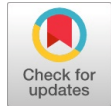


Green Hydrogen Production as a Sustainable Initiative for Alternative Energy Source: A Review

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Abstract: As global population increases with time, thus the global energy need also increases. It is important to switch over to a more environmentally friendly energy source. Due to heavy consumption of fossil fuel, global warming reaches to its new level. Now it is essential to investigate to new alternative energy sources. This study aims at hydrogen fuel to be used as an energy alternative. There are various hydrogen production processes which are classified on how friendly they are to the environment. In this paper an attempt has been made to study & review the best hydrogen fuel production method among various processes. Also, we have discussed a green initiative towards innovative and sustainable development in energy consumption. As per our conclusion, green hydrogen production is the best method. Where in green hydrogen production method electrolysis of water is carried out with help of renewable energy such as solar energy, wind energy etc.

Keywords: Hydrogen Fuel, Green Fuel, Electrolysis, Sustainable Fuel, Renewable Energy

I. INTRODUCTION

Energy has been one major requirement of the Humanity from the beginning of time & to full fill it's needs mankind has been using fossil fuel from the last two centuries. As fossil fuels are limited in the world, they are scarce and could extinct soon as well their consumption leads to environmental pollution by the transmission of Greenhouse Gases. To solve the problem of energy crises, the Renewable Energy Sources acts as a better alternative and "Hydrogen" can be said as best resource because of its Efficient Production Process & Low Cost[3]. It can be Produced by the Process of electrolysis of water & powered by solar energy.

1.1 What Is Hydrogen?

Hydrogen is comparatively an clean alternative to natural gas. It's the most abundant chemical element on the planet and it is estimated to contribute 75% of the mass of the universe.

Here on earth, vast number of hydrogen atoms are contained in water, plants, animals and, of course, humans. But while it's presence in nearly all molecules in living things, it's very scarce as a gas – less than one part per million by volume. Hydrogen can be produced from a variety of resources, such as natural gas, nuclear power, biogas and renewable power like solar and wind. The major challenge is harnessing hydrogen gas on a large scale to fuel our homes and businesses energy requirement range. Hydrogen is a better source comparatively to Traditional Fossil Fuel. The technologies which are used alongside these natural energies are solar power, wind power, hydroelectricity, biomass and biofuels[7],[8] for the transmission & transportation purposes. Natural energy can help to reduce the world's petroleum consumption. Hydrogen production is a better renewable source as it doesn't produce hazardous byproducts. Hydrogen is a regenerating fuel source; it can be produced from water, intermediately stored and can finally be used in fuel cells to burn back to water. Solar energy can be said as the most abundant renewable energy resource available and hydrogen production from solar energy can be the ultimate solution for sustainable energy generation. It would be energy efficient with the advantage of storing hydrogen reversibly in solid state materials, e.g., metal hydrides, carbon nanotube, polymers etc. [4]

1.2 Why Is Hydrogen Important as A Future Clean Energy Source?

Methane is the main constituent of natural gas from oil and gas fields. We've continued to use natural gas cause it's a readily available resource and it's comparatively cost efficient, and its ca be said as a comparatively cleaner alternative to coal which is the worst fossil fuel. Major Energy dependency on Coal has led to the formations of Greenhouse[4],[5] gases & Global Warming. A fuel is a chemical which is 'burnt' to produce useful energy out of it. Burning is a process in which chemical bonds of an element of a fuel is broken and the elements chemically would combine with oxygen later. Burning of natural gas leads to the formation of heat energy but as byproduct greenhouse gases are formed as well. But in the Case of burning hydrogen fuel the only product formed is water vapors. [1],[6]

II. CLASSIFICATION OF HYDROGEN PRODUCTION PROCESS

Hydrogen can be produced by various methods & they are classified based on colors spectrum. They are mentioned below: -

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2.1 Blue Hydrogen:

