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The Energy Challenge: Moving from Fossil Fuels to Biofuels, Hydrogen, and Green Energy Sources

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ABSTRACT

The aim of this literature research is to evaluate and identify alternative sources of energy instead of fossil fuels. Fossil fuels like natural gas, oil, and coal are known as nonrenewable resources because they are finite resources that cannot be readily replenished at the same pace as their consumption. The alternatives that will be searched for in this literature review are specifically, biofuels, hydrogen, and green energy sources which are all known as renewable. The review will then focus on hydrogen as true potential replacement of fossil fuels. In some countries, alternative renewable sources include geothermal energy, nuclear energy, solar energy, wind energy, and hydroelectric technologies. Hydroelectricity is the only renewable energy that is reliable. Generally, renewable energy sources generate most of their energy at certain times of the day, and their electricity generation does not match the peak demand hours. The intermittency of sunshine and wind cannot provide an on-demand power source 24 hours a week. Solar energy and wind are unpredictable. Unlike fossil fuel, green/renewable energy does not appear to be a one size fits all solution. The use of multiple sources is generally required to meet energy needs. Identifying those sources and evaluating their viability is the adjusted purpose of this research project.

MATERIALS AND METHODS

-Extensive Literature Research Conducted on Energy sources
-Google Scholars was used to search related articles
-Critical Understanding of Inorganic Chemistry and biochemistry
-Keywords: alternatives, energy, renewable, hydrogen, electrolysis
-Selected 7 articles out of 32 that were read for this research
-Research Experts Consulted: Professor Alberto Martinez

INTRODUCTION

Fossil fuels used today as main source of energy have a limited lifespan and a high environmental cost. Concerns on climate change and global warming are progressively raising in developed societies, which are trying to reduce their dependence on fossil fuels to generate energy. Renewable energy sources are being explored as a true alternative. These sources (biomass, hydropower, geothermal, wind, solar, etc) are naturally replenishing but flow-limited.

As wind, solar, and lithium-ion each have their own shortcomings and are not enough to meet the demands of the future, science has proven that hydrogen is the best and the cleanest option for renewable energy. Hydrogen has the potential to play a vital role in meeting the energy storage needs required to slash CO_2 emissions. It is the most plentiful element in the universe and its capability as an effective energy carrier has been well-understood for decades. Because hydrogen does not exist freely in nature and is only produced from other sources of energy, it is known as an energy carrier. It is a clean-burning fuel, and when combined with oxygen in a fuel cell, hydrogen produces heat and electricity with only water vapor as a by-product. [1]

Hydrogen can be made directly from fossil fuels or biomass, or it can be produced by passing electricity through water, breaking the water into its constituent components of hydrogen and oxygen. Some envision a future "hydrogen economy," where hydrogen is produced from a variety of energy sources, stored for later use, piped to where it is needed, and then converted cleanly into heat and electricity. [2]

Most hydrogen production today is by steam reforming natural gas. But natural gas is already a good fuel and one that is rapidly becoming scarcer and more expensive. It is also a fossil fuel, so the carbon dioxide released in the reformation process adds to the greenhouse effect. Hydrogen has very high energy for its weight, but very low energy for its volume, so new technology is needed to store and transport it. And fuel cell technology is still in early development, needing improvements in efficiency and durability. [3]

RESULTS

A simple element like hydrogen has unique properties such as, it's highly combustible and very cold as a liquid, but it also has its challenges like it's the smallest molecule to contain. Processing and storing hydrogen requires expertise. Hydrogen can be produced in different ways, typically from fossil fuels, nuclear and renewable sources. Water electrolysis is a commonly used method. During this process an electric current is used to split hydrogen from oxygen. If the electricity comes from renewable sources, the hydrogen fuel is considered to be renewable or "green" because it is produced without CO_2 emissions. Electrolysis is energy-intensive and has only recently been considered feasible as the cost of renewable power has declined and electrolysis technology has improved. Nuclear power can also provide the energy for electrolysis to split water without CO_2 emissions. U.S. utilities Exelon, FirstEnergy, Xcel Energy, and Arizona Public Service have all committed to commencing small-scale hydrogen production at nuclear plants. [4]

