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Industrial and Clean Energy Hydrogen : An Overview

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ABSTRACT

Global warming has several adverse impacts on climate and if not contained, may result in rising of sea level to a dangerous point when millions will be required to be displaced and rehabilitated. It is also responsible for climatic changes. Green house gases are the reason behind global warming. Carcon dioxide is main green house gas which is added due to continuing use of fossil fuels. To obtain carbon neutrality and Decarbonization, need of the hour is clean and carbon free source of energy. Hydrogen has emerged as a clean fuel as it does not contain carbon. But hydrogen does not occur in pure form in nature and eventually it has to be manufactured. Conventionally, it is manufactured from fossil fuels such as natural gas or coal and process is called steam reforming. This also requires source of energy. Use of fossil fuel results in green house gas. Hydrogen can also be produced by electrolysis of water and source of energy can be renewable energy like solar or wind energy. This obviates adding of greenhouse gas and is a clean process. There are several ways of producing hydrogen depending on raw input and source of energy, which quantify to what extent the produced hydrogen is green. Hydrogen offer variety of applications across many segments of industry. It is worthwhile to evaluate all manufacturing processes and applications of Hydrogen and its potential contribution in Decarbonization.

Keywords: *Hydrogen energy; Steam reforming; Hydrogen generation by electolysis; Hydrogen based fuel cells.*

1.0 Introduction

Hydrogen is used as main input for manufacture of Methanol and Ammonia. Methanol is required reactant in production of wide variety of polymers and ammonia is used for manufacturing fertilizer, pesticudes, dyes and other chemicals as well as is used as refrigerant and water purifier. Hydrogen is also used as reducing agent in steel production processes such as Blast Furnace (BF) production process and Direct reduction iron (DRI) process. Large part of Hydrogen as industrial input, is mainly used in fertilizer manufacturing and refineries. Fertilizer plants use hydrogen to produce ammonia and refineries use hydrogen as sulphar removing agent from the finished products containing sulphur such as Gasoline, Diesel, Kerosene and Natural gas through process called Hydro-desulphurisation (HDS). It is natural that these plants have captive Hydrogen manufacturing plant. The most extensively used Hydrogen manufacturing process is steam reforming process of hydrocarbons(Methene) and heat requirement is obtained by burning of fossil fuels. Fossil fuels inevitably increase the global warming gas carbon dioxide in atmosphere and also many other pollutant gases. In order to minimise and contain emission of carbon dioxide, the foremost greenhouse gas, while manufacturing Industrial Hydrogen, first emphasis should be on using:

- Low carbon fuel as source of raw input and energy. Natural gas is preferred option compared to other options such as coal.
- Carbon capturing and storing (CCS) may be applied to capture carbon dioxide and store it in a sink such as an empty oil well or any other suitable storage. The hydrogen manufacturerd with this technology is popularly called Blue Hydrogen. CCS imposes some additional cost but imperatives of decorbonising is met.
- Finally Renewable energy source such as Solar or wind, may be used for energy requirements in manufacturing of the hydrogen. Instead of Steam Reforming, The Hydrogen may also be produced

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by Electrolysis of water, which requires more energy. But the Hydrogen produced by Electrolysis of water using Renewable energy is fully decorbonized and is popularly known as Green Hydrogen. The cost of Green hydrogen may be high enough for industrial hydrogen manufacturers to adopt the process as of now. Unlike conventional steam reforming process which is continuous, Electrolysis can be readily switched off and on and this facilitates accommodation of hybrid energy system which can use various sources of energy including renewable energies.

Availability of the required renewable energy within the fertilizer plants and refineries or in a nearby area may be a concern for many of them. But the other two options can be easily adopted by most of them with immediate effect and electrolysis process can be adopted with hybrid energy system instead purely depending on fossil fuels or renewable energy.

- There should be greater emphasis on industrial and societal reuse of carbon dioxide. Several research has been conducted in this direction. Carbon dioxide can be reduced to carbon monoxide, which can then be converted to many chemicals. Carbon can also be converted and stored as liquid fuels using renewable energy, thus enabling use of fuel such as gasoline without increasing green house gases.

2.0 Hydrogen as Clean Energy Source

When fossil fuels are burnt the final products inevitably consist of water and green house gases- oxides of carbon. There may be oxides of nitrogen and other obnoxious gases such as sulphar dioxide depending on impurities in fuel and unburnt hydrocarbons too. Thus burning of fossil fuel always results in addition of carbon dioxide in atmosphere. This requires that use of fossil fuels be minimised or reduced to nil in order to achieve higher degree of Decarboniization of the atmosphere.

Hydrogen has higher heat content than fossil fuels and is free of carbon. When hydrogen is used as fuel, the final product will not contain oxides of carbon. This is very positive aspect in decorbonising and reaching the goal of carbon neutrality. Carbon neutrality is obtained, when the carbon added to the atmosphere is nullified by removing the equal amount of carbon molecules from the atmosphere. But Hydrogen does not exist in free form naturally and has to be manufactured. Manufacturing of hydrogen requires input of lots of energy which results in green house gases normally. But if hydrogen is manufactured using renewable energy resources such as solar, wind, geothermal or biomass, it can be used as storage for renewable energy. This stored renewable energy in hydrogen can then be deployed and used as source of energy without increasing green house gases in atmosphere serving as a source of clean energy. Fuel cell electric vehicles are seen as viable clean and green transportation means and advantage of hydrogen is that it can be used as fuel in fuel cells. In fact hydrogen - oxygen based fuel cells are most popular fuel cells in transportation. One of the major constraint in renewable energy resources is it's storage. Hydrogen is one of the options to store renewable energy resources. Hydrogen is inflammable and it needs safety and care in its storage and transportation in order to establish a Hydrogen supply chain from manufacturing point to refueling stations, which is not available at present in the majority of society.