In Production of blue hydrogen, the primary reactant used is natural gas and water (which at high temperature or heated water) which gives out steam as product, leading to the formation of hydrogen and used process of formation of hydrogen is known as steam reforming. This results in the formation of hydrogen but produces a by-product, carbon dioxide as well. Blue hydrogen is actually 'low-carbon hydrogen' as the steam reforming process still led to the creation of new volumes of greenhouse gases. Although carbon dioxide formed is been captured later. It can be used later in refrigeration and cooling industry or even can be converted to carbon powder to be used in fire extinguisher industry. [7],[8]

2.2 Grey Hydrogen:

The most widely used form of hydrogen production is Grey Hydrogen. In case of the formation of grey hydrogen, the reactants can be used either natural gas or methane and the process is called as steam methane reformation. Although this process should not be favored as the greenhouse gases form during the steam methane reformation process as cannot be captured during the formation of hydrogen and is therefore released in the atmosphere which is harmful for all living beings. [7],[8]

Black And Brown Hydrogen:

In Black Hydrogen production process, the reactants used is majorly black coal or in some cases lignite. This hydrogen can't be mentioned as the environmental friendly as it is a gasification process. During the Production of Hydrogen, carbonaceous or organic materials is been broken down into the greenhouse gases. Gasification takes place with specific amount of oxygen at temperature as high as more than 600 °C. Later, carbon dioxide is formed is as water reacts with carbon monoxide which also results in the production hydrogen. The Hydrogen formed in this process is in a large quantity than usual but still the process being harmful to the environment shouldn't be preferred. [7]

2.4 Pink Hydrogen:

The process used in production of pink hydrogen is electrolysis and the source of energy used is nuclear energy. The energy used is actually leverage waste energy from the heat produced in the nuclear reactor. This Process, results in high efficiencies of the production of hydrogen and comparatively low production cost. [7]

2.5 Turquoise Hydrogen:

Turquoise Hydrogen is an new formed hydrogen production process and so it not used on industrial level. In case of the production of turquoise hydrogen, methane of the natural solid carbon is produced as a byproduct with hydrogen as the primary product. This hydrogen production process can be mentioned as a low emission hydrogen production process as solid carbon is produced as a byproduct as well; this happens as pyrolysis is used in this process to avoid creation of carbon dioxide and create solid carbon. This of production of this hydrogen is known as Methane Pyrolysis. It cannot be considered to be the best hydrogen process. [7]

2.6 Yellow Hydrogen:

The Production process for yellow hydrogen can be said as a new age technology. In this Process, electrolysis is the main technology used in the production hydrogen and this process is powered by electricity. Still the cost of product is comparatively high in comparison with cost of fossil fuel. [7]

2.7 White Hydrogen:

White hydrogen is actually natural hydrogen. It is mainly found in underground cracking. Their production process is cracking which occurs in the underground. Although still there is no practical extraction process for this hydrogen from underground. [7]

2.8 Green Hydrogen:

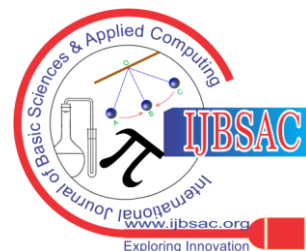
Green hydrogen can be said as the Clean Fuel which is formed without any harmful greenhouse gases. Green hydrogen is powered by using electricity which is produced from various renewable energy sources of the modern technologies. These technologies can be either be powered by wind power or solar energy. Later, these energy are been used to electrolyse the water; resulting in the production of Hydrogen. An electrochemical reaction has been carried out in an Electrolysers. Here in the Electrolysers, water has been broken down into hydrogen and oxygen. This has an extra advantage such as zero formation of carbon dioxide or greenhouse gases in the process. Green hydrogen production presently is very expensive & as well is not that efficient while working. [5], [7], [8]

