THE PROSPECTS OF HYDROGEN AS FUEL SOURCE

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1 Abstract

in recent times, hydrogen is considered as alternate fuel source for the depleting fossil fuels. It has been claimed that hydrogen as fuel source has many advantages over fossil fuels, but there are critical factors to be considered before advocating this as a viable fuel source. The rush into a hydrogen economy is neither supported by energy efficiency arguments nor justified with respect to economy or ecology. In fact, it appears, as of now, that hydrogen will not play an important role in a sustainable energy economy because the synthetic energy carrier cannot be more efficient than the energy from which it is made. There is great anxiety for finding alternate energy source in place of the dwindling (?) fossil fuel sources. This anxiety has contributed to overlook the feasibility of electrons as the primary energy source.Certain myths regarding hydrogen as a fuel source have been raised and they have been refuted too. In this article, the various aspects of hydrogen as the alternate fuel source is examined from the various points of view, but however, it appears that hydrogen as the fuel source needs more careful consideration and evaluation.

Hydrogen fuel for transport application has to wait till the cost of the fuel cell technology becomes comparable to fossil fuels.Also the conversion efficiency of fuel cells (to electric power) should be comparable to that of conventional fuel sources.In this sense, hydrogen functions only as energy carrier.

2 Introduction

"I believe that water will one day be employed as fuel, that hydrogen and oxygen that constitute it used singly or together wil furnish an inexhaustible source of heat and light of an intensity of whcih coal is not capable .....water will be the coal of the future ....Jules Verne, Mysterious Island 1876.

Energy conversion is considered as the main component of life on this universe. Almost all activities in this universe are centered around energy conversion and fuel is the main input ingredient of this process. The selection of fuel was based on the availability not much on the energy output so far. There are obvious and claimed advantages in using hydrogen as the fuel source. They are:

- It can be produced from natural gas, nuclear power, biomass, and renewable sources like solar and wind.
- When consumed in a fuel cell, it produces only water.
- Hydrogen acts as a chemical energy carrier and can be piped or transported.
- It does not produce greenhouse gas emissions when burnt.
- It can be used in fuel cells for electricity generation and heat, as well as for storing renewable energy.

For some time now, we've been hearing that hydrogen is a non-polluting fuel for transport but what are the pros and cons of its production? And why is it being used so little? "It could constitute a breakthrough for the planet as the waste generated by its use to produce energy is water vapour, but

today more than 96% of hydrogen production still derives from non-renewable sources, effectively cancelling out its green properties". [1]

Hydrogen is a perfectly clean fuel, because the only waste it produces is water vapour. In its free state it consists of two atoms (H_2) which, when combined with oxygen (O) during its use (combustion or, more commonly, in a fuel cell), generate water (H_2O). Hydrocarbons, on the other hand, are made up of carbon and hydrogen and, during combustion, when combined with oxygen, produce carbon dioxide (CO_2) and other waste that is harmful to the environment and to human health (nitrogen and sulphur oxides).

Hydrogen can be obtained by several routes like thermal, thermo-chemical, photo-chemical, photo-electro-chemical, biochemical and so on. Each of these methods have certain limitations. However, the electrolysis of water is simple method in which a low voltage current flows through water to form oxygen and hydrogen gas. Hydrogen is considered as green because it is obtained through electrolysis of water powered by electricity produced from renewable sources. Grey hydrogen, on the other hand, uses fossil fuel sources, mainly natural gas, which produce greenhouse-gas emissions, thereby undermining its zero impact on the environment.

The hydrogen combustion engine uses technology which stands out for the absence of any harmful emissions. Its main use, however, is not in the combustion engine but in a fuel cell, developed for space exploration since the 1960s, whereby an electro-chemical process combines hydrogen and oxygen to generate electrical energy, which in turn powers an efficient electric engine.

The petrol engine uses only 20/25 % of the energy introduced and consequently 75/80% of the fuel is dispersed, producing heat. These figures are not very exact, but they indicate how inefficient the combustion engine powered by petrol or diesel is.

