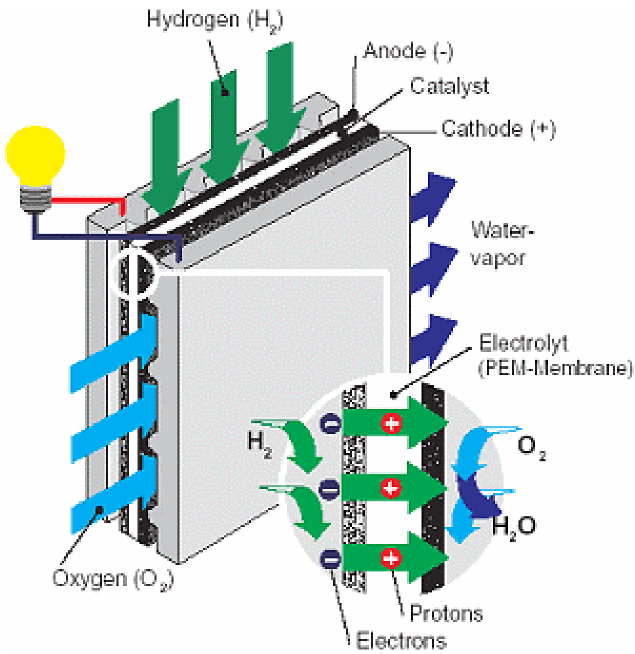
# Fuel Cells for buildings

DATASHEET 04 May 2017

Fuel cells are devices that convert the energy of a chemical reaction, typically between hydrogen and oxygen, directly into low-voltage DC electricity and into heat. There are over twenty fuel cell technologies of which some five are developed to the point where they have reliable products in the market place (in some cases third generation products) and they seem certain to play a large part in providing combined heat and power (CHP) in the hydrogen economy. For building applications, fuel cell systems offer modularity, high efficiency across a wide range of loads, minimal environmental impact and opportunities for use as CHP systems. Due to the absence of vibrations low noise fuel cells can be easily installed within buildings. Stationary fuel cells are ideal for power generation, either connected to the electricity grid to provide supplemental power and backup for critical areas, or installed as a grid-independent generator for on-site services.

Since fuel cells operate virtually silently, they reduce noise pollution as well as air pollution and the waste heat from a fuel cell can be partially used to provide steam, hot water, space heating or cooling. They are highly efficient and have relatively low maintenance requirements. In the stationary power sector, if fuel cell manufacturing costs are reduced to the level expected through volume production, electricity generating costs could eventually be as low as 3-4 p/kWh (excluding any utilisation of heat). Anyway, the full heat use is of importance for a viable business case of current applications. Presently if life-cycle cost is the decider the fuel cell will generally show far better returns, if simple pay-back is the criterion then the fuel cell will normally not be the best option. Fuel cell suppliers offer therefore various financing options as lease, PPA (Power Purchase Agreement) or contracting. In principle, a fuel cell operates like a battery. However, unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied. A fuel cell consists of an electrolyte sandwiched between two electrodes. Oxygen (or air) passes over one electrode (the cathode) and hydrogen over the other (the anode), generating electricity, water and heat. Encouraged by a catalyst the hydrogen atom splits into a proton and an electron. Those take different paths to the cathode. The proton




passes through the electrolyte. The electrons create a separate current that can be utilized before they return to the cathode, to be reunited with the hydrogen and oxygen in a molecule of water. This


©CIBSE CHP Group

whole process can be thought of as electrolysis in reverse, hydrogen and oxygen being combined rather than splitting. Typically, individual fuel cells generate power outputs of a few tens or hundreds of watts. Cells are therefore assembled in modules known as stacks to provide a larger voltage and current.

