Stationary and portable fuel cells information resource

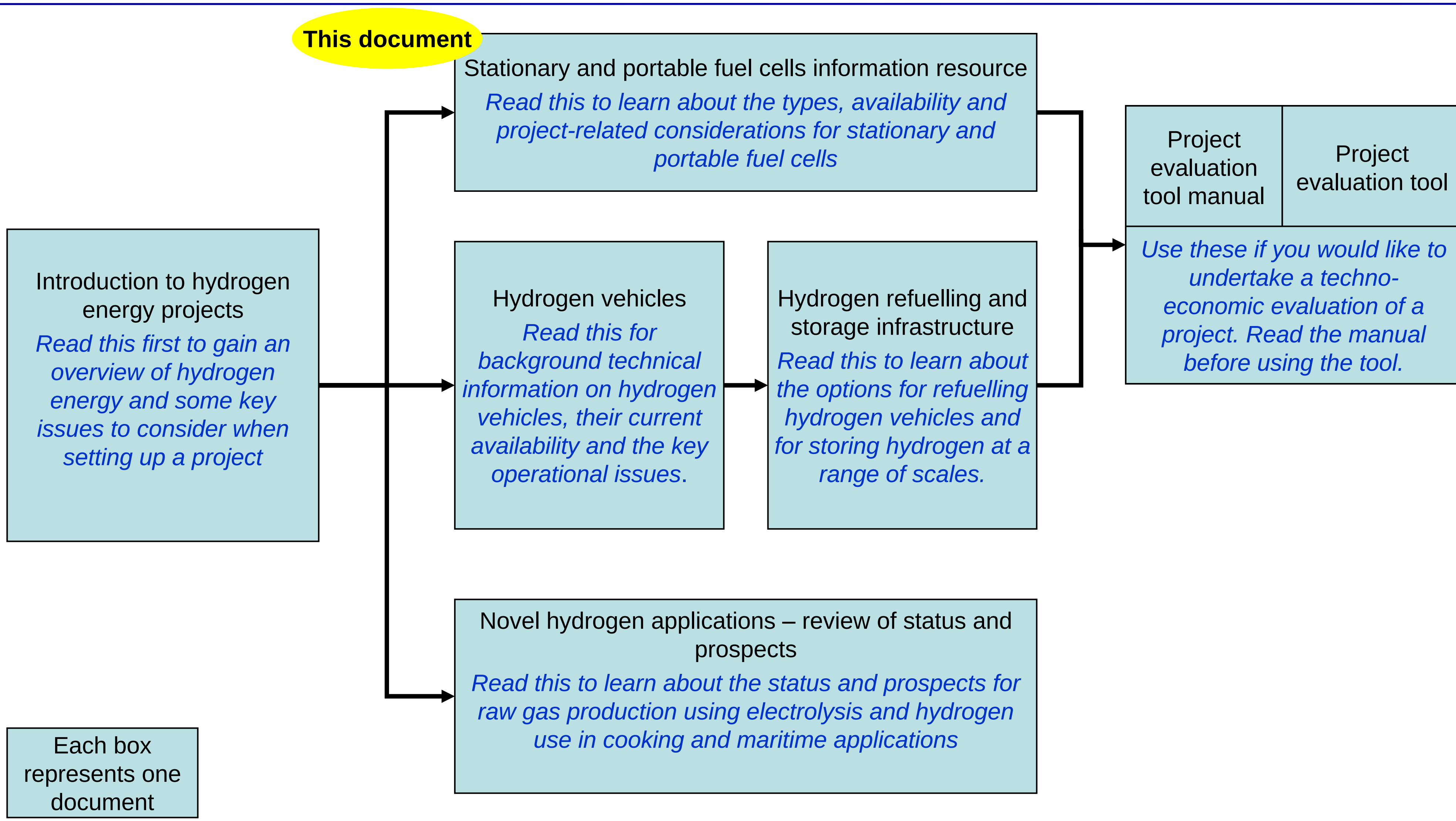
Information Resource for Highlands & Islands Enterprise

E4tech elementenergy pure

About this document

- In 2006 the HIE Renewable Energy team commissioned a consulting team to assist with the identification and assessment of hydrogen energy opportunities across the region. As part of this work the project team conducted a workshop in each LEC area to introduce the hydrogen energy opportunity and identify potential project ideas. Over 80 individual ideas surfaced, at varying levels of ambition, detail and feasibility.
- The project team worked with HIE to identify several recurrent themes among the ideas:
  - What are all the issues that need to be considered when setting up a hydrogen project?
  - What different stationary and portable hydrogen applications are there?
  - How can hydrogen be used in road vehicles?
  - How can hydrogen be stored and what refuelling facilities would be required for hydrogen vehicles?
  - What are the prospects for hydrogen use in maritime applications or cooking? Could bottled hydrogen and oxygen be produced and sold?
  - How can developers undertake technical and economic evaluation of their ideas?
- HIE judged that the best way to provide value to the LECs would be through a suite of information resources and tools based on these themes, to enable ideas to be developed and assessed further. These tools fit together as shown overleaf.

