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# Hydrogen as an alternative fuel

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**Abstract:** This paper looks at an alternative source of energy to hydrocarbons. The goal is to produce energy using hydrogen fuel cells. Hydrogen can be produced by methods such as fermentation and natural gas reforming; it is also an abundant chemical species that could be used to produce more efficient and environmentally friendly energy. However, hydrogen energy fuel is harder to store, and although it is an abundant species, it could be expensive to extract pure hydrogen. Hydrogen fuel cells can be used as an alternative to produce electric cars, boats, electric motors, and possibly for home applications in the future.

## **I. Introduction**

Due to the increase in dependency in non-renewable energy resources, there has been studies and interest in using a cleaner and more eco-friendly approach to consuming energy. Although there is not yet a current shortage of conventional fuels, such as reserves of coal, oil, and natural gas, they provide hazardous gases that helps in polluting our world even further not only that but also helps in the expansion of the earth ozone layer that protects our earth from UV rays. Therefore, research is conducted to provide a sustainable environment for future generations.

One of the methods in obtaining clean energy is the utilization of hydrogen. Hydrogen is an abundant element on Earth and stands out from the rest of the renewable forms of energy. This is because for such a small element, it is highly flammable and aids in the production of water. These desired effects can be obtained in either forms of hydrogen, which are liquid and gaseous. One kilogram of hydrogen is able to produce energy equivalent to a gallon of gasoline.

Hydrogen is being used as fuel in increasing numbers of today's motor vehicles which are expanding locally and internationally, with the goal to reduce carbon dioxide emissions. The National Aeronautics and Space Agency (NASA) have been using hydrogen as fuel in their space shuttles since the 1950's. The market is also developing for buses, material handling equipment, ground support equipment, medium and heavy duty vehicles, and stationary applications [1]. All of these applications will emit zero waste, and only releases water vapor back into the atmosphere.

The paper will discuss how hydrogen is an excellent resource of energy without all the waste associated with conventional fuels. First the paper will discuss methods of producing hydrogen to be used in several application and how they can be stored. Moreover, a brief discussion on how stored hydrogen, also known as hydrogen fuel cells, is used to provide electricity to power vehicles. Finally, some points of the advantages and disadvantages of using hydrogen for energy will be mentioned.

## II. Methods of producing hydrogen

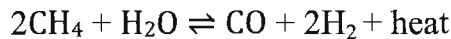
### 1. **Natural gas reforming:**

Synthesis gas (methane CH<sub>4</sub>), a mixture of hydrogen, carbon monoxide, and a small amount of carbon dioxide, is created by reacting natural gas with high-temperature steam and a pressure between 3 – 25 bars using a processing device called a reformer [2]. The process is endothermic and requires a catalyst in addition to the carbon dioxide reaction in order to successfully produce hydrogen.

This method is the cheapest, most efficient, and the most common way to extract hydrogen from hydrocarbons especially methane. The equation below shows the reaction that was mentioned to obtain hydrogen using the reforming method.

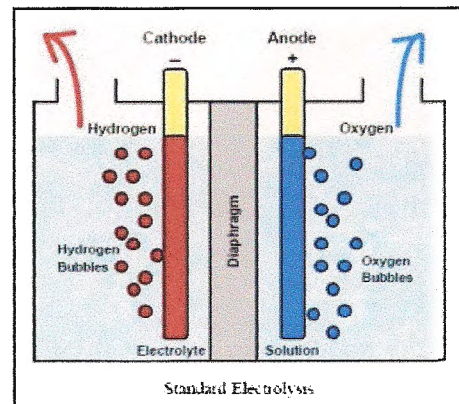


Another way to extract hydrogen is by using the partial oxidation method [2]. Hydrocarbons react with a small amount of oxygen in the process. This method is considered faster than the reforming method, however, it also yields a smaller amount of hydrogen for the same amount of fuel that is used. Therefore, it is further better to use the reforming method to produce hydrogen on a mass scale. The equation below shows the reaction that was mentioned to obtain hydrogen using the partial oxidation method.



### 2. **Electrolysis:**

Electrolysis can be simply explained as splitting or the decomposition of a water molecule into two hydrogens and one oxygen atom using an electrical current. As shown in Figure 1, two electrodes are inserted in a tank filled with water; a cathode that carries a negative charge in addition to an anode that carries the opposite charge. An electric current is then passed through the electrodes in order to start the decomposition. Since the hydrogen is positively charged in the water molecule, it will leave the apparatus in the side where the cathode is located.



**Figure 1:** Hydrogen production using electrolysis. [4]

Some of the other methods used in the splitting of the water are: High temperature electrolysis and a high pressure electrolysis. The former is the application of a high temperature to induce the atom separation [3]. This method is sometimes preferable because the reaction is more efficient and cheaper to produce in higher temperatures.

The latter however, is used by applying a high pressure ranging above a thousand psi.

Electrolysis is not considered renewable unless the electrical current produced is using a renewable source like solar power. However, hydrogen can be massed produced for a small amount of fuel, which in the long run can drastically reduce carbon emissions.

### **3. Gasification:**

Gasification is the process in which coal or biomass is reacted with high-temperature steam and oxygen in a pressurized reactor called a gasifier and converted into gaseous components [2]. The resulting synthesis gas contains hydrogen and carbon monoxide, which can be reacted with steam to produce more hydrogen.

Instead of burning coal, it is disintegrated into its basic form and inserted into a gasifier. Steam is then let through it, which as mentioned, reacts with the coal's chemicals to produce a clean way to convert coal to heat and electricity. Gasification can be seen to be the best way to produce hydrogen in order to be used in motor vehicles. It can also be used to power turbines and generate electricity.

