Water: The Future's Fuel

By Carlos Benavente

Abstract

Fossil fuel burning vehicles contribute to atmospheric pollution and the continuous temperature increase that affects the entire planet. This occurs because of the accumulation of what are known as Green House Gases (GHGs), which are responsible for trapping the energy of the Sun here on Earth. Because the pool of GHGs is becoming denser due to the burning of fossil fuels, among other contributors, the amount of energy that is trapped consequently increases, resulting in an increase in planetary temperature (The Green House Effect). If the burning of fossil fuels is responsible for the increase of GHGs in the atmosphere, the logical thing to do is to find a substitute that does not produce GHGs. An obvious replacement is hydrogen (H_2), a clean burning gas with no GHGs as byproducts. The only thing hindering the transition to H_2 is its' method of production. In today's day and age, technology has finally reached a point where water (H_2O) can be used for the production of H_2, which makes it our fuel for the future.

Introduction

The majority of people highly depend on fossil fuels to get through their day. As it is already known, vehicles use gasoline as their fuel, which is strictly derived from petroleum. Although gasoline is a tough competitor in the selections of fuel, mainly because it's fairly easy to produce, as well as use, it has many environmental flaws that are now becoming relevant issues.

The problem with using fossil fuels, specifically, petroleum, is that one of the byproducts is Carbon Dioxide (CO_2), a Green House Gas (GHG). Now, this is a problem because the increasing levels of this gas are partly responsible for the warming of our Earth, which is often referred to as Global Warming, which is possible through what is known as the Green House Effect[i]. A common misconception of the Green House Effect is that it's completely

bad for our planet; the Green House Effect is in fact good to a certain extent. We need gases to be present in our atmosphere because (i) they are responsible for reflecting back the harmful rays that are emitted from the sun and (ii) they keep our planet warm preventing life on it to freeze. Obviously, the more gas is in the atmosphere, the more heat is trapped; therefore, the gasses in the atmosphere should not be sought to be completely eliminated, rather regulated.

The issues to using fossil fuels seem to be insignificant mainly because their repercussions have not fully developed – a substitute is desperately needed before it is too late.

With the use of water (H_2O), Hydrogen (H_2) has the potential to be an environmentally safe, friendly, and sustainable energy alternative, more specifically, a better fuel alternative for our transportation, which currently relies on petroleum, a non-renewable fossil fuel. One thing to be sure of is that if H_2 is going to be used to replace fossil fuels, its manufacturing should also be independent from methods involving fossil fuels.

It has always been a farfetched idea – to use water as fuel – but the technology is ready to make this into the fuel of the future.

Today's Situation

Fossil fuels are the driving forces for our means of transportation. Specifically, the use of petroleum plays an immense part in the U.S. transportation sector, consuming at least 70% of extracted oil, which should be a concerning fact; because such a large portion of petroleum is being used for our transportation, it should be closely regulated, and like the steam engine, eventually replaced [5]. Aside from the noise-infested streets, traffic congested commutes, and smog infused air, our vehicles are contributing to the

degradation of our atmosphere as well as negatively affecting air quality for everyone. Because of the depletion of fossil fuels, there is no other option than to find a feasible alternative that will repair the damages already done.

The Power of Water

Water has been thought of being an obvious, yet crazy fuel alternative by using the energy that is locked inside of it. In essence, the splitting of H_2O in hopes to directly extract its chemical energy is theoretically impossible due to the fact that it is very stable with strong bonds. Because of this, water must be split and then recombined in order to observe any kind of energy exchange. Furthermore, to successfully achieve the splitting of H_2O, a form of electrolysis[ii] is needed, as shown in Eq. 1. Although, electrolysis would prove to be a successful method in the splitting of H_2O, it is not a feasible, let alone efficient way to obtain energy from it. Elaborating, the Enthalpy of Formation their work here. ($\Delta H_f°$)[iii] and the Enthalpy of Combustion ($\Delta H_c°$)[iv] are equal, meaning that the amount of energy needed to break a water molecule apart is equal to the energy released when H_2 and O_2 are recombined to create the H_2O molecule. This proves that although the splitting of H_2O is possible when an electrical current is run through it, it would not provide energy that can be efficiently used. The key is not to unlock the energy of H_2O, rather use what it is made of – H_2.

The use of H_2 is the true secret behind using H_2O as fuel. Its combustion would have no GHGs, including CO_2, and would be safe to manufacture. The only obstacles would be the manufacturing of H_2 that is strictly derived from H_2O with the use of renewable energy sources and developing a system that would be ideal for a vehicle.

$$2H^+(aq) + 2e^- \rightarrow H_2(g)$$

Eq 1: This equation shows a visual representation of the production of H_2 gas as negatively charged electrons (e^-) are added to H_2 cations in pure H_2O. This type of reaction is called a Reduction Reaction[v]

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(l) + 572\ kJ$$

Eq 2: This equation shows the amount of energy created for the Enthalpy of Combustion ($\Delta H_c°$)

Hydrogen: A Real Solution

I. Purpose

The idea is to use a fuel that will have little to no pollutants as byproducts when combusted. H_2 produces no GHGs, which are responsible for damaging the atmosphere and is safe to manufacture [12]. One important concept to keep in mind is that H_2 is not an energy source; rather it is an energy carrier [2]. Because of this, the challenge is to find a way to successfully and efficiently manufacture and use H_2.

