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Louisiana Energy Topic

Department of Natural Resources Technology Assessment Division

A Supplement to LOUISIANA ENERGY FACTS on Subjects of Special Interest

A Hydrogen Primer

by

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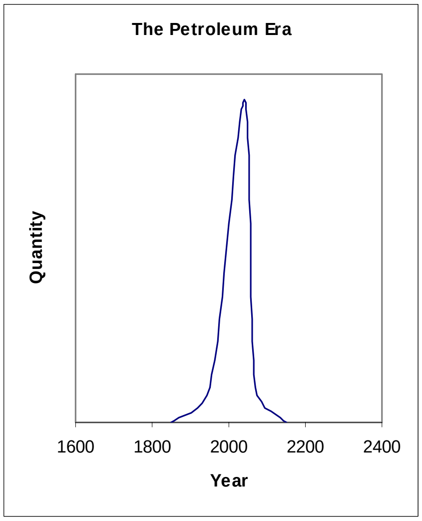
The End of Cheap Oil

Energy is inextricably linked to our society and economy. We use energy as leverage for our physical strength and intellect to perform tasks we could not otherwise accomplish. Almost everything people do in the course of a day involves, or depends on, a machine using energy to produce work. Not just any energy will do, it must be affordable energy.

It has to be affordable because people are not interested in buying energy; they are interested in buying products and services. If the energy required to create products and services is unaffordable, the products and services become unaffordable. Currently, we get affordable energy from fossil fuels, a finite resource. Of the fossil fuels, oil is the most heavily relied on, but long before we run out of oil, we will run out of cheap oil.

At some point in the future, global oil production will peak and begin to decline. Some time after this, as demand rises and supply declines, prices will rise sharply. Prices will destabilize prior to this due to speculation and anticipation. Finally, prices will increase to a level beyond what the economy can support and the era of cheap oil, that began when Edwin Drake struck oil in 1859, will come to an end.



The world oil production curve will look something like the illustration on the right. The time frame for this sequence of events is the subject of much debate and speculation. The U.S. Department of Energy's Energy Information Administration predicts a peak between 2030 and 2075 (Energy Information Administration, 2000). Other experts on the subject predict a global peak ranging from 2000 to 2015 (Williams, 2003). The point is, whether the global peak occurs now, or 50 years from now, the petroleum era will be a short, finite blip in history.

The Hydrogen Economy

In order to maintain our economy and standard of living beyond the petroleum era, we will have to transition to some other energy regime. One possibility is hydrogen.

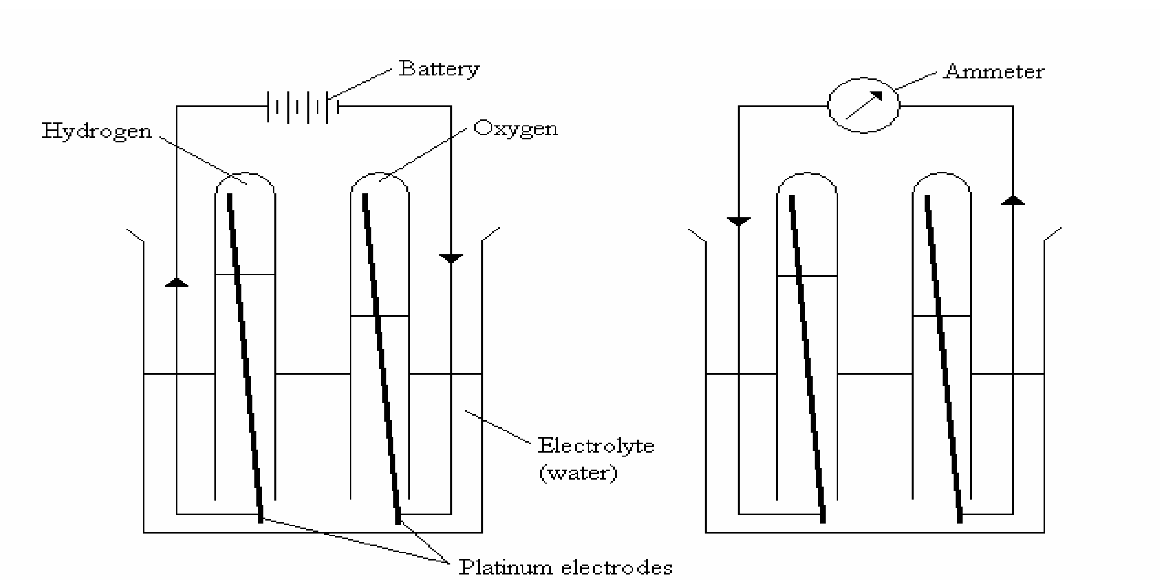
In 2002, the U.S/ Department of Energy released the National Hydrogen Energy Roadmap, and in 2003, President Bush announced $1.7 billion in funding for hydrogen energy in the State of the Union Address. Hydrogen has received a lot of attention lately, some portraying it as the cure-all for our energy problems, and some as an attempt to slash funding for research and development of other alternative energy sources.

