A

Seminar report

On

Fuel Cell

Submitted in partial fulfillment of the requirement for the award of degree
Of Electronics

SUBMITTED TO:

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Preface

I have made this report file on the topic **Fuel Cell**; I have tried my best to elucidate all the relevant detail to the topic to be included in the report. While in the beginning I have tried to give a general view about this topic.

My efforts and wholehearted co-corporation of each and everyone has ended on a successful note. I express my sincere gratitude to …………..who assisting me throughout the preparation of this topic. I thank him for providing me the reinforcement, confidence and most importantly the track for the topic whenever I needed it.

Acknowledgement

I would like to thank respected Mr…….. and Mr. ……..for giving me such a wonderful opportunity to expand my knowledge for my own branch and giving me guidelines to present a seminar report. It helped me a lot to realize of what we study for.

Secondly, I would like to thank my parents who patiently helped me as i went through my work and helped to modify and eliminate some of the irrelevant or un-necessary stuffs.

Thirdly, I would like to thank my friends who helped me to make my work more organized and well-stacked till the end.

Next, I would thank Microsoft for developing such a wonderful tool like MS Word. It helped my work a lot to remain error-free.

Last but clearly not the least, I would thank The Almighty for giving me strength to complete my report on time.

Content

What is a fuel cell?

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes.

Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes.

Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution–much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless byproduct, namely water.

One detail of terminology: a single fuel cell generates a tiny amount of direct current (DC) electricity. In practice, many fuel cells are usually assembled into a stack. Cell or stack, the principles are the same.

History of Fuel cell

The first references to hydrogen fuel cells appeared in 1838. In a letter dated October 1838 but published in the December 1838 edition of *The London and Edinburgh Philosophical Magazine and Journal of Science*, Welsh physicist and barrister William Grove wrote about the development of his first crude fuel cells. He used a combination of sheet iron, copper and porcelain plates, and a solution of sulphate of copper and dilute acid. In a letter to the same publication written in December 1838 but published in June 1839, German physicist Christian Friedrich Schönbein discussed the first crude fuel cell that he had invented.

His letter discussed current generated from hydrogen and oxygen dissolved in water. Grove later sketched his design, in 1842, in the same journal. The fuel cell he made used similar materials to today's phosphoric-acid fuel cell. 9.

In 1939, British engineer Francis Thomas Bacon successfully developed a 5 kW stationary fuel cell. In 1955, W. Thomas Grubb, a chemist working for the General Electric Company (GE), further modified the original fuel cell design by using a sulphonated polystyrene ion-exchange membrane as the electrolyte. Three years later another GE chemist, Leonard Niedrach, devised a way of depositing platinum onto the membrane, which served as catalyst for the necessary hydrogen oxidation and oxygen reduction reactions. This became known as the "Grubb-Niedrach fuel cell".GE went on to develop this technology with NASA and McDonnell Aircraft, leading to its use during Project Gemini. This was the first commercial use of a fuel cell.

In 1959, a team led by Harry Ihrig built a 15 kW fuel cell tractor for Allis-Chalmers, which was demonstrated across the U.S. at state fairs. This system used potassium hydroxide as the electrolyte and compressed hydrogen and oxygen as the reactants. Later in 1959, Bacon and his colleagues demonstrated a practical five-kilowatt unit capable of powering a welding machine. In the 1960s, Pratt and Whitney licensed Bacon's U.S. patents for use in the U.S. space program to supply electricity and drinking water (hydrogen and oxygen being readily available from the spacecraft tanks). In 1991, the first hydrogen fuel cell automobile was developed by Roger Billings.

UTC Power was the first company to manufacture and commercialize a large, stationary fuel cell system for use as a co-generation power plant in hospitals, universities and large office buildings.

Why Fuel Cells

Stationary fuel cells are an economically compelling solution for distributed electric power generation with continuous baseload availability. This “green” technology has become increasingly popular with facilities looking to implement an environmentally-friendly electric power generation system without sacrificing efficiency, availability and performance.

1.4 MW DFC1500 at a municipal facility

Fuel cells make much more efficient use of fuels than other distributed generation technologies such as reciprocating engines and gas turbines, and generate virtually no pollution such as nitrogen oxide (NOx), sulfur oxide (SOx), or particulate matter (PM_{10}) and dramatically reduced carbon dioxide (CO_2). And with availability ratings better than 90%, fuel cells are not hampered by external influences such as time of day or weather that affect other environmentally-friendly technologies such as wind turbines and solar power.

Direct FuelCell® (DFC®) power plant systems from FuelCell Energy also offer many additional features that make them an attractive addition for a wide variety of applications. The ability to generate Combined Heat and Power (CHP) and utilize a variety of fuels such as anaerobic digestor gas also help to make DFC power plants from FuelCell Energy the most efficient and economical means of generating baseload power for a wide variety of facilities across multiple markets and industries.

