Introduction to Hydrogen Production Distribution and Use

Hydrogen has been identified as a potential energy carrier in many low GHG energy scenarios. However, the technology to produce, distribute and use hydrogen in a cost-effective, low GHG manner is not yet developed.

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 limited by its ability to be efficiently stored. Many energy conversion systems that would use hydrogen must operate intermittently and thereby require a reservoir of hydrogen. This reservoir must be of reasonable size and weight, and cannot waste a significant fraction of stored energy in the filling and venting processes.

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 seven ongoing research efforts 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, Spormann and Prinz in their projects on biohydrogen generation and sensors for biohydrogen generation. The goal of these projects 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. Professor Prinz is developing nanoscale probes to monitor this bioconversion process so that it can be further optimized.

Hydrogen storage on carbon nanostructures is addressed 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 very low irreversibility.

Professors Pinsky, Stebbins and Prinz and are pursuing hydrogen usage in fuel cells in their projects on solid-polymer PEM membranes, ceramic oxide ion conductors and micro and nano scale electrochemistry. These investigations will result in a better understanding of solid oxide and polymer electrolyte fuel cells which will aid in the creation of more efficient and robust designs.

Finally, Professors Jacobson and Golden have undertaken a study of the potential environmental effects of switching to a hydrogen economy. Replacing fossil-fuel based vehicles and electric power plants with those powered by hydrogen fuel cells may affect global and regional climate, stratospheric ozone, and air pollution.