Advantages of hydrogen based economy

• Hydrogen is one of the most abundant elements present on the surface of earth, making up almost 90% of all matter.

It is present in organic matter, in fossil fuels (hydrocarbons) and in water. Thus hydrogen has the capacity to meet all energy needs of mankind; from combustion to electricity. It is also possible to produce hydrogen using renewable sources of energy . For e.

g. renewable energy sources like solar and wind power can be used to generate electricity. Electricity generated from these renewable sources of energy could be utilized for electrolysis of water, leading to production of hydrogen. (Hydrogen 2000, Inc, 29). • No emission of green-house gases: Hydrogen on combustion burns cleanly, producing only water-vapor. Thus it is free from emission of gases producing green-house effect like carbon dioxide.

• No risk of environmental pollution: hydrogen combustion is not associated with production of gases with a potential of causing environmental pollution.• Hydrogen is an environmentally and economically sustainable source of energy: Sustainable form of energy was defined by World Conservation Strategy in 1980 as “ source of energy that meets the needs of the present without compromising the ability of future generations to meet their own needs” (qtd. in Hydrogen 2000, Inc, 11). According to Brian, sustainable source of energy implies that it is renewable, re-generatable and re-usable and does not cause damage to the environment (no water, air or land pollution). • Hydrogen can be produced anywhere, from electricity and

water. Since water is freely available, hydrogen based economy will also help in achieving financial independence.

Fuel cell A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, with water and heat as its by-products. Thus a fuel cell works just opposite to an electrolyzer (as shown in figure 3), in which electricity is passed through water to produce oxygen and hydrogen (Hydrogen 2000, Inc, 37). The best thing about fuel cells is that, they serve as a continuous source of electric power, as long as they are supplied with hydrogen.(Hydrogen 2000, Inc, 37).

Other advantages of fuel cell include: zero emission of CO2 and other pollutants, high efficiency and reliability, flexibility, durability, sand ease of maintenance. Also, since fuel cells operate silently, they reduce noise pollution. Fuel cells are being considered for a numerous applications like use in vehicles, generation of electric power, defense systems, space systems etc (Hydrogen 2000, Inc, 37). There are different types of fuel cells depending on the electrolyte they use. For e. g.

an alkaline fuel cell uses potassium hydroxide as the electrolyte, whereas a PEM (proton energy membrane) fuel cell uses a solid polymer membrane as an electrolyte. Hydrogen PEM fuel cells consists of two electrodes separated by a proton exchange membrane. Hydrogen and oxygen are fed to the fuel cell on opposite sides of the membrane, resulting in production of electricity and pure water (Hydrogen 2000, Inc, 37). Different types of fuel cells are used for different applications.

Uses of Hydrogen fuel cells National Aeronautics and Space Administration (NASA), was the first to use fuel cells as a dependable source of electric power on manned as well as unmanned missions in space. NASA uses about nine thousand tons of hydrogen annually for its various space programs (Hydrogen 2000, Inc, 33). Hydrogen cells are increasingly being used in transportation, power generation and as portable power systems. Transportation The PEM (proton energy membrane) fuel cell is the technology which would be most commonly used by transportation sector. The characteristics which make PEM fuel cells suitable for use in transportation sector are: their capability to operate at low temperatures (80 ? C or lower) thus enabling them to start quickly even at normal temperatures and their capability of adjusting their output according to changing power demands. The fuel cell vehicles are expected to have high energy efficiencies of about 40 to 45 percent.

Gasoline run -internal combustion engine, on the other hand, has energy efficiency of only about16 percent. Besides significant improvement in energy efficiency and giving higher mileage, fuel cell vehicles will significantly help in significantly reducing the emission of green house gases. (Hydrogen 2000, Inc, 38). Power generation PEM cells are also being developed for power generation (Hydrogen 2000, Inc, 38). The main reasons behind the use of hydrogen based fuel cells for generation of electricity is their reliability, high efficiency, long lifetime and low emissions (Hydrogen 2000, Inc, 38).

Portable Power Systems Fuel cells are being developed for small portable electronic devices such as cellular phones, laptop computers, video cameras,

personal digital assistants (PDAs) etc. Fuel cells are also being developed to power telecommunications relay towers, buildings, highway signals and lights, wastewater treatment plants etc. In these applications, fuel cells will compete with lithium ion or nickel metal hydride batteries. The main advantage of fuel cells over these batteries is that fuel cells have a very short re-charging time in contrast to the long charging times of conventional batteries. (Hydrogen 2000, Inc, 38-39).

. Challenges that are encountered by using hydrogen as an energy source Production of hydrogen gas The major challenge in the way of switching to hydrogen economy is the production of hydrogen gas. Though hydrogen is an abundant element present on the surface of earth, being very reactive in nature, most of the hydrogen present on the surface of earth occurs in a bound form. Thus, in order to be used as a source of energy, large amounts of free hydrogen needs to be produced in an environment-friendly and cost-effective manner. For e. g.

