Clean, Green, and Efficient: Fuel Cells Head Home

By Sandra Curtin
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With the growing cost of oil and concern about global warming, people are becoming interested in cleaner, more fuel-efficient vehicle engines powered by bio-fuels or hydrogen, or by alternative energy technologies like batteries, hybrids and fuel cells. And given the rising cost of electricity and reliability issues with the power distribution system, people will soon be demanding cleaner, alternative energy sources to power, heat and cool their homes. An ideal technology to do just this is one of the same technologies being developed for cars - fuel cells.

Why would anyone want to power their home with a fuel cell? The reasons are many and varied, and include fuel flexibility, reliability, efficiency, silent operation, extended run times, low to zero emissions and energy independence, just to name a few.

Fuel cells, the devices that convert chemical energy to electrical energy without combustion, are extremely efficient at extracting energy from fuels, typically attaining 35-45% electrical efficiency when used in stationary power settings, compared to a net efficiency of 32% for electricity generated at coal-fired power plants.* Even better, a fuel cell system's total efficiency rises to 80-90% when its waste heat is used for space heating and cooling, which is known as cogeneration, or combined heat and power (CHP).

Fuel cells run on hydrogen, which can be derived from a variety of fuels ranging from ethanol and methane, to conventional hydrocarbon fuels like propane or natural gas (a reformer is used to extract the hydrogen). A fuel cell can be powered by industrially-produced pure hydrogen, a by-product of steam reforming of natural gas. Hydrogen can also be generated from water by electrolysis, decomposing it to oxygen and hydrogen gas, and solar or wind energy can be used to power this electrolytic process.

A fuel cell's only byproducts are heat and clean, drinkable water. There are no noxious emissions like those associated with boilers, furnaces and back-up power generators. Even when using hydrogen derived from fossil fuels, a fuel cell converts chemical energy to electricity with greater efficiency than burning the same fuel in an internal combustion engine. When you consider that a fuel cell's lifetime maintenance costs are low (no moving parts!) and reliability is high, the fuel cell becomes an attractive product. And to sweeten the deal, some of a fuel cell's purchase cost can be offset by federal, and sometimes state or local, incentives.

Residential-scale fuel cells can be operated in a variety of configurations. The unit can be used in a self-sufficient, grid-independent mode, providing reliable power and cogenerated heat that is immune to grid outages or fluctuations. A homeowner or small

* http://www.asme.org/NewsPublicPolicy/GovRelations/PositionStatements/Need_Additional_US_CoalFired.cfm

business is also able, if permitted by the state or power provider, to tie the fuel cell to the electric grid, pulling power from the electric network when needed and even net metering – essentially running the electric meter "backward" to send excess energy back to the grid. Fuel cell units can also be configured to provide backup power in case of grid failure, kicking in when the electricity goes out to provide a seamless uninterruptible power supply (UPS). Fuel cells can also be operated in combination with other residential alternative power systems, such as a solar, wind or geothermal.

A number of fuel cell manufacturers offer 1 kilowatt (kW) to 5 kW proton exchange membrane (PEM) fuel cells for use in backup and small-scale power and cogeneration applications. Fuel cells in this power range are being purchased by commercial enterprises and first responders requiring reliable power (the "premium power market") to ensure seamless delivery of service for critical telecommunication towers, computer systems and data banks. A few fuel cell companies are also beginning to offer similarly-sized PEM systems for the residential market.

Government and industry-led demonstration projects have been evaluating fuel cells for residential use, testing performance, reliability and durability to refine the product in preparation for wide-scale market launch, for use in homes and small buildings. These tests are being conducted in the homes of utility customers, at small businesses, and military residences, with much of the demonstration cost offset by government funding. Without this financial support, the cost to the average consumer still remains somewhat high, at about $3,000 to $4,500 per kW for a residential-scale fuel cell.

But don't despair. The cost of stationary fuel cells has already dropped significantly – just a decade ago PEM fuel cells cost about $20,000 per kW! Further product refinements, as well as eventual mass production and streamlined manufacturing processes, will continue the downward trend in fuel cell prices. According to the federal government, widespread commercialization of stationary fuel cell technology can be attained when fuel cells reach $400 to $750 per kW. In the meantime, the federal government and many states offer assistance that offset some of the purchase and installation costs, such as grants, low-interest loans and tax deductions.

Higher consumer electricity prices in Japan and Europe will likely make residential fuel cell power competitive with existing technologies much sooner than in the United States. Residential fuel cells are already on the brink of extensive distribution in Japan, where the nation's Ministry of Economy, Trade and Industry (METI) is planning to deploy 1.2 million fuel cell cogeneration units at homes and small businesses by 2010 in an effort to reduce the country's fossil fuel imports and lower greenhouse gas emissions. More than 3,300 PEM units have already been installed with government assistance and commercial sales to consumers were started in 2009. Japan's ultimate goal is for a two million homes to be powered by fuel cells by 2020.

