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RESEARCH ARTICLE

OVERVIEW OF HYDROGEN FUEL TECHNOLOGY IN RENEWABLE ENERGY

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Abstract

Hydrogen is one of the best possibilities for storing renewable energy in the power generation industry, and ammonia and hydrogen can be utilized in gas turbines to increase the flexibility of the power system. In order to cut emissions in coal-fired power plants, ammonia could potentially be used. This paper seek to see the usefulness, advantages, disadvantages, and classification of hydrogen fuel technology in renewable energy and to find various measures that could be taken in order to sustain the usage of hydrogen fuel in the subject.

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Introduction:-

Renewable energy has become an essential energy source as the globe works to reduce carbon emissions. But combustible fuels will still be needed for a variety of reasons in transportation and industry. Hydrogen, which may be created using renewable energy, could satisfy these needs. High-grade heat from hydrogen can help with a variety of energy needs that would be challenging to satisfy through direct electrification. As a result, hydrogen might be the crucial component needed to alter the world's energy system (Irena, 2022).

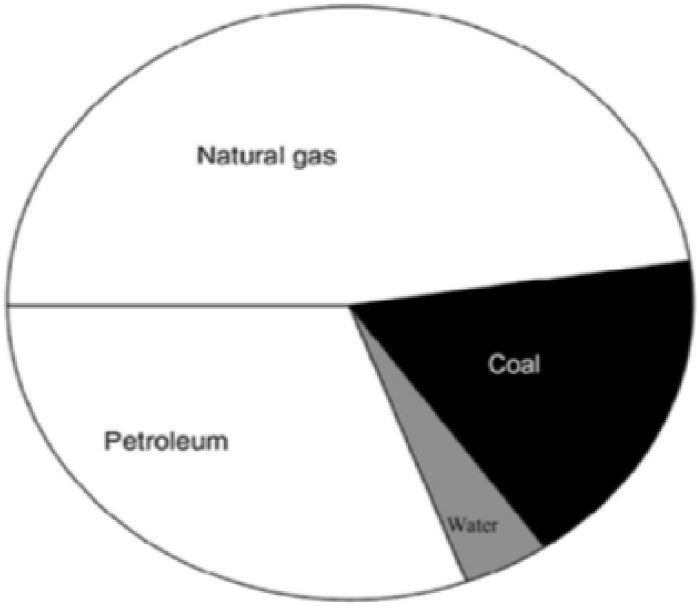
If it is possible to split water using energy from a sustainable, "non-carbon" source, such as solar or wind energy, the hydrogen that results would likewise be a real renewable energy source. Numerous additional processes that use fossil fuels can and do produce hydrogen on a massive scale, such as the decarbonization of CNG, but these methods of producing hydrogen are neither renewable nor "carbon free (Abbasi, 2011)."

Additionally, almost all of this hydrogen is produced using fossil fuels, making it come from a "unclean" source. About 2.5 tons of carbon are emitted as CO2 for every ton of hydrogen produced from hydrocarbons. About 5 tons of carbon are released into the atmosphere for every ton of hydrogen produced from coal (RB, 2010).

Table 1
Hydrogen consumption in the world.

Category	Hydrogen consumed	
	Billion m^3	Share (%)
Ammonia producers	273.7	61
Oil refineries	105.4	23
Methanol producers	40.5	9
Others	13.6	3
Merchant users	16.1	4
Total	449.3	100

In a fuel cell, hydrogen is a clean fuel that only creates water when burned. Several home energy sources, including natural gas, nuclear energy, biomass, and renewable energy sources like solar and wind, can be used to manufacture hydrogen. It is a desirable fuel choice for transportation and electricity generating applications because of these characteristics. There are numerous uses for it, including in homes, cars, and portable electricity (Eficiency, 2021).



Relative quantities of raw materials presently used for hydrogen production

However, there is a strong push to move away from an economy that depends on fossil fuels and toward one that uses hydrogen as its primary fuel. Since water is the byproduct of hydrogen's combustion, burning it produces no pollution.

The future is electric, according to almost all scenarios for global carbon reduction. The primary and most economical route to decarbonization is electrification, and there are two main reasons for this. First off, solar and wind power are now the cheapest sources of electricity generation in the majority of the world after decades of scientific advancement propelled by subsidies. Second, quick technological progress has made it possible for electricity to enter industries that have historically relied on fossil fuels, such as transportation, heating, and industrial, by making cheaper batteries, heat pumps, electric motors, and related technologies.