Parts of Fuel Cell

Polymer electrolyte membrane (PEM) fuel cells are the current focus of research for fuel cell vehicle applications. PEM fuel cells are made from several layers of different materials. The main parts of a PEM fuel cell are described below.

The heart of a PEM fuel cell is the membrane electrode assembly (MEA), which includes the membrane, the catalyst layers, and gas diffusion layers (GDLs).

Hardware components used to incorporate an MEA into a fuel cell include gaskets, which provide a seal around the MEA to prevent leakage of gases, and bipolar plates, which are used to assemble individual PEM fuel cells into a fuel cell stack.

Membrane Electrode Assembly

The membrane, catalyst layers (anode and cathode), and diffusion media together form the membrane electrode assembly (MEA) of a PEM fuel cell.

- **Polymer electrolyte membrane.** The polymer electrolyte membrane, or PEM (also called a proton exchange membrane)—a specially treated material that looks something like ordinary kitchen plastic wrap—conducts only positively charged ions and blocks the electrons. The PEM is the key to the fuel cell technology; it must permit only the necessary ions to pass between the anode and cathode. Other substances passing through the electrolyte would disrupt the chemical reaction. For transportation applications, the membrane is very thin—in some cases under 10 microns.
- **Catalyst layers.** A layer of catalyst is added on both sides of the membrane—the anode layer on one side and the cathode layer on the other. Conventional catalyst layers include nanometer-sized particles of platinum dispersed on a high-surface-area carbon support. This supported platinum catalyst is mixed with an ion-conducting polymer (ionomer) and sandwiched between the membrane and the GDLs. On the anode side, the platinum catalyst enables hydrogen molecules to be oxidized. On the cathode side, the platinum catalyst enables oxygen by reacting with the hydrogen ions generated by the anode, producing water. The ionomer mixed into the catalyst layers allows the hydrogen ions to conduct through these layers.
- **Gas diffusion layers.** The GDLs sit outside the catalyst layers and facilitate transport of reactants into the catalyst layer, as well as removal of product water. Each GDL is typically composed of a sheet of carbon paper in which the carbon fibers are partially coated with polytetrafluoroethylene (PTFE). Gases diffuse rapidly through the pores in the GDL. These pores are kept open by the hydrophobic PTFE, which prevents excessive water buildup. In many cases, the inner surface of the GDL is coated with a thin layer of high-surface-area carbon mixed with PTFE, called the microporous layer. The microporous layer can help adjust the balance between water retention (needed to maintain membrane conductivity) and water release (needed to keep the pores open so hydrogen and oxygen can diffuse into the electrodes).

Hardware

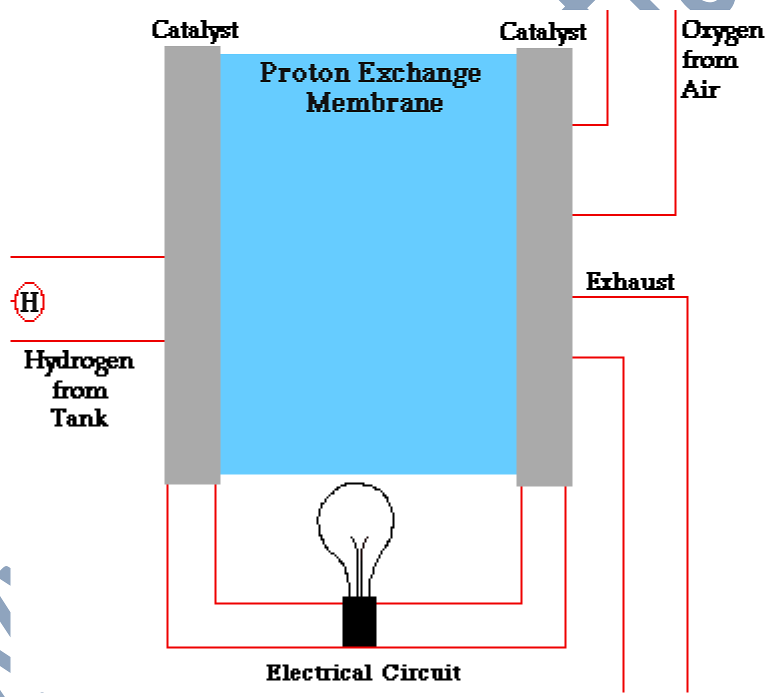
The MEA is the part of the fuel cell where power is produced, but hardware components are required to enable effective MEA operation.

- **Bipolar plates.** Each individual MEA produces less than 1 V under typical operating conditions, but most applications require higher voltages. Therefore, multiple MEAs are usually connected in series by stacking them on top of each other to provide a usable output voltage. Each cell in the stack is sandwiched between two bipolar plates to separate it from neighboring cells. These plates, which may be made of metal, carbon, or composites, provide electrical conduction between cells, as well as providing physical strength to the stack. The surfaces of the plates typically contain a "flow field," which is a set of channels machined or stamped into the plate to allow gases to flow over the MEA. Additional channels inside each plate may be used to circulate a liquid coolant.
- **Gaskets.** Each MEA in a fuel cell stack is sandwiched between two bipolar plates, but gaskets must be added around the edges of the MEA to make a gas-tight seal. These gaskets are usually made of a rubbery polymer.

