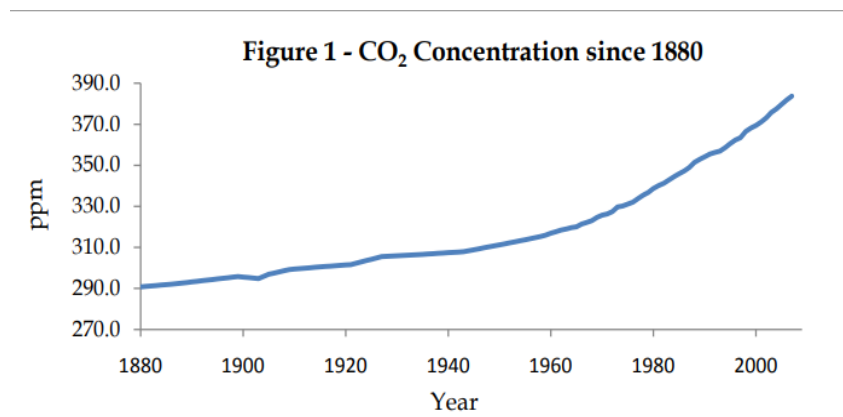


USES OF HYDROGEN AS A FUEL

INTRODUCTION:-

Currently the human civilization is under grave danger due to the uncontrolled usage of fossil fuels as the main source of energy over the past 200 years. These fossil fuels are the biggest contributors of the environmental pollution which is getting more and more evident to us. The CO₂ concentration has increased drastically since the past century (the graph is show in figure1). So we need a more sustainable source of energy which is more efficient with less or no emission of greenhouse gases. Shifting our fossil fuel dependent economy to an economy based on hydrogen as the prime source of energy is one of the best solutions we have right now. Fossil fuels are the largest contributor to the total demand of energy through out the world. These fuels are non conservative type and will get depleted after a time due to over usage. So we must produce such technologies which can produce hydrogen without less or any emissions which is harmful for the environment.



HYDROGEN AS A SUSTAINABLE ENERGY SOURCE

In the search of a sustainable energy source, Hydrogen began to be seen as the fuel that could replace the usage of fossil fuel. Many countries like Brazil, Australia, Japan, Britan, USA, Netherlands are investing huge amount of money for their plan regarding usage of Hydrogen as a renewable energy. Globally approximately 286 billion dollars were invested in 2014 for the processes

related to usage of renewable sources of energy. Hydrogen is found in great quantity on earth combined with other compounds such as water(H₂O) and hydrocarbons. The only thing is Hydrogen doesn't typically exist in environment in free form, we have to produce it from the compounds that have it.

PHYSICAL PROPERTIES OF HYDROGEN

Hydrogen is a colorless, odorless, and tasteless gas with high flammability. It has a very low density (0.08967 kg/m³) which is 14.4 folds lesser than air. Hydrogen has a high calorific value compared to the other alternatives.

Fuel	Calorific Value (MJ/kg)
Hydrogen	119.93
Methane	50.02
Propane	45.60
Gasoline	44.50
Diesel	42.50
Ethanol	27.00
Methanol	18.50

Hydrogen has the highest of energy per unit mass. The energy contained in 1 gm of hydrogen is equal to the energy in 2.8 gm of gasoline. That is why it is used as a carrier of huge amount of energy. Also when hydrogen is cooled it gets 700 time smaller in volume than when it is in gaseous state. This gives it a good edge in the storage capacity.

CHEMICAL PROPERTIES: -

Hydrogen atoms are very reactive element and therefore it is difficult to find them in the environment in free state. Hydrogen is a very less reactive element. To dissociate hydrogen into atoms we need to apply very high temperatures.

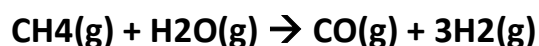
Hydrogen has a very high reductive power. It reduces the oxides and chlorides of many metals like Ag, Hg, Cu, Pb, Hg and producing the corresponding hydrides.

Now here comes a term called Flammability limit. The concentration range of a vaporized or gaseous fuel in a mixture with oxygen in air within which it will burn is called the flammability limit of the fuel. The two boundaries of the flammability limits are called Lower Flammability Limit(LFL) and Upper flammability limit. The flammability limits of Hydrogen is 4-75 volume %, 4.3-15 volume% for methane, 1.4-7.6 volume% for gasoline. Compared to the other alternatives hydrogen requires a very low amount of energy to ignite when the flammability concentration surpasses the LFL value which is only 0.02mJ while for gasoline and methane it is 0.24 and 0.28 mJ respectively. This makes it ideal for the production of high amount of energy at very low cost.

