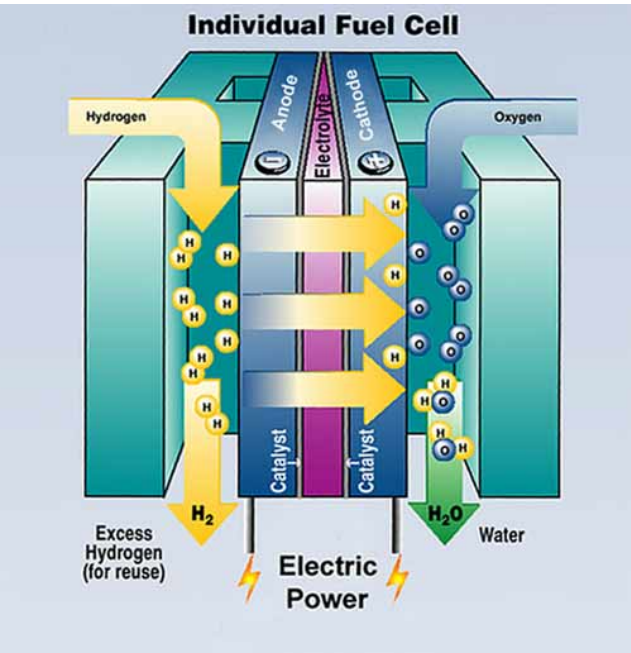
Fuel Cell Technology

Fuel Cells are electrochemical energy conversion devices similar to a battery except that they require a constant supply of fuel to generate a constant supply of electricity and some heat. Therefore unlike a battery a fuel cell cannot run out of charge and will only cease to function when there is an interruption to the fuel supply.

Basic working principles and construction

The construction of the fuel cell is essentially two bi-polar plates, an anode and a cathode (positive and negative terminals) an electrolyte separating the two and a catalyst which currently is platinum although research is being undertaken to find a cheaper alternative.



p2library.nfesc.navy.mil

Hydrogen is fed into the anode and oxygen from the air passes through the cathode, as hydrogen is a volatile element it wants to form bonds with the oxygen to stabilise and create water, however the electrolyte prevents negative ions flowing through. Due to this the hydrogen splits into its separate protons and electrons, the protons pass through the electrolyte whilst the electrons have to take an external path through wiring to join up and form water. As the electrons move from one side to the other they create an electrical current which can be used to drive a load.

Under load a single cell can be expected to produce around 0.7V, so for the production of useful output power individual cells have to be connected together in a stack. This is achieved by joining the anode of one cell to the cathode of the next by means of an interconnect.

The fuel cell differs from conventional heat engine technology as it does not rely on raising the temperature of a working fluid i.e. air in a combustion process. Therefore the efficiency of the fuel cell is not governed by the same laws (Carnot efficiency). In contrast to heat engines as the temperature of the fuel cell is raised the efficiency drops. Theoretically therefore at high temperatures 800^{o}C+ heat engines are more efficient, although due to the moving parts finding materials with adequate strength to perform at these temperatures make it impractical. With a lack of moving parts, fuel cells can use less expensive materials to operate at the same temperatures.

Various types of fuel cells are currently being researched with polymer exchange membrane fuel cells (PEMFC) being the ones likely to be seen commercially in the near future.

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Types of fuel cell

Fuel cells can be classified into two groups, low temperature and high temperature fuel cells; low temperature cells have the following characteristics:

Generally incorporate precious metal electro-catalysts to improve performance, exhibit fast dynamic response and start up times, require relatively pure supply of hydrogen as fuel.

Conversely high temperature fuel cells have the following:

Fuel flexibility (can be operated on hydrocarbon fuels), increased operating temperature reduces the need for expensive electro-catalysts, suited to co-generation due to generated waste heat, exhibit long start up times and are sensitive to thermal transients, can require expensive construction materials to withstand high temperatures, can be integrated with a gas turbine offering high efficiency combined cycles.

