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A Case Study on Hydrogen Fuel

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Abstract--- *The degrading of the air quality resulting from the emissions of the existing energy conversion devices, in addition to the recent instability of the oil prices forced the need to a more stable zero-emission distribution generation technology or combination of technologies which allows a clean, cost effective supply of energy, on demand on a large scale and in any location. Thus, renewable energy generation or the decentralized power systems like wind, photovoltaic, as well as new hydrogen and fuel cells technologies are developing nowadays to take over from fossil hydrocarbons combustion. Fuel cell is an emerging technology which could allow a clean, cost effective supply of energy on demand on a large scale and in any location. This paper will act as a literature survey to the fuel cell technology. It will introduce the different fuel cell types with their advantages and disadvantages, and their suitability for different applications. It will also discuss the technical and economic issues facing the spread of this technology, and how to move to a worldwide hydrogen technology. It will also brief the current state of fuel cells with both drivers and barriers to its market growth. Further recommended work for the advance and spread of use of the fuel cells will be also highlighted.*

Keywords--- *Hydrogen, Fuel Cell, Hydrogen Fuel Based Vehicles.*

I. INTRODUCTION

Fuel cells can potentially replace conventional power equipment in many cases as stationary power generation, transportation and battery replacement. They are already commercially available, at high costs, for applications such as portable power sources and small-scale power generation and transportation. At present there are different fuel cell types at various stages of intensive development by several manufacturers around the world. As fuel cells reduce the dependence on fossil fuels thus having a significant environmental and national security, they are the centre of interest for excessive research.

II. LITERATURE REVIEW

In light of recent hydrocarbon shortage concerns, hydrogen is receiving increased attention from the scientific community and the media for its potential role in a sustainable energy system.

Hydrogen, like electricity, is an energy carrier and not an energy source, and significant research is underway to test the feasibility of a future transition to a total hydrogen energy economy. To understand the implications of such an economy, the Iowa Energy Center funded an extensive literature search over the summer of 2006. This search included approximately 130 research reports, case studies, and other esteemed publications having to do with important aspects of the hydrogen economy (i.e. production, efficiency, electrochemical conversion, etc.). Findings of the search are focused on hydrogen production by electrolysis, several storage and delivery methods,

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electrochemical conversion to electricity in fuel cells, and process efficiencies. Because hydrogen is a chemical energy carrier (unlike electricity, which is a current of electrons), it is potentially more effective as a storage medium than other technologies like batteries, especially for use in renewable energy systems such as wind or solar power. Research efforts are currently being focused on optimizing the entire hydrogen production-to-consumption process, with increased interest in renewable energy applications. When derived from renewable resources such as wind or solar energy, hydrogen can be produced and utilized free of carbon emissions. Research efforts are being directed toward the transition to a sustainable hydrogen based economy, which is a carbon-free energy system in which hydrogen is the only energy carrier.

Hydrogen is nearly unavailable in its molecular form on earth. A number of production methods including electrolysis, steam reformation of natural gas, and coal gasification are the foci of widespread production research; but electrolysis currently offers the greatest potential for a sustainable hydrogen economy. Water electrolysis is a technique that utilizes a direct current to split water into protons, electrons, and gaseous oxygen at the anode (positive electrode) in the electrolyzer. Protons pass through an electrolyte such as a proton exchange membrane (PEM) and recombine with electrons at the cathode (negative electrode) to form diatomic hydrogen (H2). The minimum potential difference between the cathode and anode must be near 1.5 V for efficient electrolysis. Electrolysis is not yet economically feasible; this is mostly due to high aterial costs of the catalysts and electrolytes. As a result of high material costs, a significant amount of research is being performed to find cheaper, more efficient materials for use in electrolyzers. If the electrolyzer’s input electricity is generated by renewable energy alternatives, renewable-to-hydrogen systems can be fully-sustainable; a number of case studies report that renewable-to-hydrogen technology is available and ready to implement today.

Because hydrogen must first be produced to “fuel” a hydrogen economy, questions are being raised in regard to whether large-scale centralized production facilities or smaller localized production centers are more favorable. Centralized production facilities can produce large quantities of hydrogen more economically than smaller decentralized systems, but long-distance distribution of hydrogen to the facilities that electrochemically convert hydrogen into electricity incur added expense and lowered efficiency. The single most troublesome feature of hydrogen with respect to distribution is its low volumetric density. As a gas, hydrogen is about 14 times gravimetrically lighter than air. Compressed gaseous hydrogen transport is only possible in heavy, expensive vessels that can withstand pressures up to 10,000 psi, or a system of pipelines that must either be constructed from the bottom up or retrofitted from existing natural gas pipelines. Cryogenic hydrogen can be transported more easily than gaseous hydrogen, but the conversion from gaseous to liquid hydrogen is energy intensive, inefficient, and considerably expensive. At this time, pipelines are considered the most likely transport method for a hydrogen economy. Major concerns surrounding hydrogen distribution include high cost and a phenomenon known as hydrogen embrittlement that causes pipelines and storage vessels to crack and fail over time. Decentralized production of hydrogen eliminates losses associated with longdistance transport but increases the demand for effective hydrogen storage on-site. The characteristic that best sets hydrogen apart from other energy carriers such as electricity is a higher capacity to be stored for use at a later time. Storage research is primarily focused on compressed gas, cryogenic hydrogen, and metal hydrides, but a growing number of alternative methods including carbon novel materials, chemical hydrides, and glass microspheres are also being tested. Compressed gas is the most mature storage technology, but compression adds inefficiencies to the hydrogen life-cycle and requires stronger, costlier materials for tank construction. Extensive materials research is being conducted to improve compressed gas storage technology; advancements have already been made in carbon-fiber wrapped tanks, which are lighter and safer than traditional steel tanks. Cryogenic hydrogen is denser than compressed gaseous hydrogen, therefore requiring less storage volume. Energy and economic costs associated with cryogenic hydrogen storage are higher than compressed gas storage costs. Between 10 and 30 percent of the fuel value of hydrogen is required for liquefaction, and tanks must be super-insulated to maintain cryogenic temperatures near -250oC. Solid storage in metal hydrides is not yet feasible, but preliminary research suggests that metal hydrides will be prominent in the future hydrogen economy. Using the concept of temperature change, hydrogen is adsorbed within interstices of metal hydride lattices. The resulting granules can be stored more safely than compressed gas or cryogenic liquid hydrogen. Hydrogen is released from the metal hydrides by applying heat. The high costs currently associated with adsorption make metal hydride storage impractical, but economic feasibility will increase as technological advances are made.

The electrochemical conversion of hydrogen and oxygen to electricity and water in a fuel cell is the most publicized aspect of a future hydrogen economy. The fuel cell works much like an electrolyzer in reverse: diatomic hydrogen is broken into electron and proton components at the anode, electrons flow through an external circuit to be consumed as electricity, and hydrogen ions (protons) pass through the electrolyte to the cathode, where they are combined with gaseous oxygen to produce water. Fuel cells are categorized by low or high temperature operation and are classified by the type of electrolyte they contain. Examples of low temperature fuel cells include phosphoric acid (PAFC) and proton exchange membrane fuel cells (PEMFC); high temperature models include molten carbonate (MCFC) and solid oxide fuel cells (SOFC). The wide range of power outputs available make fuel cells suitable for a variety of applications. Relatively high fuel cell efficiencies are coupled with high material costs; research and development efforts will continue to focus on optimization until a feasible model is developed

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