How do fuel cells work?

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. (To learn more about electricity and electric power, visit "Throw The Switch" on the Smithsonian website Powering a Generation of Change.) 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.



Graphic by Marc Marshall, Schatz Energy Research Center

Oxygen enters the fuel cell at the cathode and, in some cell types (like the one illustrated above), it there combines with electrons returning from the electrical circuit and hydrogen ions that have traveled through the electrolyte from the anode. In other cell types the oxygen picks up electrons and then travels through the electrolyte to the anode, where it combines with hydrogen ions.

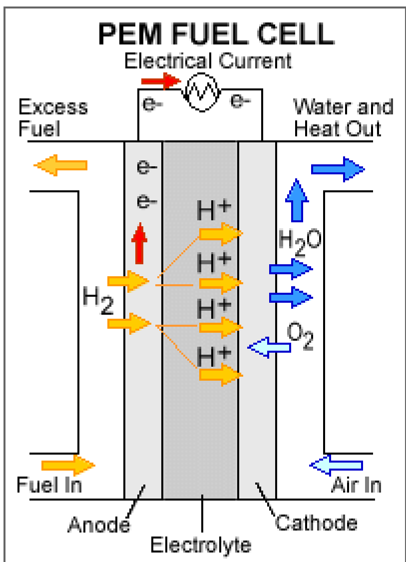
The electrolyte plays a key role. It must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction.

Whether they combine at anode or cathode, together hydrogen and oxygen form water, which drains from the cell. As long as a fuel cell is supplied with hydrogen and oxygen, it will generate electricity.

Even better, since fuel cells create electricity chemically, rather than by combustion, they are not subject to the thermodynamic laws that limit a conventional power plant (see "Carnot Limit" in the glossary). Therefore, fuel cells are more efficient in extracting energy from a fuel. Waste heat from some cells can also be harnessed, boosting system efficiency still further.

Types of Fuel Cells

Polymer Electrolyte Membrane Fuel Cells



Polymer electrolyte membrane (PEM) fuel cells—also called proton exchange membrane fuel cells—deliver high power density and offer the advantages of low weight and volume compared with other fuel cells. PEM fuel cells use a solid polymer as an electrolyte and porous carbon electrodes containing a platinum or platinum alloy catalyst. They need only hydrogen, oxygen from the air, and water to operate and do not require corrosive fluids like some fuel cells do. They are typically fueled with pure hydrogen supplied from storage tanks or reformers.

PEM fuel cells operate at relatively low temperatures, around 80°C (176°F). Low-temperature operation allows them to start quickly (less warm-up time) and results in less wear on system components, resulting in better durability. However, it requires that a noble-metal catalyst (typically platinum) be used to separate the hydrogen's electrons and protons, adding to system cost. The platinum catalyst is also extremely sensitive to carbon monoxide poisoning, making it necessary to employ an additional reactor to reduce carbon monoxide in the fuel gas if the hydrogen is derived from a hydrocarbon fuel. This reactor also adds cost.

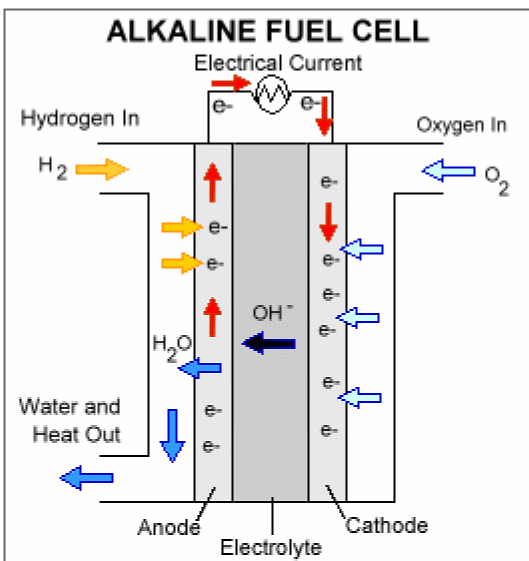
PEM fuel cells are used primarily for transportation applications and some stationary applications. Due to their fast startup time and favorable power-to-weight ratio, PEM fuel cells are particularly suitable for use in passenger vehicles, such as cars and buses.

Direct Methanol Fuel Cells

Most fuel cells are powered by hydrogen, which can be fed to the fuel cell system directly or can be generated within the fuel cell system by reforming hydrogen-rich fuels such as methanol, ethanol, and hydrocarbon fuels. Direct methanol fuel cells (DMFCs), however, are powered by pure methanol, which is usually mixed with water and fed directly to the fuel cell anode.

