HYDROGEN FOR TRANSPORTATION

Why should the use of hydrogen/fuel cell vehicles be promoted when hydrogen can be used more effectively in stationary or portable fuel-cell applications?

There are major concerns with global warming and rising oil prices, alternatives in transportation are being investigated and as research continues, a hydrogen economy has become even more promising. The Big-Three US auto manufacturers have admitted to this in a July 2009 white paper titled: "Hydrogen Research for Transportation: The USCAR Perspective." <http://www.uscar.org/guest/article_view.php?articles_id=312> (Then click to download a PDF copy of this report).The report was written by USCAR - United States Council For Automotive Research LLC which includes Chrysler, Ford and General Motors.

The report begins with the statement: *"The only known forms of energy that offer truly zero emissions from motor vehicles are electricity and hydrogen." "...electric vehicles cannot compete with hydrogen-fueled vehicles for general usage in terms of range and 'refill' time."*

Later in the article they state: *"Only hydrogen fuel cell electric vehicle technology offers the promise of true-zero emissions, superior efficiency and uncompromised functionality. Regardless of their individual strategies, the USCAR members are firm in their belief that hydrogen-FCVs [Fuel Cell Vehicles] will be an important powertrain option in our future of sustainable transportation."*

In rating modes of transportation propulsion systems, USCAR places advancements in the Internal Combustion engine (ICE) at the bottom of the list, then Hybrid Electric Vehicles (HEV), next is Battery Electric Vehicles (EV), and at the top: Hydrogen Fuel-Cell Vehicles (HFCV). When the top is reached, petroleum is no longer needed, fuel efficiency is improved and there are no emissions. Energy sustainability can be attained.

FUEL CELLS

Sir William Grove developed the first fuel cell in England in 1839. The device is similar, but opposite in function, to an electrolyzer which can split water (H_2O) into its component parts H_2 and O_2. In a fuel cell hydrogen and oxygen are allowed to combine and produce an electric current.

There are several types of fuel cells, but the most efficient, effective and cleanest type used in automobiles is the PEM (Polymer Electrolyte Membrane or Proton Exchange Membrane) Fuel Cell. USCAR's report states: *"DOE's Technology Validation program has demonstrated 58% fuel cell efficiency, nearly meeting the 60% target."* See "Types of Fuel Cells" at <http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html>

Hydrogen used in PEM fuel cells, can efficiently produce:

1. electrical power,
2. heat energy and
3. pure drinkable water as the only "waste" product.

Fuel cells are presently being used in stationary and transportation applications in many parts of the world.

One kilogram of hydrogen gas will permit a fuel cell vehicle (FCV) to travel much farther than an internal combustion engine (ICE) automobile.

Presently, fuel cells are relatively expensive because they use either platinum, palladium, Nafion® or other expensive materials as a catalyst.

Basically, a fuel cell vehicle is an electric vehicle, powered by electricity produced by a fuel cell that has no moving parts (as in an internal combustion engine) and is pollution-free.

According to the Big Three (Ford, GMC and Chrysler) "Only hydrogen fuel cell electric vehicle technology offers the promise of true-zero emissions, superior efficiency and uncompromised functionality. Regardless of their individual strategies, the USCAR members are firm in their belief that hydrogen-FCVs will be an important powertrain option in our future of sustainable transportation." <www.uscar.org/guest/article_view.php?articles_id=312>

HYDROGEN STORAGE

Hydrogen can be stored on board in either:

1. High pressure storage tanks (generally 5000 psi) most commonly used in autos today;
2. Metal Hydrides: perhaps safest form but heavy in weight;
3. Chemical Hydrides: "spent fuel" and/or byproducts must be removed from the vehicle and regenerated off-board;
4. Sorbents: carbon-based materials such as carbon nanotubes, aerogels, nanofibers (including metal-doped hybrids), as well as metal-organic frameworks, conducting polymers, and clathrates.

Hydrogen can also be stored in the form of HYTHANE which is a mixture of hydrogen and natural gas. This mixture can be used as natural gas and transported in a natural gas pipeline.

HYDROGEN AVAILABILITY

- Hydrogen is the most abundant element in the Universe.

- Approximately 72 percent of the Earth's surface is covered by water.

- Water is composed of two parts of hydrogen and one part of oxygen.

- We will never run out of hydrogen.

- When hydrogen burns, it combines with oxygen to form water (H_2O), but because of high temperatures when burned, it also produces some nitrogen oxide as oxygen combines with nitrogen from the air.

- However, when hydrogen is used in a fuel cell, it does not form nitrogen oxide. This is the cleanest and most effective way to use the energy from hydrogen.

• Hydrogen can be distributed and stored in a variety of ways.

