

# NON - CONVENTIONAL ENERGY SOURCES SUSTAINABLE POWER GENERATION

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**Abstract**— Renewable energy is clean, affordable, domestic and infinite. It produces no emissions and results in cleaner air & water for all. Electricity generation is the leading cause of industrial air pollution. Most of our electricity comes from coal, nuclear and other non-renewable power plants. Producing energy from these resources takes a severe toll on our environment, polluting our air, land & water. Renewable energy sources can be used to produce electricity with fewer environmental impacts. It is possible to make electricity from renewable energy sources without producing CO<sub>2</sub>. Solar energy is preferred most because it is a resource that is not only sustainable for energy consumption & it is indefinitely renewable (at least until the sun runs out in billions of years). Solar power can be used to generate electricity & use of skylights in home construction can also greatly reduce energy expenditure required to light rooms in a home interior during the day. Photovoltaic cells could have a sunny outlook as an energy source if they can overcome a couple of deficiencies. First and foremost, they don't generate power at night. And second, inexpensive single-junction PV cells only absorb a narrow band of wavelengths from sunlight. Clouds diminish the power of solar panels; especially in habitually foggy or overcast regions. To overcome these disadvantages we have to go for hydrogen fuel cells. By using solar energy, one mole of H<sub>2</sub>O can be dissociated into a mole of H<sub>2</sub> & half a mole of O<sub>2</sub> gas [electrolysis]. A fuel cell converts chemical energy directly into electricity by combining O<sub>2</sub> from the air with H<sub>2</sub> gas produced from electrolysis. Various industrialized countries have started identifying the most likely early markets for hydrogen as an energy carrier and fuel cells as power producing devices from micro- to macro-applications. The paper also presents possible future hydrogen energy utilization patterns for better environment and sustainable development. The interest in hydrogen as energy of the future is due to it being a clean energy, most abundant element in the universe, the lightest fuel and richest in energy per unit mass. It will provide cheap electricity, cook food, drive car, run factories, jet planes, hydrogen village and for all our domestic energy requirements. In short, hydrogen shows the solution and also allows the progressive and non-traumatic transition of today's energy sources, towards feasible safe reliable and complete sustainable energy chains. Fuel cells and other hydrogen-using technologies play a major role in a substantial transformation towards a more flexible, less vulnerable, distributed energy system which meets energy needs in a cleaner, more efficient and cost-effective way. This energy-system would be prime candidates for a risk management strategy against an uncertain future climate. With sunlight and water readily available in most parts of the world, the Solar-Hydrogen Generator can be connected to a conventional fuel cell to create a self-contained 24hours renewable electricity generator. During the day, solar energy is constantly stored as hydrogen. At any time during the day or night, the stored hydrogen can be converted to electricity through the fuel cell. Depending on the electricity demands of the user, which could be a house, an apartment, an office building, or a small community, the number of reactor vessels and storage tanks can be adjusted accordingly. Throughout the paper, current & future perspectives regarding sustainable development applications of hydrogen and electricity production in the present energy scenario are considered.

**Keywords**— a clean energy, fuel cell, power generation, present day applications

## I. INTRODUCTION

Energy is a key element of the interactions between nature and society and is considered a key input for the environment and sustainable development. Non-Conventional Energy Sources, such as solar and hydrogen energy will remain available for infinite period. One of the reasons of great worry for all of us is reducing sources of conventional energies. The rate of fossil fuel consumption is higher than the rate of the fossil fuel production by the nature. The results will be the scarcity of automobile fuel in the world which will create lot of problems in transport sector. The other aspect is pollution added by these sources in our environment which increases with more use of these sources, resulting in the poor quality of life on this planet. There is constant search of alternate fuel to solve energy shortage which can provide us energy without pollution. Hence, most frequently discussed source is hydrogen which when burnt in air produces a clean form of energy. This paper discusses some crucial energetic, environmental and sustainability issues and the role of hydrogen and fuel cell technologies as one of the potential solutions to these issues. Due to rising energy demand and reducing Conventional Energy Resources the use of "Renewable Energy" becomes important. The coming decade will see greater use of "Green Power" to ensure less dependence on "Fossil Fuels" and

to prevent environmental degradation which will result in improved quality of life of people. Energy is an important aspect in the development of any nation. In view of the rising energy demands and reducing sources of conventional energy; Energy Conservation, Management and Applications of the Non-Conventional Energy Sources becomes imperative. Hydrogen is a versatile energy carrier that can be used to power nearly every end-use energy need.