Document Map



About the authors

Element Energy

- **Element Energy is an engineering consultancy specialising in the low carbon energy sector. It formed in 2003 as a spin off from larger engineering practice Whitbybird.**
- **Services:**
  - Engineering services for low carbon energy projects
  - Innovation in new energy technologies and storage solutions
  - Strategic advice and consultancy
  - Project management and funding assistance
  - Specialist knowledge in hydrogen and fuel cell projects

E4tech

- **E4tech is a sustainable energy business consultancy, based in the UK and in Switzerland (established 1997)**
- **Services:**
  - Business strategy
  - Organisational support and interim management
  - Technology and market review to assist financing
  - Policy input for local and national government
  - Support to technology startups
  - Focus on hydrogen energy, bioenergy and sustainable buildings

PURE Energy Centre

- **The Pure Energy Centre has one aim: to give you access to the most effective energy storage techniques in the world to grow your business/community and increase your energy independence**
- **Services/products:**
  - Renewable hydrogen training courses
  - Consultancy for energy and storage technologies
  - Sales of hydrogen production units
  - R&D contract work for third parties

Commonly used acronyms

AFC Alkaline Fuel Cell

C H2 Compressed Hydrogen

CHP Combined Heat and Power

CNG Compressed Natural Gas

CRES Centre for Renewable Energy Studies (Greece)

DoE United States Department of Energy

EC CUTE European Commission Clean Urban Transport for Europe

EC HyCom EC Hydrogen Communities

FC Fuel Cell

FP6&7 Framework Programmes 6&7 (EU instrument for funding research)

H&I Highlands and Islands

H2ICE Hydrogen Internal Combustion Engine

HAZOP Hazard and Safety Operational Studies

HHV High Heating Value

HIE Highlands and Islands Enterprise

HSE Health and Safety Executive

ICE Internal Combustion Engine

LCIP Low Carbon Innovation Programme (Carbon Trust)

LEC Local Enterprise Company

LHV Low Heating Value

LNG Liquid Natural Gas

LPG Liquid Petroleum Gas

MCFC Molten Carbonate Fuel Cell

MCPs Manifold Cylinder Packs

MEA Membrane Electrode Assembly

NOx Nitrous oxides (pollutants)

O&M Operation and Maintenance

OEM Original Equipment Manufacturer

PAFC Phosphoric Acid Fuel Cell

PE Primary Energy

PEM Primary Exchange Membrane/Polymer ion Exchange Membrane

PSA Pressure Swing Absorption

R&D Research and Development

ROCs Renewable Obligation Certificates (see Defra website)

SME Small to Medium Enterprises

SOFC Solid Oxide Fuel Cell

UPS Uninterruptible Power Supply

VSA Vacuum Swing Absorption

ZEMSHIPS Zero Emission Ships

Contents

Introduction

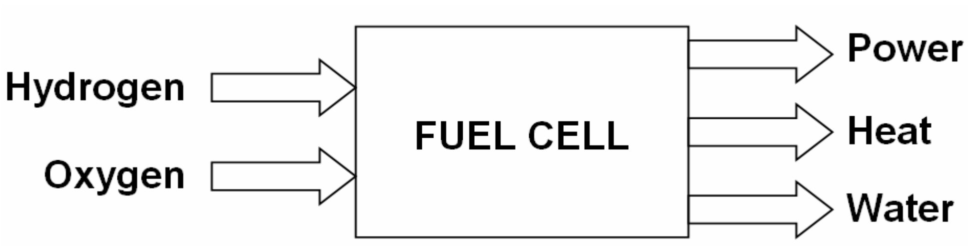
- Hydrogen fuel cells were dominant themes at the LEC workshops and it was felt that there was a need for a document which explained some of the technology, its associated applications and costs.
- This document provides a brief practical guides to fuel cells including:
  - What is a fuel cell?
  - Types of fuel cells
  - Comparison of fuel cells
  - Availability of fuel cells
  - Cost of fuel cells
  - A guide to install fuel cells
  - Common abbreviations used within the fuel cell industry

Contents

Fuel Cell Types & Features - General

What is a fuel Cell ?

A fuel cell is a device that generates electricity through a chemical reaction. Hydrogen and oxygen are used as input and hydrogen is the fuel. Electrical power, heat and water are the outputs of a fuel cell.



Every fuel cell technology has two electrodes, one positive cathode and one negative anode. They have an electrolyte, which carries electrically charged particles from one electrode to the other, and a catalyst, which accelerates the reactions at the electrodes. The main electrochemical reactions that produce electricity take place at these electrodes.

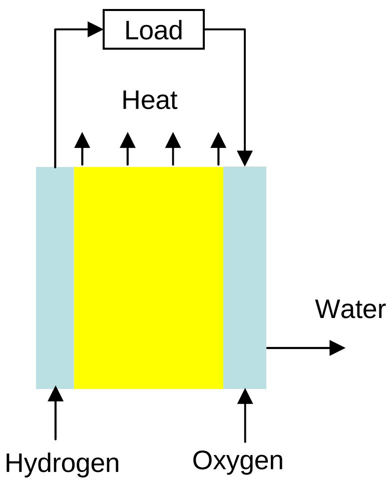
Fuel Cell Types & Features – General (continued)

What does a fuel cell do?

