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Swiss Agency for Development and Cooperation SDC

IIEC International Institute for Energy Conservation

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FUEL Cell

"A fuel cell is an electrochemical device that converts the chemical energy of a fuel and an oxidant (pure oxygen or air) directly into electricity without the intermediate step of classical, chemical combustion". Fuels cells can be classified/characterized either based on the type of electrolyte employed or based on the operating temperature range.

Fuel cells are classified primarily by the kind of electrolyte they employ. This classification determines the kind of electro-chemical reactions that take place in the cell, the kind of catalysts required, the temperature range in which the cell operates, the fuel required, and other factors. These characteristics, in turn, affect the applications for which these cells are most suitable. There are several types of fuel cells currently under development, each with its own advantages, limitations, and potential applications.

Below are the six types of fuel cells which are popular.

FUEL CELL TYPE	DIRECT METHANOL FUEL CELL	PROTON EXCHANGE MEMBRANE FUEL CELL	ALKALINE FUEL CELL	PHOSPHORIC ACID FUEL CELL	MOLTEN CARBONATE FUEL CELL	SOLID OXIDE FUEL CELL
Electrolyte type	Proton Exchange Membrane	Proton Exchange Membrane	Potassium Hydroxide (KOH)	Phosphoric Acid	Molten Mixture of alkali metal carbonates	Oxide ion conducting ceramic
Operating temperature (°C)	20 – 90	30 – 100	50 – 200	~220	~650	500 – 1000
Charge carrier	H^+	H^+	OH^-	H^+	H_3^{2-}	O^{2-}
Power range (W)	1 – 100	1 – 100k	500 – 10k	10k – 1M	100k – 10M+	1k – 10M+
Application	Fuel Cell Vehicles	Fuel cell vehicles, Electrical devices, Backup	Emergency backup, Auxiliary Power Unit (APU)	Stationary power generation	Stationary power generation	Range Extender, APU, Stationary Power generation

Fuel Cell technology offers 24x7 clean, green, reliable & affordable solutions. It can cater to single homes as well as independent buildings, townships in urban & rural areas. The new generation Fuel cell-based power generators can generate 24×7 power and fulfil the electricity, heating & cooling requirements with the use of fuels like piped natural gas (PNG), liquified petroleum gas (LPG), biogas and hydrogen, etc. Hence it is suitable for various kinds of buildings provided it has a gas supply and the output will vary depending on the gas used.

Technology	Output energy	Application	Suitable Building type
Fuel Cell	Electricity + Heat	Storage of excess power from renewable energy sources, electricity generation	All types of buildings

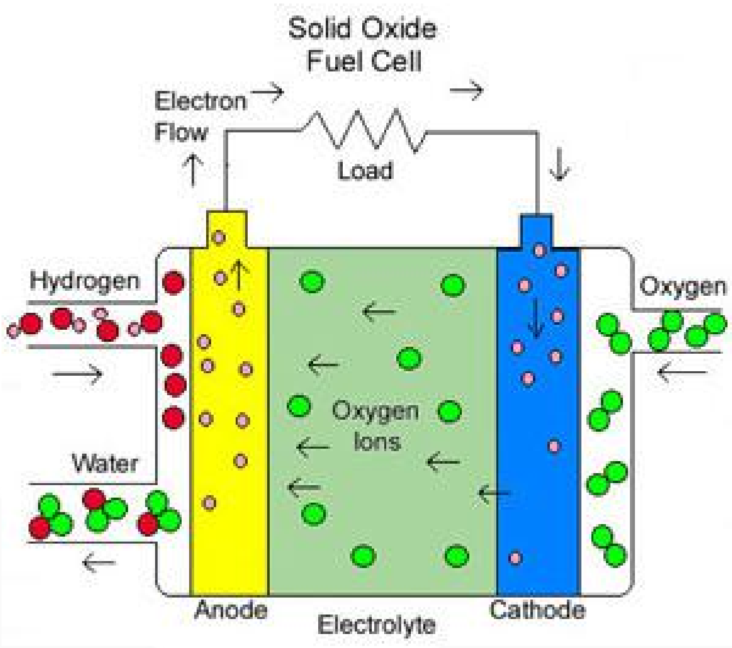
Type of gas	Gas consumption (kg/hour)	Electricity generated per (kWh/kg)	Electricity generated (kWh/kW/day)	Temperature of waste heat (°C)	Amount of heat generated (kWh(thermal)/ kWh (electricity))
LPG	0.155	6	24	100-400	1.2
PNG	0.145	7	24	100-400	1.2
Biogas	0.29	3	24	100-400	1.2

