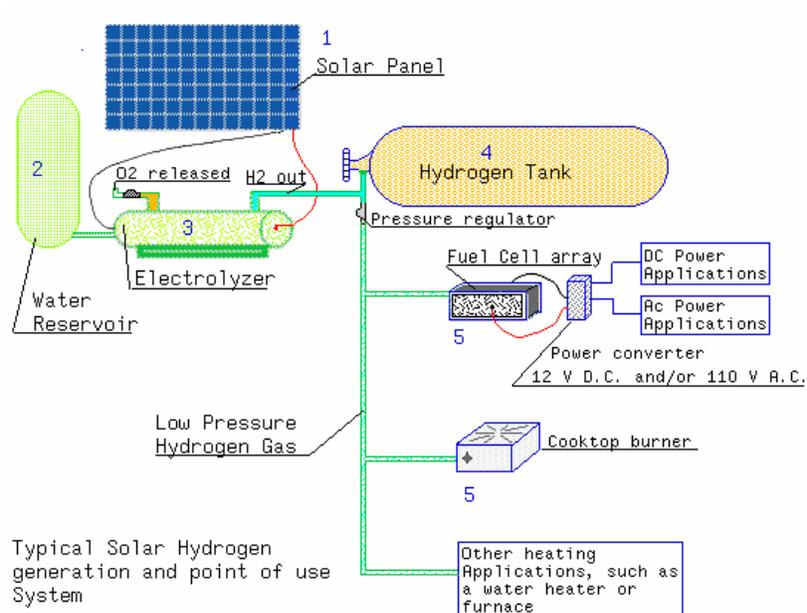


Fuel Cell Systems from Start to Finish

A Supplement Manual for Teaching Fuel Cells in the High

School Technology Education Classroom



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Introduction

Consider for a moment that availability of the electricity that powers your home will cease, whether due to the expenditure of our fossil fuels, currently burning in our power plants, or due to political disruption amongst foreign countries that are supplying most of these fuels. Would you know what to do? Would you want to wait for the utility company to figure out a solution? Do you even want or need to rely on the utility company? The answer is most definitely no. With the various means of alternative energy available and much more efficient, no home needs the utility grid (or bills) any longer. This manual was written after extensive research into one type of alternative residential energy, hydrogen powered fuel cells, in order to provide homeowners and home builders with the knowledge necessary to operate and power a home, and all of its energy components, on a clean and less expensive type of fuel. Upon reading and following this fuel cell manual, you gain the power and opportunity to leave the utility grid behind, forever. From various fuel types to the different kinds fuel cells available, from the required energy needs of a home to the installation requirements, and all other components that make a fuel cell system work, this manual covers how hydrogen, the most

abundant element on Earth, can set you free and run your home as luxuriously as you're used to.

Fuel Cell History

The fuel cell is over one hundred and sixty years old. In 1839 William Grove was experimenting with batteries and the electrolytic process when he came upon the idea of reversing the process to generate electricity.

Electrolysis uses electricity to separate hydrogen atoms from oxygen atoms in water molecules. Grove's idea was to instead combine oxygen and hydrogen to produce electricity, and water. With the use of a platinum catalyst electrode for this purpose, his efforts were successful. This research was fundamental to understanding the principles of the operation of a fuel cell.

Grove's "gas battery"

Grove called his invention a "gas battery." His fuel cell consisted of two platinum electrodes immersed in an electrolyte solution of sulfuric acid and water. This is the same type of electrolyte that is used in lead acid rechargeable batteries today. Grove was also the first person to put the fuel cell to practical work. In 1842 he connected fifty of his fuel cells together to power an electric arc. The gas battery did not attract much

attention even though Grove proved that it was a practical means of generating electricity.

Many years later, in 1889, Ludwig Mond and Charles Langer began experimenting with Grove's original concept. They were responsible for popularizing the term "fuel cell" in referring to the Grove gas battery. The name stuck and that is what we call them today. Mond and Langer's fuel cells used platinum electrodes with a clay barrier soaked in a sulphuric acid electrolyte. During this time Frederick Ostwald also researched and developed theories on the operation of the fuel cell, and later, during the first half of the 20th century, Emil Baur did experimental work with a variety of fuel cell configurations, using different electrolytes such as molten silver and clay mixed with metal oxides. His research was used by the British government to develop fuel cells for submarines.

In the late 1930s Francis Bacon designed and experimented with a fuel cell utilizing nickel gauze electrodes. Much of his later research and work found its way into the Apollo space program. In the 1950s Henry Karl Ihrig built the first fuel cell powered tractor.

Fuel cells today

During the 1980s and '90s fuel cell development took off in a big way and many small fuel cell power plants were

built. Today fuel cells are used in the NASA Space Shuttle as well as in terrestrial stationary and mobile applications with many new developments underway. They are more efficient and cleaner-running than the internal combustion engine and in the near future will probably replace those engines in motor vehicles. Automobile manufacturers now expect that fuel cells will be the prime source of power for passenger vehicles by approximately the year 2010. Fuel cells will soon power everything from laptop computers to home and industrial electrical systems.

