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A Unit of IDEX Corporation

Fuel Cell Applications

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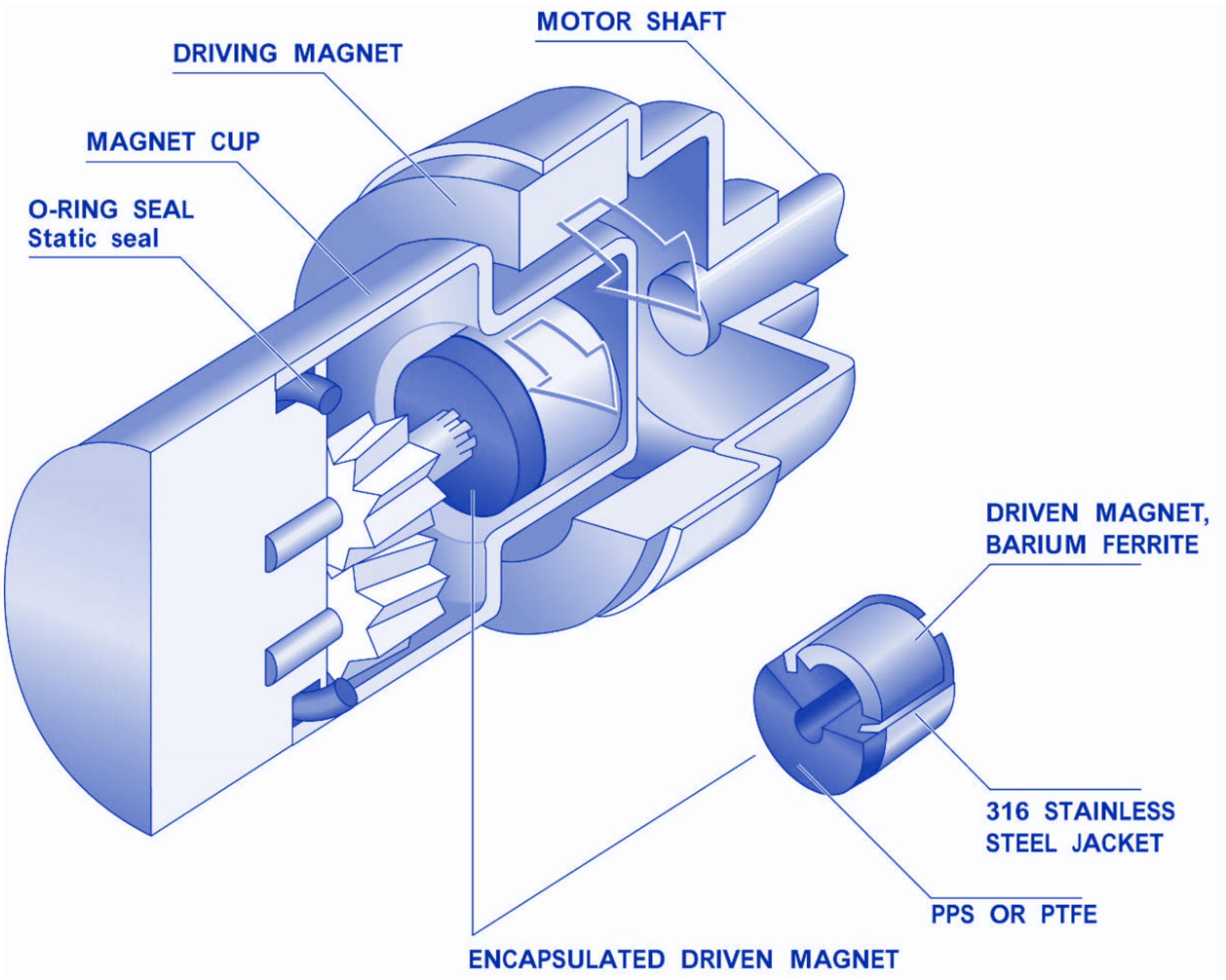
What is Magnetically-Driven?