## II. HYDROGEN

### A. Why hydrogen?

A growing number of studies undertaken by companies, governments, academics or diverse institutions or NGOs attempt to evaluate long term non-carbon energy futures. Gasoline and diesel-powered vehicles emit greenhouse gases (GHGs), mostly carbon dioxide (CO<sub>2</sub>) that contributes to global climate change. Hydrogen energy is important part of developed nation's clean energy plan. Hydrogen is the most basic of all Earth elements. The hydrogen atom is made up of a single proton and a single electron. As such, it is very abundant, but it doesn't really exist as a separate form of matter. Instead it is usually combined with other elements. To separate hydrogen gas from its companion substances takes a lot of work but it produces a powerful, nearly clean source of energy. As a gas, it can be used in fuel cells to power engines. Fuel cell vehicles (FCVs) powered by pure hydrogen emit no GHGs from their tailpipe, only heat and water. Producing the hydrogen to power FCVs can generate GHGs, depending on the production method, but much less than that emitted by conventional gasoline and diesel vehicles. FCVs could reduce our dependence on foreign oil since hydrogen can be derived from domestic sources, such as natural gas and coal, as well as renewable resources such as water, biogas, and agricultural waste. That would make our economy less dependent on other countries and less vulnerable to oil price shocks from an increasingly volatile oil market. Highway vehicles emit a significant share of the air pollutants that contribute to smog and harmful particulates. In the U.S. FCVs powered by pure hydrogen emit no harmful pollutants. If the hydrogen is produced from fossil fuels, some pollutants are produced, but much less than the amount generated by conventional vehicle tailpipe emissions. Hydrogen is Lightest fuel, Richest in energy per unit mass, Can be stored easily, Can be produced by water, direct conversion into: thermal, mechanical and electrical energy. Hydrogen has established it as a viable source of energy and world over scientists are involved in making it commercially available source of energy because of its environment friendly nature, Clean Energy/without Pollution, Most abundant element in the universe.

### B. Reasons why India should switch to a Hydrogen Energy Economy:

Investing in hydrogen development would keep the INDIA in step with global competition. Relying on the Middle East for energy weakens national strength. The INDIA could be energy self sufficient with hydrogen. Converting to a hydrogen-based economy would create thousands of permanent scientific and industrial jobs. Someday, fossil fuels will run dry. Hydrogen is renewable and, therefore, unlimited. Solving energy supply problems today will ensure our nation's stability tomorrow. Pollution from cars and airplanes has created smog clouds across many cities of the country. Hydrogen emits no toxins. Huge oil spills are becoming common, killing countless water creatures. The effects on our food chain are unknown. If hydrogen were spilled, it would evaporate immediately. The only by-product of hydrogen fuel is water. Mass consumption of oil requires continued drilling into pristine wilderness areas, wreaking havoc on some of the world's greatest ecosystems. Hydrogen production leaves no environmental scars. Indian trade balance sheets show that oil imports drain lot of foreign currency from the Indian economy every week and the solution of hydrogen atoms in the bulk.

### C. Hydrogen production:

Most hydrogen produced today is made from natural gas in a process known as steam reforming. Because this is the cheapest and most firmly established method of producing hydrogen, it is likely to predominate until production technologies based on renewable energy resources become commercially competitive. All of the methods of producing hydrogen from renewable resources face technical and economic hurdles that must be overcome if hydrogen is to fuel a sustainable transportation economy. Nonetheless, within a decade, applied research could allow each of the following methods to play a vital role in producing commercial quantities of hydrogen. The first two methods listed below use highly developed technology, while the latter three are still in the early stages of development.