When supplied by hydrogen or a large range of biofuels, fuel cells have zero $CO_2$ emissions. Currently, hydrogen is not cost effectively available whereas natural gas has a supply infrastructure in place. Fuel cells can be operated on a variety of fuels e.g. natural gas, LPG and biofuels. This sometimes requires a reformer that extracts hydrogen from hydrocarbon or alcohol fuels, which is then fed to the fuel cell. When using fuels other than hydrogen, the operation of the fuel cell will result in some emissions to the atmosphere but these would still be much smaller than emissions from the cleanest fuel combustion processes. Methanol can also be used to supply fuel cells. This is a liquid fuel that has similar properties to gasoline making it easy to transport and distribute, so methanol may be a likely candidate to power fuel-cell cars.

There are a wide variety of uses for fuel cells due to the various existing technologies. Fuel cells are powering buses, cars, boats and trains. Miniature fuel cells for cellular phones, laptop computers and portable electronics are on their way to market. Hospitals, leisure centres, call centres, large commercial, retail and industrial buildings, Universities, police stations, and banks are all using fuel cells to provide power and heat to their facilities. Waste-water treatment plants and landfills are using fuel cells to convert the methane gas they produce into electricity. Regent Street Quadrant 3 building complex has a 300 kWe fuel cell to provide base load power and the exhaust heat is used for facility heating and cooling.

There are several different types of fuel cells, each using a different chemistry. Fuel cells are usually classified by the type of electrolyte they use. Some types

**Domestic fuel cell (1.5 kWe)**

of fuel cell work well for use in stationary power generation plants, others may be useful for small portable applications or for powering cars. A number of types of fuel cell are currently the focus of development work:

**Proton exchange membrane fuel cell (PEMFC)** - This type of fuel cell is most deployed to power cars and buses and is also suitable for stationary applications like residential homes.

**Solid Oxide Fuel Cells (SOFC)** - Significant progress has been made with SOFCs in recent years but work remains to develop fully engineered systems for stationary CHP applications. These fuel cells are best suited for stationary power generators that could provide electricity in a range of 10 to 300 kW for industrial buildings or commercial applications.

**Solid Polymer Fuel Cells (SPFC)** - The SPFC is very promising for automotive and stationary applications. There is a

 ©CIBSE CHP Group

massive global effort to develop commercial systems. SPFCs are now being demonstrated in a range of commercial applications including buses, cars, CHP and distributed power.

**Phosphoric Acid Fuel Cells (PAFC)** - More than 400 commercial PAFC systems have been sold worldwide (total capacity ~44 MW). Demonstrated in the bus sector, it has been pursued as a candidate for CHP and distributed power applications. Increasingly, it is being marketed as a technology for uninterruptible power supplies (UPS) and premium power applications. It operates at a higher temperature than PEM fuel cells, so it has a longer warm-up time making it less applicable in some vehicles.

**Alkaline Fuel Cells (AFC)** - A relatively simple device, the AFC is still the preferred system for applications in space and remains a candidate for mobile applications, particularly in captive fleet vehicles. The AFC is very susceptible to contamination, so it requires pure hydrogen and oxygen. It is also very expensive, so this type of fuel cell is less likely to be commercialized.

**Molten Carbonate Fuel Cells (MCFC)** - The MCFC is successfully applied in stationary power and CHP applications in sizes up to 59 MWe. They exhaust air of around 400 °C can be used to generate more power or used directly for steam, heat or cooling applications. Due to the lower operating temperature of the system, affordable materials can be used.

## Efficiency of Fuel Cells

Fuel cells have a heat to power ratio between 0.8:1 and 1.8:1 with overall efficiencies of around 90 % when operated on hydrogen or methane. Fuel cells have power efficiencies up to 60 %, i.e. 60% of the fuel gas is converted into electrical energy.
Fuel cell systems can maintain high efficiencies at loads as low as 50%, exhibiting characteristics that are ideal for use in buildings where much of the time is spent at low load.