Fuel Types

Hydrogen is an ideal element to create energy. It's clean, renewable, and can be locally produced in abundance. Its' future is great for the possibility of eliminating our nations dependence on other countries depleting fossil fuel resources. It is an advantage to convert our energy use to hydrogen because unlike oil, it has the ability to be transported and stored without spilling any toxins and chemicals that are harmful to the environment. It also runs clean so no harm is done to the atmosphere when using it to power and heat our homes.

The possibilities of hydrogen as a source of power are endless. However, this element is not found alone in nature. It's always attached to another molecule creating

compound matter. Fossil fuels like natural gas, petroleum derived gasses like methane and propane, and other fuels such as methanol, butane, and gasoline are all example of carbon and hydrogen compound matter that can be reformed for its hydrogen for its hydrogen property. Biomass, algae, and water are also fuel packages that contain hydrogen that can be separated and fed to a fuel cell to power our homes with electricity.

Hydrogen reformers

Hydrogen reformers remove hydrogen from fuels like propane, methane, natural gas, and other fuels. The three main processes used to take hydrogen from these fuels are called catalytic steam reforming, partial oxidation, and catalytic auto thermal reforming. And still in the stages of research and development phases is steam gasification reforming of biomass, and hydrogen production of algae via biophotolysis of water. The process used depends on the type of fuel being used for hydrogen reformation but the stages in each conversion process are all generally similar.

The fuel processing system works with a series of chemical reactors that extract and prepare hydrogen for fuel cell requirements and conditions. First, sulfur is removed from the fuel source. Next the fuel is broken down

to hydrogen, carbon monoxide, and carbon dioxide. This is the primary conversion stage. Steam is then used to increase the quantity of hydrogen. After primary conversion, a shift conversion reduces the carbon monoxide product by adding more steam. This also adds more hydrogen. The final steps are purification and conditioning. This process removes any impurities and prepares the hydrogen for fuel cell conditions. The hydrogen can then be fed through a pipe led to a fuel cell source or stored in a tank.

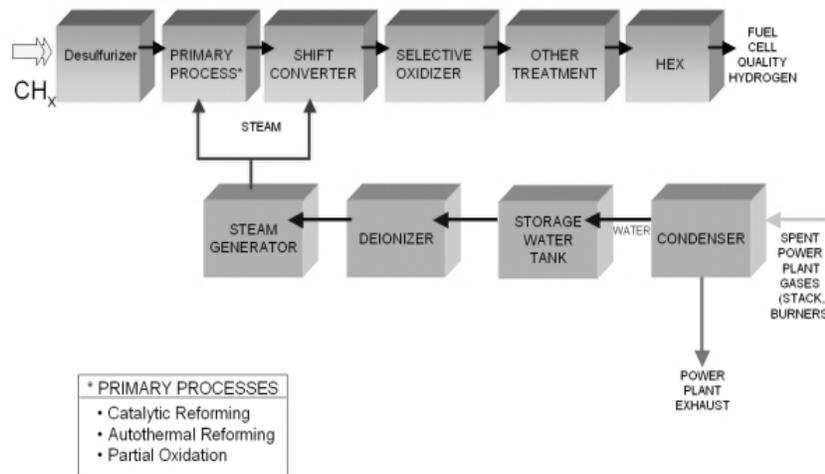


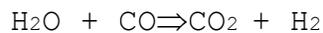
Figure 1 Basic Steps of Fuel Processing (Hydrogen Source)

Here is an example of how methanol is reformed during the catalytic steam reformation process. The molecular structure of methanol is:



The reformer removes the hydrogen and minimizes carbon monoxide pollutants by heating liquid methanol and water to

produce vaporization of the combined substances. The mix is passed through a heated chamber that contains a catalyst, which splits the methanol molecules into carbon monoxide and hydrogen. The water vapor is split into hydrogen and oxygen gases. The oxygen combines with the end product carbon monoxide end product from the methanol reaction and forms CO₂ releasing very little carbon monoxide, carbon dioxide and hydrogen (How Stuff Works, 2002).



Since there is no infrastructure or standardization for the transportation and storage of hydrogen, there is no service to have hydrogen gas brought to your home from a provider. However, small reformers for the home can be brought and will reform fuel from propane tanks or natural gas lines. The reformer can be powered by wind turbine, or solar panel connection to a fuel cell.



Figure 2 Small Fuel Processors for Home Use (Fuel Cell Store, 2002)

If one of our objectives in hydrogen reformation is to have a clean source of power, then here lies a problem.

The carbon end product in the reformation of fossil and other fuels is significantly less than that in a release of a burning combustion engine. Fuel processing may not be the most efficient process for eliminating carbon monoxide, and carbon dioxide in the atmosphere. To consider a clean atmosphere the production of hydrogen should involve no release of harmful pollutants into the air. There is a possibility of a pure hydrogen economy. In this case the hydrogen should come from renewable sources such as biomass, algae, and water. Production of hydrogen through water is the most advanced process of the three.