In the electric engine, the percentages are entirely reversed. 80% corresponds to the energy used and only 20% corresponds to the energy dispersed. However, hydrogen is not immediately and directly exploited within a car engine because it must first be converted into electrical energy to power the engine. "This passage consumes 50% of the energy and so this 80% is halved, reducing the amount of energy used to 40% which is, however, twice as much as that of a petrol engine. With the studies and experiments already under way, it is assumed that this percentage can be significantly increased, while that of the petrol/diesel engine can no longer be further optimized",

"It is anticipated that the cost of green hydrogen can become affordable in the coming years. But the hydrogen engine remains more efficient than a conventional petrol/diesel engine. Diesel offers a small financial advantage now over hydrogen, but the enormous environmental benefits would offset the higher cost. One thing is certain: hydrogen is less beneficial for light road transport compared to electric power from renewable sources. The environmental benefits are the same, but the cost of refuelling and the availability of a network for charging are better.

in spite of all these claims, grey hydrogen is still pollution free. since hydrogen is a gas, its handling gives rise to problems. In addition, the utility of hydrogen has to be evaluated in comparison with electricity and this analysis has shown that the derived hydrogen cannot be more advantages than electicity. [2]

Hydrogen energy it is often claimed, offers significant advantages(?) over traditional fuels. In terms of its clean nature, high energy efficiency, renewable potential, versatility, and capacity to drive technological innovation makes it a promising solution for reducing emissions and transitioning to a green energy future. By embracing hydrogen as a viable fuel source, one can accelerate the shift towards a more sustainable and environmentally friendly energy system. All these are the driving

force for turning to hydrogen as a fuel source but it is necessary that this claim has to be carefully examined and evaluated.

3 Methods of Producing Hydrogen

As stated, there are various methods available for producing hydrogen. A simplefied scheme is shown in Fig.1. For example there are a number of thermo-chemical cycles proposed and also