III. WHY GREEN HYDROGEN SHOULD BE CHOOSE OVER CONVENTIONAL FUELS?

The main reason is fir every pound, hydrogen contains almost three times as much energy as fossil fuels, so less of it is needed to do any work. The other reason is, it is one of the most abundant chemical elements in nature, so no chance to perish. Some of the other reasons to use Hydrogen are, it is-100% sustainable, storable, versatile that can be transformed into electricity or synthetic gas. Green hydrogen if used on a large scale can help beat the target of net zero emissions in heavy industries and transportation. As the Paris Pact signed by India should cut off its carbon emissions by 50 % by 2030 to facilitate the global change, there can be no other option than the use of green h2 by replacing the conventional coal methods or the other fossil fuels for the power generation in steel, transport and chemical industry. [1]

3.1 Advantages Using of Green Hydrogen Fuel:

Green hydrogen has additional benefit, because this method uses electricity, it also offers the potential to divert any excess electricity which is hard to store & later to electrolysis, using it to create hydrogen gas which can be stored and later used as per needs. Hydrogen is an lightweight fuel option for all transportation Vehicles. The good news is that hydrogen can be transported through gas pipelines, minimizing disruption and reducing the amount of expensive infrastructure needed to build a new hydrogen transmission network.



There would also be no need for a culture change in our home lives, as people are used to using natural gas for cooking and heating, and hydrogen energy equivalents are emerging. [3]

Future Green Hydrogen Production Technologies:

Green Hydrogen is majorly produced from electrolysis process, other than that there are various new process which are under development. These technologies are going to change the present world and will be a part of Future Life. They are mentioned as follows: [8]

4.1 Methane Pyrolysis:

In Methane Pyrolysis, Hydrogen and carbon is produced from the thermal decomposition and plasma decomposition of natural gas. The carbon formed during this process, is stored in solid form and is later is used in the other various processes whereas the Hydrogen formed from this process is free from carbon dioxide emission and thus making this an unique green hydrogen process. In this Process, hydrogen and solid carbon is separated at high temperature.

Presently various Institutions are developing process to take methane pyrolysis to commercial scale and the plasma-based technology is proved to be low cost with zero greenhouse gases emission. But the major challenge for the methane pyrolysis is said to be as the various optimizing processes for hydrogen and solid carbon production. The removal of solid carbon from the molten media is as well a major hurdle for the methane pyrolysis process as per the researchers. [3], [7]

4.2 Solar Hydrogen Production:

In Solar Hydrogen Production process, the photolytic processes is used where light energy is used to separate water into hydrogen and oxygen. In these Processes, various researches are been taking place to find the most efficient method. These new technologies are; (i) Photocatalytic Water Splitting and (ii) Photoelectrochemical Water Splitting. These technologies being in their initial stage, are not initially viable yet cost wise. Still, they can be mentioned to be the most efficient process which as also have zero impact harmful impact on the environment. [5], [7]

4.2.1 Photoelectrochemical Water Splitting Process:

In the Photoelectrochemical process, hydrogen is produced from water. This process, photoelectrochemical material uses sunlight to directly dissociate water molecules. It's a promising technology for the future or the generation of green hydrogen. [7]

4.2.2 Photocatalytic Water Splitting:

Photocatalytic water Splitting is an artificial photosynthesis process where photocatalysis is used for the breakdown of water into oxygen and hydrogen. The Photocatalytic Water Splitting Process's research majorly focuses on building a high-performance photocatalyst. Researches on it, tries to create a photocatalysts with high light absorption properties along with high rate of energy transfer and suitable physical properties. This process would be market viable only after continues improvement in efficiency, durability and cost of both processes. The present main challenge for Solar Production Energy is it's Production efficiency which needs to improve along with improvement in the photocatalyst's effectivity and durability and that of electron transfer catalyst's as well. The Solar Hydrogen Production processes

also requires the development of multifunctional materials. These multifunctional materials should be available at a dirt-cheap price with a production worldwide at a mass scale. [7]