The German government also believes that fuel cells could be the next technological advance for the county's residential heating sector to increase energy efficiency, reduce carbon dioxide emissions and to send supplemental power to the local electric grid. Germany's new stationary fuel cell development plan will demonstrate 450 PEM and solid oxide fuel cell (SOFC) units between 2007 and 2010, and scales up to 2,250 units by 2012. The government's vision is to facilitate production of 72,000 fuel cell cogeneration units per year by 2020.

In the US, the largest deployment of residential-scale fuel cells has been through the Department of Defense's Residential PEM Demonstration Project. Since inception of the program in 2001, dozens of PEM fuel cells have provided power to officers' quarters, barracks, recreational buildings and maintenance facilities at bases throughout the country. Fuel cells are regarded by the military as an emerging technology that could supply critical energy needs and support sustainable installations.

Lately, several fuel cell manufacturers have targeted their product specifically to the US residential market, including Hydra Fuel Cell Corp. and ClearEdge Power. By December 2009, Clear Edge has already deployed 250 residential-scale fuel cells.

Altogether, more than 3,500 residential-scale fuel cells have been deployed or demonstrated worldwide in back-up power, UPS and residential applications. Most have been sponsored by government entities. Yet many people are unaware of these activities.

And many people are unaware the fuel cell systems can operate in conjunction with other renewable energy systems, such as solar or wind power.

You may have read in newspapers, or seen on television about a few pioneering individuals, early adopters who installed renewable energy systems in their homes that include fuel cells. They have done this outside of any government or industry-sponsored projects, tackling the design, funding, installation and code inspection challenges on their own. They have often integrated fuel cell systems with other forms of renewable energy - like solar, geothermal and wind power - to deliver their home's electricity, heat and cooling, reducing or eliminating the need for grid power, increasing their energy efficiency, and insulating themselves from grid power outages. And they have done this hoping to inspire others, maybe even you, to follow their lead.

Probably the most recognized residential alternative energy system is located in the home of the Strizki family of Hopewell, New Jersey. Mike Strizki, a mechanical engineer with experience working on both fuel cell and solar projects, formed the non-profit Hopewell Project (http://www.hopewellproject.org) to promote renewable energy use by example. He calls his 3,000-sqaure foot home "the first solar-hydrogen residence in North America," and by this he means a real, everyday home where his family resides, having retro-fit the solar-hydrogen-fuel cell system into the house they have owned for 15 years. Strizki designed the system so that the solar panels would collect more than enough energy to power the house round-the-clock during the warmer months, storing abundant excess energy in tanks in the form of hydrogen gas. During the winter, when less solar energy is available, the energy in hydrogen is returned to the home's electrical system via a 10-kW Plug Power fuel cell. His work has proven fruitful - the renewable installation has garnered significant press since it debuted in 2006, and has been featured on national news programs and in major newspapers.

While Strizki's home may be the most recognized, the title of "America's first solar-hydrogen home" is actually held by an 800-square foot residence built by a team from the New York Institute of Technology (NYIT) for the 2005 U.S. Department of Energy's Solar Decathlon Competition (http://iris.nyit.edu/solardecathlon2005). The system differs slightly from Strizki's - solar energy powers the house by day and solar-derived hydrogen supplies a 1-kW ReliOn fuel cell that powers the house each night. After placing fifth in the competition, the NYIT team donated the house to the U.S. Merchant Marine

Academy, where an engineering professor and consultant to the project now resides. The building also serves as a clean energy research and education center.

Less well known, but just as important, is a vacation home on Stuart Island, Washington, powered by a solar-hydrogen system and a 1-kW fuel cell. The project came about in an unusual way - the owner became fascinated with fuel cells after purchasing a model Thames and Kronos Fuel Cell Car and Experiment Kit from the internet. This fascination led to a trip to the 2004 Fuel Cell Conference in Denver, and soon afterward to development of the "Stuart Island Energy Initiative" plan to deploy and field test an off-grid solar-hydrogen energy system. The project's partners believe strongly in moving the technology from theory to practice, setting up a website (www.siei.org) describing their project and experiences, "to pass on what we have learned, in order to smooth the way for other installers."

Yet another solar-hydrogen home is the Beaulieu residence in Scottsdale, Arizona (http://www.scottsdaleaz.gov/Assets/documents/greenbuilding/HydrogenHouseFactSheet.pdf). Bryan Beaulieu, a mechanical engineer, and his scientific team designed the 6,000-square foot house as a prototype for trialing a variety of renewable residential energy concepts. The prominent feature is the home's solar-hydrogen system, which produces sufficient hydrogen gas to provide supplemental power to the home, and other renewable energy devices, via an 8-kW fuel cell. The hydrogen gas is also used to replace natural gas in the home's appliances and fireplace, as well as to fuel the family car. The fuel cell's byproduct of pure, drinkable water is even used to provide moisture for the family's hydroponic garden!