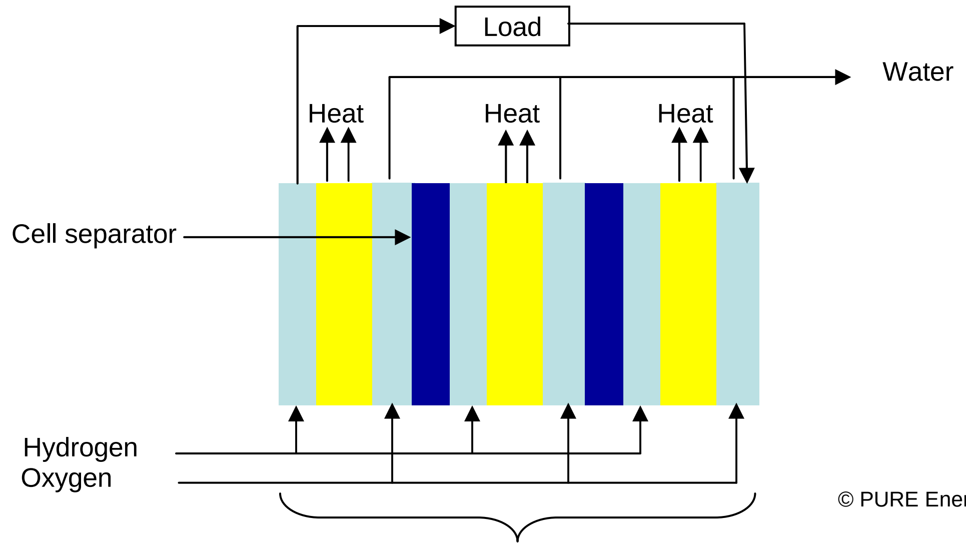
A fuel cell will produce an electrical current that can be directed outside the cell to do some sort of work, such as illuminating a light bulb or powering an electric motor. Due to the way electricity behaves, this current returns to the fuel cell, completing an electrical circuit. The chemical reactions that produce this current are the key to how a fuel cell works.

What is a fuel cell stack?

A single fuel cell generates a very small amount of direct current (DC) electricity. In practice, many single fuel cells are usually assembled into a stack. Whether it is a single cell or a stack, the principles of operation are the same.



A single fuel cell



A fuel cell stack (several single fuel cells in series)

Fuel Cell Types & Features

There are several kinds of hydrogen fuel cell technology available or in development, and each operates slightly differently. 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 ionised and therefore carry a positive electrical charge. The negatively charged electrons provide the current that pass through wires to do work. Hydrogen fuel cell types can be grouped as follow:

1. Proton Exchange Membrane (PEM). Also known as Polymer ion Exchange Membrane.
2. Solid Oxide Fuel Cell (SOFC).
3. Phosphoric Acid Fuel Cell (PAFC).
4. Molten Carbonate Fuel Cell (MCFC).
5. Alkaline Fuel Cell (AFC).

Fuel Cell Types & Features

In some fuel cell types Oxygen (or air) enters the fuel cell at the cathode where it combines with electrons returning from the electrical circuit and hydrogen ions that have travelled 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.

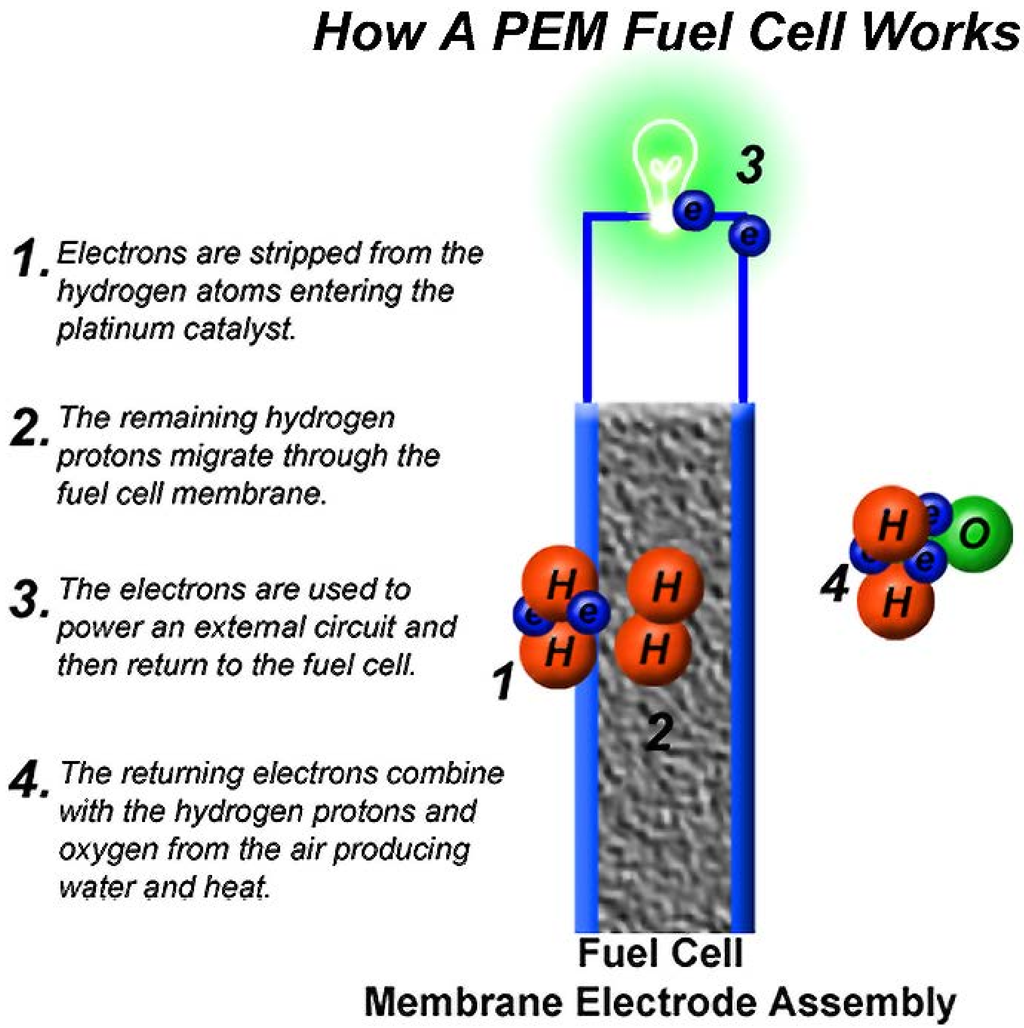
The electrolyte used in each fuel cell technology type performs a very important role as it must permit only the appropriate ions to pass between the anode and cathode. If free electrons or other substances could travel through the electrolyte, they would disrupt the chemical reaction, and in the worst case cause an explosion or fire.

