Storing Solar Energy: Creating a Personal Power Plant March 2010

The primary limitation to relying exclusively on solar or wind energy to power buildings is the problem of economically storing the energy for use when the sun isn't shining or the wind isn't blowing.

Contemporary solar collection systems can be fitted with batteries, but this solution is inadequate both as a reliable power source, and with respect to its environmental impact. Though the subject of ongoing research, batteries today are bulky, heavy, expensive, comprised of toxic materials, and their efficiency deteriorates rapidly over a limited lifespan. They are difficult to dispose of and expensive to recycle. Developers of non-combustion engine vehicles have rejected batteries for just these reasons, turning instead to hydrogen fuel cells to store energy. Fuel cells, which convert fuels to electricity and water, have their own downside, however: limited range and the lack of installed infrastructure. Without conveniently located hydrogen gas stations, the utility of cars powered by fuel cells is seriously restricted.

Imagine then, that hydrogen-sourcing problem could be solved: not just cars, but buildings could be powered by hydrogen fuel cells. In fact, using fuel cells as energy storage for buildings is even more efficient, as the heat the fuel cells generate during operation can be captured for use within the building.

How Fuel Cells Work

Fuel cells are comprised of two chambers separated by a proton exchange membrane (PEM). When hydrogen flows past the negatively charged anode, it separates into positive ions (protons) and electrons. Both are attracted to the cathode, but only the protons can pass through the PEM; the electrons travel must via an external circuit, creating an electrical current.

Meanwhile, oxygen is fed into the chamber containing the cathode, which combine with the hydrogen protons to create H_2O - water. The reaction is exothermic; it generates considerable heat as a by-product, which in a building, could be used to preheat domestic to water or serve radiant heat flooring.

A single fuel cell generates electricity at a low voltage, so they are grouped or "stacked", with more layers generating higher voltage. Current is a product of the surface areas of the electrodes. More surface area = more current. Research is ongoing to improve the efficiencies of fuel cell reactions using nanotube technology as part of the PEM, a strategy that increases the surface area available for the electrochemical reactions.

It is interesting that research and market applications of fuel cells have been focused on vehicles - a very inefficient use of the technology. Cars require converting electricity to mechanical energy, with large losses along the way. It is far more efficient to use fuel cells to generate electrical power. And using them for heat production results inefficiencies above 70%.

contact e judy@judyvansoldt.com m 415.505.4683 402 30th St San Francisco California 94131

So fuel cells need hydrogen and oxygen to create water and release energy. Based on the vehicle model, the gases would be distributed directly to each house - an expensive proposition.

Suppose there was a means of generating the hydrogen and oxygen gases required for a fuel cell to power a home within the footprint of the building? And suppose that generation could be accomplished using renewable energy, non-toxic materials at a cost of less than $30 per 100w?

Charging the Fuel Cell – Electrolyzers

Both hydrogen and oxygen are abundant Earth elements. Water contains hydrogen and oxygen, stable and safe at ambient temperatures. Separating them, a process called electrolysis[1] is used. Operating like a reverse fuel cell, water is passed through a two chambers. In one, an electrical charge catalyzes a reaction that attracts the oxygen atoms. In the other, an opposite charge catalyzes a second reaction that extracts the hydrogen atoms. These gases can be stored locally and recombined in a fuel cell to create electricity on demand[2]. It is the process of breaking the bonds between the H and O atoms in the water molecule and then recombining them that stores and releases energy.

The concept of splitting water into its component parts is not a new one. Industrial electrolyzers have been in use for years to produce hydrogen and oxygen on-site for manufacturing processes. Generally expensive, sensitive and requiring regular expert maintenance, they are unsuited for domestic use. In addition, they are generally fueled by natural gas, a non-renewable energy source.

Biomimicry

Promising research is focused on biomimicry, applying biologic principles of plant energy production and storage to human power systems. Just as plants use water and sunlight to create a form of hydrogen, energy collected from solar panels can be used to separate water into hydrogen and oxygen. This is also known as “artificial photosynthesis”.

Sun Catalytix[3], a renewable energy startup in Cambridge, MA, is one firm working on this problem. Based on research by Dr Daniel Nocera at MIT[4], their electrolyzer catalyst uses cobalt phosphate to efficiently split off the oxygen gas. Both of these elements are cheap, abundant and stable.

In January 2010, Sun Catalytix was awarded a $4million grant from the US Department of Energy’s Advanced Research Projects Agency-Energy:

> “The ability to convert electrical energy into hydrogen reducing equivalents is fundamental to an enormous number of processes. To date, most approaches to this vital task have shown poor efficiencies or relied on expensive, rare and

[1] Webster’s defines electrolysis as, “the chemical decomposition produced by passing an electric current through a liquid or solution containing ions.”
[2] www.solarhydrogensystems.com
[3] www.suncatalytix.com
[4] NPR “*Talk of the Nation”,* 20 November 2009

> easily-poisoned catalysts. Sun Catalytix's work, based on robust, self-healing, earth-abundant catalysts, will revolutionize the transformation and transportation of energy, and we are delighted to support this novel and transformative technology." - Dr. Eric Toone, ARPA-E program director.

Dr. Nocera estimates that, excluding the costs of the photovoltaics, a 100w domestic energy storage system could be built for $30. Coupled with the rapidly falling prices of fuel cells, it is possible that a viable domestic solar energy storage system – a personal fuel plant – could be a reality in the near future.

Challenges remain. Hydrogen and oxygen – explosive gases – would be stored in tanks under pressure. Using existing examples of common residential utilities like natural gas and propane, acceptable storage solutions are in development. It is critical to manage the temperature during operation; the reactions create a large amount of heat that can damage the fuel cell if not ventilated. Water levels must also be controlled: too much and electrodes are flooded and reaction stops; too little and the cell dries out and materials can crack.

But if Sun Catalytix or one of its competitors is successful, this is truly a game-changing technology. Imagine each building generating and storing all the energy it needs safely, economically, and without creating green house gases. The hydrogen generated in the home could also be used to power the fuel cell in a car. Eliminating the connection to the national energy grid and reducing our reliance on foreign oil increases national security. Locally generated power lowers demand on our infrastructure, relieving pressure to build new coal-fired or nuclear power plants. Solar power will enter the mainstream.

contact e judy@judyvansoldt.com m 415.505.4683 402 30th St San Francisco California 94131