In all four houses, the grid-independent, solar-hydrogen-fuel cell systems function in the same way. Solar panels gather the sun's energy to provide the homes' electricity. Any excess solar energy is processed through an electrolyzer, which converts water to hydrogen gas and is stored in tanks until needed. When solar power is insufficient to meet the home's energy requirements, the hydrogen is fed to a fuel cell that converts the stored power back into electricity. Because the energy of the sun is harnessed, there are no polluting emissions and no carbon footprint associated with the homes.

In the NYIT and Beaulieu homes, the stored solar hydrogen powers a fuel cell at night. The Stuart Island home uses the solar hydrogen to run a fuel cell on cloudy days. At Mike Strizki's home, sufficient energy is captured by solar panels during the warm weather months to meet the home's round-the-clock electric needs. But during five cool-weather months, when less sunlight means the solar system can only meet 60 percent of the home's power demand, the stored solar hydrogen powers a fuel cell that provides the remaining 40 percent of needed power.

Admittedly, these pioneers have had to come up with a fair amount of money to get their vision off the ground. The NYIT solar-hydrogen fuel cell project cost around $400,000, half being covered by sponsors and in-kind donations. Strizki spent more than $500,000 for the solar-fuel cell system, obtaining a $225,000 grant from New Jersey's Board of Public Utilities and donations of money and equipment, leaving a $100,000 expense that he covered out-of-pocket.

Of course, the energy cost savings (no monthly energy bills!) do not quickly make up for the initial capital and installation costs, but being an early adopter of new technology means paving the way for others. Both Strizki and the NYIT team believe that system

costs would be significantly less for the next installations. This has proven true – a company Strizki co-founded, Renewable Energy International (REI), is installing the world's second solar-hydrogen fuel cell system in a private Cayman Island home at a cost of less than $200,000, 60 percent less than the original Hopewell prototype. Strizki anticipates the price will fall further with subsequent installations, making his energy system affordable to most homeowners within less than a decade.

The owner of the Grand Cayman house, Mike Knapp (a bank chief technology officer and former physics professor), was considering clean energy systems for his 3,000-sq.ft. house when he heard of Strizki's solar-hydrogen-geothermal installation. He contacted REI about installing a similar system. His home will have the distinction of being the first carbon-neutral building in the Caymans. Knapp's goal is to show that a completely renewable energy system can be accomplished with existing technology, meeting the home's year-round energy needs and functioning, uninterrupted, through grid outages caused by hurricanes. A third client receiving REI's solar-hydrogen system is reportedly Johnny Depp, who will use the renewable installation to power his private Caribbean island home.

Yet another individual that has incorporated residential-scale fuel cell technology into a building is Scott Sklar, founder and president of distributed energy generation strategic marketing firm, The Stella Group. His firm's small office building, located behind his Arlington, Virginia home, boasts the first commercial lease of a fuel cell in the U.S. The building incorporates solar photovoltaic roof shingles, a battery bank and a small wind turbine, as well as the 5-kW Plug Power fuel cell for backup power and peak power augmentation.

Several politicians have also used their visibility to promote fuel cells and other alternative energies. Under Governor Charlie Crist's watch, a 5kW fuel cell was installed in the Tallahassee, Florida, Governor's Mansion to provide supplemental power, reducing the amount of energy the mansion draws from the city's power grid. New York's former first lady, Silda Wall Spitzer, spearheaded a "Greening the Mansion" project to halve electricity consumption and greenhouse gas emissions. This effort includes plans to replace a diesel-powered backup generator with a fuel cell unit to power to the building during grid outages.

So why are these individuals going to such effort and expense to install not just a fuel cell, but oftentimes a host of other renewable energy systems? According to a press release by former Governor Spitzer, he was "hopeful that this initiative will encourage others to pursue similar efforts with their own homes. Together, every small step can reduce our overall impact on the environment."

Members of the Stuart Island Energy Initiative indicate on their website that their off-grid home solar-hydrogen fuel cell system is "an ideal end-state for our global energy infrastructure." They point out that, "it is critical to implement new technologies in the field: Only by true field-testing does a technology become robust enough to do useful work. There as a huge difference between theory and practice."

In an REI press release, Mike Knapp said of his planned solar-hydrogen system, "The environmental benefits are important, but not the only consideration. For me, this is a financial play. The numbers work right now to make this a smart move."

As it turns out that, no matter what the rationale, this think globally, act locally mantra is beginning to work with regard to fuel cells. Mike Strizki has been contacted by folks worldwide wanting to install a similar solar-hydrogen fuel cell energy system.

And the recent sales by companies such as ClearEdge Power and Hydra Fuel Cell Corp show the growing public interest in residential fuel cells.

Hopefully this article has inspired you too, in the very least, to go out and buy an educational fuel cell toy kit. Who knows, it may motivate you – as it did the members of the Stuart Island Energy Initiative – to pursue a larger fuel cell project, encouraged by thoughts of energy independence, reliability, efficiency and clean power.

To learn more about fuel cells, and government incentives to assist in fuel cell purchases, please visit www.fuelcells.org.