World installed fuel cell capacity has doubled annually since 2004 As there is an increasing demand for the high efficiency, low (even zero) emission features offered by fuel cells the capacity is still rising and fuel cell products are

**Industrial MCFC power plant (Multiple 2.8 MW units)**

commercially available. According to the FCH-JU study of Roland Berger for example stationary fuel cells have a potential of more than 2 GW for µ-CHP installations for residential markets with an amount of approx. 2.5 m units in Europe and 3-10 GW for facilities and commercial building. 2- 8 GW is expected in five selected industries and multi GW in the utility sector, carbon capture and renewable hydrogen. This potential is expected to be exploiting with a continuous support (legislative, funding and industry commitment). About 150 MW of stationary fuel cells were shipped worldwide in 2013, an increase of about 24% over 2012 and 244% more than in 2008.

Fuel cells are more efficient than conventional engine based plant because they lack a combustion stage which means their efficiencies are not limited to those achieved by heat engines. This higher efficiency means reduced energy use and less emission of $CO_2$. They also produce virtually no emissions of oxides


©CIBSE CHP Group

of nitrogen, hydrocarbons and particulates compared to the internal combustion engine. Fuel cells running on hydrogen derived from a renewable source will emit nothing but water vapour. In addition, fuel cell systems generally have significantly lower noise and vibration levels than conventional alternatives allowing them to be sited in city centres and near to accommodation etc. Design Life is 20 years with replacement of the fuel cell stack, depending on technology between five and ten years and this cost should be factored in to overall maintenance costs. Estimates of annual maintenance, including stack replacement, range from less than £0.03/kWh to £0.015/kWh.

## Example installations

As part of their commitment to reduce energy consumption and greenhouse gas emissions TfL (Transport for London) commissioned a 200kWe PAFC fuel cell in 2008; at that time they estimated a reduction in carbon emissions of 40% and a cost saving of £90,000 per annum as a result of the CCHP installation.
The fuel cell forms part of an integrated tri-generation system providing electrical energy, heat and cooling to their Palestra building in London.

**Palestra 200 kWe fuel cell**

A 300 kWe molten carbonate fuel cell has been installed in the 38 storey Walkie-Talkie building (20 Fenchurch Street) in London. The fuel cell produces heating cooling and electricity, generating 300kW of low carbon electricity, reducing the building's carbon dioxide emissions by at least 270 tonnes per annum.

## A future hydrogen economy?

The hydrogen economy promises to eliminate many of the problems that the fossil fuel economy creates. It could reduce depletion of natural resources and eliminate pollution (including greenhouse gases) caused by burning fossil fuels. Hydrogen also allows distributed production as hydrogen can be produced anywhere that you have electricity and water. People can even produce it in their homes with relatively simple technology.

## Further Information

Galliers S, Fuel Cell Technology: The scope for building services applications [BG 9/2003] BSRIA www.bsria.co.uk (2003)

Ellis F W, Fuel cells for building applications (ASHRAE) www.ashrae.org (2002)

Fuel Cell Technologies Market Report; Fuel Cell Technologies Office (DOE) November 2014

Fuel Cell and Hydrogen International Markets – 2014 (London Hydrogen Partnership) www.hydrogenlondon.org

The role of Hydrogen & fuel cells in providing affordable secure low-carbon heat – UK H2FC SUPERGEN White Paper 2014

Advancing Europe's energy systems: Stationary fuel cells in distributed generation; Roland Berger Consultants, 2015

www.fuelcellsuk.org
www.fuelcellstore.com
www.fuelcellsworks.com
www.howstuffworks.com/fuel-cell
www.fuelcells.org
www.fuelcelltoday.com

**This datasheet was produced by the CHP Group of the Chartered Institution of Building Services Engineers (CIBSE) to inform building professionals about all forms of CHP. To join or contact the CHP Group go to www.cibse.org/chp or contact CIBSE, 222 Balham High Road, London, SW12 9BS (020 8675 5211).**

 ***©CIBSE CHP Group***