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Fuel Cell Industry Future

- According to Precedence Research, the global fuel cell market size is expected to surpass around US$ 42.3 billion by 2030 and is expanding growth at a CAGR of 25.1% from 2021 to 2030.
- The global fuel cell market size was estimated at US$ 5.63 billion in 2020.
- Transportation but also home systems
- IHS Markit data suggests the battle is over, with its prediction that by 2032 battery electric vehicle (BEV) production will reach nearly 18 million a year, with fuel cell electric vehicles (FCEV) at less than 500,000.

https://www.forbes.com/sites/neilwinton/2020/04/26/could-hydrogen-fuel-cells-revive-threaten-battery-technology-in-cars/?sh=3fa1367e55e4

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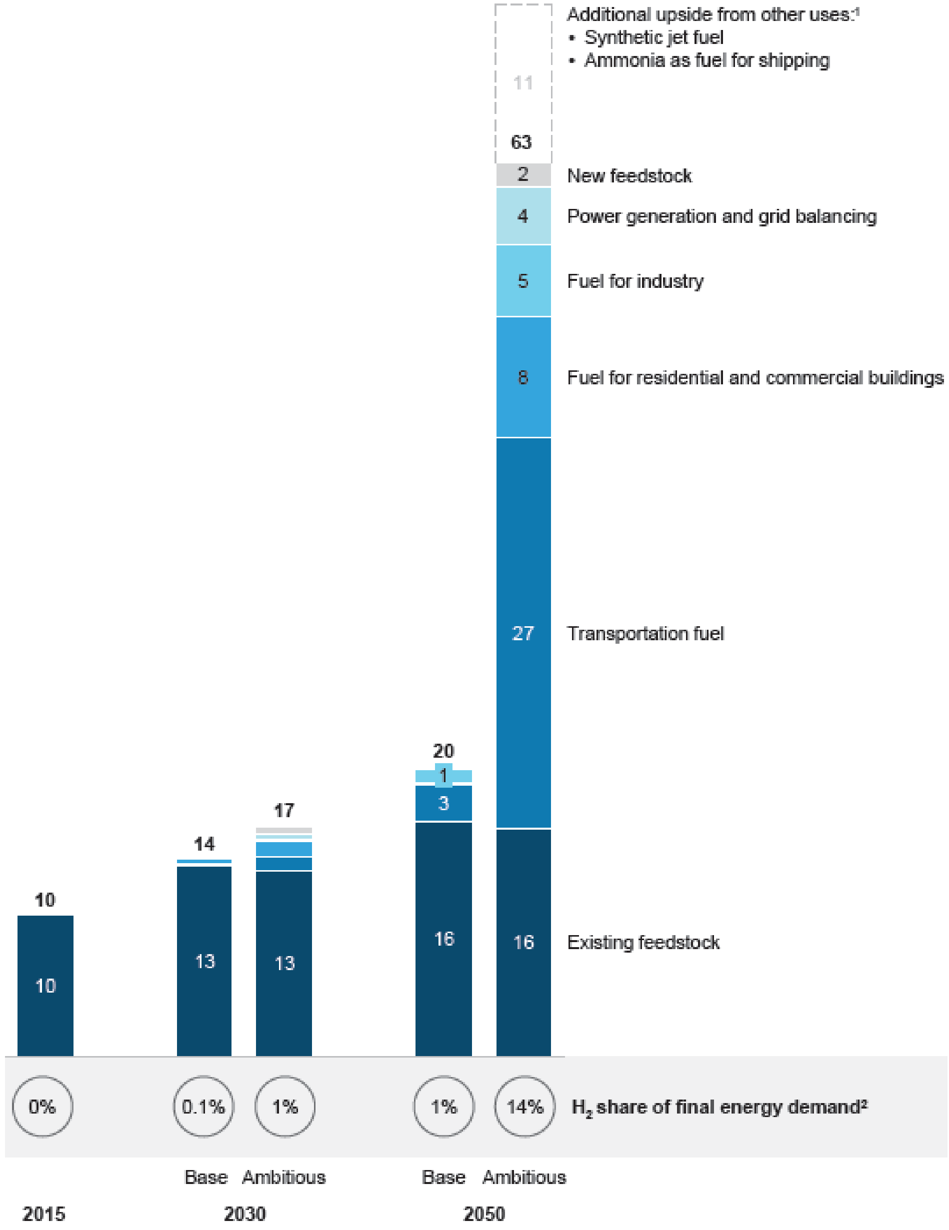
Fuel Cell Industry Future