The main issue for system operators as the world's energy systems electrify will be to meet the demand for electricity in real time in order to prevent blackouts. Matching, however, gets more difficult as solar and wind power share rises: how do you fulfill electricity demand when the sun isn't shining or when there isn't any wind?

As a chemical energy carrier, hydrogen satisfies the storage and flexibility requirements of a renewable energy source, which is one of the two main reasons it is currently "in vogue." Additionally, hydrogen can be used to decarbonize challenging industries like heavy manufacturing, transportation, aviation, or shipping.

If hydrogen is produced through electrolysis using electricity generated by renewable sources, it would appear to be the ideal complement to renewables in the effort to reduce carbon emissions(Garcia-Herrero, 2021).

The original (Hydrogen Economy) HE concepts needs to be rethought in light of the three-pronged threat that includes irreversible climate change, an imbalance between oil demand and supply, and growing pollution levels generally. With lithium ion and lithium polymer batteries, battery technology has undergone significant advancements (e.g. higher gravimetric and volumetric energy densities than traditional lead acid batteries) (Andrews, 2012).

Background of Hydrogen fuel

In a fuel cell, hydrogen is a clean fuel that only creates water when burned. Several home energy sources, including natural gas, nuclear energy, biomass, and renewable energy sources like solar and wind, can be used to manufacture hydrogen. It is a desirable fuel choice for transportation and electricity generating applications because of these characteristics. There are numerous uses for it, including in homes, cars, and portable electricity. Energy created from other sources can be transported, transported, and stored using hydrogen.

Several processes can be used today to manufacture hydrogen fuel. Today, electrolysis and natural gas reforming, a thermal process, are the two most used techniques. Solar-powered and biological processes are some additional techniques(Energy, 2021).

The processes used to produce hydrogen thermochemically. Through a series of chemical events, water is broken down into hydrogen and oxygen in this process. Heat is the only energy used to drive the chemical reactions. The constituent elements and waste heat are released when thermochemical reactions are fed heat and water. The thermochemical water breakdown (or water splitting) cycle is a name for this set of processes (or process). This technique is one of those energy conversion processes that converts thermal energy—that is, the chemical potential or heat of hydrogen combustion—into hydrogen energy. The thermochemical approach is given more attention when converting primary energy sources like solar or nuclear energy into hydrogen energy since it may be the most effective and suitable for use on a wide scale. When nuclear reactor heat is taken into account as the principal source of energy, water electrolysis competes with thermochemical degradation(B.V, 1979).