If hydrogen is to take care of all the transportation needs in the US, the amount of hydrogen needed to be produced each year would be about 150 million tones (Turner, 972). The process of extracting free hydrogen from its bound form requires energy as well. The most important method of hydrogen production involves extraction of hydrogen gas from fossil fuels (petroleum, natural gas and coal). Reaction of a hydrocarbon compound with steam results in production of hydrogen, carbon dioxide and carbon monoxide (Turner, 972). Thus the process of hydrogen production would be associated with emission of carbon dioxide and would be dependent on use of non-renewable source of energy, fossil fuels.

Another method of production of hydrogen involves the process of electrolysis (as shown in figure 3) which splits water into oxygen and hydrogen. This method also needs a lot of electricity which would come from fossil fuels. At present, in US maximum amount of hydrogen i. e. about eight million tons (which forms about 48% of the total hydrogen production) is generated from natural gas.

This is followed by oil (30%), coal (18%) and water (4%). (Turner, 972). A lot of research is still needed before the scientists can discover a method of producing hydrogen gas which would not be associated with emission of environment polluting gases or use fossil fuels. Attention is now being focused on utilizing renewable sources of energy (wind, solar energy etc) to produce electricity which could be utilized for electrolysis of water, thus liberating hydrogen without the polluting the environment or using non-renewable sources of energy like fossil fuels.

To deal with the problem of carbon dioxide emission during the manufacture of hydrogen, scientists have come up with many solutions like carbon capture or carbon sequestration which aims at reducing the amount of carbon dioxide as it comes out during the process of hydrogen production. Pacala & Socolow (970), have described the geosequesteration of CO2, in which waste carbon-dioxide is injected directly into under-ground geological reservoirs. Research is also taking place to see if CO2 can be liquefied or turned into solid and then stored underground through some mechanisms so that it does not leak and cause harm to the inhabitants of that area. (Pacala & Socolow, 970). Scientists are also trying to utilize the hydrogen producing capability of green algae for commercial production of hydrogen.

(Melis & Happe, 740). Once the technology for hydrogen production becomes refined and inexpensive, hydrogen engines and fuel-cells will power farms, vehicles, homes, and factories. Figure 3. Production of hydrogen through process of electrolysis Source: Hydrogen 2000, Inc. ” Technical Reference Guide: Renewable power”.

2000. Accessed 4 May 2007 < http://www. hydrogen2000. com/rp_guide.

pdf > Storage, transportation and distribution of hydrogen There is a requirement for an efficacious, sustainable and cost-effective system for storing and distributing large amounts of hydrogen. Hydrogen is a bulky gas, which needs to be compressed before being transported. Compressing the gas requires energy. Also, if only moderately compressed, hydrogen would contain far less energy as compared to the same volume of gasoline (Hydrogen 2000, Inc, 39). With increasing advancements in technology, new solutions to the hydrogen storage problem are emerging. For example, technology is now being developed to store hydrogen in a solid form, as chemicals like sodium borohydride (Hydrogen 2000, Inc, 389).

It might be difficult to transport hydrogen through pipelines. As a result more trucks would be required to carry hydrogen to fueling stations, further increasing the cost and carbon dioxide emission from the vehicles. Thus CO2 emission would also take place during manufacture, transport and distribution of hydrogen. According to Moore, the use of hydrogen would result in a net increase in emission of CO2, rather than decreasing it. Moore also feels that after considering the amount of CO2 released during the manufacture, transport and distribution of hydrogen, there would be little

difference in net emission of green house gases by hydrogen run vehicles in comparison to gasoline run vehicles.

High cost of fuel cells According to Day, production of the fuel cells would incur high costs. This is so as for hydrogen production, energy would be required. Also the gas needs to be compressed before it can be used in a fuel cell or internal combustion engine. Brian however argues against this issue by saying that as soon as the developmental phase of fuel cells would get over and actual mass production of fuel would begin, they would become affordable.

Also hydrogen based cars would be much more efficient than the gasoline based ones thereby giving better cost per mile.. Concerns regarding safety of hydrogen Recently there have been concerns regarding safety of hydrogen gas as a source of energy since hydrogen is a flammable gas. However recent research has shown that, while hydrogen gas can be more easily ignited in comparison to fossil fuels, it also has properties that reduce the hazard of fire or explosion (Hydrogen 2000, Inc, 32, 34).

Conclusion The vision of using energy from electricity for electrolysis in order to generate hydrogen from water and using it as a method of energy storage, at the same time reducing the emission of gases like CO2, does appear as a lucrative option, but at present largely remains unexplored and under-developed. Despite the challenges and problems associated with the use of hydrogen as an energy carrier, it does offer a ray of hope towards achieving a pollution free environment and solving the problem of global warming associated with emission of green house gases like CO2. A lot of

research and dedication is still required in order to achieve this goal . To support this, Day gives example of the country of Iceland, which is the first country in the world to commit towards development of a hydrogen-based economy through intense dedication and research over last three decades.

Production of fuel cells and other techniques utilizing hydrogen as main source of energy would also become more affordable with increasing amount of research in the field. With increasing development in the field of science and technology, it is expected that in future, fuel cells will assume an important role in meeting the world's growing demands for energy. Works cited Agarwal, Rakesh et al. " Sustainable fuel for the transportation sector". Proceedings of the National Academy of the USA, 104, 12(2007): 4828-4833.

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