The Hydrogen & Fuel Cell Letter

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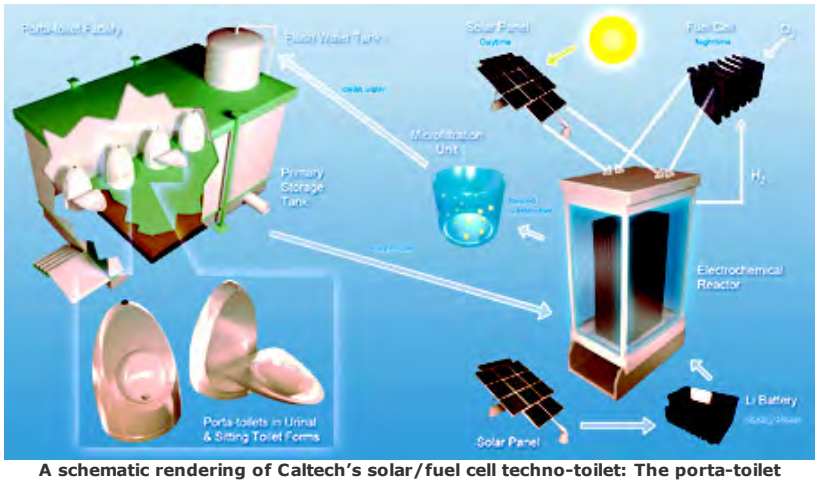
Solar/Fuel Cell-Powered Caltech-Designed Enviro-Toilet to Debut in India

PASADENA, CA - Early next month, a containerized solar- and fuel cell-powered toilet that doesn't need to be hooked to any urban sanitation or power systems and that doesn't pollute, will go on display at the "2nd Reinvent the Toilet Fair" in Delhi, India.

What's more, the high-tech toilet, designed and built by the California Institute of Technology here, produces hydrogen and fertilizer as by-products.



A schematic rendering of Caltech's solar/fuel cell techno-toilet: The porta-toilet container is on the upper left, with the primary storage tank on its right and the tank for the recycled flush water on top. The big transparent box on the lower right holds the electrochemical reactor. Above it is a solar panel, left, and the SAFC fuel cell in the upper right corner. Below the reactor is another solar panel, left, and the backup lithium-ion battery in the right lower corner. The round object near the center, halfway between the reactor and the container, is the microfiltration unit.

The two-day event is the second such fair organized by the Bill and Melinda Gates Foundation. The first one was held two years ago in Seattle where Caltech's team won the $100,000 First Place in the foundation's "Reinventing the Toilet Challenge," part of a $40 million program initiated by the Gates Foundation to tackle the problems of water, sanitation, and hygiene throughout the developing world.

$400,000 Grant to Design the Toilet

According to the World Health Organization, 2.5 billion people around the globe are without access to sanitary toilets, which results in the spread of deadly diseases. Every year, 1.5 million people - mostly those under the age of five - die from diarrhea.

A year before the Seattle show, the team headed by Caltech Prof. Michael Hoffmann was given a $400,000 grant to design the toilet which its creators say can safely get rid of human waste for about five cents per user per day. Runner-ups in the competition
included the UK's Loughborough University, the University of Toronto, and the Swiss Federal Institute of Aquatic Science and Design (EAWAG).

The system was designed and built with help from Kohler Co., Kohler, WI, a well-known manufacturer of kitchen and bath products. It's is one of two such systems that were shipped to India from the Caltech campus in early January: The one going to the Delhi fair will be installed afterwards on the campus of Mahatma Gandhi University in Kottayam in the state of Kerala in southwest India.

The second unit will go to the city of Ahmedabad, the former capital of the northwestern state of Gujarat where it will be connected to a public toilet facility.

Clément Cid, a Caltech graduate student who shepherded the project, says a production version of the system would probably cost around $1,500. But with a planned lifetime of 20 years or so, it isn't really much more expensive, even for developing economies, than digging open pits for fecal matter which have be removed every few years (A 4:50 minute video of Hoffmann and a gently clowning Cid demonstrate the system at http://tinyurl.com /caltechtoilets)

The process starts with pretreatment in a septic holding tank where sedimentation and anaerobic digestion via bacteria occur.

The liquid above the sediment - supernatant in technospeak - then goes to the electrochemical waste treatment system, or electrochemical reactor, designed by Hoffmann and his team. It oxidizes the waste at a semiconductor anode, and water is reduced at the metal cathode to form hydrogen. Chloride from table salt is oxidized to very reactive chlorine species which will increase the treatment and disinfection of the water.

After going through a microfiltration unit, the water can be used to flush the toilet again in a four-hour cycle, or as irrigation water. The sediment from the septic holding tank can be used as fertilizer.

Innovative Solid Acid Fuel Cell Powers Reactor

During daylight hours, electricity to drive the reactor comes from solar panels, with a lithium-ion battery as backup. During the night, power comes from an innovative fuel cell design, a so-called solid acid fuel cell, made by a Pasadena-based startup, SAFCell, Inc.

Solid acid fuel cell (SAFC) stacks operate at intermediate-range temperatures of 200-300 deg. C. Developed and patented by the Haile Lab of Caltech's Materials Science Department (H&FCL Feb, 08), they are chemical intermediates between normal salts and normal acids, says Calum R. I. Chisholm, CEO of SAFCell. They offer greater fuel flexibility because of high tolerances to fuel impurities - such as those found in commercial diesel, gasoline, propane, and natural gas, or the dirty hydrogen from Caltech's techno-toilet electrochemical reactor - that would damage or destroy low-temperature PEM fuels. The SAFCell stacks also avoid the need to reach high temperatures of 600-1,000 deg. C. typical for impurity-resistant traditional stack types such as molten carbonate and solid oxide. It also allows for a greater variety of low cost catalysts and "extensive" simplifications to reformer subsystems, greatly reducing overall SAFC system costs, Chisholm says.

Last June, SAFCell received a $1 million grant to demonstrate a 50 Watt propane powered fuel cell system as a light weight, wearable power unit for soldiers in the field, designed by UltraCell, Inc., Livermore, CA. And Chisholm told H&FCL he is working with a Norwegian company, Nordic Power Systems, Porsgrunn, to develop 1 kW diesel-fueled APU for mobile military applications.

For Caltech's team, the fuel flexibility of SAFC stacks were key.
"Along with hydrogen, our chlorine reactor produces other
by-products, or fuel impurities, which is why we chose the impurity-tolerant SAFCell stack over other technologies," said lead researcher Hoffmann. "Incorporating a SAFCell fuel cell into our prototype will make our toilet even more self-sustaining, which is essential for meeting not only the challenge from the Gates Foundation, but moreover, the challenges of the real world."

Cid told H&FCL his team received the 50 W fuel cell only a month ago and is still testing it. Whether this size will be the final one is not certain: "We're still trying to find the best operating conditions," he said. *Contacts: Caltech media office, Brian Bell, 626/ 395-5832, bpbell@caltech.edu; SAFCell, Inc., Calum Chisholm, 626/795-0029 x101, calum.chisholm@safcell.com.*