Each type of fuel cell has advantages and disadvantages when compared to the others, and it should be understood that none are yet cheap and reliable enough to widely replace traditional ways of generating power, such as internal combustion.

Fuel Cell Types & Features – PEM

Proton Exchange Membrane (PEM)

The most commonly available fuel cell systems utilise Proton Exchange Membrane (PEM) technology to achieve conversion from hydrogen energy to electrical energy. In a PEM fuel cell, the energy stored in hydrogen is converted to electrical energy through an electrochemical process within the Membrane Electrode Assembly (MEA) shown in diagram opposite.



Fuel Cell Types & Features – PEM

Proton Exchange Membrane (PEM) - Continued

The MEA is constructed from a solid polymer electrolyte material, in the form of a thin permeable sheet, sandwiched between two platinum and carbon catalyst electrodes. The electrolyte material in this case is known as the Proton Exchange Membrane (PEM) as it allows only Hydrogen protons to pass through its molecular structure. The catalytic anode electrode separates hydrogen protons from its associated electron enabling the hydrogen atoms to pass through the PEM. The electrons are then free to be drawn from the electrode and fed through an attached load as electrical current. The catalytic cathode electrode then re-combines the electrons and hydrogen protons with oxygen atoms present in air. This results in a reverse electrolysis reaction with the resulting by-product or exhaust being warm water vapour.

Efficiency of a PEM fuel cell is on average between 40 to 50 percent and operating temperature is approximately 80 degrees C (about 175 degrees F). The solid, flexible electrolyte will not leak or crack and PEM cells operate at a low enough temperature to make them suitable for homes and cars. Hydrogen fuel must be purified with typical requirements for purity remaining around 99.95% pure. The need for a platinum catalyst on both sides of the membrane is keeping costs high.

Commercially, the most common sizes available range between 1kW and 30kW for stationary use. Larger power units are being developed for automotive and transportation use. Generally the warranty period on PEM fuel cell technology ranges from 1500 to 3000 hours of operational life.

Fuel Cell Types & Features - SOFC

Solid Oxide Fuel Cell (SOFC)

Solid oxide fuel cells work at the highest temperature of all the fuel cell technologies available. They use a solid ceramic electrolyte, such as zirconium oxide stabilised with yttrium oxide, instead of a liquid. The solid electrolyte is coated on both sides with specialized porous electrode materials.

In these fuel cells, energy is generated by the migration of oxygen anions (negatively charged oxygen atoms) from the cathode to the anode to oxidise 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.

Electrical efficiency is about 60 percent, with potential to bring this up to 80 percent if used in a cogeneration or CHP configuration. Operating temperatures are between 800 and 1,000 degrees C (about 1,800 degrees F). At such high temperatures a reformer is not required to extract hydrogen from the fuel, and waste heat can be recycled to make additional electricity. However, the high temperature limits applications of SOFC units and they tend to be rather large, especially at higher power levels. While solid electrolytes cannot leak, they can crack.

In some configurations the SOFC consists of an array of tubes, in other variations a more conventional stack of disks are used. Some demonstration units have capacities up to 100 kilowatts.

Fuel Cell Types & Features - PAFC

Phosphoric Acid Fuel Cell (PAFC)

The phosphoric acid fuel cell (PAFC) 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. Positively charged hydrogen ions migrate through the electrolyte from the anode to the cathode. Electrons generated at the anode travel through an external electrical circuit and provide electric power. The electrons then return to the cathode where they react with hydrogen ions and oxygen to form water, which is expelled from the cell as vapour. A platinum catalyst at the electrodes is required to accelerate the reactions.

Electrical Efficiencies of PAFCs are lower than other fuel cell technologies at an average of 40 percent, but this can rise to about 80 percent if the waste heat is reused in a cogeneration system. PAFCs have an operating temperature between 150 to 200 degrees C (about 300 to 400 degrees F).

Platinum electrode-catalysts are needed in a PAFC, and internal parts must be able to withstand corrosive acids and high temperatures. These systems take longer to warm up than PEM cells. The formation of carbon monoxide (CO) around electrodes can "poison" the fuel cell.