Direct methanol fuel cells do not have many of the fuel storage problems typical of some fuel cell systems because methanol has a higher energy density than hydrogen—though less than gasoline or diesel fuel. Methanol is also easier to transport and supply to the public using our current infrastructure because it is a liquid, like gasoline. DMFCs are often used to provide power for portable fuel cell applications such as cell phones or laptop computers.

Alkaline Fuel Cells

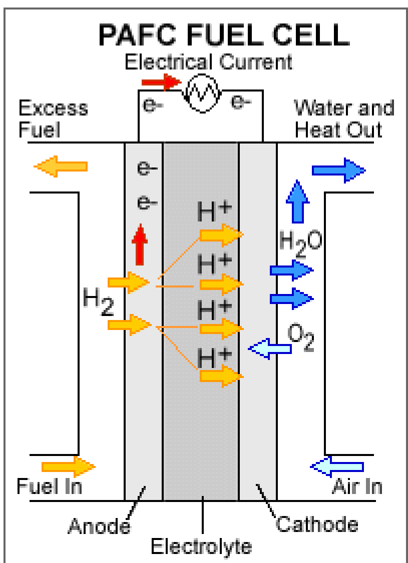


Alkaline fuel cells (AFCs) were one of the first fuel cell technologies developed, and they were the first type widely used in the U.S. space program to produce electrical energy and water on-board spacecraft. These fuel cells use a solution of potassium hydroxide in water as the electrolyte and can use a variety of non-precious metals as a catalyst at the anode and cathode. High-temperature AFCs operate at temperatures between 100°C and 250°C (212°F and 482°F). However, newer AFC designs operate at lower temperatures of roughly 23°C to 70°C (74°F to 158°F). In recent years, novel AFCs that use a polymer membrane as the electrolyte have been developed. These fuel cells are closely related to conventional PEM fuel cells, except that they use an alkaline membrane instead of an acid membrane. The high performance of AFCs is due to the rate at which electro-chemical reactions take place in the cell. They have also demonstrated efficiencies above 60% in space applications.

The disadvantage of this fuel cell type is that it is easily poisoned by carbon dioxide (CO_2). In fact, even the small amount of CO_2 in the air can affect this cell's operation, making it necessary to purify both the hydrogen and oxygen used in the cell. This purification process is costly. Susceptibility to poisoning also affects the cell's lifetime (the amount of time before it must be replaced), further adding to cost. Alkaline membrane cells have lower susceptibility to CO_2 poisoning than liquid-electrolyte AFCs do, but performance still suffers as a result of CO_2 that dissolves into the membrane.

Cost is less of a factor for remote locations, such as in space or under the sea. However, to compete effectively in most mainstream commercial markets, these fuel cells will have to become more cost-effective. To be economically viable in large-scale utility applications, AFCs need to reach operating times exceeding 40,000 hours, something that has not yet been achieved due to material durability issues. This obstacle is possibly the most significant in commercializing this fuel cell technology.

Phosphoric Acid Fuel Cells

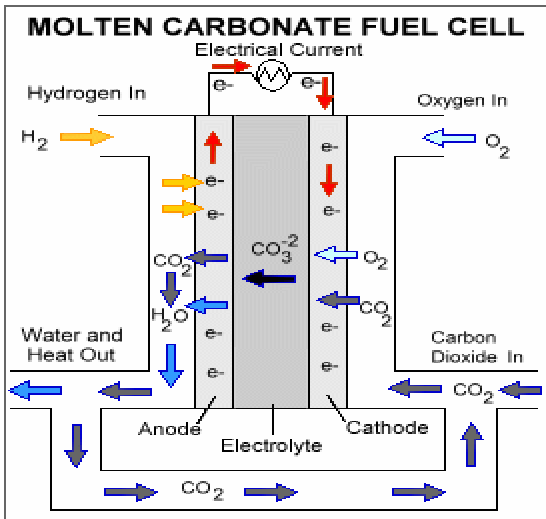


Phosphoric acid fuel cells (PAFCs) use liquid phosphoric acid as an electrolyte—the acid is contained in a Teflon-bonded silicon carbide matrix—and porous carbon electrodes containing a platinum catalyst. The electro-chemical reactions that take place in the cell are shown in the diagram to the right.

The PAFC is considered the "first generation" of modern fuel cells. It is one of the most mature cell types and the first to be used commercially. This type of fuel cell is typically used for stationary power generation, but some PAFCs have been used to power large vehicles such as city buses.

PAFCs are more tolerant of impurities in fossil fuels that have been reformed into hydrogen than PEM cells, which are easily "poisoned" by carbon monoxide because carbon monoxide binds to the platinum catalyst at the anode, decreasing the fuel cell's efficiency. PAFCs are more than 85% efficient when used for the co-generation of electricity and heat but they are less efficient at generating electricity alone (37%–42%). PAFC efficiency is only slightly more than that of combustion-based power plants, which typically operate at around 33% efficiency. PAFCs are also less powerful than other fuel cells, given the same weight and volume. As a result, these fuel cells are typically large and heavy. PAFCs are also expensive. They require much higher loadings of expensive platinum catalyst than other types of fuel cells do, which raises the cost.