Benefits of gasification is its flexible use, where it can use the waste from coals, in this case sulfur, and convert it to hydrogen sulfide. This compound can be used in the chemical industry to further create a better use for it. Moreover, waste emissions is very low compared to using natural gas, which is seen as the cleaner alternative to gasoline and coal.

### **4. Fermentation:**

Biomass is converted into sugar-rich feedstock that can be fermented to produce hydrogen. In other words, bacteria is used for the production of hydrogen. Since some strains of bacteria can thrive without light, it can be used to produce hydrogen all day and all night. An example of this is by using *Rhodobacter sphaeroides* SH2C to convert molecular fatty acids into hydrogen [5].

### III. Hydrogen fuel cells

A fuel cell is basically an energy conversion device that can efficiently capture and use the power of hydrogen. There are two main types of fuel cells; stationary and portable fuel cells.

Stationary fuel cells are used as a backup power source; provide power for remote locations and in distributed power generation. The latter is used to power personal vehicles, trucks, buses, marine vessels, and other specialty vehicles such as lift trucks and ground support equipment, as well as provide auxiliary power to traditional transportation technologies.

#### **How do hydrogen fuel cells function?**

As shown in Figure 2, a single fuel cell consists of electrolyte between two electrodes, an anode, and a cathode. Bipolar plated fuel cells directly convert the chemical energy in hydrogen to electricity, with pure water and potentially useful heat as the only by-products. Hydrogen-powered fuel cells are not only pollution-free, but also can have more than two times the efficiency of traditional combustion technologies.

In a Polymer Electrolyte Membrane (PEM) fuel cell, which is widely regarded as the most promising for light-duty transportation, hydrogen gas flows through channels to the anode, where a catalyst causes the hydrogen molecules to separate into protons and electrons.

The membrane allows only the protons to pass through it. While the protons are conducted through the membrane to the other side of the cell, the stream of negatively-charged electrons follows an external circuit to the cathode. This flow of electrons is outputs power in the form of heat and electricity that can be used to power the motors. The more cells that are stacked, the more energy the block can produce or be prolonged. Hydrogen fuel cells emit zero waste, where only water vapor is produced as the exhaust.

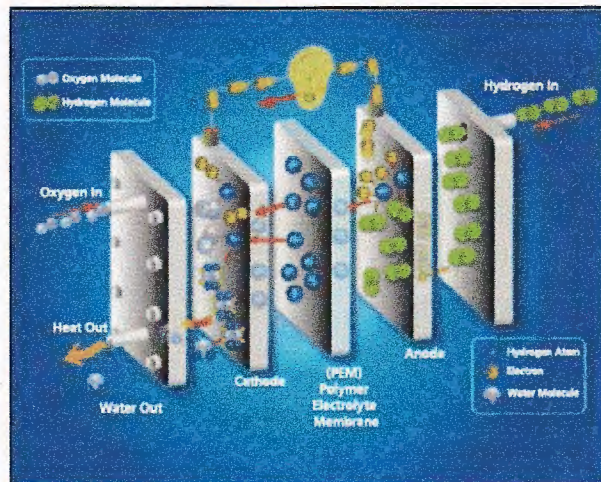


Figure 2: Hydrogen fuel function. [6]

#### **IV. Advantages of hydrogen as a fuel**

Hydrogen fuel cells play an important role in providing power and storing them. As stated earlier, fuel cells can function as a power backup storage for large and small scale power grids, moreover, fuel cells can provide electrical power for remote locations.

Besides stationary fuel cells, portable fuel cells play a significant role in the transportation industry. This is due to the fact that that hydrogen is zero emission fuel and its high efficiency; hydrogen fuel cells are two to three times more efficient than an internal combustion engine.

Other than its role in providing electrical power, hydrogen fuel is considered the best fuel when comparing to conventional fuels in terms of emission. Moreover, chemicals within the fuel cell, do not degrade overtime unlike batteries. This allows for a longer duration of use and the need to dispose is eliminated.

#### **V. Disadvantages of hydrogen as a fuel**

The disadvantage of hydrogen fuel lies in the methods of storing it. Hydrogen used to power fuel cells used in transportation needs more space to store than gasoline and diesel. This is due to the fact that hydrogen has low energy content by volume. Overcoming this challenge is important for light-duty vehicles because they often have limited size and weight capacity for fuel storage.

Another thing that is a disadvantage of using hydrogen is the cost of extracting it. Currently, although hydrogen can be mass produced, it can be costly to do so since it requires other forms of energy. Furthermore, when other energy sources are used to extract hydrogen, a small amount of waste still end up going to the environment.

## **VI. Conclusion**

In conclusion, although hydrogen fuel is considered the best alternative fuel to our daily used conventional fuels; such as coals and gasoline. However, the chemical properties of hydrogen can be a nuisance when implementing it in daily applications like motor vehicles for daily transportation needs.

Although there are companies like Toyota that are implementing hydrogen fuel cells in their future generation of vehicles, the process still needs further research to ensure sustainability and reliability to provide consumers with a reason to move away from fossil-fueled vehicles. Furthermore, California has started to provide hydrogen stations available for cars using hydrogen fuel cells to recharge, much like electric cars recharge stations.

If hydrogen, in combination with other renewable energies, are implemented into people's daily lives and are proved to be reliable; carbon emissions will reduce dramatically. This can result, in the repair of the ozone layer, cleaner air, and the well-being of our planet. All in all, a better place will be left for future generations.

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