However, in the present study/evaluation, only the solid oxide fuel cells (SOFC) are considered owing to their high efficiency in electricity and heat generation.

Solid Oxide Fuel Cells

A solid oxide fuel cell (SOFC) is an energy conversion device that produces electricity by electrochemically combining a fuel and an oxidant across an ionic conducting oxide electrolyte. Solid Oxide fuel cells (SOFC) use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O2) as electrolyte. Efficiency is about 60 percent, and operating temperatures are about 1,000 ˚C (about 1,800 ˚F). Cells output is up to 100 kW. 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.

Figure 1: Drawing of a solid oxide cell



SOFCs have a number of advantages due to their solid materials and high operating temperature.

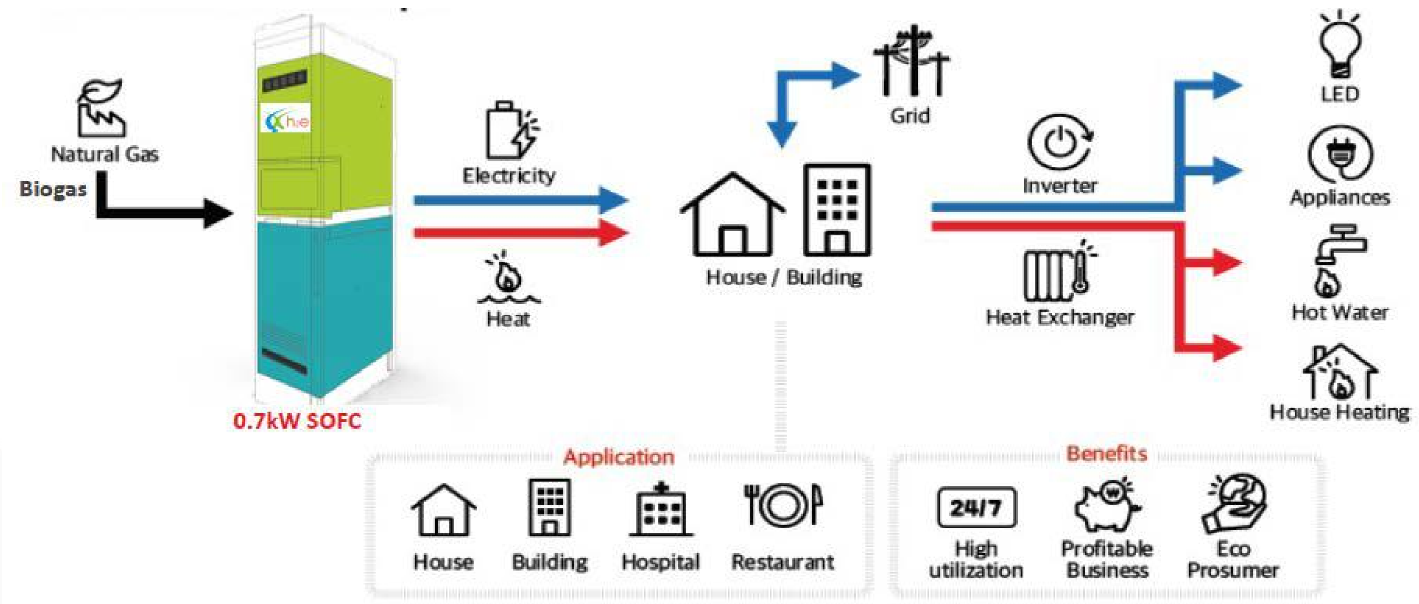
1. Since all the components are solid, as a result, there is no need for electrolyte loss maintenance and also electrode corrosion is eliminated.
2. Since SOFCs are operated at high temperature, expensive catalysts such as platinum or ruthenium are totally avoided.
3. Due to high-temperature operation, the SOFC has a better ability to tolerate the presence of impurities as a result as a result the life of the SOFC increases.
4. Costs are reduced for internal reforming of natural gas.
5. Releasing negligible pollution is also a commendable reason why SOFCs are popular.