Exhibit 2

Hydrogen demand potential across sectors – 2030 and 2050 vision

Million metric tons per year



[1] Assuming that 20% of jet fuel demand would be met by synthetic fuel and 20% of marine bunker fuel by ammonia
[2] Demand excluding feedstock, based on IEA final energy demand for the US
Note: Some numbers may not add up due to rounding

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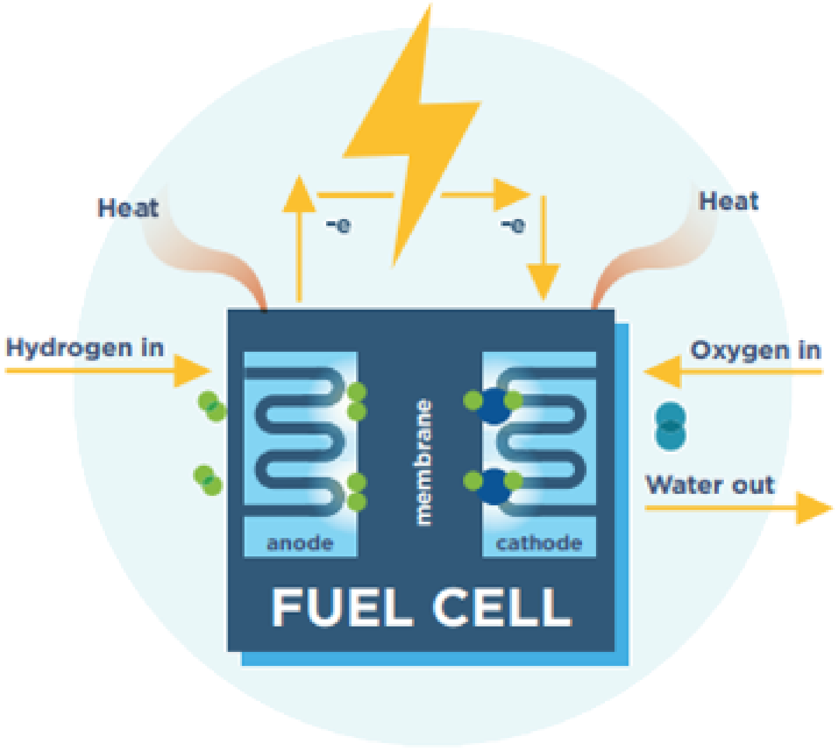
Fuel Cell Technology

HOW FUEL CELLS WORK

A fuel cell is an electrochemical energy conversion device – it utilizes hydrogen and oxygen to generate electricity, heat, and water.

1. The hydrogen atoms enter at the anode.
2. The atoms are stripped of their electrons in the anode.
3. The positively charged protons pass through the membrane to the cathode and the negatively charged electrons are forced through a circuit, generating electricity.
4. After passing through the circuit, the electrons combine with the protons and oxygen from the air to generate the fuel cell's byproducts: water and heat.



