

**Comparison of Fuel Cell Technologies**

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Electrical Efficiency (LHV)	Applications	Advantages	Challenges
<b>Polymer Electrolyte Membrane (PEM)</b>	Perfluorosulfonic acid	<120°C	<1 kW - 100 kW	60% direct H <sub>2</sub> <sup>i</sup> 40% reformed fuel <sup>ii</sup>	<ul style="list-style-type: none"> <li>Backup power</li> <li>Portable power</li> <li>Distributed generation</li> <li>Transportation</li> <li>Specialty vehicles</li> </ul>	<ul style="list-style-type: none"> <li>Solid electrolyte reduces corrosion &amp; electrolyte management problems</li> <li>Low temperature</li> <li>Quick start-up and load following</li> </ul>	<ul style="list-style-type: none"> <li>Expensive catalysts</li> <li>Sensitive to fuel impurities</li> </ul>
<b>Alkaline (AFC)</b>	Aqueous potassium hydroxide soaked in a porous matrix, or alkaline polymer membrane	<100°C	1 - 100 kW	60% <sup>iii</sup>	<ul style="list-style-type: none"> <li>Military</li> <li>Space</li> <li>Backup power</li> <li>Transportation</li> </ul>	<ul style="list-style-type: none"> <li>Wider range of stable materials allows lower cost components</li> <li>Low temperature</li> <li>Quick start-up</li> </ul>	<ul style="list-style-type: none"> <li>Sensitive to CO<sub>2</sub> in fuel and air</li> <li>Electrolyte management (aqueous)</li> <li>Electrolyte conductivity (polymer)</li> </ul>
<b>Phosphoric Acid (PAFC)</b>	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% <sup>iv</sup>	<ul style="list-style-type: none"> <li>Distributed generation</li> </ul>	<ul style="list-style-type: none"> <li>Suitable for CHP</li> <li>Increased tolerance to fuel impurities</li> </ul>	<ul style="list-style-type: none"> <li>Expensive catalysts</li> <li>Long start-up time</li> <li>Sulfur sensitivity</li> </ul>
<b>Molten Carbonate (MCFC)</b>	Molten lithium, sodium, and/or potassium carbonates, soaked in a porous matrix	600 - 700°C	300 kW - 3 MW, 300 kW module	50% <sup>v</sup>	<ul style="list-style-type: none"> <li>Electric utility</li> <li>Distributed generation</li> </ul>	<ul style="list-style-type: none"> <li>High efficiency</li> <li>Fuel flexibility</li> <li>Suitable for CHP</li> <li>Hybrid/gas turbine cycle</li> </ul>	<ul style="list-style-type: none"> <li>High temperature corrosion and breakdown of cell components</li> <li>Long start-up time</li> <li>Low power density</li> </ul>
<b>Solid Oxide (SOFC)</b>	Yttria stabilized zirconia	500 - 1000°C	1 kW - 2 MW	60% <sup>vi</sup>	<ul style="list-style-type: none"> <li>Auxiliary power</li> <li>Electric utility</li> <li>Distributed generation</li> </ul>	<ul style="list-style-type: none"> <li>High efficiency</li> <li>Fuel flexibility</li> <li>Solid electrolyte</li> <li>Suitable for CHP</li> <li>Hybrid/gas turbine cycle</li> </ul>	<ul style="list-style-type: none"> <li>High temperature corrosion and breakdown of cell components</li> <li>Long start-up time</li> <li>Limited number of shutdowns</li> </ul>

<sup>i</sup> NREL Composite Data Product 8, "Fuel Cell System Efficiency," [http://www.nrel.gov/hydrogen/docs/cdp/cdp\\_8.jpg](http://www.nrel.gov/hydrogen/docs/cdp/cdp_8.jpg)

<sup>ii</sup> Panasonic Headquarters News Release, "Launch of New 'Ene-Farm' Home Fuel Cell Product More Affordable and Easier to Install," <http://panasonic.co.jp/corp/news/official.data/data.dir/2013/01/en130117-5/en130117-5.html>

<sup>iii</sup> G. Mulder et al., "Market-ready stationary 6 kW generator with alkaline fuel cells," ECS Transactions 12 (2008) 743-758

<sup>iv</sup> Doosan PureCell Model 400 Datasheet, [http://www.doosanfuelcell.com/attach\\_files/link/PureCell%20Model%20400%20Datasheet.pdf](http://www.doosanfuelcell.com/attach_files/link/PureCell%20Model%20400%20Datasheet.pdf)

<sup>v</sup> FuelCell Energy DFC300 Product Specifications, <http://www.fuelcellenergy.com/assets/DFC300-product-specifications1.pdf>

<sup>vi</sup> Ceramic Fuel Cells Gennex Product Specifications, <http://www.bloomenergy.com/fuel-cell/es5-data-sheet/>

**For More Information**

More information on the Fuel Cell Technologies Office is available at <http://www.hydrogenandfuelcells.energy.gov>.