Fuel

Most fuel cells run on hydrogen which is combined with oxygen in the cell to form water. (Although research is being carried out into metal-air fuel cells which use stored energy in aluminium, see http://fuelcell-magazine.com/articles/april01-2.htm for more information)

High temperature fuel cells can also run directly on other fuels, i.e. hydrogen-rich gasses such as methane. This is achieved by using a reformer, a device which turns hydrocarbon or alcohol fuels into hydrogen, thus generating heat and other gasses dependant on the composition of the fuel. The hydrogen is extracted and 'cleaned up' using various devices. Even so the results do not generate pure hydrogen; this reduces the efficiency of the cell. Therefore most research is concentrating on pure hydrogen cells.

Pure hydrogen can be formed in several ways, however the easiest is by electrolysis of water which is a high energy consumer (i.e. passing an electric current through the water to separate the hydrogen atoms from the oxygen atoms) If the electricity to perform this comes from a renewable source then the fuel cell is a renewable energy source, however if the electricity comes from the burning of fossil fuels then the cell is not a renewable resource.

The problem with pure hydrogen apart from the amount of energy required to produce it, is storage and transportation. Hydrogen can be stored as a liquid but only at very low temperatures so is easier stored as a gas. If ignited, hydrogen burns rapidly with a nonluminous flame that can't readily scorch you at a distance, emitting only one-tenth the radiant heat of a hydrocarbon fire and burning 7% cooler than gasoline. Although firefighters dislike hydrogen's clear flame because they need a viewing device to see it in daylight, victims generally aren't burned unless they're actually in the flame, nor are they choked by smoke.

Usage

Fuel cells are able to be used in various applications for providing off grid power, replacing batteries in boats, mobile homes and other mobile applications. Recently unmanned flights have been made in prototype aeroplanes powered by fuel cells, with a manned flight expected to take place by Boeing in summer 2007.

However the most high profile reason for the research investments is to produce

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hydrogen fuel cell powered automobiles which are competitive with petrol and diesel driven buses, lorries, vans, cars etc…
This can be seen through the CUTE project which involves the operation of nearly 50 hydrogen powered buses on three continents around the globe. 34 hydrogen fuel cell buses will operate in Amsterdam, Beijing, Barcelona, London, Luxemburg, Madrid, Perth (Western Australia), and Reykjavik while 14 hydrogen buses powered with internal combustion engine (ICE) will come onto the streets of Berlin. The project will also see the development of new generations of more efficient and more competitive buses in both technologies.

Comparing the efficiency of a fuel cell powered car to a petrol driven or battery powered car shows how effective this technology could be in the automotive industry.

Since all three types of car have many of the same components (tyres, transmission etc…) the efficiencies can be calculated purely from where mechanical power is generated.

A fuel cell using pure hydrogen has the potential to be 80% efficient i.e. 80% of the energy in the hydrogen is converted to electricity, this still needs to be converted to mechanical work, a process which requires a motor/inverter which are again around 80% efficient this gives a total efficiency of 64%. Honda's FCX concept vehicle (above) has a 60% efficiency. Assuming the hydrogen is produced using electrolysis using renewable electricity.

The efficiency of a petrol powered car is surprisingly low due to the amount of heat generated and wasted whilst the car is in operation, heat is lost in the exhaust gases and the radiator. The engine also wastes energy turning various fans, pumps and generators which keep it operating. This gives an overall efficiency of around 20% i.e. 20% of the thermal energy content in the fuel becomes mechanical work.

A battery powered electric car has a high efficiency as the battery is around 90% efficient and the motor/inverter is around 80% efficient giving a total efficiency of approximately 72. However the electricity to power the car has to be generated somewhere, if this is in a combustion process (coal/gas) only around 40% of the energy in the fuel is converted to electricity. This AC electricity then has to be converted to DC in a process which is 90% efficient giving a total efficiency of 26%. If a renewable electricity source was used this would rise to 65% efficient.