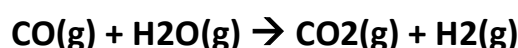
METHODS OF PRODUCTION OF HYDROGEN:-

1. STEAM REFORMING OF HYDROGEN:-

PROCESS:- In this process methane gas is reacted with water vapor in the presence of nickel catalyst at 700-1100 degree Centigrade. The products are Carbon mono oxide and hydrogen.



The next reaction occurs between CO and H₂O at lower temperature to produce CO₂ and H₂.

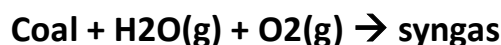


ADVANTAGES:- This is the least expensive and economical process for the production of hydrogen available to us. It has a efficiency of range 65%-75%.

DISADVANTAGES:- The sources which are used here are non-renewable. The reaction emits Carbon dioxide.

2. HYDROGEN FROM COAL(GASIFICATION):-

PROCESS:- This process uses pulverized coal blown into the gasifier by a mixture of steam and oxygen. The gasifier is operated at atmospheric pressure and at high temperatures of about 1,600–1,900 °C (2,900–3,450 °F). The product is syn gas which is a mixture of H₂,CO,CO₂,CH₄.

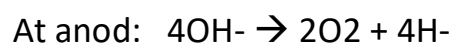
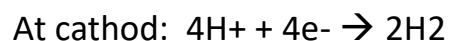


ADVANTAGES:- Since coal is a low cost resource and easily available the whole process is less expensive.

DISADVANTAGES :- This process is less efficient with a efficiency of 45%. It also emits CO₂ as a product.

3. ELECTROLYSIS OF WATER:-

Process:- It is the decomposition produced by passing electric current through a liquid or solution containing ion kept in an electrolytic cell containing cathode and anode. Upon dissociation the H^+ ions go to the anode and absorb electrons to form hydrogen gas. While the hydroxyl ions go to the cathode and release electrons to form O_2 and H^+ ions.



ADVANTAGE:- DEPENDS ONLY ON ELECTRICITY SOURCE.

DISADVANTAGE:- The input energy is more compared to the output energy. Moreover the source of energy used is electricity. If coal is used to produce the electricity it will inversely affect the environment by emitting CO_2 in the environment.

4.SOLAR-HYDROGEN SYSTEM:-

PROCESS:- This process involves the using of photovoltaic cells for the production of electric energy and then this electricity is passed through electrolyser into water. Then water decomposes into oxygen and hydrogen gases. (Same reaction mechanism as electrolysis of water).

ADVANTAGE:- It is an emission free process with no production of CO_2 or any other harmful gases. Also this process has an efficiency of 65%.

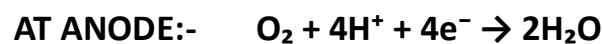
DISADVANTAGE:- The disadvantage of this process is that it is a very expensive process. Using photovoltaic cells for the generation of electrical energy is itself a costly process.

APPLICATIONS OF HYDROGEN AS A FUEL:

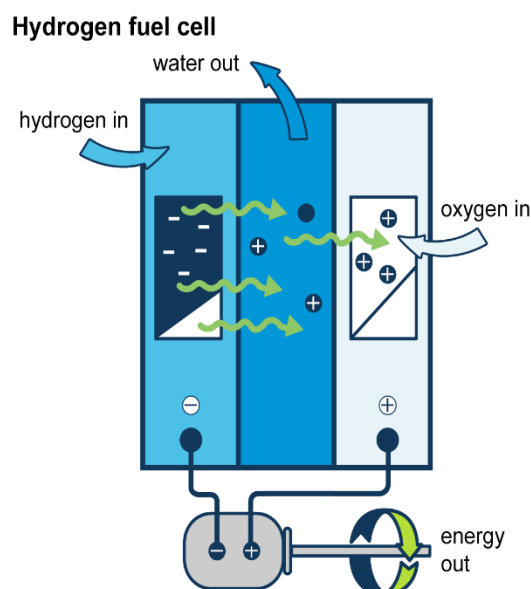
HYDROGEN FUEL CELLS FOR PRODUCING ELECTRICITY:-

