Direct Methanol Fuel Cell

Anode catalysts: PtRu
Cathode catalyst: Pt
Operating temperature(°C): 80 - 100

Advantages:

- Eliminates the need of a fuel reformer
- Smaller fuel cell system
- Cheaper

Disadvantage:

- The fuel cell rection still produces carbon dioxide, which is a greenhouse gas that leads to global warming.

Electrochemical Equation

Anode : $CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^-$

Cathode : $\frac{3}{2} O_2 + 6H^+ + 6e^- \rightarrow 3H_2O$

Cell : $CH_3OH + \frac{3}{2} O_2 \rightarrow CO_2 + 2H_2O$

Molten Carbonate Fuel Cell

Electrolyte: Liquid solution of Li, Na and/or K carbonates
Operating temperature(°C): 600 - 1000
Application: Electric utility
Advantage: High temperature advantages
Disadvantage: High temperature enhances corrosion and breakdown of cell components

Note: High temperature advantages include higher efficiency, and the flexibility to use more types of fuels and inexpensive catalysts as the reactions involving breaking of carbon to carbon bonds in large hydrocarbon fuels occur much faster as the temperature is increased.

Electrochemical Equation

Anode: $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$

Cathode: $\frac{1}{2} O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$

Cell: $H_2 + \frac{1}{2} O_2 + CO_2 \rightarrow H_2O + CO_2$

Proton Exchange Membrane Fuel Cell

Electrolyte: Solid organic polymer poly-perfluorosulphonic acid

Operating temperature(°C): 60 - 100

Application: Electric utility, Portable power, Transportation

Advantages:

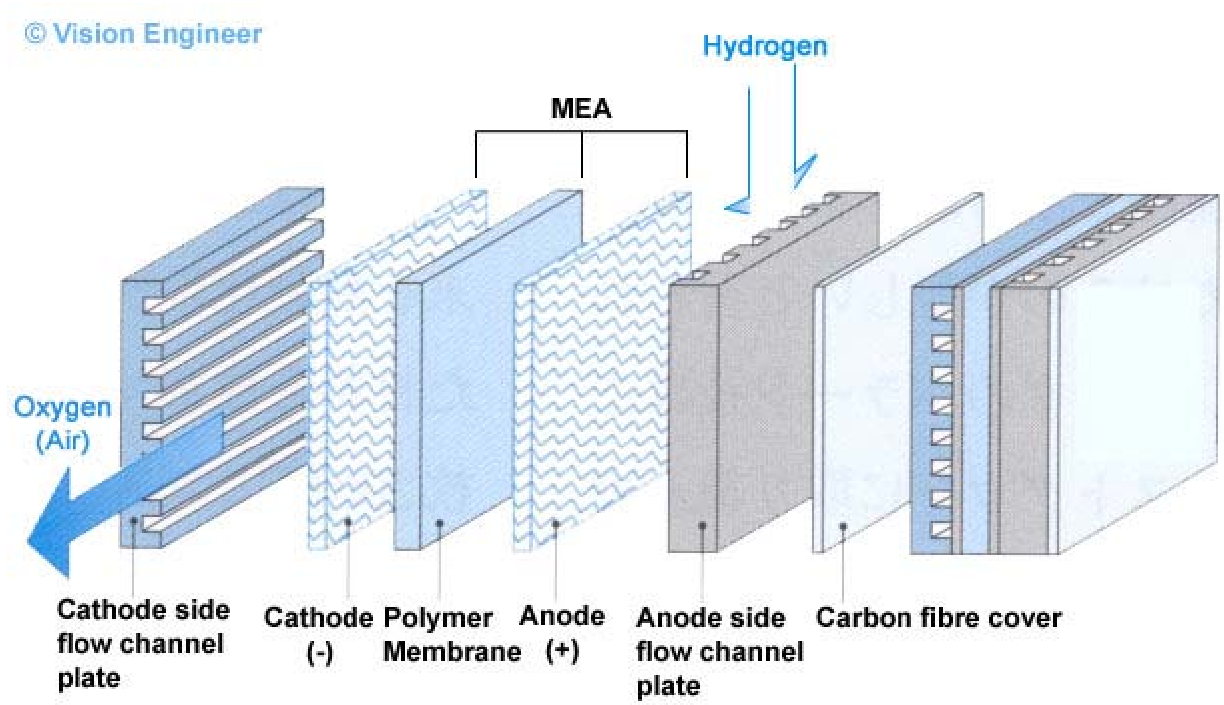
- Solid electrolyte reduces corrosion & management problems
- Low temperature
- Quick start-up

Disadvantages:

- LT requires expensive catalyst; High sensitivity to fuel impurities

Electrochemical Equation

Anode:	$H_2 \rightarrow 2H^+ + 2e^-$
Cathode:	$\frac{1}{2} O_2 + 2H^+ + 2e^- \rightarrow H_2O$
Cell:	$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$



Reforming Methanol

Goal: Remove as much of the hydrogen (**H**) as possible from this molecule, while minimizing the emission of pollutants such as **CO**.

Hot methanol molecules hits catalyst, splits into **CO** and **H_2**:

$$CH_3OH \rightarrow CO + 2H_2$$

Water vapor reacts with **CO** to for **CO_2**

$$H_2O + CO \rightarrow CO_2 + H_2$$

Reforming Natural Gas

Natural gas is processed using a similar reaction.

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

$$H_2O + CO \rightarrow CO_2 + H_2$$

Neither of these reactions is perfect; some methanol or natural gas and carbon monoxide make it through without reacting. These are burned in the presence of a catalyst, with a little air to supply oxygen. This converts most of the remaining CO to CO_2, and the remaining methanol to CO_2 and water.

Fuel-Cell-Powered Electric Car

If the fuel cell is powered with pure H_2, it can be up to 80% efficient.
80 % of the energy content of the H_2 becomes electrical energy.

Unfortunately, hydrogen is difficult to store in a car. reformer to convert Refroming MeOH to H_2, the drops the overall efficiency to 30 to 40%.

Electrical energy still needs to be converted into mechanical work.
A reasonable value for the efficiency of the motor/inverter is about 80%

Overall efficiency of about **24** to **32**%.

Gasoline-Powered Car

Efficiency of a gasoline-powered car is surprisingly low

All heat in exhaust or radiator is wasted energy. Energy used to turn the pumps, fans and generators.

Overall efficiency of an automotive gas engine is about **20%.**

Battery-Powered Electric Car

Battery is about 90% efficient (generates some heat or require heating)
Electric motor/inverter is about 80% efficient.
Overall efficiency of about 72%

The electricity used to power the car had to be generated somewhere. If it was generated at a power plant that used a combustion process (rather than nuclear, hydroelectric, solar or wind), only ~ 40% of the fuel required by the power plant was converted into electricity.

Charging the car requires the conversion of AC to DC. ~ 90% efficiency.
Overall efficiency of **26%.**

If the electricity for the car is generated by a hydroelectric plant for instance (free energy) and the efficiency goes up to 65%.