Use of Hydrogen as a Fuel

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Abstract— A fuel is any material that can be made to react with other substances so that it releases energy as heat energy or to be used for work. It is solely applied on those materials who can be transferred to an energy source by changing their chemical properties. Material such as coal, gas, or oil that is burned to produce heat or power. The heat energy produced by combustion/burn is used to do mechanical works with the help of various mechanisms and machines (i.e. heat pumps, heat engines). Combustion exerts highly toxic pollutants (i.e. NOx, CO2). Hydrogen and fuel cells are not synonymous; they can be deployed in combination or separately. Fuel cells can operate on natural gas, which avoids combustion and thus 90% of airborne pollutants. Hydrogen can be burnt in engines and boilers with no direct CO2 and near-zero NOX emissions. When used together, hydrogen fuel cells are zero-emission at the point of use, with overall emissions dependent on the fuel production method (as with electricity).

Keywords: Fuel cell, Hydrogen, Global warming, Electricity, Energy

I. INTRODUCTION

In this paper, we review the current technology for the storage of hydrogen on board a fuel cell-propelled vehicle. Having outlined the technical specifications necessary to match the performance of hydrocarbons. Considering increasing Energy demands and consequent high consumption of conventional fuels (i.e., petroleum, natural gas and coal), are being deplectrd rapidly. Also, their combustion products are causing global problems, such as the greenhouse effect, ozone layer depletion, acid rains and pollution, which are posing great danger for our environment. Now it is the time to use available Energy stored in hydrogen. It is available at any time and at any place on Earth. Hydrogen has fallen in and out of favour since the oil shocks of the 1970s, but remains a marginal energy system option. However, pure hydrogen is not a natural resource. It is stored in a compound with other molecules. For example, water consists of 66% hydrogen, hence the well-known symbol H2O. The hydrogen molecules can be extracted using an electrolysis process to produce electrical energy. And the beauty of it is that the only by product of this process is water, making it truly clean technology. Hydrogen can be stored and used as renewable energy for seconds, minutes, weeks or months as a 100% green energy supply. Stored hydrogen can also be used to run heavy duty mobility and everyday fuel cell vehicles. By recombining hydrogen and oxygen, a flow of electrons is created that results in electricity that can be used to run electric engines. Hydrogen can play a major role alongside electricity in the low-carbon economy. Electricity is being decarbonised rapidly and has the ability to cross over into heat and transport. Hydrogen possesses this same versatility and enables routes to deeper decarbonisation through providing low carbon flexibility and storage.

A. History

1) In 1671, Robert Boyle discovered and described the reaction between iron filings and dilute acids, which results in the production of hydrogen gas.(1)
2) In 1766, Henry Cavendish was the first to recognize hydrogen gas as a discrete substance, by naming the gas from a metal-acid reaction "inflammable air". He speculated that "inflammable air" was in fact identical to the hypothetical substance called "phlogiston".(2)
3) Hydrogen was liquefied for the first time by James Dewar in 1898 by using regenerative cooling and his invention, the vacuum flask. He produced solid hydrogen the next year.(3)

B. Why to use?

Since the conversion fuel to energy takes place via an electrochemical process, not by combustion. It is clean, quiet and highly efficient process i.e. two to three times efficient than fuel burning. It operate in fuel cells likely battery, but it does not run down nor does it require charging.

– Large hydrogen supply
– Its price per Kw is coming down
– Safer than petrochemicals
– No hazardous to environment

Costs have significant potential to fall with mass production and can achieve parity with electric alternatives by 2025–2030. Driving range and refuelling time are significantly better than premium electric vehicles, which is particularly advantageous for buses, heavy goods and other highly-utilised vehicles.

C. Hydrogen Production

Hydrogen can be produced from coal, natural gas, biomass or electricity, and transported by pipeline or by road to the point of consumption, or produced locally in a decentralised system. Hydrogen is mostly derived from fossil fuels at present, as these have the lowest costs(4). Steam reforming is an efficient process to produce hydrogen from gases and light oils, whereas coal, biomass and heavy oils must undergo gasification. Although both of these technologies currently have high CO_2 emissions, carbon capture and storage (CCS) can reduce emissions greatly, or even deliver negative CO_2 emissions when using biomethane and biomass feedstocks. Another source of hydrogen is via electrolysis. Numerous types of electrolysers have been developed commercially but all have high capital costs, which might reduce in future, and high fuel costs for electricity, which can be reduced through efficiency improvements or finding source of cheap electricity such as surplus renewables.