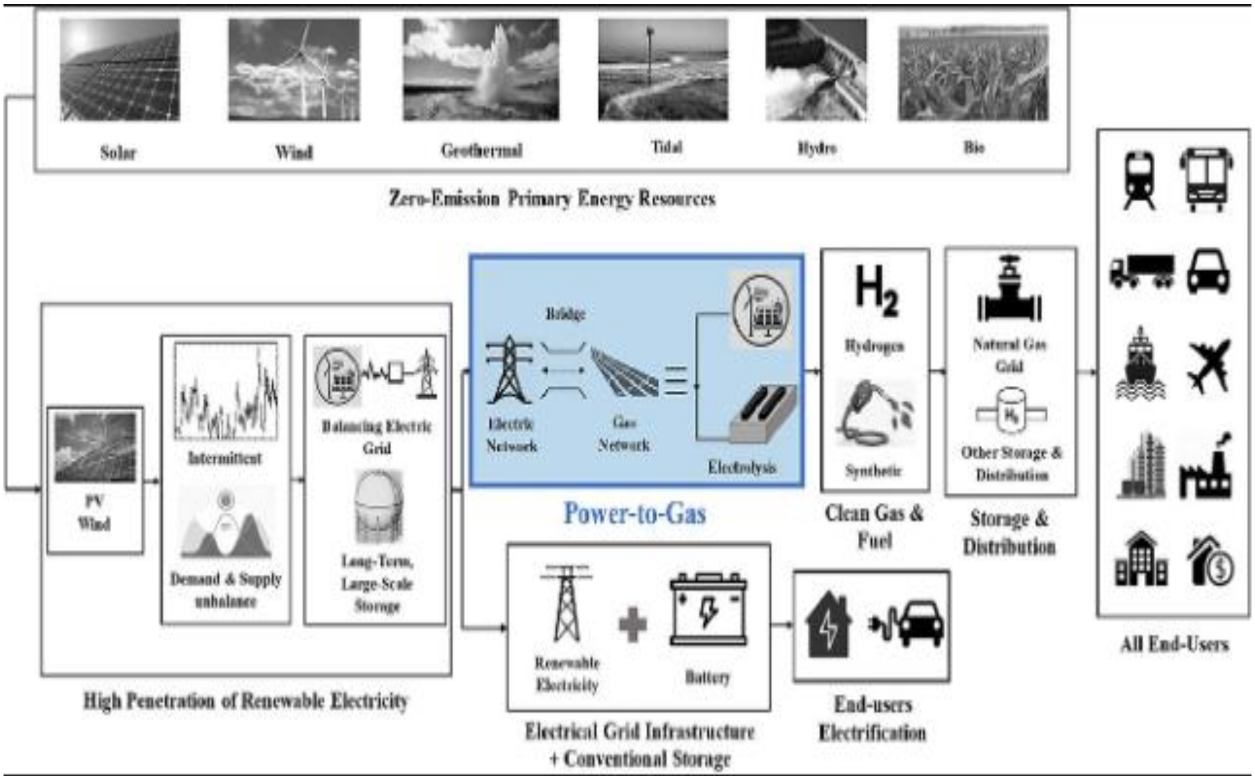
Hydrogen Generation by Electrolysis

The simplest method now available for producing hydrogen directly from water is electrolysis. Although traditional low temperature electrolysis can be connected to all reactors that are already in operation, it will not be cost-effective. Numerous potential methods for producing hydrogen at greater temperatures, including high temperature steam electrolysis and other thermochemical methods, have been identified. Since most of these procedures are more efficient than low temperature electrolysis in this situation, using high temperature reactors to produce hydrogen presents a workable option. Proton exchange membrane (PEM) electrolysis and high temperature steam electrolysis (HTSE) using oxygen conducting ceramics are two other methods of electrolysis that are being evaluated for use on an industrial scale(Beta, 2020).

The role of hydrogen in sustaining energy strategy

The reimagined HE, or what we'll refer to as the "Hydrogen in a Sustainable Energy (HISE) strategy), is firmly embedded in the context of a zero-greenhouse gas emission economy in terms of both the production of hydrogen from renewable sources and consumption, rather than just as a reaction to finite fossil fuel reserves. There is no long-distance transmission of hydrogen via pipelines to centers of consumption in HISE, which entails decentralized distributed production of hydrogen from a wide range of renewables and feedstocks. In HISE, hydrogen is no longer the single and exclusive energy carrier and store in every sector of the economy. Instead, hydrogen and electricity play complementary roles as energy vectors, and hydrogen and batteries play complimentary roles as energy storage(Bahman & Shabani, 2012). As was also previously discussed, HISE rejects nuclear fission power input and exclusively emphasizes renewable energy sources, along with a strong focus on energy efficiency and demand management, in an all-encompassing sustainable energy strategy similar to that espoused over a long period of time by Amory Lovins and his coworkers(Weizsacker & Lovins, 1997). In HISE, hydrogen is used for longer-duration energy storage on centralized grids that heavily rely on inputs from renewable energy sources, and bulk hydrogen storage is also used as the strategic energy reserve to ensure national and global energy security in a world that depends more and more on RE(Andrews & Shabani, 2012).

P2G technology, which involves converting electrical energy into a gaseous energy carrier, offers hope for sustainable energy systems in the future since it can solve a number of problems that arise with systems that are entirely powered by renewable resources(Alireza, Kinnon, & JackBrouwer, 2018). High amounts of solar and wind require a significant amount of storage, which can be achieved by producing hydrogen using a P2G technique(Lewandowska-Bernat & Desideri, 2018). P2G allows for the production of hydrogen only from surplus renewable energy, which has the dual benefits of balancing the electrical grid by utilising a large amount of variable, unpredictable renewable electricity and providing high capacity, long-term energy storage for seasonal shifting needs. The most economical method for long-term energy storage was likewise demonstrated to be hydrogen synthesis using P2G(Marchenko & Solomin, 2017). By merging both renewable energy sources and hydrogen energy systems, newly created smart energy systems offer more effective, affordable, and sustainable solutions(Dincer & Acar, 2018). Because they enable the production of hydrogen using excess renewable energy and the generation of power from hydrogen when renewable energy is insufficient, energy management strategies and predictive controllers are crucial parts of combined renewable energy sources and hydrogen energy systems(Eriksson & Gray, 2017)