Hydrogen is almost always found as part of another compound, such as water (H_2O) or methane (CH_4), and it must be separated into pure hydrogen (H_2) for use in fuel cell electric vehicles. Hydrogen fuel combines with oxygen from the air through a fuel cell, creating electricity and water through an electrochemical process. Electrolysis is an electric current that splits water into hydrogen and oxygen. If the electricity is produced by renewable sources, such as solar or wind, the resulting hydrogen will be considered renewable as well and has numerous emissions benefits. [5]

Hydrogen energy storage and transportation issues are present and inspiring issues. Storage and transportation operations are important as production processes. Those processes play a very essential role in the hydrogen energy economy. The common strategy for the storage of hydrogen are compressed gas, cryogenic liquid hydrogen, and solid hydrogen. Also, the density of the hydrogen stored as a liquid is greater than the density of its stored as compressed gas, and it stores more energy per unit volume. In the liquid hydrogen storage method, hydrogen is stored for a short time due to its low boiling point. On the other hand, In the solid state storage method, a large amount of hydrogen can be stored in a small volume. It is more efficient than the other two methods because it needs less volume. There are two ways of storage for the solid storage method. One is nanostructured materials that can store more hydrogen with nanotechnology. The solid storage method also uses complex hydrides, such as lithium borohydride ($LiBH_4$), sodium borohydride ($NaBH_4$), magnesium borohydride ($Mg(BH_4)_2$), and calcium borohydride ($Ca(BH_4)_2$). [6]

In a polymer electrolyte membrane (PEM) electrolyzer, the electrolyte is a solid specialty plastic material. Water reacts at the anode to form oxygen and positively charged hydrogen ions (protons). The electrons flow through an external circuit and the hydrogen ions selectively move across the PEM to the cathode. At the cathode, hydrogen ions combine with electrons from the external circuit to form hydrogen gas. (as shown in figure 1) [7]

Anode Reaction: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$
Cathode Reaction: $4H^+ + 4e^- \rightarrow 2H_2$