HYDROGEN PRODUCTION

• Commercially, most hydrogen is obtained from natural gas by steam reformation. This is undesirable because carbon is released in the reaction. In this process, the four hydrogen atoms are stripped from methane (CH_4), the major component of natural gas, the carbon atom combines with oxygen from the air and/or water and forms carbon dioxide (CO_2) as a waste product. The process could be acceptable if the CO_2 were sequestered at the gas well head, it could be reinjected back into the well and displace or "strip" the well of its natural gas since CO_2 is more dense than CH_4.

• Conversion of waste biomass into hydrogen by a process called **plasma gasification**. This is one of the most promising sources of hydrogen and, at the same time, the wise use and elimination of solid wastes. The process involves physically breaking down waste molecules into atoms to produce "syngas" which is composed basically of hydrogen and carbon monoxide. The carbon monoxide can be easily removed to provide pure hydrogen. The process is explained at:
<http://www.disclose.tv/action/viewvideo/17660/Startech___waste_to_energy_plasma_technology>

• Many industries "burn off" excess hydrogen from their manufacturing process instead of saving it. This "excess" hydrogen should be collected and used beneficially.

• Electrolysis of water (splitting water into H_2 and O_2 with a direct electric current):
  - *"Ideally, 39 kWh of electricity and 8.9 liters of water are required to produce 1 kg of hydrogen at 25° C and 1 atmosphere pressure. Typical commercial electrolyzer system efficiencies are 56%–73% and this corresponds to 70.1–53.4 kWh/kg." ("Technology Brief: Analysis of Current-Day Commercial Electrolyzers," NREL, Golden, CO NREL/FS-560-36705, September 2004.)*
  - The National Renewable Energy Laboratory found that *"a kilogram of hydrogen (roughly equivalent to a gallon of gasoline) could be produced by wind powered electrolysis for between $5.55 in the near term and $2.27 in the long term."*
  - A more recent study indicates *"that hydrogen can be produced at the point of use for prices ranging from $4.03/kg in the near term to $2.33/kg in the long term."*
  - An alkaline electrolyzer is capable of producing *"hydrogen at 6,500 psig (pound-force per square inch gauge) without a compressor. Present hydrogen tanks use 5,000 psi (pounds per square inch)."*
  - Using "off-peak" electricity (i.e. midnight to 5:00 AM) -
    (Especially from nuclear plants to keep units running at full capacity)
  - Using Renewable Energy to produce the needed electricity.
    (Including: wind turbines, photovoltaics, hydropower, low tech water turbines, waves, tides, etc.)

• A "newly developed technology generates hydrogen by adding aluminum or magnesium to what is known as "functional water" in the boiling state. The amount of hydrogen generated is 2.0L per 1g of aluminum or 3.3L per 1g of magnesium. This makes it possible to generate the amount of hydrogen required to generate 1kWh of electricity for a cost of merely 18 cents or so, the world's lowest cost."
<http://www.sustainablecitynetwork.com/product_news/read/article_35ff9f7c-d930-11df-b59a-00127992bc8b.html>

- Water photolysis.

- Hydrogen-producing algae.

- Hydrogen-producing bacteria.

- 90% efficiency conversion of ethanol to hydrogen at room temperature using a cobalt and phosphorus catalyst.
- Hydrogen from water using Boron or other chemicals, etc.

INFRASTRUCTURE

The USCAR researchers seem to believe that 12,000 hydrogen stations would put hydrogen within two miles of 70 percent of the US population. They don't seem to realize that Americans are inventive people. It's not necessary to provide refilling stations for launching the hydrogen economy. More than two years ago the writer of this article installed a 7.2 kilowatt photovoltaic array on his rooftop. The local utility is paying $0.225/kWh while residential customers pay the utility a little more than $0.10/kWh. This program is good for only ten years. At the end of this period an electrolysis device could be added to the system to produce hydrogen by electrolyzing water. The hydrogen could then be stored and used in a stationary fuel cell to produce electricity, heat and water when needed, or it could be used to fill a hydrogen tank to provide energy for a fuel cell automobile. Honda is also working on a unit that customers can plug into their residential 120V electrical outlets to produce all of the hydrogen needed.

SUMMARY

- See Honda's Clarity at <http://automobiles.honda.com/fcx-clarity> This attractive vehicle is capable of 60 miles per kilogram (*"it gets the gasoline equivalent of 65 mpg on the highway and 70 in town"*); 270 miles per tank; seats four people; produces 134 horsepower; with 100kW power output, It accelerates eagerly up to a governed top speed of 100 mph, and is a zero-emissions vehicle.

- *"In 2004, the United States used 140 billion gallons of gasoline, so there is the potential to economically supply all of the current gasoline needs with wind-generated hydrogen."* (NREL)

- Potentially there is sufficient hydrogen available in solid waste (garbage) to satisfy a large part of our energy demands - see plasma gasification above.

- Hydrogen can replace fossil fuels to provide electricity and transportation fuels.

- Domestic resources can be used to produce the hydrogen and lead to energy independence.

- The FOSSIL FUEL ECONOMY can be replaced by the HYDROGEN ECONOMY!