However, SOFCs also have some disadvantages.

1. SOFCs operate high temperature, so the materials used as components are thermally challenged.
2. The relatively high cost and complex fabrication are also significant problems that need to be solved.
3. The high temperature limits applications of SOFC units and they tend to be rather large.

Figure Below[1] depicts the schematic of the fuel cell and its integration in buildings.

Figure 2: Fuel cell power generator and its varied applications



The capital cost of SOFC is expected to be ~INR1,75,000/- per kW of installation. Unlike solar PV, the fuel cell owners must bear the operational cost in the form of fuel costs. Hence the payback depends on the cost of gas and capacity utilization. Along with electricity, the thermal energy from the fuel cell power pack can be used for water heating or as a source of heat in a vapour absorption refrigeration machine. Fuel cell power packs are modular, and the solutions are easily scalable and replicable across different locations and types of buildings.

National Status

The last few years has seen considerable research activity in hydrogen fuel cells in India mainly via R&D work sponsored by the MNRE, DST, CSIR etc.

Technology providers from India

The key players operating in the Indian market includes: Thermax Limited and h2e Power.

[1] *Source: H2e Power*

Case Study

Transport for London (TfL) acquired a 20-year lease for the Palestra building in Southwark in 2006 and now occupies eleven of the building's twelve floors. The hydrogen fuel cell unit was manufactured by UTC Power, based in the USA. The unit was supplied to the site by Logan Energy Limited. The hydrogen fuel cell and associated plant cost was USD 3,083,376. Operational cost savings of the fuel cell CCHP have been estimated at USD 115,626 a year when compared against conventional grid supplied electricity and mains–fed gas fired boilers. While the capital cost of a fuel cell plant is high, the savings in fuel and maintenance can result in reduced payback periods where all the heat is utilized for water heating and cooling via absorption chillers. In the Palestra fuel cell, hydrogen is extracted from a mains natural gas supply by a steam reformer. Oxygen is sourced from an ambient air supply to the unit. The fuel cell comprises a phosphoric acid electrolyte sandwiched between two electrodes. Air and hydrogen are respectively passed over the two electrodes and energy released in a chemical reaction is converted into low–voltage DC electricity, with heat and water produced as by products. Individual cells only generate a small amount of power and so several cells are assembled into a stack to provide sufficient power for the Palestra building. Hydrogen fuel cells work continuously, providing a supply of hydrogen and oxygen fuel is maintained. The unit (Pure Cell Model 200) is capable of providing 200 kWe of electricity, in addition to 138 kWth of heat. This, in addition to heat generated by the RECHP, is used to pre–heat the building's domestic hot water supply. The RECHP is capable of supplying of 834 kWe electricity and 987 kWth of heat, giving the combined CCHP system a power capacity of 1034 kWe. the fuel cell had generated 288 MWh of electricity, 332 MWh of heat and had saved around 116 tonnes of CO_2 (against an equivalent conventional power supply). The fuel cell is currently operating at approximately 36% efficiency although over time the electrical output is anticipated to reduce, and the heat output will increase. It has been estimated that the hydrogen fuel cell results in carbon dioxide emissions savings of 30% when compared to a building supplied by a conventional gas and electricity supply.