- Using electricity from renewable resources, such as hydropower, to split the water molecule through electrolysis.
- Converting organic matter into hydrogen through the gasification processes of partial oxidation, pyrolysis and steam reforming.
- Using sunlight to heat catalysts that trigger the splitting of water into hydrogen and oxygen.

- Collecting hydrogen generated as a waste product by some strains of algae and bacteria.
- Heating water to more than 5,600 degrees Fahrenheit to break the molecular bonds and make it decompose into its constituent parts.

Hydrogen is produced at low pressure but must be transported and dispensed at high pressure to reduce its volume to manageable levels. For applications supplied from a central Hydrogen production facility, the costs of compressing, transporting and storing the hydrogen fuel all add significantly to the cost of generating the gas. Electrolysers generate Hydrogen by splitting the water molecule  $H_2O$  into its constituent elements Hydrogen and Oxygen in a process which is the reverse of the electrochemical action which takes place in a fuel cell. An electric current is passed through the water between two electrodes. Hydrogen is formed at the cathode connected to the negative supply voltage terminal and Oxygen is formed at the anode connected to the positive supply voltage terminal. The rate at which Hydrogen is produced is directly proportional to the current passing between the electrodes. The calorific energy content of Hydrogen is about 39 kWh/Kg. Taking into account the process inefficiencies; it takes over 50 kWh of electricity to generate 1 Kg of Hydrogen. The conversion efficiency of the electrolysers used to create hydrogen is between 60% and 80% depending on the current and the materials used for the electrolytes and the electrodes.

#### D. Hydrogen storage:

Hydrogen is the lightest chemical element and offers the best energy to weight ratio of any fuel. The major drawback to using hydrogen is that it has the lowest storage density of all fuels. However, it is possible to store large quantities of hydrogen in its pure form by compressing it to very high pressure and storing it in containers which are designed and certified to withstand the pressures involved.

##### 1) Storage in Liquid Form

Liquid Hydrogen can be stored at low pressure (0.5 M Pa) (72.5 psi) but must be kept cold. Cooling circuits and insulation are needed to keep it below its boiling point of 20.3°K (-252.9°C). The weight of a tank and cooling system to hold 10 Kg of hydrogen is around 150 Kg. Considerable energy must also be expended to get the temperature down and to keep it there.

##### 2) Storage in Gaseous Form

Because of its low density in gaseous form, even at very high pressure, Hydrogen is not an attractive storage medium on a volumetric basis. For automotive use; the space reserved for fuel storage is limited. To hold sufficient Hydrogen in a reasonable sized container to power a vehicle over the industry benchmark of about 300 miles between regular fuelling stops, the gas must be stored at very high pressure. This needs expensive containment vessels made from carbon fibre or Kevlar capable of withstanding very high pressures of up to 70 M Pa (about 10,000 psi). Compressing a gas also requires energy to power the compressor and higher working pressures will mean that more energy will be lost to the compression step. The current generation of storage cylinders can store around 7.5% of Hydrogen by weight and higher pressure vessels storing over 10% by weight are under development.

##### 3) Storage in Hydride Form :

Certain metal hydrides have ability to absorb hydrogen rather like a sponge and to release it later, either at room temperature or through heating. Practical systems are able to absorb Hydrogen up to 1% or 2% of their weight or up to 5% or more at higher temperatures. Removing heat drives the adsorption process. Adding heat reverses the chemical reaction and causes the Hydrogen atoms to reform as Hydrogen molecules. The system operates at relatively low pressures of around 2.4 M Pa (350 psi) providing a safe method of storing and delivering Hydrogen at a constant pressure. It is likely however that the use of metal hydride Hydrogen storage will be confined to small applications because of the low energy density and the cost and time needed to fill and extract the Hydrogen. The performance of metal hydrides unfortunately deteriorates over time due to impurities in the gas which contaminate the active surface of the alloy.