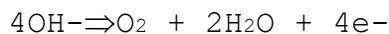
Electrolysis

Electrolysis can be defined as splitting water with electricity to produce hydrogen and oxygen. Electrolyzers are the units used to perform the process. Using a positive electrode called an anode, and a negative electrode called a cathode immersed in water containing an electrolyte solution such as lye to help conduct the flow of ions. A permeable membrane or a plastic mesh screen is set in the middle of the solution as a barrier to keep the electrodes from attracting. A power source like a battery, solar panels, or a wind turbine can be used to power the electrolyzer. At the cathode end a negative charge is generated by the power source that produces an electrical

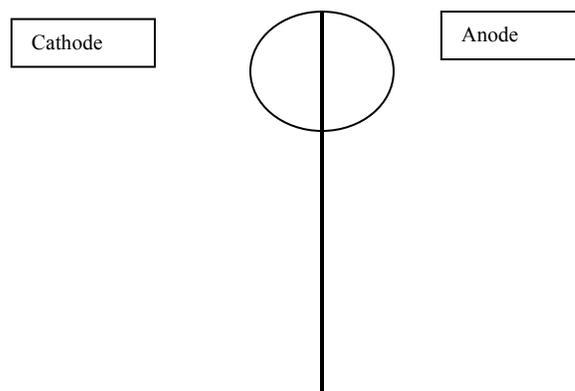
pressure through the water. The anode end is positively charged so it begins to absorb the flow of electrons. Water molecules at the cathode or negative end are split up into positively charged hydrogen ions (H+) and negatively charged hydroxide ions (OH-). Now the positive hydrogen atoms attract the electrons from the cathode and form a stable hydrogen molecule that travels to the surface.



The anode causes the negatively charged Hydroxide ions to travel to the anode for stability. The anode moves the negative charge from the hydroxide, and the hydrogen recombines with three other hydroxide molecules to form one molecule of oxygen and two of hydrogen. And finally stable oxygen bubbles travel to the surface.



Now, a closed circuit is created producing continuous supply hydrogen and oxygen elements.



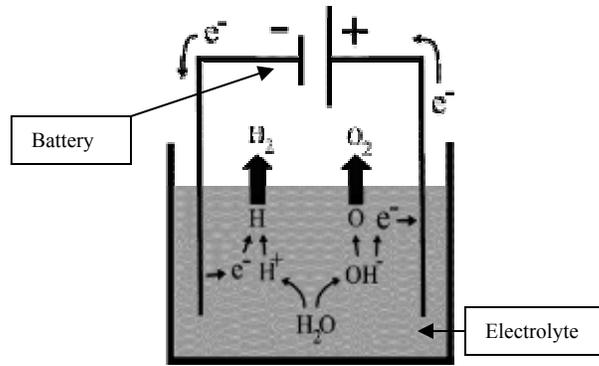


Figure 3 Electrolysis (New Mexico Solar Energy Association, 1999)

Electrolyzers can be bought or home built.



Figure 4 Small Home Appliance Electrolyzer (Fuel Cell Store, 2002)

One of the biggest challenges for making energy for a pure hydrogen economy through electrolysis is generating enough electricity without using fossil fuels that run the current utility grid as primary means of electricity to power the electrolysis process. To get pure hydrogen energy, solar cells, wind turbines hydroelectric dams, and other alternative energy sources can generate electricity

and can be done on a residential scale. However to have the independence of a pure hydrogen economy we would have to double our use of electricity to produce enough hydrogen before our society can enjoy its benefits.

Types of Fuel Cells

Steven Bodzin (1998) of the Home Energy Magazine writes that "on June 17, 1998, a single-family home in Latham, New York, became the first house to be powered entirely by a residential fuel cell (RFC). The fuel cell produces a steady 6 kW of power. It is equipped with batteries to accommodate a peak load of up to 10 kW. According to its manufacturer, Latham's Plug Power LLC, the device will eventually be able to generate electricity from natural gas for about 7 cents/kWh. This RFC is the first in what boosters hope will be a revolutionary change in residential power generation." The fuel cell is possibly the energy future of the world. It combines cheap, abundant, renewable energy with the amazing fact that the one waste they produce is water. With this technology our reliance on the Middle East and their oil supply will become a thing of the past. Imagine being able to have all of your energy need supplied by the sun. The introduction of fuel cell cars will bring with it the ability to fill up with fuel right at your house.

There are essentially nine different types of fuel cell; Proton Exchange Membrane Fuel Cells (PEMFC), Alkaline Fuel Cells (AFC), Phosphoric-acid Fuel Cells (PAFC), Solid Oxide Fuel Cells (SOFC), Molten Carbonate Fuel Cells (MCFC), Protonic Ceramic Fuel Cell (PCFC), Zinc-Air Fuel Cells (ZAFC), Direct Methanol Fuel Cells (DMCF), and Regenerative Fuel Cells (RFC). Of these nine, only the Proton Exchange Membrane is feasible for automobile and residential use, although the regenerative fuel cell is a possibility in that arena as well in the future. Most of the research right now is being done with the PEMFC (How Stuff Works, 2002).