Existing phosphoric acid cells have outputs up to 200 kW, although sizes up to 11 MW units have been tested.

Fuel Cell Types & Features - MCFC

Molten Carbonate Fuel Cell (MCFC)

Molten carbonate fuel cells work quite differently from the other technologies available. These fuel cells use either molten lithium potassium or lithium sodium carbonate salts as the electrolyte. When this is heated to a temperature of around 650°C these salts melt and generate carbonate ions (CO3) 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.

MCFCs exhibit up to 60 percent efficiency, which can rise to 80 percent if the waste heat is utilized for cogeneration. Operating temperature is about 650 degrees C (1,200 degrees F).

The high temperature limits damage from carbon monoxide "poisoning" of the cell and waste heat can be recycled to make additional electricity. The usual nickel electrode-catalysts are inexpensive compared to the platinum used in other fuel cells. But the high temperature also limits the materials and safe uses of MCFCs.

Units with output up to 2 megawatts (MW) have been constructed, and designs exist for units up to 100 MW.

Fuel Cell Types & Features - AFC

Alkaline Fuel Cell (AFC)

Alkaline fuel cells technology is the most developed of the fuel cell technologies and has been used to provide power and drinking water to space missions.

Alkaline fuel cells electrochemistry differs somewhat to PEM in that it generally uses an aqueous solution of potassium hydroxide (also known as KoH or caustic) in water as their electrolyte. In alkaline fuel cells hydroxyl ions (OH-) migrate from the cathode to the anode. At the anode, hydrogen gas reacts with the OH- ions to produce water and release electrons. Electrons generated at the anode supply electrical power to an external circuit then return to the cathode. There the electrons react with oxygen and water to produce more hydroxyl ions that diffuse into the electrolyte.

Alkaline fuel cells can have efficiency of up to 70 percent achievable, and operating temperature is between 150 to 200 degrees C (300 to 400 degrees F). They are also the cheapest type of fuel cell to manufacture so it is possible that they could be used in small stationary power generation units.

Available fuel cell outputs range from tens of watts (W) up to 5 kilowatts (kW). Larger units have been operated in the past, however their development has reduced significantly as their power density is around ten times lower than that of a PEM fuel cell making them too bulky for use in road vehicle power trains and startup time is slow.

Comparison of main fuel cell types & features

	PEM	SOFC	PAFC	MCFC	AFC
Electrolyte	Polymer Ion	Ceramic	Phosphoric Acid	Molten Carbonate Salt	Potassium Hydroxide
Temperature (°C)	Ambient -80°C	600-1000	170-200	600-700	150-200
Fuels	H2 / Reformate	H2/CO2/CH4 Reformate	H2 / Reformate	H2/CO/ Reformate	H2 Reformate
Oxidant	O2/Air	O2/Air	O2/Air	CO2/O2/Air	O2/Air
Conductive Ion	H+	O-	H+	CO3-	OH-
Electrical efficiency (HHV)	40-50%	45-55%	40-50%	50-60%	40-50%
Power range (kW)	1-250	1-900	50-200	1-2MW	0.6-12
Development stage	Commercialised (Production Prototypes)	Commercialised (Production Prototypes)	Commercialised (Mature Tech)	Commercialised (Production Prototypes)	Commercialised (Mature Tech)
Average Life (h)	1500-3000	3000-6000	65000	N/A	1500-3000
Advantages	Quick start up High power density Solid electrolyte	Solid electrolyte High efficiency Fuel flexibility	High tolerance to impurities High efficiency	High efficiency Fuel flexibility	High performance
Disadvantages	Expensive catalyst Sensitivity to impurities	Breakdown of cells Slow start up	Large size Heavy Expensive catalyst	Breakdown of cells Slow start up Complex management	Sensitive to CO2 Corrosive material

Potential applications for fuel cell types

	PEM	SOFC	PAFC	MCFC	AFC
Industrial and municipal cogeneration	No	Yes	Yes	Yes	No
Distributed power	Yes	Yes	Yes	Yes	Yes
Passenger cars	Yes	No	No	No	No
Heavy duty vehicles	Yes	No	No	No	No
Road vehicles - auxiliary power unit	Yes	Yes	No	No	Yes
Commercial Buildings	Yes	Yes	Yes	Yes	Yes
Large scale grid power	No	Yes	Yes	Yes	No
Portable generators	Yes	No	No	No	No
Back up power for small buildings	Yes	Yes	No	No	Yes
Combined heat and power for small bldgs	Yes	Yes	No	No	Yes
Primary power for small buildings	Yes	Yes	No	No	Yes