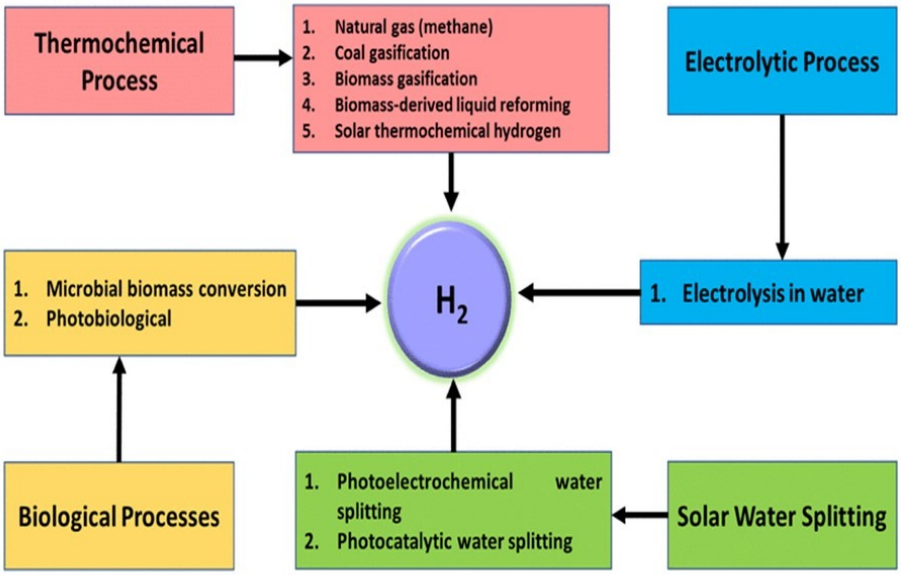

Figure 1: A simplified scheme for the production of Hydrogen

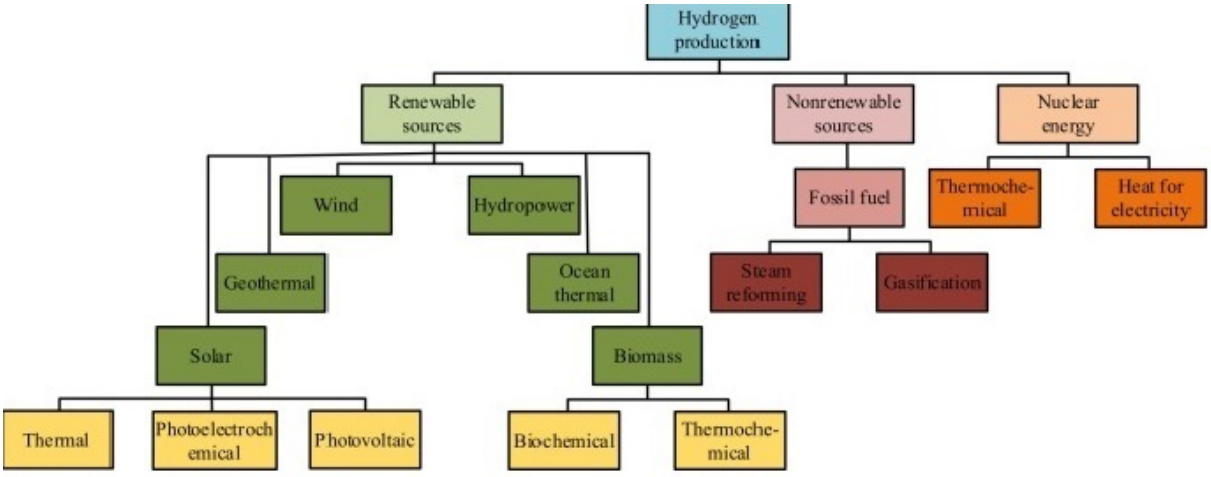

Figure 2: An expanded scheme for the various methods of production of Hydrogen

tested. Similarly, various biochemical routes have been tested. However, most of these methods are not cost effective, even the photo-e;ectrp-chemical method whcih was once thought to be an economic way for water splitting.Electrolytic production of hydrogen has also been under investigation in terms of choice of electrode materials and medium but however the cost effectiveness still eludes.

The following seven myths on hydrogen economy have been advocated. They are

- Hydrogen is too dangerous to ever be used on a large scale
- Hydrogen is a dirty fuel that is part of the problem, not the solution
- Hydrogen is inefficient and not economically viable
- Using hydrogen at scale will require a whole new energy infrastructure
- Tansporting hydrogen over huge distances is very expensive
- Transport can be fully electrified, so why do we need hydrogen?
- If hydrogen is so fantastic, we would have started to use it years ago

Dharmini Mistry on Oct 1, 2024 have wrutteb against some of these myths. He argues that the statement that hydrogen is unsafe due to its explosive nature, While hydrogen is highly flammable, so are many other fuels in common use today, like gasoline and natural gas. Advances in technology have made it possible to safely produce, store, and transport hydrogen. Rigorous safety standards and infrastructure, similar to those used for other fuels, are continuously being developed and refined to mitigate risks.

Ricardo Gorini Regarding the myth that Hydrogen is Too Expensive to Compete with Other Fuels,he argues that Hydrogen production costs are indeed high today, especially for green hydrogen. However, just as the cost of wind and solar power have fallen dramatically over the last 20 years, the cost of hydrogen is expected to fall significantly as technology improves, and economies of scale are realized. Ongoing developments in electrolyzer technology, such as solid oxide and proton exchange membrane (PEM) electrolysers, will help lower costs. Additionally, with increased government and industry collaboration, the hydrogen economy is expected to grow rapidly

regardubg the myth that Hydrogen is Inefficient Compared to Battery Electric Solutions his argument While it's true that hydrogen fuel cells may have lower life 'cycle energy efficiency compared to battery electric vehicles (BEVs), they offer distinct advantages in areas where BEVs struggle. These include heavy-duty applications, long-distance travel, and quick refueling. For sectors like long-haul transportation and industrial processes, hydrogen's advantages make it a more viable solution.