Proton Exchange Membrane (PEM)

The Proton Exchange Membrane Fuel Cell uses one of the simplest reactions of any fuel cell. Invented by G.E. in the 1950's the Proton Exchange Membrane Fuel Cell was used by NASA to power the Gemini space project.

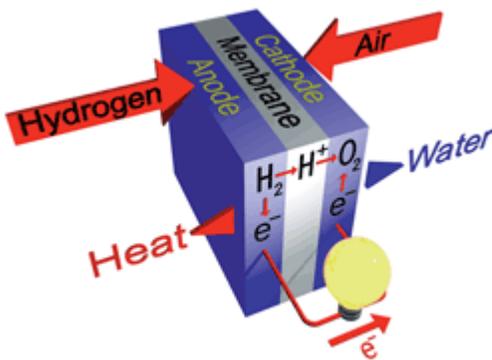


Figure 5 Basic PEM Fuel Cell Design (Fuel Cell Today, 2002)

Within the PEM there is a thin polymer membrane, such as poly perfluorosulphonic acid, which is permeable to protons but not electrons. The electrodes are usually made from carbon. As the hydrogen is released into the fuel cell on the anode side it is split into hydrogen ions and electrons. The hydrogen ions pass through the electrolyte membrane to the cathode while the electrons are diverted through an external circuit and provide power. Oxygen, in the form of air, is supplied to the cathode side and combines with the electrons and the hydrogen ions to make water (Fuel Cell Today, 2002).

These fuel Cells operate at about 80 degrees C. At this low temperature electrochemical reactions occur very slowly. To speed up the reaction a thin layer of platinum is attached to each electrode. Each electrode/electrolyte unit, or MEA (membrane electrode assembly), is placed between two field flow plates to complete the fuel cell. These plates have groves cut into them that help route the fuel to the electrodes and then conduct the electrons away from the assembly. Each fuel cell will produce about 0.7 volts which is enough to power one light bulb. To generate enough power for a home we have to place many of these fuel

cells together into a fuel cell stack (Fuel Cell Today, 2002).

PEM Fuel Cells are prime candidates for automotive and residential uses because the low operation temperatures allow for fast start up and they have a high power density which makes them compact. PEM Fuel Cells are also very efficient producing about 40-50% of the maximum theoretical voltage, and they can vary their output quickly based on shifts in demand (Fuel Cell Today, 2002).

The main barriers to PEM Fuel Cells are that the membrane materials and catalysts are still relatively expensive. Current research is being conducted to develop less expensive replacement for these materials. Another barrier is that they require pure hydrogen to operate and can be poisoned by impurities such as carbon monoxide. This susceptibility to poisoning can be attributed to the low operating temperature which requires the use of a highly sensitive catalyst. Again, current research is being done to eliminate this problem.

Alkaline Fuel Cells (AFC)

AFC's are another fuel cell that has been widely used by NASA to produce energy and drinking water for the US Space Shuttle. Their operating temperature is 150 to 200 degrees C (about 300 to 400 degrees F). They use an aqueous

solution of alkaline potassium hydroxide soaked in a matrix as the electrolyte. This is advantageous because the cathode reaction is faster in the alkaline electrolyte, which means higher performance. Until recently they were too costly for commercial applications, but several companies are examining ways to reduce costs and improve operating flexibility. They typically have a cell output from 300 watts to 5 kW (Fuel Cell Today, 2002).

Phosphoric-acid Fuel Cells (PAFC)

The phosphoric acid fuel cell is currently the most commercially advanced fuel cell technology. As the name suggests, these cells use liquid phosphoric acid as the electrolyte, usually contained in a silicone carbide matrix. Phosphoric acid cells work at slightly higher temperatures than PEM or alkaline fuel cells - around 150 to 200°C - but still require platinum catalysts on the electrodes to promote reactivity. The anode and cathode reactions are the same as those in the PEM fuel cell with the cathode reaction occurring at a faster rate due to the higher operating temperature.

This increased temperature also imparts a slightly higher tolerance to impurities and phosphoric acid cells can function with 1-2 per cent carbon monoxide and a few ppm of sulphur in the reactant streams.

The efficiency of phosphoric acid cells is lower than that of other fuel cell systems, at around 40 per cent, and these systems also take longer to warm up than PEM cells. Despite these drawbacks, there are a number of advantages of this technology including simple construction, stability and low electrolyte volatility. Phosphoric cells have been used to power buses and a number of these units are in operation but it is unlikely that these cells will ever be used in private vehicles. A considerable research effort over the last 20 years has, however, resulted in phosphoric acid cells being successfully developed for stationary applications. There are currently a number of working units with outputs ranging from 0.2-20MW installed around the world providing power to hospitals, schools and small power stations (Fuel Cell Today, 2002).