PROCESS:-The fuel cell works between 2 electrodes. A positive(cathode) and a negative electrode (anode). Hydrogen is supplied to the anode and it breaks down into Proton(H^+) and electron(e^-). Both proton and electron reaches cathode following two different paths.The Electrolyte used facilitates this process. The most common electrolyte used is polymerElectrolyte membrane. The electrons doesn't pass through the electrolyte membrane while The protons are allowed to pass through directly. The electrolyte membrane is also used as a catalyst in the electrodes to pass this process. So the electrons follow external circuit to reach the cathode. This passing of electric charge produces electric current flow through the external circuit which can be used for different applications.

REACTIONS:-

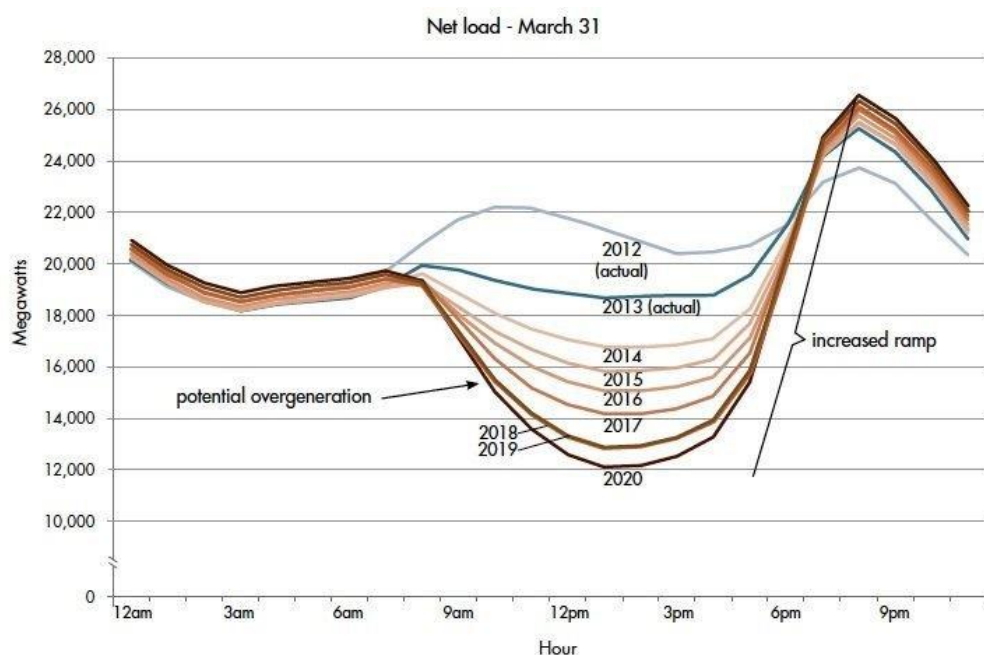


In the anode air is passed producing water. The only by-product of the process is water which is generated in the of vapor. So this is a good application of hydrogen in the generation of electricity without affecting the environment.



FUEL CELLS FOR VEHICLES:- Hydrogen fuel cells can be used as a replacement for conventional gasoline based combustion engines. Here there will be 0 emission except steam. It has two to three times more efficiency than combustion engines powered by gasoline. The only reason why hydrogen fueled cars are not in much use today is because of high price of fuel cells and lacking of hydrogen fuel refilling stations.

ENERGY STORAGE:- Solar energy and wind energy are clean energies but solar energy can only be produced when there sunlight and wind energy only when wind is blowing. Solar energy is very common during the day light times When the demand is relatively much less but faces shortage of supplies during the non production hours i.e in the nights when the demand increases significantly. So we need a source of energy which can be stored after Production and can generate high amount of energy in the high demand hours. For this Hydrogen is ideal fuel because it can be produced by electrolysis and can be stored as compressed gas or cryogenic liquid.



USAGE IN BUILDINGS:- Hydrogen boilers can be used to heat up space and water. Many industries across the natural gas chain is preferring hydrogen over conventional natural gas for their boilers. To reduce the CO₂ emission from residential buildings hydrogen utensils can be used for cooking purposes also. Although heating applications using hydrogen will increase the cost of energy system costs because of the current inefficiencies in production of hydrogen.