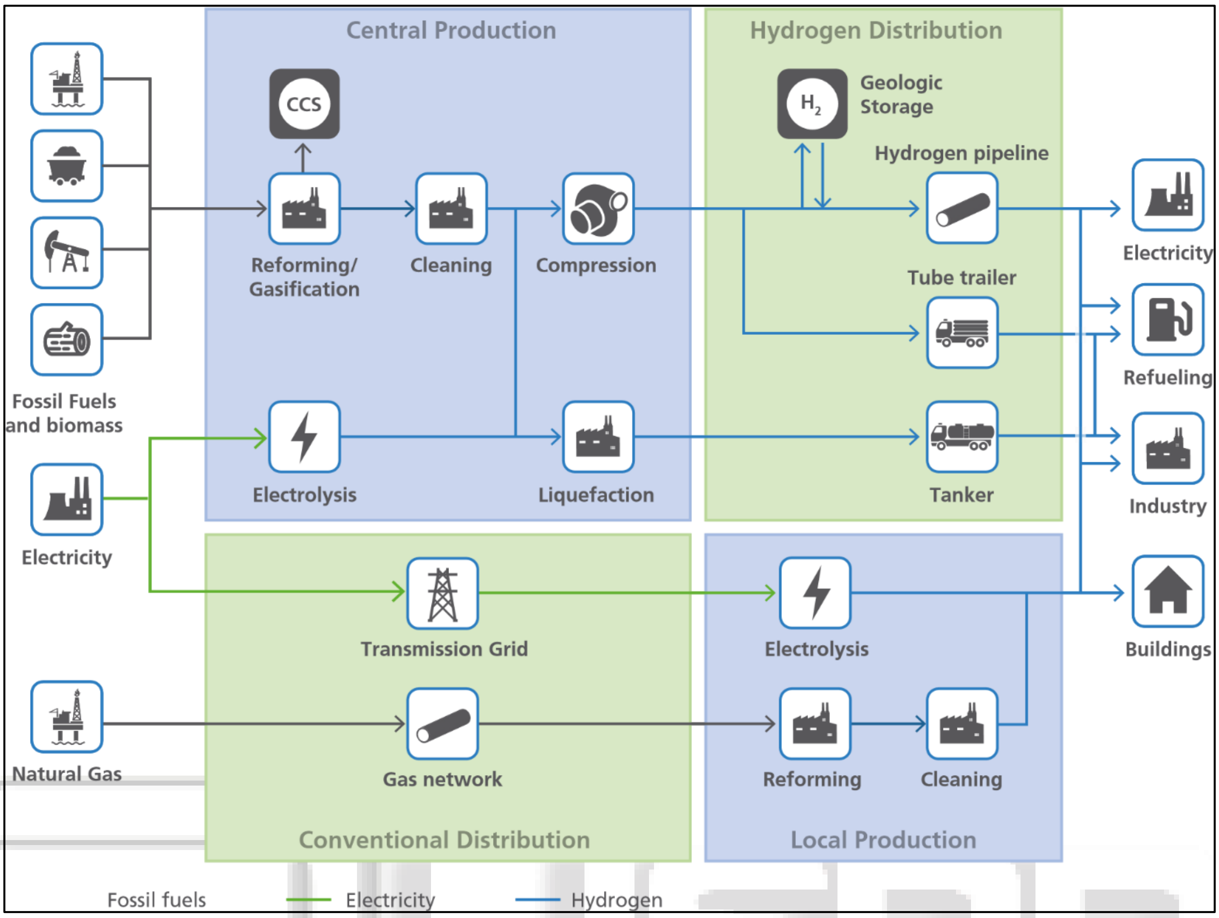

Fig. 1

Alkaline electrolysers are the principal commercial technology used to produce hydrogen via electrolysis at present. A direct voltage current is applied between an anode and a cathode submerged in an alkaline electrolyte. While alkaline capital costs tend to be lower than for other electrolysers technologies, plant output cannot be easily varied and overall costs are very sensitive to the price of electricity. Several novel hydrogen production technologies are at an early stage of development, including high-temperature steam electrolysis, solar thermo-chemical water splitting and biological hydrogen production.