Solid Oxide Fuel Cells (SOFC)

Solid oxide fuel cells work at even higher temperatures than molten carbonate cells. They use a solid ceramic electrolyte, such as zirconium oxide stabilized with yttrium oxide, instead of a liquid and operate at 800 - 1,000°C.

In these fuel cells, energy is generated by the migration of oxygen anions from the cathode to the anode to oxidize the fuel gas, which is typically a mixture of

hydrogen and carbon monoxide. The electrons generated at the anode move via an external circuit back to the cathode where they reduce the incoming oxygen, thereby completing the cycle.

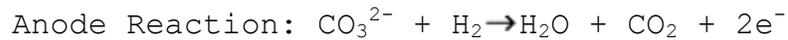
As with the molten carbonate fuel cell, the high temperature means that these cells are resistant to poisoning by carbon monoxide as this it is readily oxidized to carbon dioxide, as shown above. This removes the need for external reforming to extract hydrogen from fuel and these cells can again use petroleum or natural gas directly. Solid oxide fuel cells also exhibit the highest tolerance to sulphur contamination of all the technologies so far. These cells are more stable than MCFCs due to the solid electrolyte but the construction materials needed to contain the high temperatures generated tend to be more expensive.

These cells can reach efficiencies of around 60 per cent and are expected to be used for generating electricity and heat in industry and potentially for providing auxiliary power in vehicles (Fuel Cell Today, 2002).

Molten Carbonate Fuel Cells (MCFC)

Molten carbonate fuel cells work quite differently from those discussed so far. These cells use either molten lithium potassium or lithium sodium carbonate salts as the

electrolyte. When heated to a temperature of around 650°C these salts melt and generate carbonate ions which flow from the cathode to the anode where they combine with hydrogen to give water, carbon dioxide and electrons. These electrons are routed through an external circuit back to the cathode, generating power on the way.



The high temperature at which these cells operate means that they are able to internally reform hydrocarbons, such as natural gas and petroleum, to generate hydrogen within the fuel cell structure. At these elevated temperatures there is no problem with carbon monoxide poisoning, although sulphur remains a problem, and the platinum catalysts can be substituted for less expensive nickel species. The excess heat generated can also be harnessed and used in combined heat and power plants. These fuel cells can work at up to 60 per cent efficiency and this could potentially rise to 80 per cent if the waste heat is utilized (Fuel Cell Today, 2002).

The high temperatures do, however, present some problems. The cells take a considerable time to reach the operating temperature, making them unsuitable for transport applications and the temperature and corrosive nature of

the electrolyte probably mean that they are unsafe for home power generation. The high power generating efficiencies mean that they are attractive for use in large-scale industrial processes and electricity generating turbines. Current demonstration cells have produced up to 2 MW but designs up to 50 and 100 MW capacities are on the drawing board (Fuel Cell Today, 2002).

Direct Methanol Fuel Cells (DMFC)

These cells are similar to the PEM cells in that they both use a polymer membrane as the electrolyte. However, in the DMFC, the anode catalyst itself draws the hydrogen from the liquid methanol, eliminating the need for a fuel reformer. Efficiencies of about 40% are expected with this type of fuel cell, which would typically operate at a temperature between 120-190 degrees F or 50 -100 degrees C. This is a relatively low range, making this fuel cell attractive for tiny to mid-sized applications, to power cellular phones and laptops. Higher efficiencies are achieved at higher temperatures. A major problem, however, is fuel crossing over from the anode to the cathode without producing electricity. Many companies have said they solved this problem, however. They are working on DMFC prototypes used by the military for powering electronic equipment in the field (Fuel Cell Today, 2002).

Regenerative Fuel Cells

Still a very young member of the fuel cell family, regenerative fuel cells would be attractive as a closed-loop form of power generation. Water is separated into hydrogen and oxygen by a solar-powered electrolyser. The hydrogen and oxygen are fed into the fuel cell which generates electricity, heat and water. The water is then recirculated back to the solar-powered electrolyser and the process begins again. These types of fuel cells are currently being researched by NASA and others worldwide (Fuel Cell Today, 2002).