Size / noise

The size of a fuel cell stack is dependant upon the requirements, for a competitive fuel cell powered car to be produced on a mile for mile running basis, the size of fuel cells will have to be reduced.

With regards to noise, all power is generated from the fuel cell in a completely silent process. The only noise that would be heard in a car for example would be the motor driving the wheels. In

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other applications which are not driving motors there would be no noise.

Current barriers

There are several reasons preventing hydrogen moving into large scale commercial use in the near future. Although the technology is ready for use, currently the expense of producing the cells is too great for large scale commercial production.

Secondly the expense and difficulty of producing enough hydrogen for the large scale commercial use of fuel cells. If the power for electrolysis were to come from renewable energy sources, we currently don't have the capacity in the UK to move into large scale production.

Furthermore, a generation and distribution network for the transportation of hydrogen would have to be put in place, whether this is pipelines or delivery trucks. Finally if there was mass transit of hydrogen and commercial use, new legislation would have to be drawn up for first response to follow when attending an accident involving hydrogen, whether a fire at a production plant or a traffic collision involving hydrogen powered cars. Although some research suggests that collisions between hydrogen powered vehicles would be safer than between petrol cars.

Current usage

Examples of use in the UK are few although Woking's Pool in the Park scheme has used a fuel cell powered CHP system (the first in the UK). The fuel cell is designed to support the Pool in the Park's heating and power systems and Woking Park's lighting. Excess heat produced is used to power the centre's air conditioning, cooling and dehumidification requirements via heat fired absorption cooling. The CHP station is also designed to provide energy services for the Leisure Centre with surplus electricity exported to the Council's sheltered housing schemes.

In Canada Investment is being made into Hydrogen powered busses similar to those in the CUTE project. More information can be found at http://www.fuelcellsworks.com/Supppage7274.html

This demonstrates the potential fuel cells have to be integrated into every application in the future.

Environmental benefits

The environmental benefits of using fuel cells are massive, so long as the hydrogen is being produced by means which do not produce any CO_2 then the entire process would be carbon neutral. The only emissions would be water vapour which if pure hydrogen is used would be pure enough to drink.

Cost

Currently the cost of fuel cells is around £1500 and researchers expect that once the cost has fallen below £750 their mass market launch will be commercially viable. Unfortunately 70% of the fuel cell's cost is built up from the material costs for proton exchange membranes, precious metal catalysts, gas diffusion layers and bi polar plates.

Availability

Fuel cells can currently be bought from some manufacturers although they are mainly available for research and development projects. Predictions for mass market availability vary dependant on the source used. Currently expectations are that fuel cells will be able

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to be purchased off the shelf between 2010 and 2015

Grants

Currently there are no grants available under the Low Carbon Buildings Programme due to the fact there are no accredited installers. However once appropriate standards have been developed grants will be made available. See www.lowcarbonbuildings.org.uk for the latest information or call 0800 915 0990.

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More Information

Installers

No accredited installers are currently available. Please refer to the Low Carbon Buildings Programme's approved installer list for grant-funded installations. This will be updated as and when installers become available. Call 0800 9150990 or go to www.lowcarbonbuildings.org

Some installers located in Cornwall:

No installers currently listed.

For up to date lists of local installers visit: http://www.csep.co.uk/page140g.html

We advise that you obtain at least 2 comparable written quotes from different installers and check the VAT discount for renewable technologies has been applied. For more information on VAT discounts, please see: http://customs.hmrc.gov.uk/channelsPortalWebApp/channelsPortalWebApp.portal?_nfpb=true&_pageLabel=pageVAT_ShowContent&id=HMCE_CL_000514&propertyType=document#downloadopt

Other information:

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Energy Saving Trust		www.energysavingtrust.co.uk
Woking Council case study		http://www.woking.gov.uk/environment/Greeninitiatives/sustainablewoking/fuelcell.pdf
Fuel Cell Today, up to date information on fuel cells, hydrogen and competing technology from around the world		http://www.fuelcelltoday.com