D. Fuel cell production

A fuel cell is an electrochemical energy conversion device which converts chemical hydrogen and oxygen into water, and in the process it produces electricity.

$$_2H_2 + O_2 \rightarrow {}_2H_2O \ (+285 \text{ kl/mol})$$

Types of fuel cell-

- Proton exchange membrane fuel cell
- Phosphoric acid fuel cell
- Solid acid fuel cell
- Alkaline fuel cell
- High-temperature fuel cells
- Electric storage fuel cell

Widely Proton exchange membrane fuel cell is used. A proton exchange membrane fuel cell transforms the chemical energy liberated during the electrochemical reaction of hydrogen and oxygen to electrical energy, as opposed to the direct combustion of hydrogen and oxygen gases to produce thermal energy. A proton exchange membrane fuel cell transforms the chemical energy liberated during the electrochemical reaction of hydrogen and oxygen to electrical energy, as opposed to the direct combustion of hydrogen and oxygen gases to produce thermal energy.

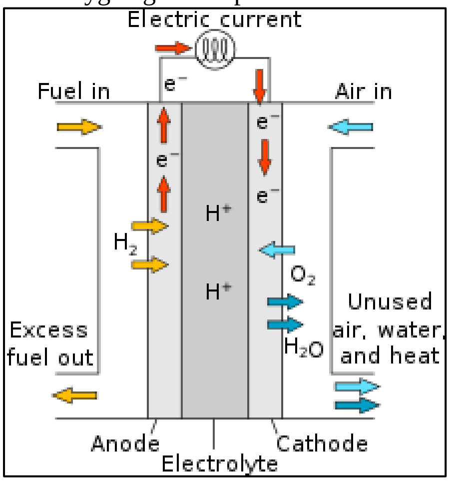

Fig. 2

To function, the membrane must conduct hydrogen ions (protons) but not electrons as this would in effect "short circuit" the fuel cell. The membrane must also not allow either gas to pass to the other side of the cell, a problem known as gas crossover (5). The PEMFC is a prime candidate for vehicle and other mobile applications of all sizes down to mobile phones, because of its compactness. The major application of PEM fuel cells focuses on transportation primarily because of their potential impact on the environment, e.g. the control of emission of the greenhouse gases (GHG). Other applications include distributed/stationary and portable power generation. Most major motor companies work solely on PEM fuel cells due to their high power density and excellent dynamic characteristics as compared with other types of fuel cells(6).

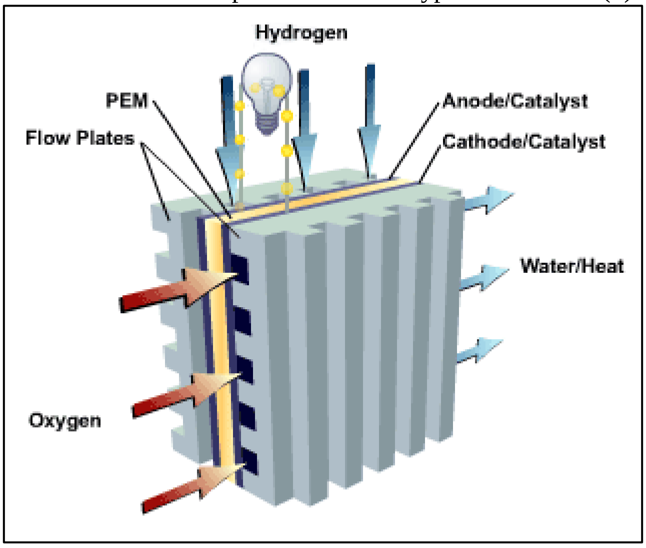

Fig. 3

E. Discussion

An alternative fuel must be technically feasible, economically viable, easily convert to another energy form when combusted, be safe to use, and be potentially harmless to the environment. Hydrogen is the most abundant element on earth. Although hydrogen does not exist freely in nature, it can be produced from a variety of sources such as steam reformation of natural gas, gasification of coal, and electrolysis of water. Hydrogen gas can used in traditional gasoline-powered internal combustion engines (ICE) with minimal conversions. However, vehicles with polymer electrolyte membrane (PEM) fuel cells provide a greater efficiency. Hydrogen gas combusts with oxygen to produce water vapor. Even the production of hydrogen gas can be emissions-free with the use of renewable energy sources.However, in fuel cell vehicles, such as the 2009 Honda FCX Clarity, 1 kg provides about 68 miles of travel (7). Of course the price range is currently very high. Ongoing research and implementation toward a hydrogen economy is required to make this fuel economically feasible. The current focus is directed toward hydrogen being a clean alternative fuel that produces insignificant greenhouse gas emissions. If hydrogen is the next transportation fuel, the primary energy source used to produce the vast amounts of hydrogen will not necessarily be a renewable, clean source. Carbon sequestration is referenced frequently as a means to eliminate CO2 emissions from the burning of coal, where the gases are captured and sequestered in gas wells or depleted oil wells. However, the availability of these sites is not widespread and the presence of CO2 may acidify groundwater. The possibility of a hydrogen economy that incorporates the use of hydrogen into every aspect of transportation requires much further research and development. The most economical and major source of hydrogen in the US is steam reformation of natural gas, a nonrenewable resource and a producer of greenhouse gases. The electrolysis of water is a potentially sustainable method of producing hydrogen, but only if renewable energy sources are used for the electricity. Furthermore, the infrastructure for a hydrogen economy will come with high capital costs. The transport of hydrogen through underground pipes seems to be the most economical when demand grows enough to require a large centralized facility.

