

# Apollo Energy Systems, Inc.

## FUEL CELL COMPARISONS:

	Phosphoric Acid Fuel Cell	Proton Exchange Membrane Fuel Cell	Liquid Molten Carbonate Fuel Cell	Solid Oxide Fuel Cell	Apollo Solutions Alkaline "APOLLO™" Fuel Cell (1)
	PAFC	PEM	MCFC	SOFC	AFC
Electrolyte	Liquid Phosphoric Acid	Ion Exchange membrane (solid polymer)	Liquid Molten Carbonate	Ceramic	Potassium Hydroxide
Catalyst	Platinum	Platinum	Nickel	Perovskites	Non Precious Metals
Cell Operating Temperature (deg °C)	205 C	Room temperature to 80°C	650 C	800-1000 C	Room temp. to 80°C
Electrical System Efficiency (% LHV)	36-45	32-40	43-55	43-55	50-60
Price per kW	\$2,000	\$4,000	\$5,000	\$5,000	\$2000
<b>Some Applications</b>					
Cogeneration	X	X	X	X	X
Utility Power	X		X	X	X
Distributed Power	X	X	X	X	X
Utility Repowering	X		X	X	X
Passenger Vehicles		X			X
Heavy Duty Vehicles	X	X		X	X
Portable Power		X			X
Specialty Power		X			X

### Dynamics of Competing Technologies:

**PAFC/MCFC/SOFC:** These three technologies are high temperature (Phosphoric Acid which operates at 205 degrees C, Liquid Molten Carbonate which operates at 650 degrees C and Solid Oxide which operates at 800 to 1,000 degrees C). Because of the high temperature operation, and time to go to these high temperatures from ambient temperature, these fuel cells are not applicable to electric cars. They are used mostly in large standby power plant applications (e.g. backup power).

**PEM/AFC:** These are low temperature fuel cell technologies. The AFC have the highest voltage and highest efficiency of the five fuel cells. The PEM is an acid based fuel cell and requires a heavy loading of platinum in its electrodes and in the Membrane. The PEM fuel cell must be kept at a certain degree of moisture consistently in order to prevent drying out. To overcome this problem, a moisturizing machine must be used to force moist air through the fuel cell. These low temperature fuel cells don't suffer from the same limitations as their high temperature counterparts and thus can be used for both electric car and backup power applications.