4.3 Biological Hydrogen Production:

In case of the Production of Biological hydrogen, hydrogen is produced with help of natural resource and organic matter. They are nothing but sunlight as the universal natural resource of light and organic matter can be mentioned as specialized microorganisms, such as green algae and cyanobacteria. In Natural Metabolic Process, microbes consumes water and produce hydrogen as a byproduct. This process is still at it's budding stage of development but it's estimated production capacity is around 1,500 kg/day in the long future. [7]

4.4 Biomass Gasification:

In Biomass Gasification Process, uses heat, steam and oxygen to convert biomass and form hydrogen & other products with any combustion process. It is a Process which is carried out at a temperature higher than 700°C. Here new growing biomass removes the carbon dioxide present in the atmosphere which later results in the low net carbon emissions in the environment, especially if combined with carbon capture in the future. The most common organic material used as a Biomass sources consists of forestry crops and residues, agricultural crops and residue, sewage, industrial waste, animal waste, and municipal solid residues. Gasification can be clarified as the environmentally beneficial process as the hydrogen is produced via gasification. Still this cannot be consider a viable process as the system has not provided yet the required results to prove it's efficiency along with that another major challenge is the cost of the reactor and the cost of carbon capturing mechanism which the process economically less viable. But, it can also be said as the cost of constructing Pipelines carrying pure hydrogen gas are technically feasible and have successfully worked in cities of US, Germany, the Netherlands, France and Belgium for decades. [2], [3], [7]

IV. RESULT

We Believe that with Research referred for the paper we say that Green Hydrogen can change the World Prospective in the Energy Generation but still there is a Long to Go. The Major Problem with Hydrogen is it's Storage which isn't Efficient Enough to meet the requirements of the Industrial Standards and it's Round Transfer Efficiency which is less than 37%. We can See New Emerging Technologies with Bright Future but are not Mature Enough. We Believe that by the End of this Decade; New Upcoming Technologies will Solve the Hydrogen Storage Problem and it's Round Transfer Efficiency.

V. CONCLUSION

This review paper aims at the in-depth study of using green hydrogen as an alternative to the conventional fossil fuels.



Green Hydrogen Production as a Sustainable Initiative for Alternative Energy Source: A Review

The topics covered in this paper gives a nutshell idea of the green hydrogen. The most copious element in the universe – hydrogen can be manufactured from various sources right from carbon to water. Efforts are being made to arise as a net carbon emitting manufacturer. The hydrogen is categorized based on the color spectrum of how it is manufactured and its impact on the environment. Ranging from blue, grey, yellow, white, and green, the green being the most prominent among all. Choosing Green Hydrogen over the traditional fossil fuels can be helpful because there are many advantages to it contains three times more energy than the conventional ones, cleaner, sustainable, versatile etc. On the other hand, if worked on certain drawbacks like making it cheaper, ease of its transportability etc. can help achieve the target of net zero emission.

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Authors Contributions	All authors have equal participation in this article.

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Omkar Naik is a Final Year Chemical Engineering Student, Presently Studying in Priyadarshini College of Engineering. This is his 3rd International Journal Paper. His last 2 Papers were on "Microbial Fuel Cell working with Hydrodynamic Cavitation". They were;

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2. Kunjan Junghare and **Shyam Kodape**, "Study of kinetics, isotherm and preparation of adsorbent for fluoride removal", Virtual International Conference on Chemical Sciences in Sustainable Technology and Development (IC 2 S 2 TD-2020) on 1st– 3rd December (2020).
3. Kunjan Junghare, **Shyam Kodape**, "Synthesis of adsorbent from aluminium tin trash for defluoridation: An electrolytic approach", paper presentation at Indian Institute of Technology Delhi, 72nd Annual session of Indian Institute of Chemical Engineers CHEMCON-2019, 15th -19th Dec 2019.

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