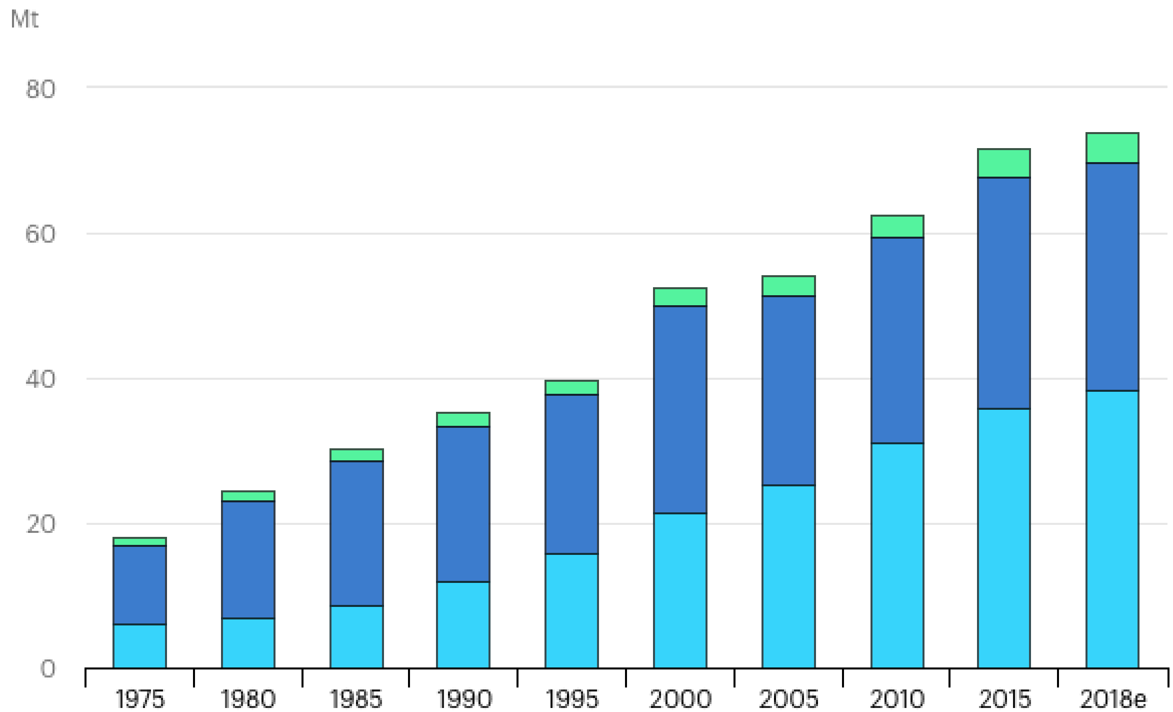
Various Energy Source

In order to reduce CO2 emissions, energy storage needs must be met. Hydrogen has the potential to be a key component of this solution. It is the most prevalent element in the universe, and its effectiveness as an energy carrier has long been recognized. Early in the new millennium, there was a lot of planning and investment, but hydrogen technologies fell short of expectations in terms of performance and financial returns.

To solve shortcomings, technological developers have continued to work, and significant progress has been made. Hydrogen is increasingly emerging as a workable option for grid storage, transportation, metals refining, and heat for buildings and industrial applications because to advances in the production, storage, transmission, and use of hydrogen technologies(Lindsey, 2011).

Future of hydrogen fuel technology

Energy and hydrogen have a long history together; more than 200 years ago, hydrogen powered the first internal combustion engines and is now a crucial component of the modern refining sector. It emits no greenhouse gases or pollutants directly and is light, storable, and energy-dense. But adoption of hydrogen in areas where it is virtually nonexistent, like transportation, buildings, and power generation, is necessary for it to significantly contribute to clean energy transitions.The Future of Hydrogen is a thorough and unbiased examination of hydrogen that outlines the current state of the industry, the ways in which hydrogen may contribute to the development of a clean, secure, and cost-effective energy future, and how to go about realizing its promise(Birol, 2019).