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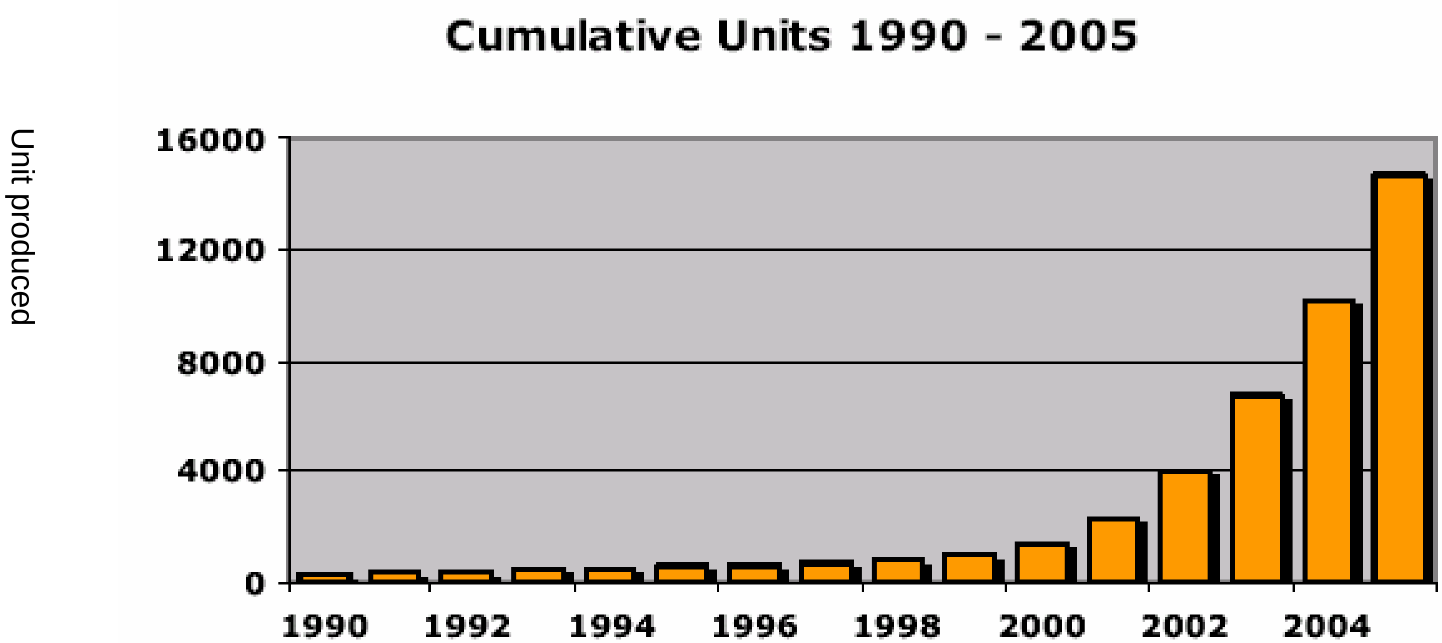
Fuel cell availability – Market Growth

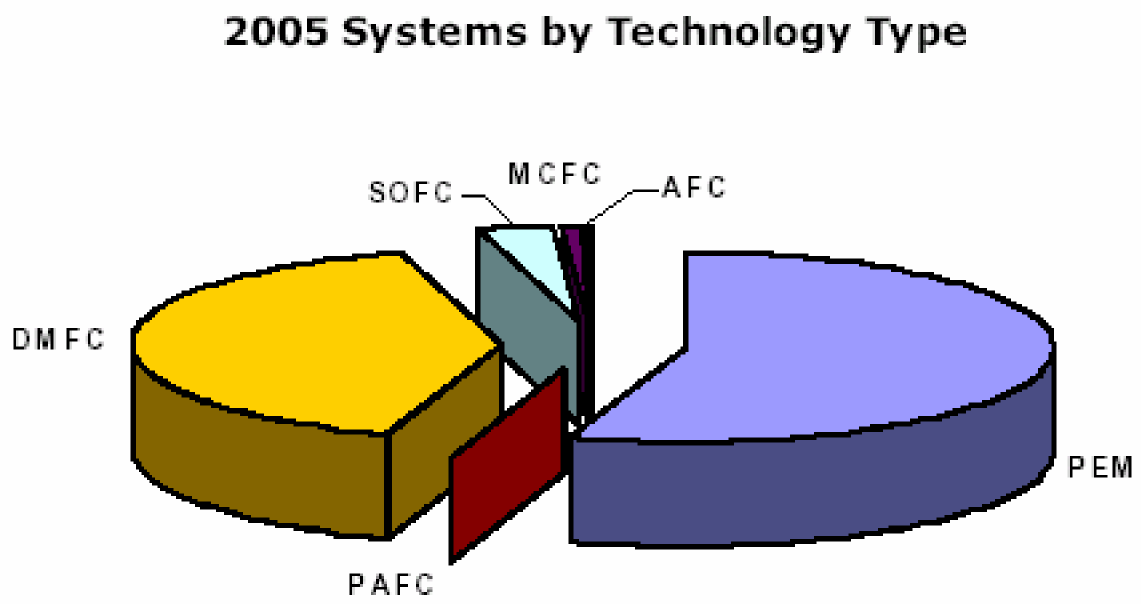
The worldwide production of fuel cells has grown since the beginning of the 1990 to reach almost 15,000 units in 2005



Fuel cell today – January 2006

Fuel cell availability – By technology type

PEM fuel cells are still dominating the market place for fuel cells numerically. This is mainly due to their applications within the automotive industry. Other technologies are now being installed mainly for stationary applications.



Fuel cell today – January 2006

Fuel cell availability – Large scale stationary applications

Molten carbonate fuel cells are currently the technology of choice for large scale applications. The main company selling this type of fuel cells is FuelCell Energy (based in USA) as its fuel cell has undergone several pre-commercial demonstration project.

Phosphoric acid fuel cells (PAFC) have lost market share, though sales remains the same as previous years. Their main producer UTC plans to revive PAFC sales with the launch of a new product. This has the potential to operate for 80,000 hours; the longest operating lifetime available on the market.