Zinc-Air Fuel Cells (ZAFC)

In a typical zinc/air fuel cell, there is a gas diffusion electrode (GDE), a zinc anode separated by electrolyte, and some form of mechanical separators. The GDE is a permeable membrane that allows atmospheric oxygen to pass through. After the oxygen has converted into hydroxyl ions and water, the hydroxyl ions will travel through an electrolyte, and reaches the zinc anode. Here, it reacts with the zinc, and forms zinc oxide. This process creates an electrical potential; when a set of ZAFC cells are connected, the combined electrical potential of these cells can be used as a source of electric power. This electrochemical process is very similar to that of a PEM

fuel cell, but the refueling is very different and shares characteristics with batteries. Metallic Power is working on ZAFCs containing a zinc "fuel tank" and a zinc refrigerator that automatically and silently regenerates the fuel. In this closed-loop system, electricity is created as zinc and oxygen are mixed in the presence of an electrolyte (like a PEMFC), creating zinc oxide. Once fuel is used up, the system is connected to the grid and the process is reversed, leaving once again pure zinc fuel pellets. The key is that this reversing process takes only about 5 minutes to complete, so the battery recharging time hang up is not an issue. The chief advantage zinc-air technology has over other battery technologies is its high specific energy, which is a key factor that determines the running duration of a battery relative to its weight. When ZAFCs are used to power EVs, they have proven to deliver longer driving distances between refuels than any other EV batteries of similar weight. Moreover, due to the abundance of zinc on earth, the material costs for ZAFCs and zinc-air batteries are low. Hence, zinc-air technology has a potential wide range of applications, ranging from EVs, consumer electronics to military (Fuel Cell Today, 2002).

Protonic Ceramic Fuel Cell (PCFC)

This new type of fuel cell is based on a ceramic electrolyte material that exhibits high protonic conductivity at elevated temperatures. PCFCs share the thermal and kinetic advantages of high temperature operation at 700 degrees Celsius with molten carbonate and solid oxide fuel cells, while exhibiting all of the intrinsic benefits of proton conduction in polymer electrolyte and phosphoric acid fuel cells (PAFCs). The high operating temperature is necessary to achieve very high electrical fuel efficiency with hydrocarbon fuels. PCFCs can operate at high temperatures and electrochemically oxidize fossil fuels directly to the anode. This eliminates the intermediate step of producing hydrogen through the costly reforming process. Gaseous molecules of the hydrocarbon fuel are absorbed on the surface of the anode in the presence of water vapor, and hydrogen atoms are efficiently stripped off to be absorbed into the electrolyte, with carbon dioxide as the primary reaction product. Additionally, PCFCs have a solid electrolyte so the membrane cannot dry out as with PEM fuel cells, or liquid can't leak out as with PAFCs (Fuel Cell Today, 2002).

Residential Fuel Cells

Imagine a future where the electricity needed to run your home or business is generated from a small appliance located inside your building. All the electricity to run computer servers and sensitive electronics is generated right at the point of use - in the server rack itself, right next to that equipment. And imagine this "point of use" power being uninterruptible, digital quality power -- free from the power outages, surge and sag conditions, transients, and other problems inherent with grid-supplied power. Imagine generating electricity with no combustion, so the only emissions are a little heat and pure water (Avista Labs, 2002). Residential fuels will revolutionize the way we live our lives. There are three big things that we will be able to eliminate from our society that are currently damaging our environment and reducing our quality of life. Smog will be a thing of the past along with other air pollutions, the need for drilling in areas that are controversial because of the environmental damage caused by drilling, and our reliance on the Middle East, or any other country, for any kind of energy supply.

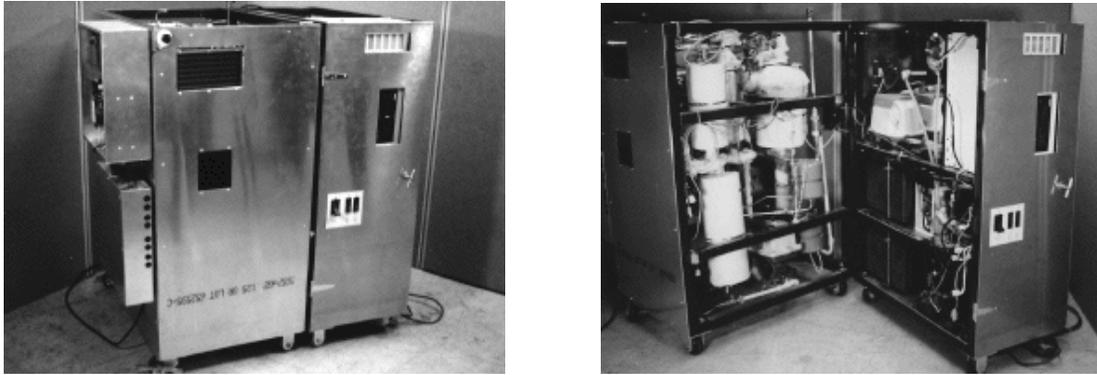


Figure 6 Residential Fuel Cells (Bodzin, 1998).

A big question that faces the RFC technology involves the maintenance issue. This is a very new technology that few consumers know much about. What will the average homeowner that invests in this technology be looking at down the road to maintain this unit? Manufacturers of the RFC's are promoting the virtually maintenance free life of these units. An annual checkup to replace air filters and the membranes need to be replaced every seven years.

Figure 7 lists a number of fuel cell manufacturers and their websites for further research. This list includes all types ranging from portable to residential and automotive to commercial.