Molten Carbonate Fuel Cells



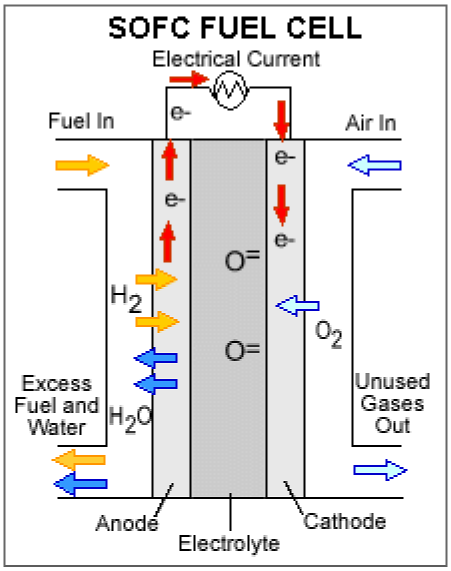
Molten carbonate fuel cells (MCFCs) are currently being developed for natural gas and coal-based power plants for electrical utility, industrial, and military applications. MCFCs are high-temperature fuel cells that use an electrolyte composed of a molten carbonate salt mixture suspended in a porous, chemically inert ceramic lithium aluminum oxide matrix. Because they operate at extremely high temperatures of 650°C (roughly 1,200°F) and above, non-precious metals can be used as catalysts at the anode and cathode, reducing costs.

Improved efficiency is another reason MCFCs offer significant cost reductions over phosphoric acid fuel cells. Molten carbonate fuel cells, when coupled with a turbine, can reach efficiencies approaching 65%, considerably higher than the 37%–42% efficiencies of a phosphoric acid fuel cell plant. When the waste heat is captured and used, overall fuel efficiencies can be over 85%.

Unlike alkaline, phosphoric acid, and PEM fuel cells, MCFCs do not require an external reformer to convert fuels such as natural gas and biogas to hydrogen. At the high temperatures at which MCFCs operate, methane and other light hydrocarbons in these fuels are converted to hydrogen within the fuel cell itself by a process called internal reforming, which also reduces cost.

The primary disadvantage of current MCFC technology is durability. The high temperatures at which these cells operate and the corrosive electrolyte used accelerate component breakdown and corrosion, decreasing cell life. Scientists are currently exploring corrosion-resistant materials for components as well as fuel cell designs that increase cell life without decreasing performance.

Solid Oxide Fuel Cells



Solid oxide fuel cells (SOFCs) use a hard, non-porous ceramic compound as the electrolyte. SOFCs are around 60% efficient at converting fuel to electricity. In applications designed to capture and utilize the system's waste heat (co-generation), overall fuel use efficiencies could top 85%.

SOFCs operate at very high temperatures—as high as 1,000°C (1,830°F). High-temperature operation removes the need for precious-metal catalyst, thereby reducing cost. It also allows SOFCs to reform fuels internally, which enables the use of a variety of fuels and reduces the cost associated with adding a reformer to the system.

SOFCs are also the most sulfur-resistant fuel cell type; they can tolerate several orders of magnitude more of sulfur than other cell types can. In addition, they are not poisoned by carbon monoxide, which can even be used as fuel. This property allows SOFCs to use natural gas, biogas, and gases made from coal. High-temperature operation has disadvantages. It results in a slow startup and requires significant thermal shielding to retain heat and protect personnel, which may be acceptable for utility applications but not for transportation. The high operating temperatures also place stringent durability requirements on materials. The development of low-cost materials with high durability at cell operating temperatures is the key technical challenge facing this technology.

Scientists are currently exploring the potential for developing lower-temperature SOFCs operating at or below 700°C that have fewer durability problems and cost less. Lower-temperature SOFCs produce less electrical power, however, and stack materials that will function in this lower temperature range are still under development.

Reversible Fuel Cells

Reversible fuel cells produce electricity from hydrogen and oxygen and generate heat and water as byproducts, just like other fuel cells. However, reversible fuel cell systems can also use electricity from solar power, wind power, or other sources to split water into oxygen and hydrogen fuel through a process called electrolysis. Reversible fuel cells can provide power when needed, but during times of high power production from other technologies (such as when high winds lead to an excess of available wind power), reversible fuel cells can store the excess energy in the form of hydrogen. This energy storage capability could be a key enabler for intermittent renewable energy technologies.