Fuel Cell Technology

Cell Technologies

Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Electrical Efficiency (LHV)	Applications	Advantages	Challenges
Polymer Electrolyte Membrane (PEM)	Perfluorosulfonic acid	<120°C	<1 kW - 100 kW	60% direct H_2;[i] 40% reformed fuel[ii]	• Backup power • Portable power • Distributed generation • Transportation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up and load following	• Expensive catalysts • Sensitive to fuel impurities
Alkaline (AFC)	Aqueous potassium hydroxide soaked in a porous matrix, or alkaline polymer membrane	<100°C	1 - 100 kW	60%[iii]	• Military • Space • Backup power • Transportation	• Wider range of stable materials allows lower cost components • Low temperature • Quick start-up	• Sensitive to CO_2 in fuel and air • Electrolyte management (aqueous) • Electrolyte conductivity (polymer)
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a porous matrix or imbibed in a polymer membrane	150 - 200°C	5 - 400 kW, 100 kW module (liquid PAFC); <10 kW (polymer membrane)	40%[iv]	• Distributed generation	• Suitable for CHP • Increased tolerance to fuel impurities	• Expensive catalysts • Long start-up time • Sulfur sensitivity
Molten Carbonate (MCFC)	Molten lithium, sodium, and/or potassium carbonates, soaked in a porous matrix	600 - 700°C	300 kW - 3 MW, 300 kW module	50%[v]	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Suitable for CHP • Hybrid/gas turbine cycle	• High temperature corrosion and breakdown of cell components • Long start-up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	500 - 1000°C	1 kW - 2 MW	60%[vi]	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Solid electrolyte • Suitable for CHP • Hybrid/gas turbine cycle	• High temperature corrosion and breakdown of cell components • Long start-up time • Limited number of shutdowns

Fuel Cell Technology – Backup Power

Cell Phone Towers

ReliOn fuel cells at AT&T sites in Arvada and Byers, CO

Figure 15: IdaTech PEM Back-up Unit
Photo courtesy of IdaTech LLC, NREL/PIX 19192.

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Fuel Cell Technology – Transportation

FCEV

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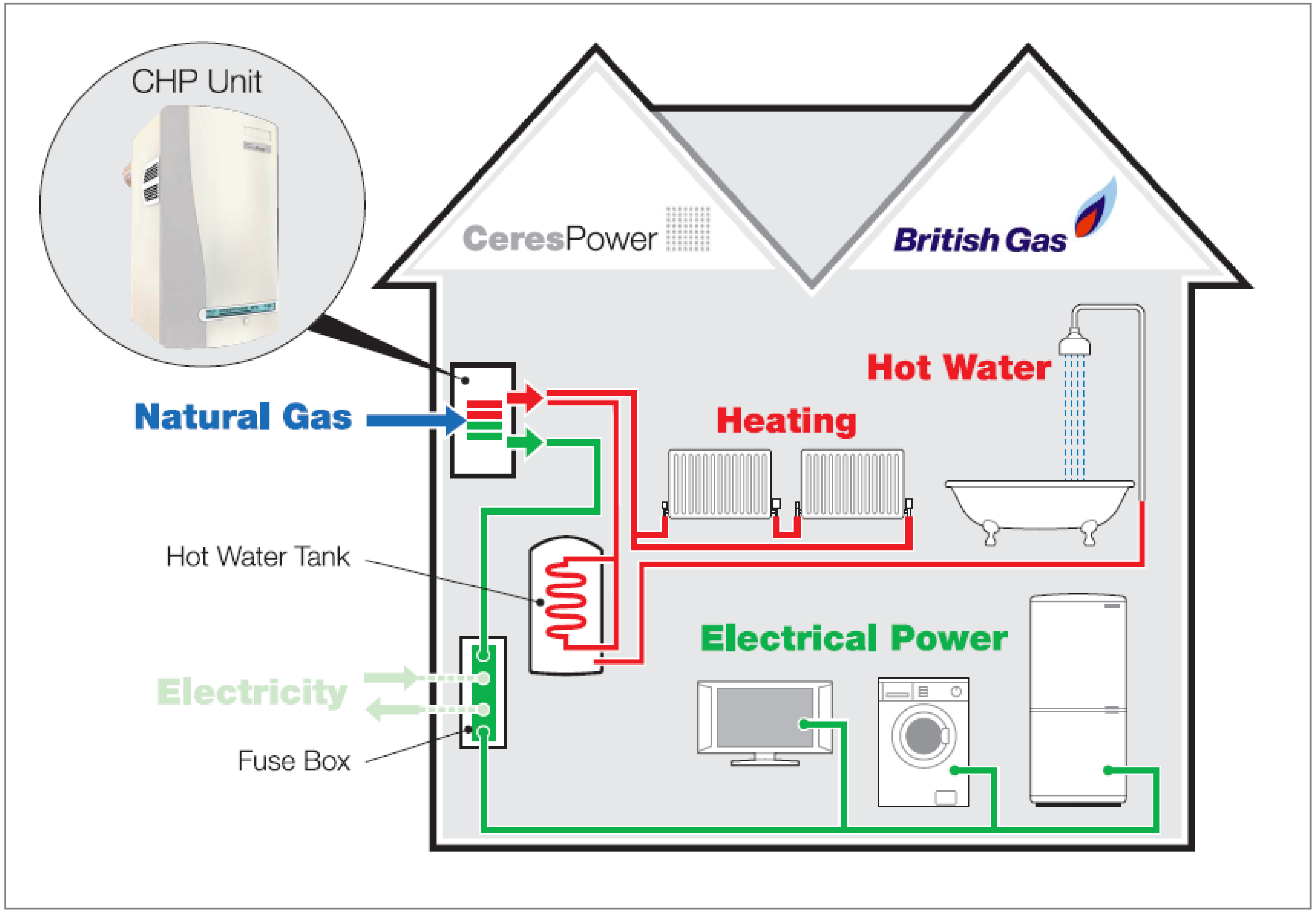
Fuel Cell Technology – Stationary Residential