The reasons for the wide ranging characterizations of hydrogen energy, other than political, are due to the fact that, in theory, hydrogen does indeed seem like a miracle solution to many energy problems, but many significant barriers exist to put it into practice. The following is an introduction to hydrogen and some of the possibilities and problems associated with a hydrogen based economy.
No one knows, yet, exactly what a hydrogen economy would look like, but the front running scenario would be based on hydrogen fuel cells producing electricity. The electricity would then be used to power vehicles, homes, businesses, etc. In this scenario, hydrogen is not an energy source, but rather a carrier. Hydrogen can, also, simply be used as a combustion fuel in an internal combustion engine. The only emission is pure water. Ford and BMW are actively pursuing this option as an alternative motor vehicle fuel.

Fuel Cells

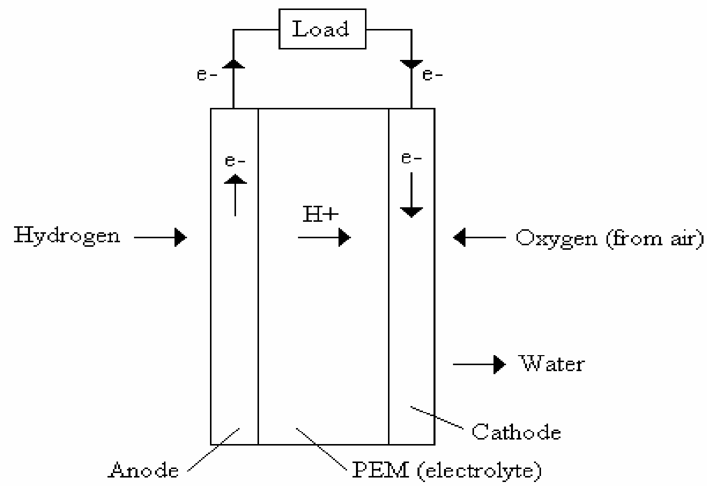
A hydrogen fuel cell is a simple device that uses hydrogen and oxygen to produce an electric current. Sir William Grove is credited with the discovery of the fuel cell in 1839. His experiment was based on the known fact that, if an electric current was applied to water, it would separate into its constituents, hydrogen and oxygen (Figure 1). Grove's experiment simply showed that, if the electric current was removed, the reaction would reverse, and the hydrogen and oxygen would recombine into water and produce an electric current (Figure 2).

Figure 1 **Figure 2**



A practical fuel cell is more complex than the one shown in Figure 2, although the operating principle remains the same. One of the simplest types of a hydrogen fuel cell is the proton exchange membrane (PEM) fuel cell. A PEM is a specially designed polymer that functions as the electrolyte in the fuel cell assembly. The basic components of a PEM fuel cell are shown in Figure 3. Basically, a PEM fuel cell operates as follows: Hydrogen is fed to the anode and separated into hydrogen ions (protons) and electrons. The PEM allows the hydrogen ions to pass through to the cathode, but not the electrons. The electrons are given a separate path to the cathode, enabling electrical energy to be extracted. Oxygen is supplied to the cathode which combines with the hydrogen ions and electrons to form water. Another way of understanding the operation of a fuel cell is to think of the hydrogen as being "combusted," or oxidized, but, instead of producing heat energy, the reaction produces electrical energy. The voltage produced from this reaction is small, less than one volt. For this reason, several cells are connected in series, called a fuel cell stack, to produce the desired voltage. A typical PEM fuel cell is about 50% efficient, that is, it converts 50% of the energy contained in hydrogen into electricity. The efficiency can be increased substantially by capturing the waste heat and using it for space heating, water heating, or process heat. When the waste heat is utilized in a cogeneration setup, efficiencies can reach 90%.