### III. FUEL CELL

A fuel cell is a device that converts directly the chemical energy stored in gaseous molecules of fuel and oxidant into electrical energy. When the fuel is hydrogen the only by-products are pure water and heat. The overall process is the reverse of

water electrolysis. In electrolysis, an electric current applied to water produces hydrogen and oxygen; by reversing the process, hydrogen and oxygen are combined to produce electricity and water (and heat). the basic configuration of a single fuel cell is always composed of an ionic conductor separating two electronic conductors, whatever the specific materials constituting these different parts and the exact running conditions. The fuel is always oxidized at the anode and simultaneously, the oxidant is always reduced at the cathode leading to the formation of water and heat side-product without other emissions (when hydrogen is the fuel source). The operating temperature is determined by the temperature range at which the conductivity of the electrolyte used is sufficient for the transport of protons without losses, and its mechanical resistance is optimum. Low temperature fuel cells typically operate below 200°C whereas high temperature fuel cells operate above 600°C. In the intermediate temperature range, no fuel cells systems do exist yet due to a lack of suitable electrolytes. Both anodic and cathodic reactions can be catalysed by platinum. While hydrogen oxidation reaction (HOR) over Pt is intrinsically very fast, oxidation reduction reaction (ORR) over Pt is very slow. The voltage loss at the anode under practical current densities such as 0.4 A/cm<sup>2</sup> is about 10 mV and at the cathode is over 400 mV. Due to these kinetic limitations, energy lost is released as waste heat and the reaction is exothermic: cogenerated heat can be used outside the fuel cell in combined heat and power units.

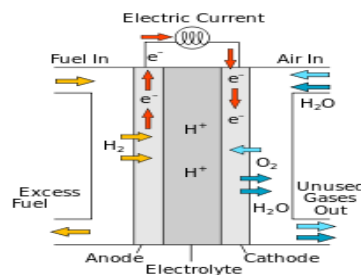


Fig.1. fuel cell working

At the anode:  $H_2 \rightarrow 2H^+ + 2e^-$

At the cathode:  $\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$

Combination of the two half-cell reactions gives the overall combustion reaction:  $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

The purpose of a fuel cell is to produce an electrical current that can be directed outside the cell to do work, such as powering an electric motor or illuminating a light bulb or a city. Because of the way electricity behaves, this current returns to the fuel cell, completing an electrical circuit. The chemical reactions that produce this current are the key to how a fuel cell works. There are several kinds of fuel cells, and each operates a bit differently. But in general terms, hydrogen atoms enter a fuel cell at the anode where a chemical reaction strips them of their electrons. The hydrogen atoms are now "ionized," and carry a positive electrical charge. The negatively charged electrons provide the current through wires to do work. If alternating current (AC) is needed, the DC output of the fuel cell must be routed through a conversion device called an inverter.

A. *Types of fuel cells*

- The Proton Exchange Membrane Fuel Cell (PEMFC)
- The Direct Methanol Fuel Cell (DMFC)
- The Alkaline Fuel Cell (AFC)
- The Phosphoric Acid Fuel Cell (PAFC)
- The Molten Carbonate Fuel Cell (MCFC)
- The Solid Oxide Fuel Cell (SOFC)

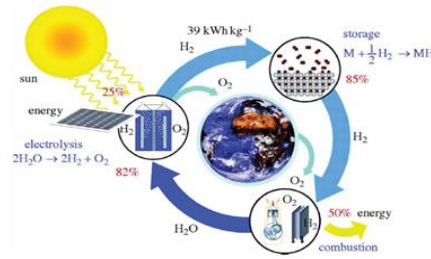


Fig.2.The Hydrogen Energy Cycle

#### IV. HYDROGEN POWER

Hydrogen power systems such as hydrogen fuel cells for electricity and heat generation can be extremely efficient over a large range of sizes (from one kilowatt to hundreds of megawatts). Some systems can achieve high efficiencies when heat production is combined with power generation. Additionally, smaller-scale distributed hydrogen systems offer combined heat, power and fuel opportunities. Fuel cell systems integrated with hydrogen production and storage can provide fuel for vehicles, energy for heating and cooling, and electricity to power our communities. These clean systems offer a unique opportunity for energy independence, highly reliable energy services, environmental and economic benefits. Hydrogen powered internal combustion engines can also be used with rotary generators to generate electricity as shown in the following diagram:

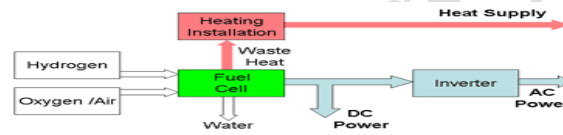


Fig.3.Fuel cells used in CHP applications

##### A. Hydrogen electric hybrids

By combining onboard engines or fuel cells that generate power with electrical systems that store power, electric hybrids may offer greater market potential than vehicles powered solely by single systems. Demonstrations of hybrid technology involving hydrogen indicate that these vehicles may be lighter, smaller, more versatile, and offer better performance than vehicles running solely on hydrogen engines, fuel cells, or batteries. Fuel cells are two to three times as energy efficient as combustion engines. An internal combustion engine loses more than 80 percent of the energy it generates, either as waste heat or friction. When a hydrogen fuel cell is used, the energy loss is 40 to 60 percent, so the percent of energy that is delivered as movement is much greater. Various technological hurdles must be overcome before fuel cells can compete effectively, in terms of overall performance and cost, with internal combustion engines in automotive applications. Fuel cell demonstration projects now under way around the world will likely yield improved solutions to these technical challenges.

##### B. Hydrogen power management

Though some fuel cells may be required to provide a steady operating current and voltage, most systems must be responsive to variable demands. This means that the system should provide for a variable output current and as a consequence, all the fuel, air and water flows must be varied accordingly. At the same time the heat dissipation will change and the temperature must be maintained within its designed operating range. The same will apply to the reformer if this is part of the system.

The fuel cell system output voltage is fixed but the application may require a different voltage or, in the case of most distributed power generators, an alternating current output. In these cases DC/DC converters or AC inverters may be an integral part of the system.



C. *Electrical Output*

1. Voltage

Fuel cells typically generate about 0.6 Volts to 0.9 Volts DC per cell. Due to the internal impedance and losses within the cell, the output voltage falls as the current is increased. Multiple cells in a stack must be used to provide higher voltages.

2. *Current and Power*

The current output from a single cell is directly proportional to the area of the electrodes. As with batteries the effective area of the electrodes and hence their potential current carrying capability can be increased without increasing their physical size by making the surface porous and using materials with very fine particle size. Typical power outputs are about 1 Watt /cm<sup>2</sup> of electrode plates.

3. *Dynamic Response*

PEM fuel cells operate at relatively low temperatures of around 80°C (176°F) which allow reasonably fast warm-up times (currently 10 to 20 seconds) compared with high temperature fuel cells which take as much as 30 minutes to reach their operating temperature. This is particularly important for automotive applications which require quick start-ups.

4. *Efficiency*

Because the energy conversion in fuel cells is accomplished in a single direct conversion process, much higher efficiencies are possible than with conventional electricity generation by means of steam turbines which involve three energy conversion processes.

**Fuel Cells**

**Chemical Energy ⇒ Electrical Energy**

**Steam Turbine Generators**

**Chemical Energy ⇒ Heat ⇒ Mechanical Energy ⇒ Electrical Energy**

Since the fuel cell energy conversion is a chemical process, the maximum efficiency is not determined by Carnot's Law which applies to heat engines. The energy released by a chemical reaction is determined by the change in Gibbs free energy. For the chemical reactions involved in fuel cells the maximum theoretical efficiency is over 85% which is between two and three times the typical efficiency of a heat engine. As noted above, the output voltage of a fuel cell falls as the current drawn from it increases. The net effect of this is that the efficiency also drops as the power drawn from the cell increases so that the efficiency is almost proportional to the output voltage. The typical operating efficiency of a fuel cell running at 0.7 Volts is about 50%. This means that 50% of the energy content of the hydrogen input is converted into electrical energy; while the remaining 50% will be dissipated as heat or lost through incomplete oxidation within the cells. The waste heat from the fuel cell electricity generating process can be used in combined heat and power (CHP) applications to provide local heating and thus improve the overall energy utilisation efficiency of the Hydrogen fuel. This is particularly attractive for high temperature fuel cell systems.