F. Future Scope

In the future, hydrogen will join electricity as an important energy carrier, since it can be made safely from renewable energy sources and is virtually non-polluting. It will also be used as a fuel for 'zero-emissions' vehicles, to heat homes and offices, to produce electricity, and to fuel aircraft. Hydrogen has great potential as a way to reduce reliance on imported energy sources such as oil. But, before hydrogen can play a bigger energy role and become a widely used alternative to gasoline, many new facilities and systems must be built.

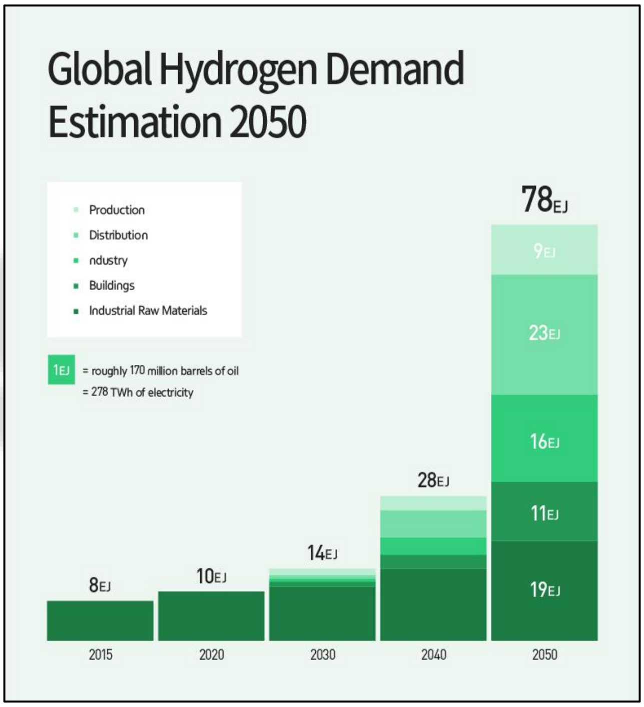

Fig. 4: Global Hydrogen Demand (8).

It can be widely use in transportation, stationary power stations, telecommunications, micro power.

G. Properties

- Hydrogen is odourless, colourless gas.
- It is lightest element that its density is 14 times less than air.
- Hydrogen is liquid at temperature below 20.3k.
- Hydrogen has highest energy content per unit mass of all fuels.
- Its heating value is three time more than gasoline i.e. 141.9MJ/Kg.

H. Advantages

- Renewable in Nature.
- Clean fuel due to low emission of NOx & CO_2.
- High purity level available.

- Requires low ignition energy.
- Environment friendly.

I. *Applications*

- Vehicles, buses, forklifts.
- Aeroplanes, boats, submarines.
- Portable power systems.
- Electricity- Hydrogen technologies can support low-carbon electricity systems dominated by intermittent renewables and/or electric heating demand.
- Heat- Hydrogen technologies can support low-carbon electricity systems dominated by intermittent renewables and/or electric heating demand.

II. Conclusion

Pure hydrogen, like electricity, does not occur naturally and must be produced and then transported to its point of use. Compared to some fuels, hydrogen is relatively difficult to handle and the costs of installing and operating hydrogen distribution infrastructure need careful consideration. In the longer term hydrogen pipelines are the most cost-effective means for distributing large quantities of hydrogen, and can also enable the use of hydrogen for heat, industry and power sectors. Hydrogen storage is still a major research problem. While progress has been made, current systems are inadequate or marginal. Using Hydrogen can helps to diminish global warming.

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