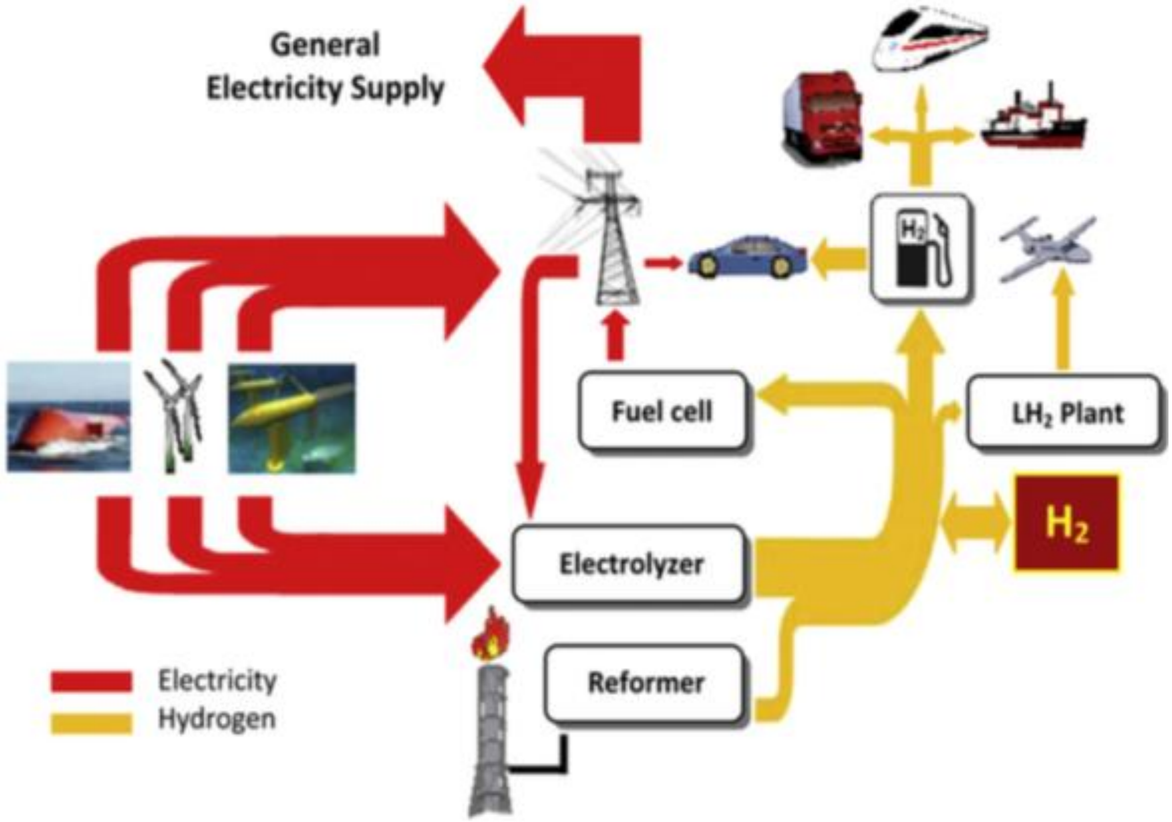


Today, providing hydrogen to industrial users is a significant global industry. The global demand for hydrogen, which has increased more than triple since 1975, is still on the rise. To produce hydrogen, 6% of the world's natural gas and 2% of its coal are used.

As a result, the production of hydrogen results in annual CO_2 emissions of about 830 million tonnes, which is equal to the combined emissions of the United Kingdom and Indonesia.

The cost of producing hydrogen has decreased, and there has been a notable improvement in efficiency. Recently, new methods for producing hydrogen using fossil fuels and renewable energy have been successful in meeting US DOE performance goals(J. Larminie, 2003). Additionally, the capacity for storing hydrogen has advanced significantly. Recent years have seen significant advancements in metal hydride technology, liquid storage, and compressed storage, all of which have been demonstrated very successfully at 5000 and 10,000 psi(G. Sandrock, 2003). Glass microspheres, poly-hydride complexes, and alanates are some of the recently developed novel hydrogen storage techniques. Additionally, hybrid hydrogen storage methods that combine metal hydride storage with pressurized storage are beginning to show promise(Broouwer, 2009).

The EU expects hydrogen to play a significant role in delivering the deep emissions reductions required between 2030 and 2050 to achieve climate neutrality, and for this reason is predominantly focusing on the development of renewable hydrogen(Palgrave, 2021).



However, the EU also envisages a temporary use of other forms of low-carbon hydrogen to decarbonise existing fossil-based hydrogen production. Overall, the EU foresees a gradual trajectory for hydrogen deployment in Europe with three different phases.

In order to address growing concerns about carbon emissions and climate change as well as the future accessibility and security of the energy supply, the development of hydrogen generation, hydrogen storage, and fuel cell technologies is expected to play a key role. According to a study conducted on behalf of the Department of Trade and Industry, hydrogen energy presents a chance to achieve important UK policy objectives for a sustainable energy future(Edwards & Kuznetsov, 2008).