5. *TB -5000*

TROPICAL S.A. presents its all new TB-5000 Hydrogen Fuel Cell Power System, producing 5000W nominal electric power using the Proton Exchange Membrane (PEM) technology. The membrane on the fuel cell stack is converting hydrogen into electric power and the only "pollutant" is clean water. This power generator produces high quality electric power 110V or 230V AC & 12V, 24V or 48 DC (other voltages on request). It is designed to used as an Uninterruptable Power System (UPS), back-up power system, as a standalone power generator providing electricity to our homes, in grid back up, as solar hybrid, in telecommunication towers or military applications or remote applications.

## V. APPLICATIONS

### *Stationary applications (1 kW-5 MW)*

Among fuel cell applications, stationary applications are the most diversified category. This is due to a wide power range from one kW to multi MW, and many possible end users (civilian/military, industrial/utility services, private individuals...) with different objectives, specifications, and budgets. Requirements on size and weight are less critical and modularity is definitely an advantage: several types of fuel cells are eligible and a large spectrum of fuels is available.

Small stationary CHP fuel cell power plants (0.1-5 MW) are a good alternative in such remote locations where grid lines are expensive and/or difficult to install: islands, mountainous areas, sparsely populated regions, etc. They offer a competitive energy solution to many communities that are currently not connected to the electric grid without the need to build a heavy infrastructure. The low maintenance and fuel-transport associated costs, and a very limited environmental footprint make fuel cell remote power plants close-to-ideal for this application. Use of propane fuel is strongly considered as an early-adopter target market for rural residential areas and small businesses in remote sites. Alternatively, hydrogen could be produced by renewable energy sources (wind, hydro or solar) and used for local transport. Clearly, there is an avenue for market growth of decentralized power by fuel cells in an increasingly sustainable world. As compared to lead-acid battery and diesel-powered generators traditionally used by communication centers, fuel cell-powered UPS (0.5-200 kW) offer a greater reliability and more predictable performance over a wide range of operating conditions including harsher (colder/warmer) climates. They are well suited for powering networks for extended periods of time in data centers, banks, and other sensible government or commercial buildings where power interruption must be absolutely avoided. Backup power systems are being deployed across government agencies to demonstrate the increased security brought by fuel cells.

Larger stationary CHP fuel cell units (250-400 kW) can also be installed on the premises of an institutional building, e.g. school, hospital, industrial facility, and provide heat and primary power in addition to backup power. With a combined efficiency of 70-80%, cogeneration systems reduce primary energy consumption by 20 to 30%. Energy costs would be reduced especially during periods of peak demand. Moreover, along with high reliability, the voltage output delivered by fuel cells is consistently steadier than that coming from the electric grid. Voltage fluctuations, which are highly deleterious to computer systems, would be less than an issue with fuel cell powering.

### *Automotive applications (50-250 kW)*

This section is limited to the application of fuel cells for light-duty vehicle and bus propulsion. The other related application as an auxiliary power unit onboard the vehicle will be treated in the next section "Niche transport applications".

#### *Light-duty vehicles (50 kW)*

Almost all major car manufacturers have demonstrated prototype fuel cell vehicles and have announced plans for production and commercialization in the near to midterm future (5-10 years). The race to develop a viable fuel cell vehicle and bring it to market began during the 1990s and continues today. The key drivers for the development of automotive fuel cell technology are its efficiency, low or zero emissions, and fuel that could be produced from local sources rather than imported.