Fuel Cell Manufacturers

The Fuel Cell Store – <http://www.fuelcellstore.com>

- Residential fuel cells available in fall of 2002

Avista Labs – <http://www.avistalabs.com>

- Portable and residential fuel cells available now

IdaTech - <http://www.idatech.com/>

- FCS 1200 1.2kW residential fuel cell: Available 2002

International Fuel Cells - <http://www.ifc.com/>

- 200 kW fuel cell power plant. Commercial/Industrial Sold over 200 units.

- PEM based stationary Fuel Cell Light Commercial/ Residential Expected in 2003

FuelCell Energy, Inc. - <http://www.fce.com/>

- 300 kW fuel cell power plant. Commercial Ready late '01, planned use in German hospital.

- >1 Mega Watt DFC(R) power plant. Commercial/Industrial use expected in 2001

H Power Corp. - <http://www.hpower.com/>

- 1-10 kW fuel cells Remote/Residential Late 2001.

- Sub-kW fuel cell products. Residential Now available

Plug Power, Inc. - <http://www.plugpower.com/>

- GE HomeGen 7000 -- 7-35 kW fuel cell. Residential use ready in 2002

Astris Energi, Inc. - <http://www.astrisfuelcell.com/>

- 4 kW home fuel cell system, fuel-cell driven golf cart.

Residential/Commercial use, ready in early 2001

Johnson Matthey Plc - <http://www.matthey.com>

- Micro-fuel cell, 2-50 kW. Residential use available as early as 2001

Figure 7 Fuel cell manufacturers

Power Inversion

For alternative energy systems, such as hydrogen-operated fuel cells, an inverter is essential for providing the necessary alternating current, or AC power needed by a standard household electrical system. Because a fuel cell produces electricity, but as a direct current, or DC power, at a lower voltage, and the various electrical components within a home run on AC power, fuel cell systems often come with, but will always require an inverter. A power

inverter essentially converts the low voltage direct current electricity to a higher voltage alternating current that satisfies the demands of most modern household appliances and resembles the type of current provided by the utility company. It is the reason that fuel cell systems in residential application don't warrant changing the numerous and varying electrical components and appliances within a home.

Inverters come in a wide variety of power capacities and one should be chosen according to the power needs, and supply from the fuel cell system, for each individual home application. An inverter is distinguished by the alternating current wave that they produce. The main two types are modified sine wave inverters and true sine wave inverters. An older, now obsolete type of inverter is called square wave, but is no longer considered a reliable way to invert power because it is not suited to run most modern household appliances. The modified sine wave inverter is the less expensive of the two main types; its sine wave resembles a stair step pattern. The wave, representing the power level, raises straight from zero to upper peak voltage, straight back to zero and then straight to lower peak voltage and back to zero, resting at each level momentarily. Modified sine wave inverters will run

many household appliances, perhaps a television or radio, but are known to produce occasional electrical noise. Sensitive equipment will run erratically or not at all on a modified inversion, but this type of inverter is suitable for RV solar-electrical systems and remote cabin applications, very efficiently.

The true sine wave inverters are the most reliable for household use; they provide the type power supplied by the utility company. Unlike the modified sine wave, true sine wave power passes from the upper and lower peak voltages in a smooth, curved wave, not in the stair step pattern. All appliances and electrical equipment will run as intended on true sine wave power and using a true sine wave inverter can produce AC power better than the utility company provides. Although these inverters are more expensive than modified sine wave inverters, the resulting power supply is more reliable and advantageous.

Power inverters are available in a wide variety of sizes, or power output capacity, which should be matched to the size of electrical load it is intended to run. Deciding and adding up the various circuits one may want to be powered through the inverter can determine this. There are two different output capacity ratings that apply to power inverters. One is the continuous output, or the

maximum wattage the inverter can supply on a long-term basis. The other is the inverter's surge capacity, which describes the output possible on a momentary basis, accounting for appliances such as refrigerators and water pumps that require up to three times as much energy to start up than they require running. Both output capacity ratings should be considered when selecting the size inverter needed for ones residential fuel cell system.

A great advantage to the use of inverters within grid-connected homes is that they allow the consumer to sell excess power back to the utility company. When an inverter is used in conjunction with solar, wind or water generators, the inverter can use the utility grid as an energy bank, storing excess alternative energy to be sold back to the utility company, or the cost/value to be deducted from the utility bill.

Mechanical Components

A residential fuel cell system, currently, will not include all the energy supply components needed in a residence. These components, primarily hot water supply, heat supply and electricity are dealt with individually with regard to fuel cell power provision. Although the Fuel Cell Store.Com does have a residential fuel cell that is all-inclusive with regard to these components, it is

very expensive, practically unaffordable. Only time and increased demand will lower the cost and increase the marketed selection and options of all-inclusive fuel cell systems.

Perhaps the most obvious energy component within a home is electricity, which is completely supplied by a fuel cell. With the addition of a power inverter, a fuel cell system addresses all the alternating current electrical voltage needs of a household. Every household appliance imaginable will run the way it is intended from electricity supplied by a fuel cell containing a power inverter. These appliances can also include a hot water heater and a furnace or heating element, although these components are very demanding of electric energy.