Ideally, the splitting of H_2O would be the best method to obtain H_2, but this approach, as mentioned before, requires electricity. If this reaction were to occur in an onboard vehicular system, then the easiest approach that comes to mind is to use similar technology that electric vehicles (EVs) use. The issue with this is that the electricity that EVs use comes from a plant that uses fossil fuels to produce the electricity, which would make the production of a clean burning fuel, H_2, pointless. As stated, the production of H_2 should involve "green" technology.

II. Inspiration

The world has been powering itself by way of the free energy of the Sun for billions of years, which makes it the ultimate example of the course of action we should take. Plants use a chemical process called photosynthesis, which essentially involves taking the energy of Sun and H_2O and storing it for its own use. Plants can serve as a model for the splitting of H_2O due to the fact the Solar Energy is both clean and free. Although it might seem difficult

to think that the secret to plants can be unlocked, a Harvard professor, Daniel G. Nocera, has developed a way to use solar energy to successfully achieve the splitting of H_2O.

III. Technology

It has been called "The Artificial Leaf," because even though it is not made of organic materials, it mimics nature and opens up a new pathway in the ultimate goal of clean energy. The way that this works is that Nocera's leaf is placed in water, while being exposed to sunlight, and as a result H_2 bubbles are created. Essentially, the leaf is acting as a catalyst for electrolysis, but instead of using electricity from a battery or the grid, it uses the power of the Sun, which makes this the key to obtaining H_2 from H_2O.

Implementation

There are two routes that can be taken with the proposed technology for the manufacturing of H_2, which are (i) the artificial leaf can be implemented in an onboard system for instant production of H_2 or (ii) a facility that uses the artificial leaf technology to produce and store H_2 ready to be used by the consumer.

I. H2 Engines

Today's vehicles use an internal combustion engine (ICE), which take small amounts of gasoline and due to pressure, ignites it to produce large amounts of energy in the form of heat and expanding gas. Obviously, if H_2 is used, ICEs must be modified in order for them to work with H_2, as seen in Figure 1.

Currently, there are many examples of engines that try to use H_2 as their main fuel, but there are only two major types (i) those that use an external fuel mixture preparation and (ii) those that use direct-cylinder fuel injection [3].

The difference between both is that even though the external fuel mixture

preparation engine is a simple design and very efficient, it lacks power, while the direct-cylinder fuel injection engine may possess high power, but it lacks thermal efficiency [3]. Furthermore, as stated, there are other experimental engines, such as the spark ignition (SI) engine, which shows potential, but due to the fact H_2 has an auto-ignition temperature of about 576°C, the engine would not be able to ignite the fuel with its pressure alone; an ignition source would be required [12].

In summation, there are different types of H_2 engines that possess true potential, but all must be further modified to work hand in hand with technology similar to Nocera's Artificial Leaf in order to have a constant onboard supply of H_2.

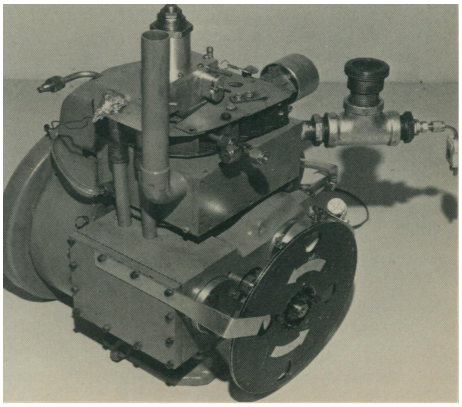

Fig 1: This image shows a H_2 modified ICE that can potentially power a vehicle [11]

II. H2 Facilities and Possibilities

As previously stated, H_2 engines would be the ultimate goal, but there are also other options for the production of H_2 for the use of fuel. For example, technology such as the Artificial Leaf can also be implemented in facilities that would be dedicated to producing H_2 from H_2O, from which the H_2 would then be transported to designated fueling stations ready to be used. The other option would be to implement the H_2O splitting technology directly into homes and public locations. This would then reduce the transportation cost that would have to be considered in the previous option.

Conclusion

H_2 is the desperately needed solution with the potential to repair all the damage caused by the production and use of fossil fuel products, such as gasoline. Furthermore, along with its' methods of production, it proves to be green; this is crucial to the repair of our atmosphere and quality of air.

The splitting of H_2O by way of solar technology, such as Nocera's Synthetic Leaf technology, can provide a surplus of H_2, which would then be ready for use as clean fuel. The uses for H_2 are limitless; it can be used to fuel vehicles, cities, and even homes. Modifications to engines will continue to become more powerful and efficient, homes will potentially become personal power stations for everyday energy consumption, and our cities will be powered with clean energy. Therefore, the transition to clean energy is inevitable and crucial to the health of the planet. The time is right for the next step: innovating and implementing the technology that makes the Earth's fuel into our fuel.

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[i] A process where the Sun's radiation is trapped and distributed to the surface of the Earth because of Green House Gases

[ii] A reaction where there is a gain of electrons

[iii] A chemical decomposition involving an electric current running through an ionized liquid/solution

[iv] Energy that is required to break stable bonds in a compound into its' elements

[v] Energy that is released in the form of heat when a compound is completely combusted with O_2

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Carlos Benavente is a Senior Mechanical Engineering major, Environmental Science and Sustainability minor, at the University of California, Merced. Although his passion has always been for Engineering and Mathematics, he finds the race to find methods for sustainable energy important. Increasing levels of atmospheric pollutants and society's dependency on fossil fuels (non-renewable source) have inspired him to find alternative methods that will yield green, efficient, and environmentally friendly solutions; the main problems being atmospheric pollution and Global Warming. Upon graduation, he hopes to pursue his graduate studies focused on a mixture of both Mechanical and Environmental Engineering.