CHP



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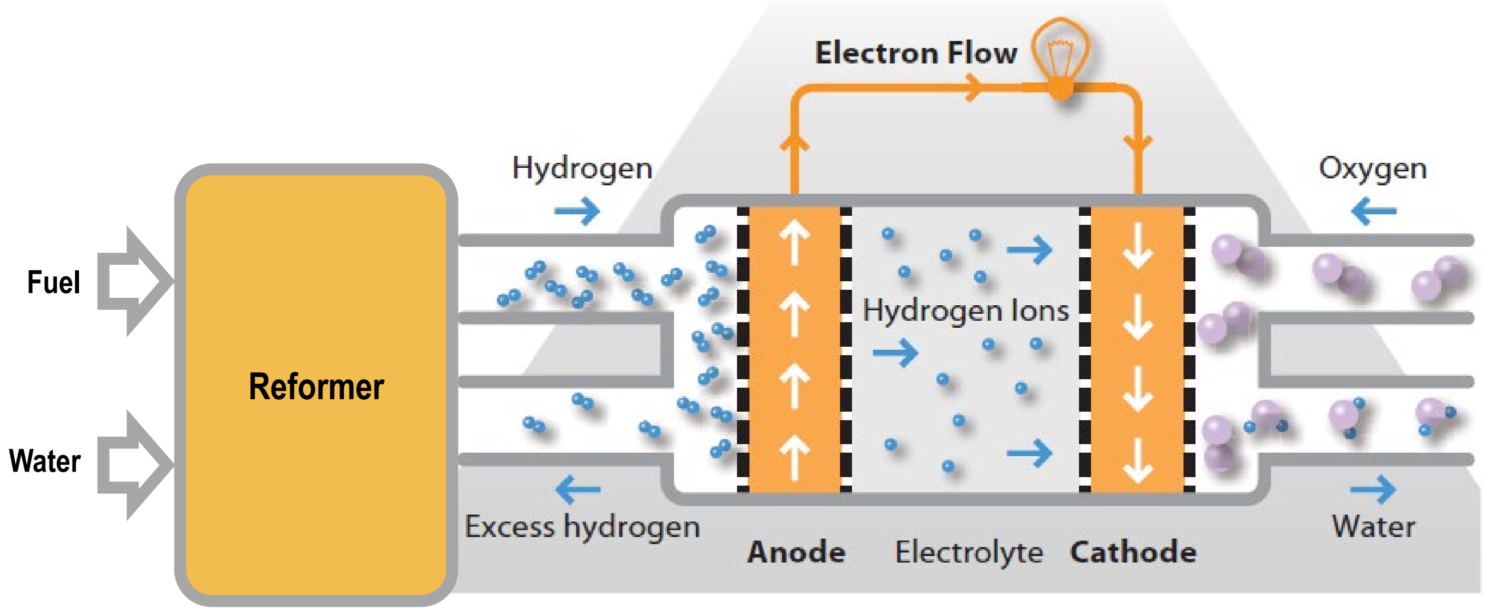
Fuel Cell Technology Block Diagram