Figure 3



<u>Hydrogen Production and Transportation</u>

The good news about utilizing hydrogen as an energy carrier is its abundance and its environmental benefits. The bad news is that it is always chemically bound to something else, usually oxygen and carbon. In order to obtain hydrogen, energy has to be exerted to break its chemical bonds with other elements. In general, with current technology, the energy required to obtain hydrogen renders the process uneconomical. While fuel cells have their own set of significant obstacles to overcome before being technologically and economically viable, the problems associated with obtaining and distributing hydrogen are generally thought to be more difficult to solve.

The ultimate objectives of hydrogen production for use as an energy carrier are producing it economically and renewably. There are several ways to produce hydrogen, some of them economical, and some of them renewable, but none that are both, as yet.

Over 9 million tons of hydrogen is produced yearly in the U.S. Most of it is used to make ammonia, while other users include refining, chemical, and food industries. Ninety five percent of this hydrogen is produced by using steam to reform natural gas (fossil fuels contain lots of hydrogen). This method can be economic, depending on the price of natural gas, but natural gas will eventually suffer a fate similar to that of oil since steam reformation of natural gas is a non-renewable source of hydrogen.

Renewable hydrogen production is accomplished by using renewable generated electricity (solar, wind, etc.) to perform electrolysis on water. Electrolysis, whether using renewable or non-renewable electricity, is inefficient, usually making it uneconomic. There are other ways of obtaining hydrogen including thermal water splitting, thermochemical water splitting, gasification of coal, and thermal and biological conversion of biomass. All of these methods are being investigated to determine their economic and technical feasibility.

The other major problem associated with hydrogen is transportation. Hydrogen gas is extremely lightweight, making it necessary to compress or liquefy it in order to be contained in a reasonably sized volume for transportation by ship or truck. This adds considerably to the cost. Hydrogen can be transported effectively by pipeline, but few dedicated hydrogen pipelines currently exist. In the beginning stages, hydrogen will have to be produced on or near site. As hydrogen usage expands, the economics will change and, depending on technological advances, central hydrogen production may make sense.

Transition and the Future

This discussion, so far, focuses on the current state of hydrogen in relation to its use as an energy carrier. It's clear that a hydrogen based energy regime will have to begin with the non-renewable production of hydrogen for economic reasons. As the transition to a new energy regime occurs, the technology and economics will change, hopefully leading to the economic, renewable production of hydrogen. For example, hydrogen will accelerate the development of wind and solar power by enabling the storage of energy produced by these intermittent sources. This would allow wind and solar to move into geographic areas that are not, otherwise, ideal for their usage. Another renewable technology that may mesh well with hydrogen is off shore geothermal electricity generation. This technology uses the temperature difference in water depth to drive a thermodynamic cycle and generate electricity. Although the process is extremely inefficient, the size of the resource is huge, including all tropical oceans and the Gulf of Mexico. The electricity can then be used to electrolyze sea water to produce hydrogen, which is then liquefied and shipped to shore for distribution.

The Louisiana Connection

Whether or not hydrogen proves to be the foundation of future energy production, a lot of resources are being directed towards hydrogen and fuel cell development. Louisiana is one of the few places in the country that has an existing hydrogen infrastructure. Air Liquide, Air Products, and Praxair operate hydrogen pipelines in Louisiana, and Louisiana is home to many chemical plants and refineries that produce and use hydrogen. The existence of this hydrogen market creates a ripe environment for hydrogen and fuel cell development. If taken advantage of, Louisiana could become a hub of hydrogen and fuel cell development. For example, in the largest fuel cell transaction to date, Dow Chemical and General Motors recently announced a deal in which GM will provide fuel cells to the Dow plant in Freeport, Texas. Dow will use excess hydrogen generated as a byproduct from chlorine production to feed the fuel cells. The electricity generated by the fuel cells will be used for general power in the plant. The fuel cells are expected to produce 35 megawatts of power over the life of the project. Dow and GM are discussing plans for similar projects at other Dow plants.

We will still be using fossil fuels well into the future, but, eventually we'll have to derive energy from some other source. A lot will be at stake for Louisiana when this happens. Everyone knows what would happen to Louisiana's economy if the oil and gas industry weren't here. If electricity produced via hydrogen turns out to be the alternative, and we take advantage of the opportunity, Louisiana could continue its role as a leader in energy production and technology well into the future.

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