Ecen though there are many alternate ways of producing hydrogen from various sources like water, natural gas or biomass. one has to establish the efficiencies of each of these processes clearly not only from the point of view of cast of production but also the impact on environment, and the suitable one has to be established.

Hydrogen as the fuel for transport purposes has many challenges and barriers. Apart from the safety point of view, the fuel cell technology (a device used to convert fuel to electricity) has many barriers to cross. First issue is the conversion efficiency which it is claimed to be high today but still the conversion process has to have its own efficiency limitation.

The main points in favour of hydrogen are: Hydrogen is the most abundant element in the universe and it produces almost no pollution when burnt, making it a desirable source of power.
There are many ways to produce hydrogen, which determines whether it is defined as grey, blue,

green or pink hydrogen.
As we continue to innovate and improve hydrogen production methods and as the cost of renewable and nuclear energy continues to fall, the role of hydrogen in our energy systems is set to grow.

Tavke 1 Comparison of Hydrogen with other fuels

Parameter	Hydrogen	Natural gas	petrol Diesel	LPG
Calorific Value MJ/kg	120=142	49-54	41-44	36-40
Density at STP kg/cu.m	0.08	0.6 780	720	510
Phase at STP	gas	gas	liqid	liquid
Auto ignition temp in degrees	500-540	580	247-280	410-580
Diffusion coeff (sq.cm/sec)	0.61	0.16	0.05	0.11

Methods of Producing Hydrogen

- steam Methane Reforming
- Partial oxidation
- Auto Thermal Reforming
- Methanol Reforming
- Pyrolysis, Oxidation and Reduction of Biomass
- Electrolyis of water
- Fermentation of organic Materials
- Thermochemical Splitting of water

Hydrogen will play an increasingly important role in the push toward greater use of renewable energy and the reduction in carbon emissions from the transportation sector, electrical energy generation and transmission, and the production of commodity chemicals, such as ammonia and polyolefins.

Table 2. Summary of hydrogen safety related properties compared with other fuels

Property	comparsion wih other fuels	Risjs
Leak probablility	Higher than other fuels	Dangerous
Volume of fuel released in leak	Higher than other fuels	same as other fuels
Energy of fuel released in leak	Lower than other fuels	safe
Diffusivity and buoyancy	higher than other fuels	safe
Lower flammability in air	Higher than other fuels	same as other fuels
Minimum ignition energy	Lower than other fuels	same as other fuels
Ignition energy	same as other fuels	same as other fuels
Flame velocity	Higher than other fuels	Dangerous
Lower detonability air /fuel ratio	Higher than other fuels	safe
Explosive energy per energy stored	Lower thqn other fuels	safe
Flame visibility	Lower than other fuels	Dangerous
Flame emissivity	Lower than other fuels	safe
Flame fumes toxicity	Lower than other fuels	safe
Fuel toxicity	Lower than other fuels	safe

Table 3. Comparison properties of hydrogen and hydrocarbon fuels.

Property	Hydrogen	Methane	Propane	Ethanol	Methanol	gasoline
Chemical formula	H_2	CH_4	C_3H_8	C_2H_5OH	CH_3OH	C_8H_{18}
Molecular Weight	2.02	16.04	44.1	46.07	32.04	102
Molar carbon to hydrogen ratio	0.00	0.25	0.375	0.333	0.250	0.444
Stiometric air/fuel ratio mass	34.32	17.20	15.67	9.0	6.47	15.41
Latent heat of vapourization (kJ/kg)	446	509	449	921	1176	348
Lower heating value (MJ/kg)	119.91	40.02	46.40	16.86	19.93	44.50
Flammability limit (% by volume)	4.1-74	5.3=15	2.2-9.5	4.3-19	7.3-16	1.4-6.7
Self ignition temp (K)	855	813	755	696	747	530
Combustion speed in air(m/s)	2.933	0.355	0.432	0.455	0.455	0.356
Ocatane number	130+	120+	104	100	100	86-94

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There appears to be an anxiety to implement hydrogen as the alternate fuel source. Though it is expected to be so, one has to consider the following points before implementing such a transition in our energy source.