Applications

Power

Stationary fuel cells are used for commercial, industrial and residential primary and backup power generation. Fuel cells are very useful as power sources in remote locations, such as spacecraft, remote weather stations, large parks, communications centers, rural locations including research stations, and in certain military applications. A fuel cell system running on hydrogen can be compact and lightweight, and have no major moving parts. Because fuel cells have no moving parts and do not involve combustion, in ideal conditions they can achieve up to 99.9999% reliability. This equates to less than one minute of downtime in a six-year period.

Since fuel cell electrolyzer systems do not store fuel in themselves, but rather rely on external storage units, they can be successfully applied in large-scale energy storage, rural areas being one example. There are many different types of stationary fuel cells so efficiencies vary, but most are between 40% and 60% energy efficient. However, when the fuel cell's waste heat is used to heat a building in a cogeneration system this efficiency can increase to 85%. This is significantly more efficient than traditional coal power plants, which are only about one third energy efficient. Assuming production at scale, fuel cells could save 20–40% on energy costs when used in cogeneration systems. Fuel cells are also much cleaner than traditional power generation; a fuel cell power plant using natural gas as a hydrogen source would create less than one ounce of pollution (other than CO_2) for every 1,000 kW·h produced, compared to 25 pounds of pollutants generated by conventional combustion systems. Fuel Cells also produce 97% less nitrogen oxide emissions than conventional coal-fired power plants.

One such pilot program is operating on Stuart Island in Washington State. There the Stuart Island Energy Initiativehas built a complete, closed-loop system: Solar panels power an electrolyzer, which makes hydrogen. The hydrogen is stored in a 500-U.S.-gallon (1,900 L) tank at 200 pounds per square inch (1,400 kPa), and runs a ReliOn fuel cell to provide full electric back-up to the off-the-grid residence. Another closed system loop was unveiled in late 2011 in Hempstead, NY.

Fuel cells can be used with low-quality gas from landfills or waste-water treatment plants to generate power and lower methane emissions. A 2.8 MW fuel cell plant in California is said to be the largest of the type.

Cogeneration

Combined heat and power (CHP) fuel cell systems, including Micro combined heat and power (MicroCHP) systems are used to generate both electricity and heat for homes (see home fuel cell), office building and factories. The system generates constant electric power (selling excess power back to the grid when it is not consumed), and at the same time produces hot air and water from the waste heat. As the result CHP systems have the potential to save primary energy as they can make use of waste heat which is generally rejected by thermal energy conversion systems. A typical capacity range of home fuel cell is 1–3 kW_{el} / 4–8 kW_{th}. CHP systems linked to absorption chillers use their waste heat for refrigeration.

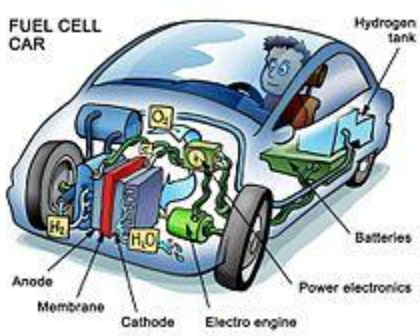
The waste heat from fuel cells can be diverted during the summer directly into the ground providing further cooling while the waste heat during winter can be pumped directly into the building. The University of Minnesota owns the patent rights to this type of system.

Co-generation systems can reach 85% efficiency (40–60% electric + remainder as thermal). Phosphoric-acid fuel cells (PAFC) comprise the largest segment of existing CHP products worldwide and can provide combined efficiencies close to 90%.Molten Carbonate (MCFC) and Solid Oxide Fuel Cells (SOFC) are also used for combined heat and power generation and have electrical energy efficiences around 60%.Disadvantages of co-generation systems include slow ramping up and down rates, high cost and short lifetime. Also their need to have a hot water storage tank to smooth out the thermal heat production was a serious disadvantage in the domestic market place where space in domestic properties is at a great premium.

Delta-ee consultants stated in 2013 that with 64% of global sales the fuel cell micro-combined heat and power passed the conventional systems in sales in 2012. The Japanese ENE FARM project will pass 100,000 FC mCHP systems in 2014, 34.213 PEMFC and 2.224 SOFC were installed in the period 2012-2014, 30,000 units on LNG and 6,000 on LPG.

Fuel cell electric vehicles (FCEVs)

Main articles: Fuel cell vehicle, Hydrogen vehicle and List of fuel cell vehicles