Solid oxide fuel cells (SOFC), which were promised to be the technology of choice for large scale applications, have not yet moved from pre-commercial applications. Reports suggest that this type of fuel cells will be ready for larger demonstration programme by year 2008-2010.

Fuel cell availability – Small stationary, residential and automotive

The technology of choice for small stationary, residential and automotive application is the PEM fuel cell. PEM fuel cells are continuing to develop while Alkaline fuel cells (AFC) are less well known in these markets. This is mainly due to the difficulty in implementing a stable management system required to control an AFC, its expensive catalyst and sensitivity to CO2. Further to this, most of the companies that have investigated this technology have redirected their efforts to PEM (or other) or have become insolvent. On the other hand, small SOFC developments are picking up, though they are still at early stage of their demonstration programmes.

In small stationary applications, it is found that PEM fuel cells are the main option. These are being sold for back up applications and a small number for primary power. There is almost no competition from the other fuel cell technologies in this market.

The PEM fuel cell also dominates the residential market. SOFC are now starting to compete in this market as they are more efficient and their high operating temperature makes them ideal for combined heat and power applications.

Again, the PEM fuel cells dominates the automotive market with most of the worldwide market share for car and bus applications. SOFC have also a small market share in the automotive industry, though they are only used as experimental auxiliary power units (especially for heating and cooling the vehicle).

Fuel cell availability – Portable applications and others

The portable applications market is dominated by PEM and its subset Direct Methanol Fuel Cell (DMFC). Very few companies are currently active in the non DMFC market, though others are now making their entry. DMFCs being actively pursued by a growing number of companies, with Asian electronics companies being particularly active. Another key customer for the portable fuel cells is the defence sector to replace batteries.

In the other sectors (small and niche markets such as wheelchairs), it is again the PEM technology that is mostly used. This is due to the variety of fuel cells stack that are available on the market.

Fuel cell availability – Summary of availability by application

	PEM	SOFC	PAFC	MCFC	AFC
Industrial and municipal cogeneration	Almost none	A few demonstrations	Most of the market to date	Growing market share	Almost none
Distributed power	Few	Few	Most of the market to date	Growing market share	Almost none
Passenger cars	Most of the market	None	None	None	Almost none
Heavy duty vehicles	Most of the market	None	Almost none	None	Almost none
Road vehicles - auxiliary power unit	Few	Few	None	None	Almost none
Commercial Buildings	Few	Few	Some	Few	Almost none
Large scale grid power	None	None	None	None	None
Portable generators	Share market with DMFC	None	None	None	None
Back up power for small buildings	Most of the market	None yet	None	None	Almost none
Combined heat and power for small bldgs	Most applications to date	Growing number of demonstrations	None	None	Almost none
Primary power for small buildings	Some (linked to renewables)	Almost none	None	None	Almost none

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Fuel Cell Economics

Fuel cells are not yet fully commercialised and are produced in low volumes. As such, they are more expensive than other form of generation apparatus. It is forecasted that when fuel cells will be manufactured in large quantities, the cost will drop dramatically making fuel cells competitive with other technologies in many applications.

Capital cost:

Cost of the first fuel cell used in the space programme in the 1970's was $600,000 per kW

Today fuel cell costs are about $4,500 per kW

Running cost:

The main running cost is fuel. For a PEM, if you buy your hydrogen directly from a supplier, then the running cost varies between £3.75/kWh to £8.75 per kWh. This depends on where you are located and contract terms with gas suppliers. If you electrolyse your own hydrogen from a renewable source, then the hydrogen is 'free' on a variable cost basis. Similarly, if you produce your hydrogen using a natural gas reformer, then you need to define the cost of your natural gas from your supplier (in m3) and remove the efficiency of your reformer to compute the variable cost of hydrogen.

Maintenance cost:

The main maintenance cost is related to the replacement of a fuel cell stack after its installation. As a rule of thumb a fuel cell stack costs about 1/3rd of the complete fuel cell. This is true only for fuel cells that have a power rating of over 3kW.

Refer to the accompanying project evaluation tool for a more detailed examination of fuel cell economics

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Important considerations for installing a fuel cell

There are four major aspect to be taken care of when installing a fuel cell

1 – The most important is safety (safety of people and equipment)

2 – How to interface your fuel cell with your load and hydrogen system?

3 – Where to get your hydrogen from?

4 – Type of fuel cell technology required and what are the installation guidelines. Corrosive material may be used in certain fuel cell types, hence safety must be considered when selecting a fuel cell technology.

Important considerations for installing a fuel cell

Safety

As fuel cells use hydrogen, a flammable energy carrier, there is a need to be extremely vigilant when using and installing them. There are currently several standards that can be accessed for installing a fuel cell. When using a fuel cell you will need a good understanding about the potential dangers of hydrogen. The Health and Safety Executive have produced a booklet on fuel cell hydrogen which can be used as a starter:

http://www.hse.gov.uk/press/2004/e04022.htm

Important considerations for installing a fuel cell

Interfacing - Intermediary energy buffer

As for any generator technology, it takes time for a fuel cell to reach its full power. Also a fuel cell control system has to be capable of meeting variations in load demand. The variation in load demand are sometimes not instantaneous in the fuel cell (depending on the technology) and the time it takes for a fuel cell to deliver its full power from a cold start means that there is a need for an energy buffer.

