Hydrogen Fuel Cells

Fuel Cells

A fuel cell is an open system galvanic cell device that transforms chemical energy into electricity.

The electricity is generated when a chemical reaction occurs within the cell and releases electrons to flow through a circuit.

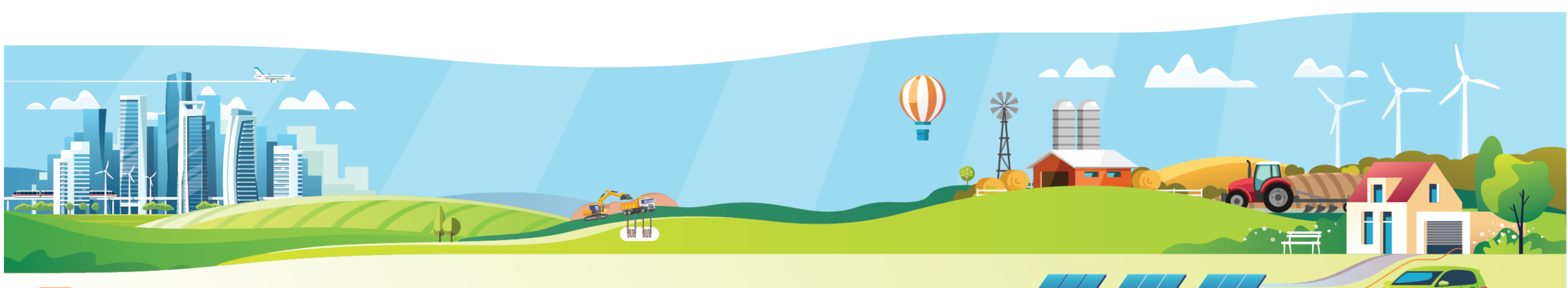
Fuel cells consist of two electrodes, an anode and a cathode, catalysts and an electrolyte membrane. The catalysts speed up the reactions that occur at the electrodes to produce electricity. While the electrolyte membrane separates the electrodes but allows charged ions to move from one electrode to the other.

Electricity can be continuously generated in a fuel cell with an external supply of the required fuels. Typically fuel cells use hydrogen as the fuel source. Hydrogen fuel cells work by passing hydrogen through the anode side of a fuel cell where the hydrogen molecules split into electrons and positively charged ions, which take different paths to the cathode. The negatively charged electrons are forced through a circuit, generating an electric current. The positively charged ions pass through the electrolyte to the cathode and combine with oxygen to produce water molecules. With an overall chemical reaction of

$$2\,H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\,H_2O_{\,(g/l)} + \text{heat}$$

A single fuel cell only generates a tiny amount of direct current (DC) so many individual fuel cells are joined together to form stacks to increase the electricity generated and the stacks can then be combined into larger systems. If alternating current (AC) is needed, the DC output of the fuel cell system must go through a conversion device called an inverter.

Fuel cell systems can vary greatly in size and power as there are several types of fuel cells that function in slightly different ways. The type of electrolyte used dictates the cell's operating characteristics, advantages and limitations and therefore its applications. The ways fuel cells can be used varies, from providing power to homes and businesses, moving a variety of vehicles including cars, buses, trucks, forklifts and trains.



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Types of Hydrogen Fuel Cells

Property	Alkaline Fuel Cell (AFC)	Direct Methanol Fuel Cell (DMFC)	Molten Carbonate Fuel Cell (MCFC)	Phosphoric Acid Fuel Cells (PAFC)	Proton Exchange Membrane Fuel Cell (PEMFC)	Solid Oxide Fuel Cell (SOFC)
Electrolyte	aqueous potassium hydroxide	polymer membrane	molten alkali metal carbonates	phosphoric acid in a silicon carbide structure	thin, permeable acidic polymer membrane	dense ceramic compound of metal oxides
Electrode / Catalyst	nickel	platinum-ruthenium	nickel	platinum on carbon	platinum	non-platinum
Electrical Efficiency (with*CHP)	60% (80 - 90%)	40%	50 - 60% (70 - 80%)	40% (~80%)	40 - 60%	50% - 60%, (70 - 80%)
Operating Temperature	70 °C	60 - 130 °C	650 °C	150 - 200 °C	80 °C	1,000 °C
Fuel and other requirements	• pure compressed hydrogen gas • pure compressed oxygen gas	• liquid methanol	• hydrogen gas or natural gas • carbon dioxide to replace consumed electrolyte carbonate ions	• hydrogen gas or natural gas	• pure hydrogen gas • oxygen	• hydrogen gas or natural gas
Cell Output	300W - 5kW			100 – 400 kW	50 - 250 kW	100 kW
Unit Outputs			2 MW	11 MW		
Anode Half Reaction	$2H_2^{+} + 4(OH)^- \rightarrow 4H_2O + 4e^-$	$CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$	$H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$	$H_2 \rightarrow 2H^+ + 2e^-$	$H_2 \rightarrow 2H^+ + 2e^-$	$H_2 + O^{2-} \rightarrow H_2O + 2e^-$
Cathode Half Reaction	$O_2 + 2H_2O + 4e^- \rightarrow 4(OH)^-$	$^3/_2 O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$	$½ O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$	$½ O_2 + 2H^+ + 2e^- \rightarrow H_2O$	$½ O_2 + 2H^+ + 2e^- \rightarrow H_2O$	$½ O_2 + 2e^- \rightarrow O^{2-}$
Application	• primarily used in controlled aerospace and • underwater applications	• mobile electronic devices and chargers • portable power packs • specialty vehicles (forklifts)	• deployed in stationary applications, providing high-quality primary and back-up power to utilities and businesses	• high-energy demand applications, such as hospitals, schools and manufacturing and processing centres	• cars • specialty vehicles (forklifts) • stacked for stationary use (data centres, telecommunication & residential markets)	• small residential auxiliary power units supplying heat and power to homes, • large-scale stationary power generators for larger buildings and businesses.
Advantages	• non-platinum electrode / catalysts • low operating temperature • waste heat can be recycled	• platinum-ruthenium can draw hydrogen from liquid methanol with our reforming • methanol has relatively high energy density • methanol is easier to transport	• internal reforming of the natural gas into hydrogen • non-platinum electrode / catalysts • waste heat can be recycled to make additional electricity • more resistant to impurities than other fuel cell types • not prone to poisoning by CO_2 or CO	• resistant to poisoning by CO • waste heat can be recycled	• low operating temperature • Fast start-up time, can meet dynamic power requirements • solid, flexible electrolyte will not leak or crack	• internal reforming of the natural gas into hydrogen • non-platinum electrode / catalysts • waste heat can be recycled to make additional electricity
Limitations	• highly sensitive • can fail when exposed to carbon dioxide	• platinum electrode / catalysts	• highly corrosive electrolyte • low durability of the fuel cell • severe constraints on the way that stacks are engineered	• internal parts must be corrosion resistant • platinum electrode / catalysts	• fuels must be purified • platinum electrode / catalysts • platinum catalyst poisoning (CO) • water management is complex	• low durability (can crack) • high temperature limits applications of SOFC units • they tend to be rather large

*Combined Heat & power