METHODS OF STORAGE:-

Hydrogen needs to be stored for future use. Hydrogen can be stored in compressed gas hydrogen storage, liquid hydrogen storage and solid hydrogen storage. Gaseous and liquid hydrogen can be stored both in geological storage and in high pressure tanks.

Gaseous and liquid hydrogen are most commonly stored in tanks for small scale storage and mobile applications. In liquid H₂ tanks liquid hydrogen can be stored by compression followed by cooling in cryogenic system. This is a costly process with work needed about 15.2 kWh/kg. While to store gaseous hydrogen a high-pressure tank(350-700bar) is used. The tanks have a high discharge rate and high efficiency of about 99% making them suitable for short term applications.

For long term storage of much higher quantities of H₂ geological storages are used. For example: salt caves , aquifers, and depleted natural gas or oil reservoirs. These locations store hydrogen at high efficiency and low operating costs.

In solid hydrogen storage, chemical storage method is used. In this method hydrogen can be stored in solid state materials. Various materials have been explored in the search for a suitable material that meets the requirements established by the U.S. Department of Energy (US-DOE), such as a storage capacity of more than 8% by weight and an operating capacity of 40–85 °C . Several materials are available for this purpose, such as sorbents, light metal hydrides and complex metal hydrides. Sorbent systems are carbon based materials and metal organic framework where hydrogen is connected to the surface via physisorption. But this process requires very low operating temperatures which is not feasible to achieve . Metal hydrides are the best

method to store hydrogen because they require viable working temperature and has a good H₂ storage capacity.

ADVANTAGES OF USING HYDROGEN AS A FUEL: -

1. **CLEAN SOURCE OF ENERGY:** - hydrogen is a clean source of energy with 0 carbon emission which supports the decreasing the pollution in our environment. There is only one byproduct of hydrogen fuel cells that is Water(steam). So hydrogen doesn't have any adverse effect on environment.
2. **High efficiency than conventional fossil fuels:** - Hydrogen fuel cells have higher efficiency compared to the other sources of energy. A conventional combustion based power plant generates electricity at 33-35% efficiency compared to up to 65% for hydrogen fuel cells.
3. **More powerful than conventional fuels:** - hydrogen has the highest calorific value compared to other fuels. So it produces more calories of energies compared to its competitors at a higher efficiency.
4. **No carbon footprints:** - hydrogen fuel cells don't emit any greenhouse gases. So it has no carbon footprints. It has only one by-product which is water(steam).
5. **DEMOCRATISATION OF POWER SUPPLY:** - large scale usage of hydrogen as a fuel will decrease the countries dependence upon fossil fuel based energy and it will democratize energy and power generation around the world. This will solve the problem of rising price when stocks are limited.

DISADVANTAGES OF USING HYDROGEN AS A FUEL: -

EXTRACTION: - hydrogen doesn't exist in pure form freely in nature. So they need to be extracted from elements containing hydrogen like water through electrolysis. But the energy required in this extraction process itself gets higher than the energy produced afterwards. Also the whole extraction process is too costly.

INVESTMENT IS REQUIRED : - for upgrading hydrogen fuel cells to a level where it can be used as a viable source of energy, it will require large amount of investments. It will also require political attention and

investments for the development in order to make the technology more matured and advanced.

HIGH COST OF CATALYSTS: - In fuel cells the electrodes need to be covered with a certain types of catalysts. The materials used here are very costly materials like iridium and palatinum. This increases the initial cost of fuel cells.

HYDROGEN STORAGE: - The storage of hydrogen is much more complex than that of fossil fuels. So this increases the overall cost of using hydrogen as fuels.

INFRASTRUCTURES: - Fossil fuels are being used for many decades. So the infrastructure is based on fossil fuels only. We need to develop the infrastructure for hydrogen based energy for the large scale usage of it.

CONCLUSION: -

Despite of all the disadvantages hydrogen can still be considered as our way out from the dependency upon fossil fuels toward a future with clean and green energy. Many countries are coming forward with their plans in production and usage of hydrogen. In fact NASA is working on using hydrogen as a resource with the water produced as a by-product from it being used for drinking purpose by the astronauts. There are many more scopes in hydrogen based energy system which will save our world from environmental pollution. So we need to come forward with varieties of ideas to support this revolution in energy system which is in the verge of happening.