Configuration of components in a fuel cell car

Toyota Mirai

Element One fuel cell vehicle

Automobiles

As of 2015, two Fuel cell vehicles have been introduced for commercial lease and sale in limited quantities: the Toyota Mirai and the Hyundai ix35 FCEV. Additional demonstration models include the Honda FCX Clarity, and Mercedes-Benz F-Cell. As of June 2011 demonstration FCEVs had driven more than 4,800,000 km (3,000,000 mi), with more than 27,000 refuelings. Demonstration fuel cell vehicles have been produced with "a driving range of more than 400 km (250 mi) between refueling".They can be refueled in less than 5 minutes. The U.S. Department of Energy's Fuel Cell Technology Program claims that, as of 2011, fuel cells achieved 53–59% efficiency at one-quarter power and 42–53% vehicle efficiency at full power, and a durability of over 120,000 km (75,000 mi) with less than 10% degradation. In a Well-to-Wheels simulation analysis that "did not address the economics and market constraints", General Motors and its partners estimated that per mile traveled, a fuel cell electric vehicle running on compressed gaseous hydrogen produced from natural gas could use about 40% less energy and emit 45% less greenhouse gasses than an internal combustion vehicle. A lead engineer from the Department of Energy whose team is testing fuel cell cars said in 2011 that the potential appeal is that "these are full-function vehicles with no limitations on range or refueling rate so they are a direct replacement for any vehicle. For instance, if you drive a full sized SUV and pull a boat up into the mountains, you can do that with this technology and you can't with current battery-only vehicles, which are more geared toward city driving."

In 2014, Toyota introduced its first fuel cell vehicle in Japan, the Mirai, at a price of less than US$100,000, although former European Parliament President Pat Cox estimates that Toyota will initially lose about $100,000 on each Mirai sold. Hyundai introduced the limited production Hyundai ix35 FCEV. Other manufacturers that have announced intentions to sell fuel cell electric vehicles commercially by 2016 include General Motors, Honda, Mercedes-Benz, and Nissan.

Criticism

Some experts believe that fuel cell cars will never become economically competitive with other technologiesor that it will take decades for them to become profitable. Elon Musk stated in 2015 that fuel cells for use in cars will never be commercially viable because of the inefficiency of producing, transporting and storing hydrogen and the flammability of the gas, among other reasons. Professor Jeremy P. Meyers estimated in 2008 that cost reductions over a production ramp-up period will take about 20 years after fuel-cell cars are introduced before they will be able to compete commercially with current market technologies, including gasoline internal combustion engines. In 2011, the chairman and CEO of General Motors, Daniel Akerson, stated that while the cost of hydrogen fuel cell cars is decreasing: "The car is still too expensive and probably won't be practical until the 2020-plus period, I don't know."[104]

In 2012, Lux Research, Inc. issued a report that stated: "The dream of a hydrogen economy ... is no nearer". It concluded that "Capital cost ... will limit adoption to a mere 5.9 GW" by 2030, providing "a nearly insurmountable barrier to adoption, except in niche applications". The analysis concluded that, by 2030, PEM stationary market will reach $1 billion, while the vehicle market, including forklifts, will reach a total of $2 billion. Other analyses cite the lack of an extensive hydrogen infrastructure in the U.S. as an ongoing challenge to Fuel Cell Electric Vehicle commercialization. In 2006, a study for the IEEE showed that for hydrogen produced via electrolysis of water: "Only about 25% of the power generated from wind, water, or sun is converted to practical use." The study further noted that "Electricity obtained from hydrogen fuel cells appears to be four times as expensive as electricity drawn from the electrical transmission grid. ... Because of the high energy losses [hydrogen] cannot compete with electricity." Furthermore, the study found: "Natural gas reforming is not a sustainable solution"."The large amount of energy required to isolate hydrogen from natural compounds (water, natural gas, biomass), package the light gas by compression or liquefaction, transfer the energy carrier to the user, plus the energy lost when it is converted to useful electricity with fuel cells, leaves around 25% for practical use."

Joseph Romm, the author of *The Hype About Hydrogen* (2005), devoted two articles in 2014 to updating his critique of the use of fuel cells in cars. He stated that FCVs still had not overcome the following issues: high cost of the vehicles, high fueling cost, and a lack of fuel-delivery infrastructure. "It would take several miracles to overcome all of those problems simultaneously in the coming decades." Most importantly, he said, "FCVs aren't green" because of escaping methane during natural gas extraction and when hydrogen is produced, as 95% of it is, using the steam reforming process. He concluded that renewable energy cannot economically be used to make hydrogen for an FCV fleet "either now or in the future." Greentech Media's analyst reached similar conclusions in 2014.

In 2009, Steven Chu, then the United States Secretary of Energy, stated that hydrogen vehicles "will not be practical over the next 10 to 20 years". In 2012, however, Chu stated that he saw fuel cell cars as more economically feasible as natural gas prices have fallen and hydrogen reforming technologies have improved.

Buses

Toyota FCHV-BUS at the Expo 2005.

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.[115]
- 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 Autobus), includes three additional buses.

Forklifts

A fuel cell forklift (also called a fuel cell lift truck) is a fuel cell powered industrial forklift truck used to lift and transport materials. In 2013 there were over 4,000 fuel cell forklifts used in material handling in the US, of which only 500 received funding from DOE (2012). The global market is 1 million fork lifts per year. Fuel cell fleets are operated by various companies, including Sysco Foods, FedEx Freight, GENCO (at Wegmans, Coca-Cola, Kimberly Clark, and Whole Foods), and H-E-B Grocers. Europe demonstrated 30 Fuel cell forklifts with Hylift and extended it with HyLIFT-EUROPE to 200 units, with other projects in France and Austria. Pike Research stated in 2011 that fuel-cell-powered forklifts will be the largest driver of hydrogen fuel demand by 2020.