Therefore, when designing a fuel cell system, one has to look into introducing an energy buffer such as supercapacitors, battery banks, or even a flywheel.

Most fuel cell manufacturers will construct their products with the correct amount of intermediate energy buffer integrated within them. However, there are times that you will need to include a buffer and care must be taken to ensure that this requirement is identified in the early stages of system design.

Important considerations for installing a fuel cell

Interfacing - Power conditioning

A fuel cell generates variable DC power. It also generates this power with a variable DC voltage, which cannot be directly used by a load. Hence, power delivered in this unregulated state is unsuitable for most applications and will need conditioning.

If regulated DC power is required the fuel cell will need to be connected to a DC/DC converter in order to provide a smooth power output for use with standard DC loads.

If alternating current (AC) is needed, the DC output of the fuel cell must be routed through a conversion device called an inverter. This converts the DC power into AC power with a constant voltage and frequency.

Most fuel cell manufacturers now include power conditioning electronics to provide a regulated output for DC applications. However it is important to ensure that this is the case in the early stages of system design. In most cases inverters will need to be purchased separately for AC applications.

Contents

Short guide for a stationary fuel cell installation (steps 1&2)

This section provides a basic six step guide for installation of a fuel cell. It concentrates on the technical issues that must be considered before any installation takes place. This guide only provides high level information and you may be required to get further professional advice before undertaking a fuel cell installation. Note that this is an interactive process and you may need to perform a risk assessment all the way through your design and installation process.

Step 1. Determine basic load parameters

a – Gather electric load profile (e.g., daily, seasonal and yearly if required)

b – Identify thermal loads (e.g., building heating, hot water requirements)

c – Determine load operating hours (day or night, connection to white meter?, week-end load requirements)

Step 2. Determine fuel cell installation design requirements

a – Identify all electrical interface (e.g., do you need an inverter?, electrical protection requirements, connection to available electrical panel, do you need to design a control system)

b – Determine any thermal interface requirements (e.g., identify appropriate standard for connecting fuel cell to current thermal load, check temperatures matching, design a control system, pipes)

d – Determine site and space availability for the fuel cell (e.g., is it a secure site, any ignition sources)

Short guide for a fuel cell installation (steps 3&4)

Step 3. Determine fuel cell technology and availability

a – Determine fuel cell usage regime (e.g., is it only for back up purpose, combine heat and power, primary power, etc)

b – Define if the size of the fuel cell matters (e.g., if fuel cell compactness is of importance, the PEM is the choice, else any type of fuel cell can be used)

c – Identify fuel cell technology to be installed (e.g., if less than 100kW, required only for back up power and no need for thermal load then PEM is the reference, if CHP required, then either one of PAFC, SOFC or MCFC must be used. Note: use table provided in 'fuel cell availability' to select fuel cell technology.

Step 4. Determine hydrogen requirements

a – Hydrogen grading (e.g., do you need very pure hydrogen or low purity hydrogen can be used (check manufacturer data sheet for this information, also the type of technology that you use will determine the hydrogen grading to be used)

b – Determine quantity of hydrogen to be used (check manufacturer data sheet for fuel cell hydrogen consumption rate)

c – Identify source or supplier of hydrogen (e.g., where and how to obtain hydrogen, is it better to install a renewable hydrogen system or a reformer?, what is the cheapest option? Is it viable?)

Short guide for a fuel cell installation (steps 5&6)

Step 5. Risk assessment

a – Determine the standards required for the safe installation of the fuel cell (e.g., earthing, lightning, appropriate zone, fuel cell, inverter, etc)

b – Gather a team of trained engineers and performed a risk assessment.

c – Document the risk assessment.

d – Refine your design according to the findings of the risk assessment.

e – Implement the new design as per changes made in d.

Step 6. Installation and commissioning

a – Prepare the site for the fuel cell installation (e.g., secure area from potential vandalism, identify wiring requirements including colour and number coding)

b – Install fuel cell as per manufacturer guidelines.

c – Commission fuel cell

Contents

Relevant suppliers

Small scale fuel cells		Large scale fuel cells
BCS fuel cells	PlugPower	MTU
Bosh	Vaillant	UTC
Hydrogenics	Idatech	Toshiba
Altergy Freedom	Relion	FuelCell Energy
Alternative Fuel systems	Sulzer Hexis	Ballard
APC	Sanyo electric	Fuji Electric
APS Energia	Acumentrix	Siemens Westinghouse
Ceramic Fuel Cells	Ballard	Ansaldo Fuel Cells
Cosmos Oil	Baxi (European Fuel Cell)	Ishikawajima-Harima Heavy Industry (IHI)
Hydra Fuel Cell	IRD fuel cell	Bharat Heavy Electric Ltd
Kyocera	Fuel Cell Technologies (FCT)	Mitsubishi
Arcotronics	Fuji electric	Rolls Royce
Eneco	Global Thermoelectric	
Helion	Intelligent Energy	
Viessman	Voller	
Roen Est	Ceres Power	
Fuel Cell Scotland	SiGen	
Anuvu	Nuvera Fuel Cells	
Apollo Energy Systems		
Axane		
Astris energy		

For more information see http://www.fuelcelltoday.com