#### *Fuel cell buses*

As of August 2011, there were a total of approximately 100 fuel cell buses deployed around the world. Most buses are produced by UTC Power, Toyota, Ballard, Hydrogenics and Proton Motor. UTC Buses had accumulated over 970,000 km (600,000 mi) of driving by 2011. Fuel cell buses have a 39–141% higher fuel economy than diesel buses and natural gas buses. Fuel cell buses have been deployed around the world including in Whistler, Canada; San Francisco, United States; Hamburg, Germany; Shanghai, China; London, England; São Paulo, Brazil; as well as several others. The Fuel Cell Bus Club is a global cooperative effort in trial fuel cell buses. Notable Projects Include:

- 12 Fuel cell buses are being deployed in the Oakland and San Francisco Bay area of California.
- Daimler AG, with thirty-six experimental buses powered by Ballard Power Systems fuel cells completed a successful three-year trial, in eleven cities, in January 2007.

- A fleet of Thor buses with UTC Power fuel cells was deployed in California, operated by SunLine Transit Agency.

The first Brazilian hydrogen fuel cell bus prototype in Brazil was deployed in São Paulo. The bus was manufactured in Caxias do Sul and the hydrogen fuel will be produced in São Bernardo do Campo from water through electrolysis. The program, called "Ônibus Brasileiro a Hidrogênio" (Brazilian Hydrogen Auto bus), includes three additional buses.



Fig.4.Hydrogen fuelled bus

### Airplanes

Boeing researchers and industry partners throughout Europe conducted experimental flight tests in February 2008 of a manned airplane powered only by a fuel cell and lightweight batteries. The fuel cell demonstrator airplane, as it was called, used a proton exchange membrane (PEM) fuel cell/lithium-ion battery hybrid system to power an electric motor, which was coupled to a conventional propeller. In 2003, the world's first propeller-driven airplane to be powered entirely by a fuel cell was flown. The fuel cell was a unique Flat Stack design, which allowed the fuel cell to be integrated with the aerodynamic surfaces of the plane.

There have been several fuel-cell-powered unmanned aerial vehicles (UAV). A Horizon fuel cell UAV set the record distance flown for a small UAV in 2007. The military is especially interested in this application because of the low noise, low thermal signature and ability to attain high altitude. In 2009 the Naval Research Laboratory's (NRL's) Ion Tiger utilized a hydrogen-powered fuel cell and flew for 23 hours and 17 minutes. Fuel cells are also being used to provide auxiliary power in aircraft, replacing fossil fuel generators that were previously used to start the engines and power on board electrical needs. Fuel cells can help airplanes reduce CO<sub>2</sub> and other pollutant emissions and noise.



Fig.5.Hydrogen powered airplane

### Submarines:

The Type 212 submarines of the German and Italian navies use fuel cells to remain submerged for weeks without the need to surface. The U212A is a non-nuclear submarine developed by German naval shipyard Howaldtswerke Deutsche Werft. The system consists of nine PEM fuel cells, providing between 30 kW and 50 kW each. The ship is silent giving it an advantage in the detection of other submarines. A Recent naval paper has theorized about the possibility of a Nuclear-Fuel Cell Hybrid whereby the fuel cell is used when silent operations are required and then replenished from the Nuclear reactor (and water). Such a system could potentially give a submarine week of stealth capability at a time with the endurance of a Nuclear reactor. It is not known if any such submarines have been built.

### Portable power systems:

Portable power systems that use fuel cells can be used in the leisure sector (i.e. RV's, Cabins, Marine), the industrial sector (i.e. power for remote locations including gas/oil well sites, communication towers, security, weather stations etc.), and in the military sector. SFC Energy is a German manufacturer of direct methanol fuel cells for a variety of portable power systems. Ensol Systems Inc. is an integrator of portable power systems, using the SFC Energy DMFC.