How water and heat could alternatively be supplied for a home from the excess heat energy produced from running a fuel cell. If a fuel cell system contains a storage component to trap the heat from the hydrogen conversion reaction, this heat can in turn be used to heat water and also be diffused throughout the home for heating purposes. This is the most efficient and effective way to operate a residence on a fuel cell system, for it provides all necessary energy, however these all inclusive fuel cell systems are rare and expensive. Another option for

heating a fuel cell operated home is to purchase a hydrogen-run heater or furnace. Because hydrogen is already in supply for the fuel cell, another line could easily be run to a furnace; eliminating the need for the excessive amount of electricity that furnace would need from the fuel cell.

Again, traditional electric hot water heaters and electric furnaces can still work with a fuel cell; it will only require the fuel cell to have a much higher energy output. If a homeowner can incorporate the heating and hot water elements required in a home into their fuel cell system by utilizing the heat produced in the hydrogen conversion reaction, optimum energy efficiency and use of the fuel cell system can be achieved.

Fuel Cell System Installation

The installation and operation of fuel cell systems for residential application is not currently regulated or even addressed with regard to building codes, due to their relative non-residential use in the past. However, companies that sell these residential fuel cell systems have very outlined procedures for installing them, whether inside or outside the home. The general components of a fuel cell system are as follows: a mounting slab (paving blocks or a foundation), connections for the fuel supply

(hydrogen gas, methane gas, etc.), electrical output connection to the home load panel, optional heat recovery tank, and optional external communications with home thermostat/energy management system. For indoor installations of a fuel cell system, one would additionally need to provide a means of air supply and exhaust.

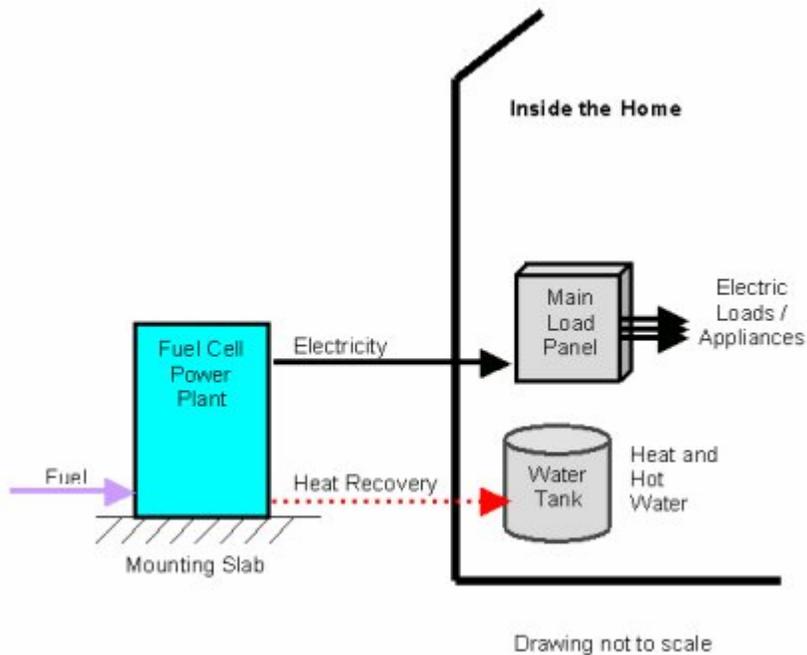


Figure 8 RFC Setup ()

Currently, only the suppliers and manufactures of residential fuel cell systems are “qualified” to install them, however this could be considered subjective. Because of the simplicity of the design of a fuel cell system, one who desired the education and could effectively utilize the resources available to them could feasible install a fuel cell. It is recommended, however, that upon purchasing a

fuel cell system, a homeowner allow the manufacturer to install the product to insure proper and correct operation and avoid any negation of warranties involved. Because these fuel cell systems can grow very expensive, installation by the company that makes and sells them is the most reliable approach. In addition, installation costs are often found to be included in the cost of a fuel cell system. Perhaps this is due to the fact that fuel cell technology for residential application is a fairly new concept and there aren't many professionals that have the necessary installation know-how, except those who work for fuel cell system manufacturers.

Summary

The purpose of this guide is to give interested homeowners complete information necessary for hydrogen energy conversion. In this manual we have covered the types of fuels that can be reformed to produce hydrogen, the basic process of fuel processing and electrolysis, various types of fuel cells and fuel cell operation, fuel cell mechanical components and materials necessary for residential use, and maintenance and system installation. There are several advantages to using hydrogen to power and heat your home. Hydrogen gives us a clean, abundant source

of renewable energy, it allows us to be independent of the utility grid which saves money over time, and provides us with our own locally produced efficient supply of heat and electricity. The use of fuel cells sheds new light on the future of energy production. Don't be left in the dark.

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