New fuel cell drives around hydrogen economy roadblocks

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As gasoline prices climb ever higher and the U.S. Senate backs oil drilling in Alaska's Arctic National Wildlife Refuge, the possibility of a hydrogen economy -- where drivers tank up on clean-burning hydrogen fuel -- gleams more brightly. But two Northwestern University engineers stress the need to get more out of the fuel we are already using.

"A hydrogen economy is not a perfectly clean system," said Scott A. Barnett, professor of materials science and engineering. "You have to process fossil fuels at a plant to produce hydrogen fuel as well as develop an infrastructure to get that fuel into vehicles. We have bypassed these technological hurdles by basically bringing the hydrogen plant inside and pairing it with a high-temperature fuel cell in one compact unit that has a fuel efficiency of up to 50 percent."

In a paper to be published online today (March 31) by the journal Science, Barnett and graduate student Zhongliang Zhan report the development of a new solid oxide fuel cell, or SOFC, that converts a liquid transportation fuel -- iso-octane, a high-purity compound similar to gasoline -- into hydrogen which is then used by the fuel cell to produce energy. The cells could lead to cost-effective, clean and efficient electrical-power sources for applications ranging from aircraft and homes to cars and trucks.

Although only demonstrated on a small scale, Barnett and Zhan's fuel cells are projected to have a 50 percent fuel efficiency when used in a full-sized fuel cell generator, which would improve on other technologies. Higher fuel efficiencies mean less precious fuel is consumed and less carbon dioxide, a greenhouse-effect gas related to global warming, is produced. Internal combustion engines have a "well-to-wheels" efficiency of a mere 10 to 15 percent. Current hydrogen fuel cells that require hydrogen plants and new infrastructure have been calculated to have a 29 percent fuel efficiency while commercial gas/electric hybrid vehicles already have achieved 32 percent.

"The advent of hybrid vehicles has shaken up the fuel cell community and made researchers rethink hydrogen as a fuel," said Barnett, who drives a Toyota Prius and foresees his new fuel cells being developed for use in battery/SOFC hybrid technology for vehicle propulsion or in auxiliary power units. "We need to look at the solid oxide fuel cell -- the one kind of fuel cell that can work with other fuels beside hydrogen -- as an option."

A fuel cell is like a battery that can be replenished with fresh fuel. It consists of two electrodes sandwiched around an electrolyte material that conducts ions between them. Oxygen enters at the cathode, where it combines with electrons and is split into ions that travel through the electrolyte to react with fuel at the anode. Fuel cells are environmentally friendly: water and carbon dioxide are the only by-products. In the process, the oxygen ions traversing the electrolyte produce a useful current. Heat is also generated.

Because conventional solid oxide fuel cells operate at such high temperatures (between 600 and 800 degrees Centigrade) Barnett recognized that the heat could be used internally for the chemical process of reforming hydrogen, eliminating the need for hydrogen plants with their relatively low fuel efficiency. Barnett and Zhan found the optimal temperature for their system to be 600 to 800 degrees.

The real key to the new fuel cell is a special thin-film catalyst layer through which the hydrocarbon fuel flows toward the anode. That porous layer, which contains stabilized zirconia and small amounts of the metals ruthenium and cerium, chemically and cleanly converts the fuel to hydrogen.

"A major drawback of using solid oxide fuel cells is that carbon from the fuel is deposited all over the anode because of the high temperatures," Barnett said. "But our thin film catalyst, plus the addition of a small amount of oxygen, eliminates those deposits, making it a viable technology to pursue with further research. We have shown that the fuel cell is much more stable with the catalyst and air than without."

"The main drawback of fuel cells has been their complexity and high cost," said Barnett. "The simple design of our system, which brings the hydrogen reformer in house, is a great advantage for a range of applications. For example, imagine a unit cheap enough to be used for auxiliary power in cars or diesel trucks. It would supply electricity continuously, cleanly, quietly and efficiently even when the engine is not running. This work has the potential to lead us in that direction."

Source: Northwestern University