FC Components are Standard at the Block Diagram Level



Implementation Varies Widely from Customer to Customer

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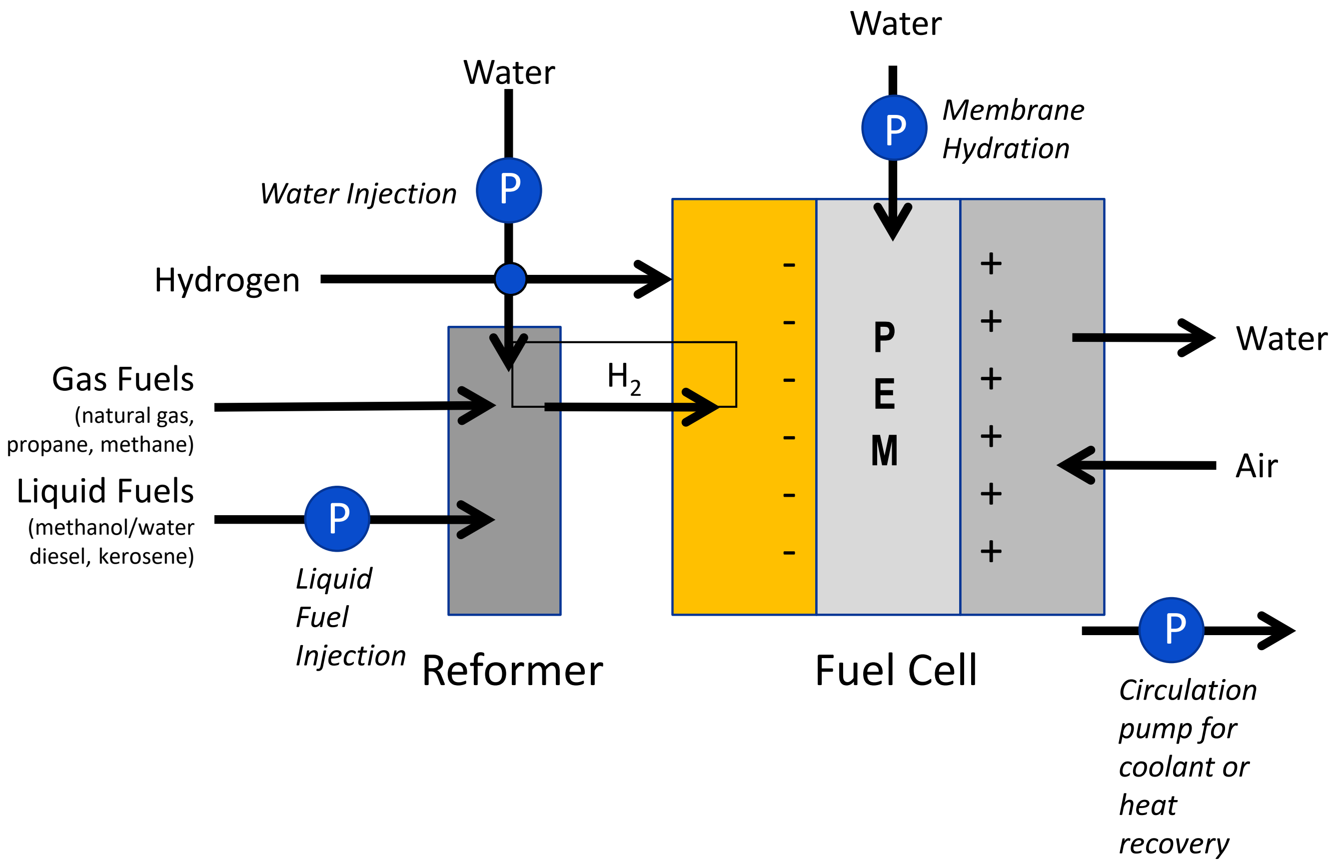
Fuel Cell Technology & Micropump Products



