Introduction to Hydrogen Production Distribution and Use

Hydrogen has been identified as a potential energy carrier in some low GHG energy scenarios. However, the technology available to produce, store and use hydrogen in a cost-effective way with low emission of greenhouse gases is not sufficient for large-scale deployment.

Hydrogen can be produced from fossil fuels or from water splitting. When hydrogen is derived from hydrocarbons (fossil fuels), the chemical energy to be stored in the hydrogen is already present in the primary fuel. The key challenges to this form of production lie in controlling the chemical reactions and the extraction of hydrogen. Production from fossil fuels in a low GHG scenario will also require CO_2 capture and sequestration. Conversely, extraction of hydrogen from water requires that energy be supplied from an external resource, but does not present the challenge of unwanted emissions at the point of conversion.

Hydrogen's appeal as an energy carrier is currently limited by the availability of methods to store it efficiently. Many energy conversion systems that would use hydrogen operate either intermittently or independent of energy infrastructure and thereby require a reservoir of hydrogen. This reservoir must be of reasonable size and weight, and cannot require a significant fraction of stored energy to fill, vent, or move. Hydrogen storage options utilizing chemical potential must use sufficiently reversible reactions to meet these goals.

The two most likely candidates for the conversion of energy stored in hydrogen to useful work are internal combustion engines and fuel cells. Today's engine technology could be adapted for use with hydrogen at efficiencies comparable to hydrocarbon fueled engines, while advanced engine technology could push the boundaries of efficiency even further. Fuel cells hold the promise of higher efficiency than traditional engines, as well as other engineering tradeoffs that might make for quieter and possibly more reliable prime movers.

GCEP has six ongoing and two completed research activities in the hydrogen technology area, spanning the fields of hydrogen production and storage, fuel cells, and atmospheric impact of hydrogen. Production is addressed by Professors Swartz and Spormann in their efforts on biohydrogen generation. The goal of these activities is to develop an engineering system based on a microorganism that can use the energy in sunlight to split water into hydrogen and oxygen. Professors Swartz and Spormann are developing the organism as an engineered hybrid between two naturally occurring organisms: one which harvests solar energy and stores it chemically, and the other which supplies stored chemical energy to the water splitting reaction. A completed project by Professor Prinz developed sensors in support of this effort and nanoscale probes to explore and monitor cellular processes *in vivo*.

Hydrogen storage on carbon nanostructures is addressed in an effort led by Professors Cho, Clemens, Dai and Nilsson. The goal of this project is to develop a high surface area, engineered nanocomposite material with the ability to adsorb and release hydrogen with high reversibility.

Professors Pinsky and Stebbins are pursuing hydrogen usage in fuel cells in their projects on solid-polymer PEM membranes and ceramic oxide ion conductors for SOFCs. These investigations will result in a better understanding of solid oxide and polymer electrolyte materials, possibly leading to new classes of high efficiency, high current density, and low cost semipermeable conductors. Professor Prinz has completed a project developing techniques to perform microscale impedance measurements on fuel cell materials during operation. This work has provided a window into the electrochemical dynamics and structure of the fuel cell three phase boundary and is transferable to other nanoscale systems.

Finally, Professors Jacobson and Golden have undertaken a study of the potential environmental effects of large-scale utilization of hydrogen. They are investigating how replacing fossil-fuel based vehicles and electric power plants with those powered by hydrogen fuel cells might affect global and regional climate, stratospheric ozone, and air pollution.