Most companies in Europe and the US do not use petroleum powered forklifts, as these vehicles work indoors where emissions must be controlled and instead use electric forklifts. Fuel-cell-powered forklifts can provide benefits over battery powered forklifts as they can work for a full 8-hour shift on a single tank of hydrogen and can be refueled in 3 minutes. Fuel cell-powered forklifts can be used in refrigerated warehouses, as their performance is not degraded by lower temperatures. The FC units are often designed as drop-in replacements.

Motorcycles and bicycles

In 2005 a British manufacturer of hydrogen-powered fuel cells, Intelligent Energy (IE), produced the first working hydrogen run motorcycle called the ENV (Emission Neutral Vehicle). The motorcycle holds enough fuel to run for four hours, and to travel 160 km (100 mi) in an urban area, at a top speed of 80 km/h (50 mph). In 2004 Honda developed a fuel-cell motorcycle that utilized the Honda FC Stack.

Other examples of motorbikesand bicyclesthat use hydrogen fuel cells include the Taiwanese company APFCT's scooter using the fueling system from Italy's Acta SpA and the Suzuki Burgman scooter with an IE fuel cell that received EU Whole Vehicle Type Approval in 2011. Suzuki Motor Corp. and IE have announced a joint venture to accelerate the commercialization of zero-emission vehicles.

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 FlatStack™ 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_2 and other pollutant emissions and noise.

Boats

The world's first certified Fuel Cell Boat (HYDRA), in Leipzig/Germany

The world's first fuel-cell boat HYDRA used an AFC system with 6.5 kW net output. Iceland has committed to converting its vast fishing fleet to use fuel cells to provide auxiliary power by 2015 and, eventually, to provide primary power in its boats. Amsterdam recently introduced its first fuel-cell-powered boat that ferries people around the city's famous and beautiful canals.

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 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).

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 wellsites, 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.

Advantages and Disadvantage of Fuel Cell

A fuel cell is a device that generates electricity by a chemical reaction. Every fuel cell has two electrodes, one positive and one negative, called, respectively, the anode and cathode. The reactions that produce electricity take place at the electrodes.

Every fuel cell also has an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which speeds the reactions at the electrodes. Hydrogen is the basic fuel, but fuel cells also require oxygen. One great appeal of fuel cells is that they generate electricity with very little pollution—much of the hydrogen and oxygen used in generating electricity ultimately combine to form a harmless by-product, namely water.

Hydrogen does not occur free in nature; it can be made by "re-forming" natural gas or another fossil fuel, or by using electricity to split ("electrolyze") water into its components of oxygen and hydrogen. In this sense, hydrogen is like electricity: the energy to generate it can be obtained from sources ranging from the burning of high-sulfur coal to pollution- free photovoltaic cells (solar cells).

Advantages:

1. Most abundant element:

Hydrogen is the most abundant element in the Universe, which makes up about 3/4 of all matter. Anywhere there is water (H_2O) you have hydrogen and oxygen.

2. Hydrogen has the highest energy content:

Energy content of hydrogen is the highest per unit of weight of any fuel. Therefore it offers the most "bang for the buck". When water is broken down into HHO, otherwise known as oxyhydrogen or Brown's Gas, it becomes a very, very efficient fuel.

3. Hydrogen is non-polluting:

Along with its effectiveness as a fuel, hydrogen is non-polluting. The only byproduct of hydrogen when it burns is heat and water.

4. Hydrogen is a renewable fuel source:

Hydrogen is very plentiful. The trick is to break the water molecules down to release it.

5. Reduce dependency on foreign oil:

It will greatly reduce the import of highly expensive oil demands of our country.

Disadvantages:

1. Hydrogen is currently very expensive, not because it is rare (it's the most common element in the universe!) but because it's difficult to generate, handle, and store, requiring bulky and heavy tanks like those for compressed natural gas (CNG) or complex insulating bottles if stored as a cryogenic (super-cold) liquid like liquefied natural gas (LNG).

2. It can also be stored at moderate temperatures and pressures in a tank containing a metal-hydride absorber or carbon absorber, though these are currently very expensive.

Conclusion

In the next hundred years, the world as we know it will undergo dramatic changes. As the world's supply of fossil fuels begins to reach total depletion, the leaders of government, industry and science scramble to find answers to the inevitable energy crisis.

Focusing on and developing renewable energy resources will not only dramatically affect the air quality and the environment, but it will also level the playing field in the global political arena. Implementing clean energy technology over the next century could save money, create jobs, reduce greenhouse emissions and sharply reduce air and water pollution. Clearly renewable energy is the key to sustainable development.

Reference

- www.google.com
- www.wikipedia.com
- www.studymafia.org