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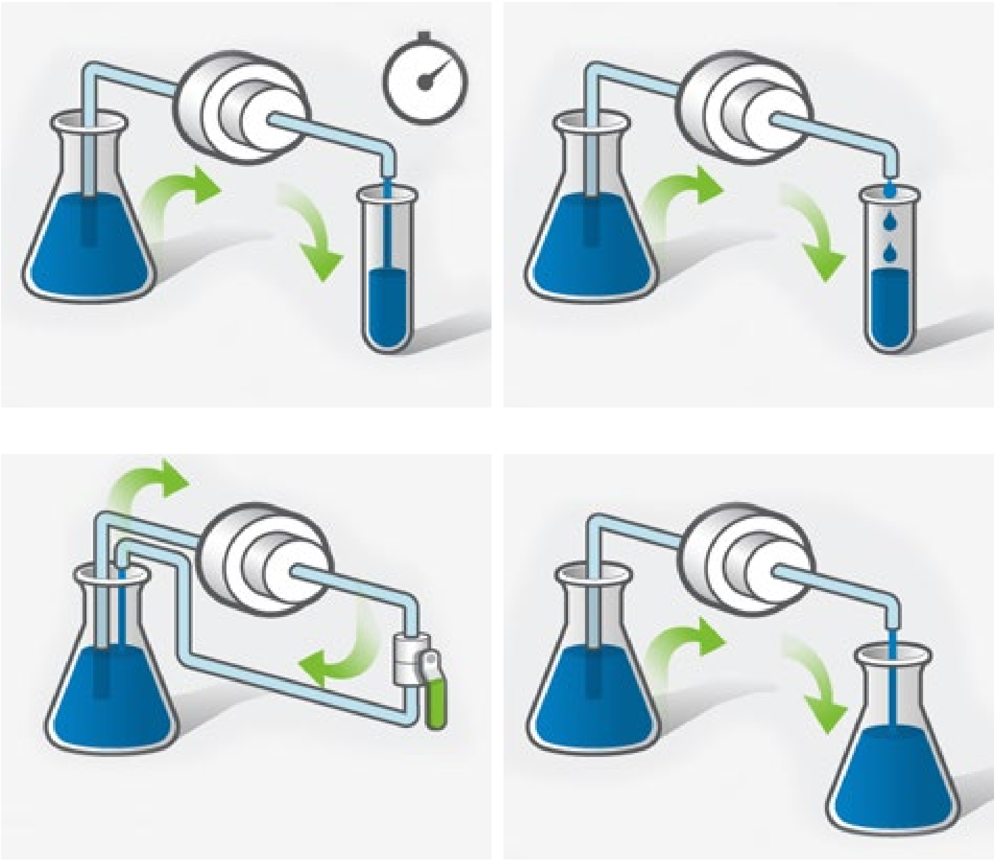
Fuel Cell Technology

- Reformer fuel supply pump (liquid fuel reformers)
- Reformer hydration pump (gaseous fuel reformers)
- Cell membrane hydration pump
- Water transfer pump for heat recovery
- Coolant circulation pump (SOFC and micro-CHP units)



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Product Solutions for Fuel Cell Equipment

GAF Series Specifications

- Displacements:
  - 0.017 ml/rev (X21) | 0.042 ml/rev (V21) (as special request)
  - 0.092 ml/rev (T23)
- Min Flow Rate: 8.5 mL/min (0.002 US gpm)
- Max Flow Rate: 506 mL/min (0.134 US gpm)
- Max Differential Pressure: 17.3 Bar (250 psi)
- Max System Pressure: 21 Bar (300 psi)
- Temp range: -46 to 177 °C (-50 to 350 °F)

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Product Solutions for Fuel Cell Equipment

GJ Series Specifications

- Displacements:

  0.316 ml/rev (N21) | 0.64 ml/rev (N23)

  0.91 ml/rev(N25) | 1.23 ml/rev (N27)
- Min Flow Rate: 158 mL/min (0.041 US pm)
- Max Flow Rate: 6.8 L/min (1.8 US gpm)
- Max Differential Pressure: 5.6 5 Bar (80 psi)
- Max System Pressure: 21 Bar (300 psi)
- Temp range: -46 to 121 °C (-50 to 250 °F)

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Thank You!

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