## VI. MORE APPLICATIONS

- Providing power for base stations or cell sites
- Distributed generation
- Emergency power systems are a type of fuel cell system, which may include lighting, generators and other apparatus, to provide backup resources in a crisis or when regular systems fail. They find uses in a wide variety of settings from residential homes to hospitals, scientific laboratories, data centers,
- Telecommunication equipment and modern naval ships.
- An uninterrupted power supply (UPS) provides emergency power and, depending on the topology, provide line regulation as well to connected equipment by supplying power from a separate source when utility power is not available. Unlike a standby generator, it can provide instant protection from a momentary power interruption.
- Base load power plants
- Solar Hydrogen Fuel Cell Water Heating
- Hybrid vehicles, pairing the fuel cell with either an ICE or a battery.
- Notebook computers for applications where AC charging may not be readily available.
- Portable charging docks for small electronics (e.g. a belt clip that charges your cell phone or PDA).
- Smart phones, laptops and tablets.
- Small heating appliances
- Food preservation, achieved by exhausting the oxygen and automatically maintaining oxygen exhaustion in a shipping container, containing, for example, fresh fish.
- Breathalysers, where the amount of voltage generated by a fuel cell is used to determine the concentration of fuel (alcohol) in the sample.
- Carbon monoxide detector, electrochemical sensor.

## VII. ADVANTAGES

### A. Efficiency

Fuel cells combine many of the advantages of both internal combustion engines (ICE) and batteries. Thanks to the direct conversion of chemical energy into electrical energy, fuel cells are 2-3 times as efficient as ICEs for vehicle propulsion: the net electrical efficiency of a FC ranges between 40 and above 50% in a driving schedule, which is favourably compared to the 21-24% efficiency range of ICEs “from well to wheel”, i.e. accounting for the type of fuel used and its entire life cycle. Now if we add in the calculations the reforming process of gasoline and methanol or the use of compressed hydrogen in the calculations the efficiencies are 33, 38, and about 50%, respectively.

In cogeneration mode with simultaneous use of electricity and heat, a global efficiency has to be considered. This explains that stationary systems like fuel cell power plants can attain energy efficiencies of 85%. Thanks to the thermal yield the global efficiency is roughly doubled with respect to the use of electrical yield only.

**Readily Available:** Hydrogen is a great source of energy for a number of reasons; the biggest one being that it is so readily available. While it may take some work to access, there is no element in the universe as abundant as hydrogen.

**No Harmful Emissions:** Another advantage to using hydrogen energy is that when burned, it leaves almost no harmful by products. In fact, when used in NASA’s spaceships, the burned hydrogen gas leaves behind clean drinking water for the astronauts.

**Environment Friendly:** Hydrogen is also non-toxic, which makes it a rarity among fuel sources. Nuclear energy, coal, and gasoline are all either toxic or found in hazardous environments. This makes hydrogen ideal for use in a number of ways other fuel sources can’t compete against it.

**Used as Fuel in Rockets:** Hydrogen energy is also very powerful and very efficient. It’s powerful enough to propel spaceships and safer than using any other similar product to accomplish such an energy-intensive duty. In fact, hydrogen is three times as powerful as gasoline and similar fossil fuels, meaning it takes less of it to accomplish more.

**Fuel Efficient:** Hydrogen energy is very efficient fuel source than traditional sources of energy and produces more energy per pound of fuel. This clearly means that a car loaded with hydrogen fuel will go much farther than the one using same amount of traditional source of energy.



**Renewable:** Unlike non-renewable sources of energy which can't be produced again and again as they are limited; hydrogen energy can be produced on demand. Hydrogen is available in plenty. All we need is fossil fuels to break the water molecules to separate it from oxygen.

### VIII. CONCLUSION

Hydrogen fuel cell vehicle does not generate any pollution and is qualified as Zero Emission Vehicle (ZEV). If another fuel is used and reformed onboard, the propulsion system has some emissions generated during the reforming process, but those emissions are in general still much lower than the emissions from an internal combustion engine (ICE); therefore the fuel cell vehicles using a fuel reformer are typically qualified as Ultra Low Emission Vehicles (ULEV). Fuel cell-powered vehicles also generate significantly less greenhouse gases than the comparable gasoline-, diesel-, or methanol-powered ICEs. Hydrogen is the only fuel that results in a zero-emission vehicle, particularly if hydrogen is produced from renewable sources. Use of hydrogen as transportation fuel could reduce dependency on imported oil. A fuel cell system that runs on pure hydrogen is relatively simple, has the best performance, runs more efficiently, and has the longest stack life. Hydrogen is nontoxic and, despite its unfair reputation, has some very safe features. So, we can see a world of hydrogen in future.

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