Hydrogen Economy: A Carbon-Free Alternative to Liquefied Natural Gas (LNG)

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ABSTRACT:

Key terms used:

Climate Change, Hydrogen, Storage, Carbon free

We as a society are being more conscious about our environment and sustainability. Hence combating climate change is one of the key challenges of our times. One way of doing so is to switch from fossil fuels to non-carbon fuels like hydrogen(H_2). In this paper we assess the viability of hydrogen(H_2) as a replacement to LNG. The main hindrance to Hydrogen adoption is the cost of production. Many countries are incentivising Hydrogen(H_2) as it promises cleaner environment and sustainability.

1.INTRODUCTION

Climate change has become a key issue in our lives. In the past few years we have seen many consequences like rising sea levels, Rising temperatures, adverse climate patterns etc. It has become an utmost priority to counter climate change. Countries around the world have taken huge strides to combat climate change. One of the main reason for climate change is the release huge amounts Carbon Dioxide (CO_2) into atmosphere. A key way of reducing it is switching to less carbon containing fuels. The go to alternative is Natural gas. But this too has a problem as it only reduces not eliminates the release of Carbon Dioxide (CO_2). A more complete method is switching to non-carbon fuels. This is where hydrogen comes into picture. The bi-product of combustion of hydrogen is water, which is non-polluting. Hydrogen economy is a term used to cover the usage of hydrogen gas for heating, transportation, energy storage. It has gained a significant international attention in the past few years as countries try to reduce their carbon foot prints. Hydrogen is considered as a replacement of liquefied natural gas (LNG) because it does not release any green-house gases on combustion. In past hydrogen was not considered viable because of the cost of production and lack of technology for production. But as more and more countries are exploring ways to become carbon neutral; hydrogen is emerging as a strong contender. Countries like Japan, Germany and France have heavily invested in hydrogen infrastructure. In this paper we will discuss how hydrogen can be used to replace natural gas as a fuel in terms of usage, production, Transportation and storage and handling.

1.1 ABOUT HYDROGEN

Hydrogen is the most abundant element in the universe. Roughly 75% of matter in the universe is hydrogen. On Earth Hydrogen is mostly present as water. It has a boiling point of 20.271 K (–252.879 °C) and calorific value of about 120 MJ/Kg. Natural gas which consists mostly of methane has a boiling point of 90.694 K (–161.5 °C) and calorific value of about 50 MJ/Kg. Today hydrogen is mainly used in fertilizer industry for production of ammonia, in petroleum industry for cracking.

2.PRODUCTION

Today vast majority of hydrogen is produced through steam reforming. But this is not a solution as it produces carbon dioxide and carbon monoxide as by products. The mainstream methods of producing carbon neutral hydrogen is via electrolysis and methane pyrolysis. In electrolysis, high energy electric current is passed through water via electrodes to convert water into oxygen (O_2) and hydrogen (H_2). The main hindrance for large scale adoption of this method is the high energy requirement and the subsequent cost. This is where the concept of “green hydrogen” comes into picture. In green hydrogen we use electricity generated from renewable sources like solar panels, wind farms etc. This helps solve one of the most crucial problem of renewable energy; intermittent production and storage. By converting electricity from renewables into hydrogen we can store it for future use. Many new techniques like high pressure electrolysis and high temperature electrolysis are being developed to bring down the cost of production of hydrogen. A recent development of carbon-free and economical production of hydrogen is methane pyrolysis. Here methane is directly converted into free carbon and hydrogen. The carbon can be sent to landfills or used for other applications. One advantage of this method is we can use existing naturals gas wells for production of hydrogen.

3.TRANSPORTATION

For transportation we will be looking into bulk solutions only. Currently hydrogen can be transported in bulk using pipelines and hydrogen tankers. A major advantage of hydrogen is that current pipeline network used for natural gas transportation can be used with little modification for hydrogen. As for the hydrogen tankers the technology already exists. LNG is a cryogenic liquid and the LNG spheres on board a LNG tanker are designed for cryogenic temperatures. The same technology can be used for hydrogen tankers. One alternate method is to transport hydrogen in form of ammonia (NH_3). This is being discussed because ammonia has

a higher boiling point than hydrogen (H_2) which can bring down transportation cost. Ammonia can be converted into nitrogen (N_2) and hydrogen (H_2) in presence of a catalyst.

4.STORAGE AND HANDLING

4.1 STORAGE

At present large scale storage of hydrogen is in pure molecular form. It is achieved either by storing in highly pressurised vessels or by storing liquefied hydrogen in cryogenic storage tanks (similar to LNG storage tanks). Storage of compressed hydrogen is done by compressing hydrogen (H_2) to 350-700 bar. This is not a common method of storage because of the high costs involved. The most prevalent storage method for hydrogen is in liquid form. Hydrogen is liquefied by bringing its temperature to –253 °C. This eliminates the need for high pressure vessels. This technology of cryogenic storage is already being used for LNG storage. Double walled vessels are used for maximum insulation. Spherical shape is chosen for its least surface area; reducing heat transfer with the environment. Similar to LNG storage boil off gas is vented to maintain the pressure (and temperature) inside the vessel. One potential new method is storing hydrogen (H_2) in form of ammonia (NH_3). This is also viable solution as it is being done in fertilizer industries around the world. Similarly, Methanol and Formic acid are also being considered. New techniques of hydrogen storage are being developed around the world like: storing hydrogen (H_2) in form of metal hydrides or by adsorption on metal surfaces.

4.2 HANDLING & SAFETY

Since liquefied hydrogen storage is the most prevalent storage, we will be discussing the safety aspects of the same. Hydrogen is colourless, odourless, tasteless, flammable gas. It has a wide flammability range of 4% to 74.2% by volume. It has a low ignition energy requirement. All these necessitate the instalment of hydrogen gas detectors around the storage facilities to detect the presence of hydrogen gas in the vicinity of storage. Hydrogen flame is non luminous and can be nearly invisible in bright conditions. This necessitates hydrogen flame detectors. Since we are dealing with cryogenic storage it comes with its own challenges. But the solutions for these problems already exist because of familiarity with LNG storage which is also cryogenic.

5.COST OF PRODUCTION

The cost of production of hydrogen via electrolysis is around $5-$6 per Kg of Hydrogen. This converts to around $0.042 per MJ. For LNG cost is around $4 per MMBtu. This converts to around $0.00379 per MJ.

6.RESULT:

We have looked into hydrogen as a replacement for LNG. The main hindrance is the cost of production of hydrogen (H_2). This could be overcome in the coming decades as new and improved methods of production are being developed. Many Governments are also subsiding hydrogen (H_2) production industries in various forms due to prospect of Carbon free economy. Transportation and Storage for hydrogen can be done with the present technologies available for LNG. Hydrogen(H_2) will also make renewables like solar and wind more attractive as we would be able to store the surplus in the form of hydrogen(H_2).

7.CONCLUSION

We have looked into hydrogen (H_2) as a carbon free replacement for liquefied natural gas (LNG). Today it is not price competitive with LNG. But as more and more countries strive to become carbon free economy hydrogen becomes a clear option. The main cost of hydrogen lies in the production of hydrogen which will come down in the coming years as technology progresses and many countries around the world incentivise hydrogen(H_2). It would complement other renewable forms of energy like solar and wind because it helps us store the surplus energy created during off-peak time. In the coming decades we would see a slow but sure transition to hydrogen as it promises a much less polluted environment and help us meet our climate targets in the long run.

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