atmosphere, forming a greenhouse gas; and stimulating industry in south Georgia's peanut country, where unemployment is high.

Community Power Corp. (CPC) and its neighbor, Ascent Power Systems, recently completed a lab-scale test of gasifying biomass, then using the gas to power an SOFC. The biomass tests used wood chips, coconut shells, or pecan shells. The coconut shell tests, according to Ascent's Petersen, were in concert with Shell Oil, to aid coconut farmers in the Philippines who need a productive way to use disposed coconut shells. He explains that Arizona, a pecan-growing state, gives energy credit for producing energy from renewable sources, and the test using Ponderosa pine shavings was done for the US National Forest Service to determine if waste products from logging and forest fires could be used as an energy source. **John Reardon** of Community Power, whose thermal gasification process is making the biofuel for Ascent for the tests, notes their plan to "scale up our fuel cell test for up to 5 kW." He says that the combination of biomass gasification in a hybrid system with fuel cells, along with microturbines and a heat recovery steam engine, would result in 70% energy conversion--the "highest-efficiency energy system."

Photo: Courtesy of Lee Petersen

Lee Petersen

BIOLOGICAL FUEL CELLS Fuel cells need not be big, clunky boxes that sit outside buildings or in rooms, nor need they be streamlined to fit in an automobile. They can be very small and can run on microbes. **Chris Melhuish** and colleagues at the University of the West of England in Bristol are producing small biological fuel cells to power robots--what Melhuish calls, "intelligent autonomous systems." He says, "I want to build a class of robots that ... go to a place you don't want to be at a time you don't want to be there." His group is powering some of the robots with a microbial fuel cell (MFC). Melhuish describes building a robot with "smart guts." On the group's Web site for the EcoBot Project (www.ias.uwe.ac.uk/energy_autonomy/EcoBot_web_page.html), they describe the gut as including microbes--current models use *Escherichia coli*--which produce NADH. A mediator oxidizes NADH to NAD^+. The mediator, which has gained electrons, can be reoxidized, losing its electrons; this forms the source of the electrical power. Meanwhile, the microbial metabolism yields hydrogen ions (H^+), which travel through a membrane similar to a PEM. The electrons and ferricyanide within the cell's cathodic chamber pick up the hydrogen and the cycle begins anew. Melhuish's problem is finding an appropriate food source for his MFC. Now, they are feeding the fuel cell glucose, but at present, the fuel cells are inefficient. "It's cheaper to feed someone a sandwich than to feed one of these robots," says Melhuish.

Mechanical engineer **Liwei Lin**, codirector of the Berkeley Sensor and Actuator Center at University of California, Berkeley, has designed a miniature MFC as an energy source for microelectromechanical systems (MEMS). In this case, the group is using the yeast, *Saccharomyces cerevisiae*, to produce the NADH at the anode.[1] "The technology," says Lin, "is quite similar to integrated circuits [ICs]." He adds, "Because the manufacturing process is similar to IC, so the manufacturing cost actually could be pretty low." Lin explains that these microsized power sources are needed to power tiny sensors, some called "smart dust," that are 1 mm x 1 mm particles. "The most convenient way to get power is looking to what's the natural resource to generate power," Lin states. He sees his small fuel cells as powering devices, which he calls microsurgeons, that could function within the human body and utilize the body's glucose as the fuel. He notes that the end product would be carbon dioxide--the same as in cellular respiration. This is not coming to the market soon. "We have some limited success," says Lin, whose MFC program is very small, supporting only one student.

Although MFCs are probably distant from the marketplace, development of efficient fuel cells that will utilize biomass are closer to commercialization. The European Union just earmarked $2 billion (US) for fuel cell research and development for 2003-2006,[2] and although research funding for fuel cells exists in the United States, FuelCell Energy's Maru believes that once companies demonstrate the "usefulness and generally low emissions" of fuel cells in wastewater treatment, government funding and subsidies for their use will be increased.

Myrna E. Watanabe is a freelance science writer in Patterson, NY.

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