1. Hydrogen production requires energy (electricity or other sources) and hence one has to consider the net gain in energy source which can be considerably reduced ultimately.

2. The derived fuel source namely hydrogen cannot be better than the primary source which is employed to produce hydrogen.

3. The disadvanages of using hydrogen are given in table and it appears that hydrogen as a fuel is in noway better than the convntional fuel sources.

4. All alternative fuel options are accompanied by benefits and challenges. Prerequisites for introducing a new fuel include the availability of sufficient production and distribution facilities as well

as an adequate bunkering infrastructure. In addition, new fuels in many cases require extensive on-board modifications, which lead to increased complexity and cost

5.Environmental impact: If not produced using renewable sources, hydrogen can be polluting.
6. High cost: Producing hydrogen can be expensive.

7. Storage and transport challenges: Hydrogen is difficult to store and move.

8. Infrastructure limitations: There is limited infrastructure for using hydrogen.

9. High flammability: Hydrogen can be explosive.

In short a comparison of pros and cons of employing hydrogen as fuel source are summarized in Table

Table 4.Comparison Table on Pros and Cons of Hydrogen Fuel

Pros	cons
Clean power source	Not free in nature must be extracted
Abundant and inexhaustible form of energy	Extraction cost may be high
No Noise Pollution	Highly flammable in nature
More efficient than another source of energy	Regulatory issues must be considered
Versatile fuel can be used in various sectors	Storage and transportation can be an issue
Long-range	Maybe not eco-friendly

Around 15 years ago, pundits were focused on "peak oil" — the idea that the world was running out of oil, or at least inexpensive oil, and that a reckoning was coming. Events of the past decade have proven that theory wrong. Instead of declining oil production and rising prices, we've seen the opposite, nowhere more than here in the United States. These statements and situation clearly show that the fear that oil reserves are dwindling is not true and petroleum technology will be in practice for some time now.

Hydrogen is categorized by colour tabs, based on its source. We can divide it into 'grey' hydrogen (produced from fossil fuels), 'blue' hydrogen (produced from fossil fuels with carbon capture and storage) or 'green' hydrogen (produced from renewable electricity).

Advantages of Hydrogen fuel:

- Readily Available: It is a basic earth element and is available in abundance.
- Doesn't Produce Harmful Emissions: When it burns, it doesn't emit harmful substances. The only by-product or emission from the usage of hydrogen fuel is water. It makes this fuel 100% clean.
- Environmentally Friendly: It is a non-toxic substance which is rare for a fuel source.
- Fuel-Efficient: Compared to diesel or gas, it is much more fuel-efficient as it can produce more energy per pound of fuel.

Disadvantages of Hydrogen Fuel:

- Expensive: Although it is widely available, it is time-consuming to separate hydrogen gas from its companion substances.
- Difficult to Store:

- Hydrogen is very difficult to store. Its transportation even in a small amount is very expensive.
- Not Easy to Replace Existing Infrastructure: There is not much infrastructure that can support hydrogen as fuel. Also, cars need to be refitted in order to accommodate hydrogen as fuel.]
- Highly Inflammable: Since it is a very powerful source of fuel, hydrogen can be very flammable. Hydrogen gas burns in air at very wide concentrations – between 4% and 75%.

Comparison of technologies for the production of hydrogen is given in Table

Table The cost and other parameters are given

Proces	energy required kWh/Nm^3	Status of technology	Efficency(%)	cost relative to SMR
steam Methane reforming(SMR)	2.25	mature	70=80	1
Coal gasification	8.6	Mature	60	1.4-2.6
Electrolysis	3.54	Mature	27	3-10
Biomass gasification	-	R and D	45-50	2 - 2.4
Photoelectrochemical water splitting	-	R and D	-	-
Photocatalytic	-	R and D	-	-
Photobiological	-	R and D	less than 1	
thermochemical cycles		R and D	35-40	6

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