Advantages of hydrogen fuel technology
According to(Energy C. , 2020)thereare different advantages of hydrogen fuel technology:

1. **It is numerously produced locally:** On-site production of hydrogen is an option, as is central production followed by distribution. Methane, gasoline, biomass, coal, or water can all be used to make hydrogen gas. Depending on the sources employed, variables such as pollution levels, technological difficulties, and energy requirements change.
2. **It is practically a clean Energy Source: T**he byproducts of burning hydrogen to make fuel are completely harmless and have no known adverse effects. In fact, hydrogen is used by aviation businesses as a source of drinking water. Hydrogen is typically transformed into drinking water for astronauts on ships or space stations after it has been used.
3. **It is not toxic:** It is unusual for a fuel source because it is non-toxic. This indicates that it respects the environment and does not hurt or negatively impact human health. This feature makes it desirable compared to other fuel sources like nuclear energy and natural gas, which are difficult to harness safely or exceedingly dangerous. Additionally, it permits the use of hydrogen in locations where other fuels might not be permitted.
4. **It reduces pollution greatly:**Electricity is created in a fuel cell when hydrogen and oxygen are mixed. This electricity can be utilized for a variety of purposes, including driving an electric motor to generate heat. The benefit of employing hydrogen as an energy carrier is that the only byproducts of its reaction with oxygen are water and heat.

5. **It can be used in powering space ships:** The effectiveness and power of hydrogen energy make it a perfect fuel for spacecraft. Its power is so great that it can launch spacecraft to exploration missions very quickly.
   In addition, it is the most secure form of energy to use for such a demanding operation. In actuality, hydrogen energy has a 3 times greater energy density than gasoline and other fossil-based fuels. This suggests that, in theory, less hydrogen is required to carry out a significant task.

Disadvantages of hydrogen fuel technology

According to (Forbes, 2021) there are some noticeable disadvantages of hydrogen fuel:

1. Utilizing Fossil Fuels to Produce Hydrogen: When it is true that hydrogen fuel cells don't release any dangerous gases while they are in use, this isn't the case throughout the process of producing hydrogen fuel. In fact, hydrogen energy is almost energy-neutral, which means that the energy required to manufacture it is almost equal to the energy it generates.One of the most plentiful elements on earth is hydrogen, but it is usually bound to other elements and needs to be separated in order to be used as a source of energy.
2. Storage of hydrogen and Transportation: Lift truck fuel cells require hydrogen in the gas form, which can be kept in high-pressure tanks or kept as a liquid at cryogenic temperatures.There is a waste of energy inherent in both hydrogen storage techniques. About 13% of the hydrogen's total energy must be expended in compression, and about 40% must be lost in liquefaction.It costs a lot of money to set up the infrastructure needed for using hydrogen fuel cells. In addition to worrying about the costs associated with hydrogen gas deliveries or constructing an on-site plant to manufacture hydrogen gas, organizations will need to engage with their local government and fire department to acquire approval.
3. Hydrogen Energy Cannot Sustain the Population: Although there is a plentiful supply of hydrogen, its extensive use is limited by the high expense of capturing it. As you are aware, changing the status quo is quite difficult.The world is still ruled by energy derived from fossil fuels. Additionally, there is no framework in place to guarantee future affordable and sustainable hydrogen energy for the typical automobile owner.Even if hydrogen were to become inexpensive right away, it would take years for it to overtake other energy sources since gasoline stations and automobiles would need to be modified to meet the needs of hydrogen(Hydrogen, 2020). It would cost a lot of money to do this.
4. Storage Complication: The reduced density of hydrogen is one of its characteristics. In actuality, it has a far lower density than gasoline. To ensure its usefulness and efficiency as an energy source, it must be compressed into a liquid state and stored in the same way at lower temperatures.

Conclusion:-

Many countries of the world are shifting focus from the well-known fossil fuel that has served the entire populate over years. There is certainly no household that does not depend on this one way or the other. May used for transportation, power, domestic use (cooking gas) etc. However, with the increase in world population human kind seek for an alternative that not only replace the old method but also serve as a better means. The world in the 21st century knew about renewable energy as a perfect replacement for fossil, with special focus on Solar and Wind. This paper however focuses on bringing hydrogen to lime light in order to sustain renewable energy. It also looked at the background, future of hydrogen fuel technology, advantages, disadvantages and how it can be a means of sustenance especially with more focus on it.

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