The use of hydrogen prima facie, appears in following areas:

- Energy
- Transportation
- Buildings and household
- Agriculture

2.1 Energy

Fossil fuels are used as fuel and non fuel (as Raw material) in manufacturing sector among industries in approximate ratio of 65% as fuel source and 35% as raw material. Requirement of manufacturing energy alone, in an industrialized society is estimated to be 75% of total industrial energy and among manufacturing sector, Chemical, petroleum & coal, primary metal, food and paper industry are dominant shareholders. As Fuel, it finds applications in:

- Heating required in industrial processes.
- As boiler fuel for generating process steam or hot water and.
- Fuel for generating electricity in boilers, gas turbines, generators etc.

Hydrogen is a clean substitute for fossil fuels in all these applications thereby resulting in

considerable reduction in carbon dioxide emissions. Hydrogen used as direct fuel in combustion results in only water and burnt gases does not contain carbon dioxide. However since nitrogen is available in air, possibilities are that it will contain nitrogen oxides (NOx). But NOx production can be controlled by controlling temperature and can also be captured. For heating up to 400 °C , focussing type solar collectors are most green options, but cost may be a factor. But if temperature requirement is above 400°C then solar collectors may not be feasible option. Hydrogen can be used as fuel in boilers to produce process steam and hot water. Hydrogen can be used in Thermal power plant steam generators to produce thermal electricity reducing considerably the green house gases as well as other gaseous pollutants and harmful suspended particles. It can be burnt in combustion chambers of gas turbines to generate energy instead of fossil fuels or can be mixed partly.

2.2 Transportation

Transport vehicles can be powered by hydrogen in two ways:

- Using hydrogen as fuel in internal combustion engines or gas turbines instead of carbon based fuels like Gasoline, Diesel etc.
- Using hydrogen based fuel cells as source of power in Fuel Cell Electric vehicles(FCEV).

Fuel cell can also be used as auxiliary power unit in vehicles. If hydrogen is directly burnt as fuel, exhaust tail end gases will not have carbon dioxide but may still have obnoxious Nitrogen Oxides (NOx). Fuel cell based vehicles are zero emission, since only output is water. Fuel cell have been designed for different and almost all size of transportation means from scooters to small trucks and for trains and aeroplanes. Hydrogen was fuel used in rockets and auxiliary power unit of spacecrafts are fuel cells. It was also thought to produce hydrogen in moving vehicles using Methanol by conventional reforming process to avoid transportation and refueling of hydrogen. But this requires high level of technical competence and more research is called for to achieve it.

Deployment of fuel cell or direct hydrogen fuel vehicles require a hydrogen supply chain, a network from hydrogen manufacturing point to hydrogen storage to finally hydrogen refueling stations.This involves transportation and storage of a highly inflammable gas, necessitating high degree of safety. In few part of advanced countries, it is already there in place and operational.

2.3 Buildings and households

In buildings and households, hydrogen can be used as fuel for space heating instead of fossil fuel as well as for electricity requirements. In addition in can be partly supplied in natural gas network of households resulting in less green house gas emissions.

2.4 Agriculture

Agriculture is heavily dependent on fossil fuel for its energy requirements of farming equipment. Farmers have space availability which can be used to generate solar and wind power. Solar and wind power are intermittently available and not stable source. Hydrogen can be used to store intermittent renewable solar and wind energy for farming energy requirements. Hydrogen powered fuel cell tractors are already made in few countries. Other sectors which also are energy intensive, are mining and construction.

3.0 Challenges, Alternatives and Further Developments

It can be easily concluded from the above note that our full focus should be, to produce Hydrogen as green as possible and use it in most efficient way to achieve maximum level of Decarbonization. Like hydrogen is being used to store renewable energy, technology can be developed to reduce carbon dioxide to either carbon mono-oxide or carbonic liquid fuels using renewable energy making it possible to recycle carbon. Ammonia can be alternative to hydrogen in setting up transport, storage and Refueling stations chain in some countries as its network is already available along distributed fertilizer plants. Ammonia though hazardous, is less inflammable compared to hydrogen and has higher calorific Value also.

A new research area is production of hydrogen by a biological process called Biophotolysis. Biophotolysis uses sunlight as source of energy. This process can be divided into two stages. In first stage Algae is cultivated in water using photosynthesis. Later stage is Bacterial decomposition of Algae to finally produce Hydrogen. Important observation in this research is, if Algae is

deprived of sulphur, normal photosynthesis does not take course and instead of oxygen, hydrogen is produced in light due to activation of an enzyme. If the process is successfully upgraded to a greater efficiency, energy requirements of hydrogen production will be obtained merely from sunlight.