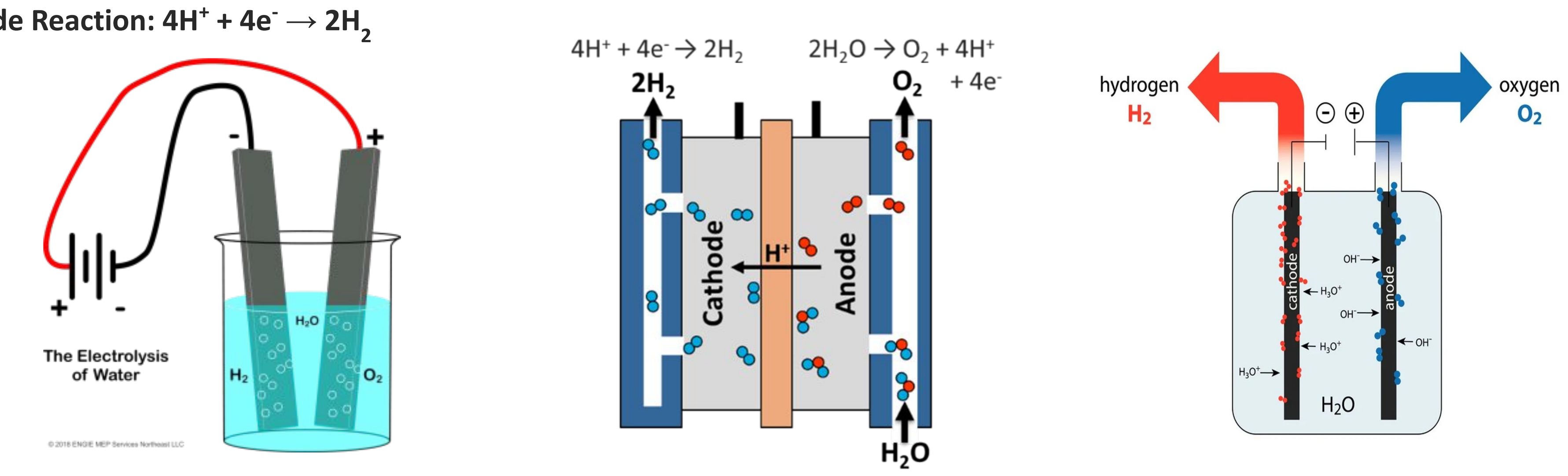

Figure 1. Left: Schematic representation of a simple water electrolysis. Center and right: Schematic representation of a fuel cell

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DISCUSSION

Hydrogen can be produced and used without toxic pollution or CO_2 emissions. It burns clean when mixed with oxygen from the atmosphere and can be used as a source of heat or to power an internal combustion engine. Hydrogen can also be fed into a fuel-cell device that converts hydrogen's chemical energy into electricity. In either case, the only emission produced is water vapor. When hydrogen fuel cells are used to power an electric motor, the system is more than twice as efficient as conventional internal combustion engines.

Hydrogen rarely exists in isolation but is amassed in enormous quantities in water, hydrocarbons, and biomass. Efficient extraction of hydrogen from these compounds is critical for wide-scale deployment. Currently, about 95% of hydrogen is produced by splitting it from natural gas through a process called "steam-reforming." Hydrogen produced in this manufactured to as "gray" and is generally not considered an effective climate solution because it gives off CO_2 as a byproduct. However, it is possible to capture and sequester the CO_2 to produce "blue" hydrogen at an additional cost of about 30%. The oil and gas sector, in particular Shell, BP, and Repsol, are interested in the blue hydrogen approach because it could help preserve the value of their natural gas assets. Commonly used methods of storage as compressed gas and liquid hydrogen. Compressed gas transport by steel, aluminum, and carbon fiber reinforced plastic composite materials.

Hydrogen production via electrolysis may offer opportunities for synergy with dynamic and intermittent power generation, which is characteristic of some renewable energy technologies. For example, though the cost of wind power has continued to drop, the inherent variability of wind is an impediment to the effective use of wind power. Hydrogen fuel and electric power generation could be integrated at a wind farm, allowing flexibility to shift production to best match resource availability with system operational needs and market factors.

CONCLUSION

Electrolysis is a leading hydrogen production pathway to achieve Hydrogen Energy. Hydrogen produced via electrolysis can result in zero greenhouse gas emissions, depending on the source of the electricity used. The source of the required electricity including its cost and efficiency, as well as emissions resulting from electricity generation must be considered when evaluating the benefits and economic viability of hydrogen production via electrolysis. In many regions of the country, today's power grid is not ideal for providing the electricity required for electrolysis because of the greenhouse gases released and the amount of fuel required due to the low efficiency of the electricity generation process. Hydrogen production via electrolysis is being pursued for renewable (wind, solar, hydro, geothermal) and nuclear energy options. These hydrogen production pathways result in virtually zero greenhouse gas and criteria pollutant emissions; however, the production cost needs to be decreased significantly to be competitive with more mature carbon-based pathways such as natural gas reforming. [5] [6] Although the compressed gas method and liquid state storage method are widely used in hydrogen storage, the method to be used for the future is the solid state storage method. The solid-state storage method also consists of complex hydrides, chemical hydrides, magnesium-based alloys, and intermetallic compounds. Complex hydrides have high hydrogen storage capacity.

Today's grid electricity is not the ideal source of electricity for electrolysis because most of the electricity is generated using technologies that result in greenhouse gas emissions and are energy-intensive. Electricity generation using renewable or nuclear energy technologies, either separate from the grid or as a growing portion of the grid mix, is a possible option to overcome these limitations for hydrogen production via electrolysis. The U.S. Department of Energy and others continue efforts to bring down the cost of renewable-based electricity production and develop more efficient fossil-fuel-based electricity production with carbon capture, utilization, and storage. Wind-based electricity production, for example, is growing rapidly in the United States and globally. [7]