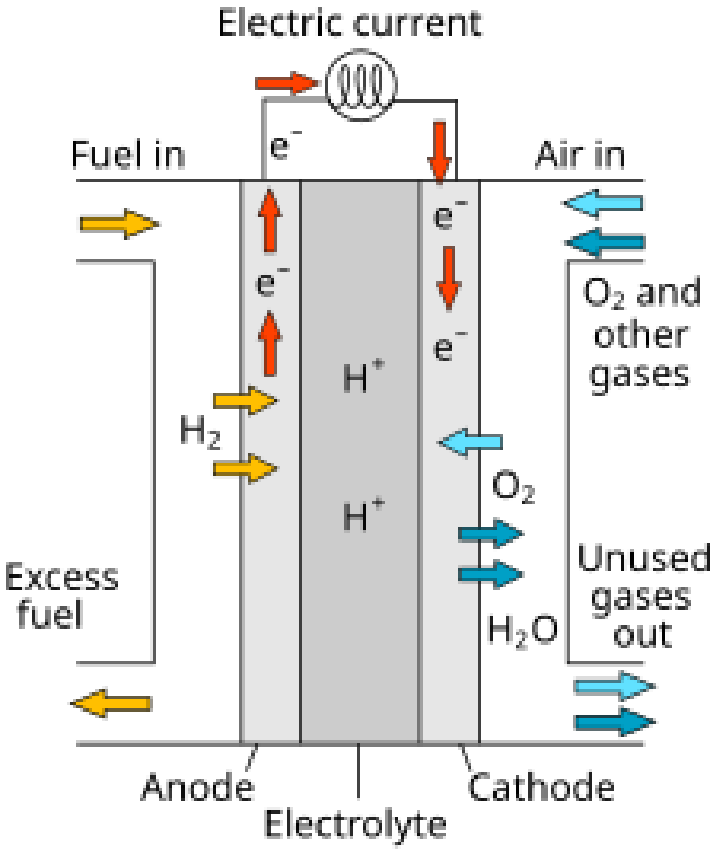
Fuel Cell

Fuel cell is an electrochemical device that directly converts the chemical energy of a fuel (like hydrogen, methanol, or natural gas) and an oxidant (usually oxygen from air) into electricity, water, and heat, without combustion.

- ✓ Works like a battery, but does not run down as long as fuel and oxidant are supplied.
- ✓ Clean and efficient (no harmful combustion products if hydrogen is used).
- ✓ Continuous power source (unlike primary batteries, which get exhausted).



https://en.wikipedia.org/wiki/Fuel_cell

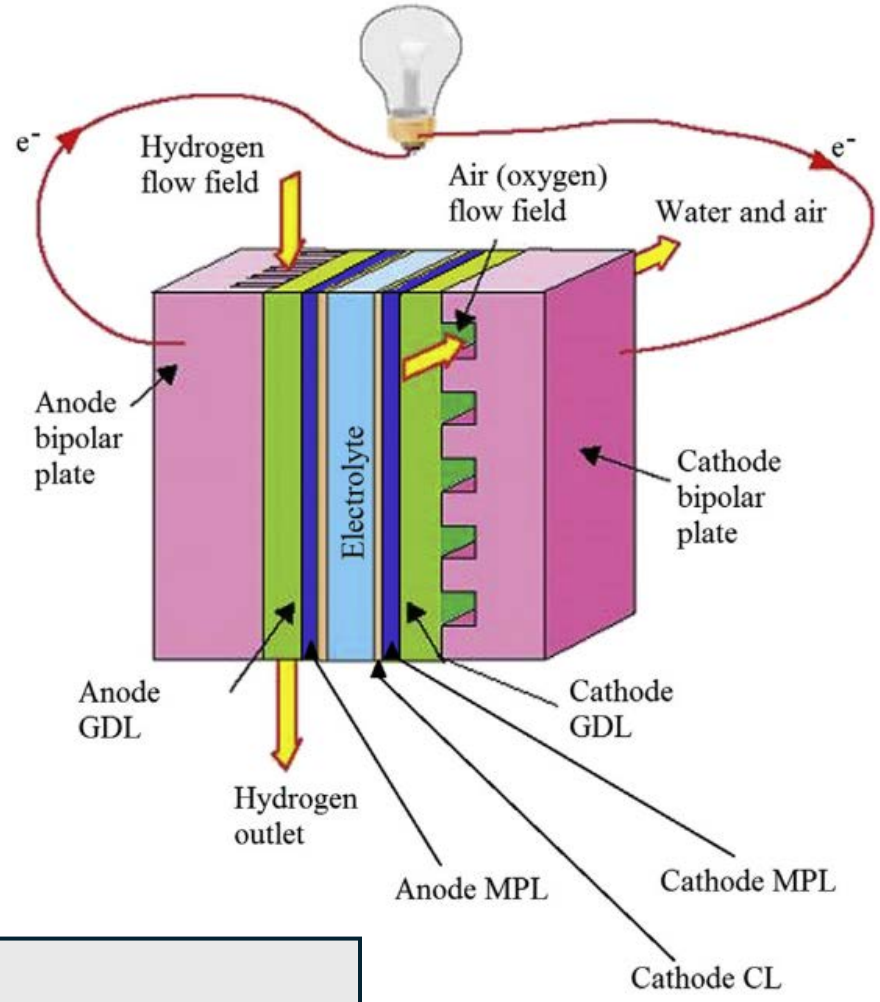
Fuel Cell: Components

Anode → where fuel (H_2) is oxidized.

Cathode → where oxygen is reduced.

Electrolyte → allows only specific ions (like H^+ or O^{2-}) to pass through, keeping charges balanced.

Catalyst → usually platinum, speeds up reactions.



Proton exchange membrane (PEM)

Gas diffusion layer (GDL) Micro-porous layer (MPL) Catalyst layer (CL)

https://doi.org/10.1016/j.ijhydene.2016.08.179

Fuel Cell: Working Principle

Hydrogen Fuel Cell Chemistry:

Anode (Oxidation):

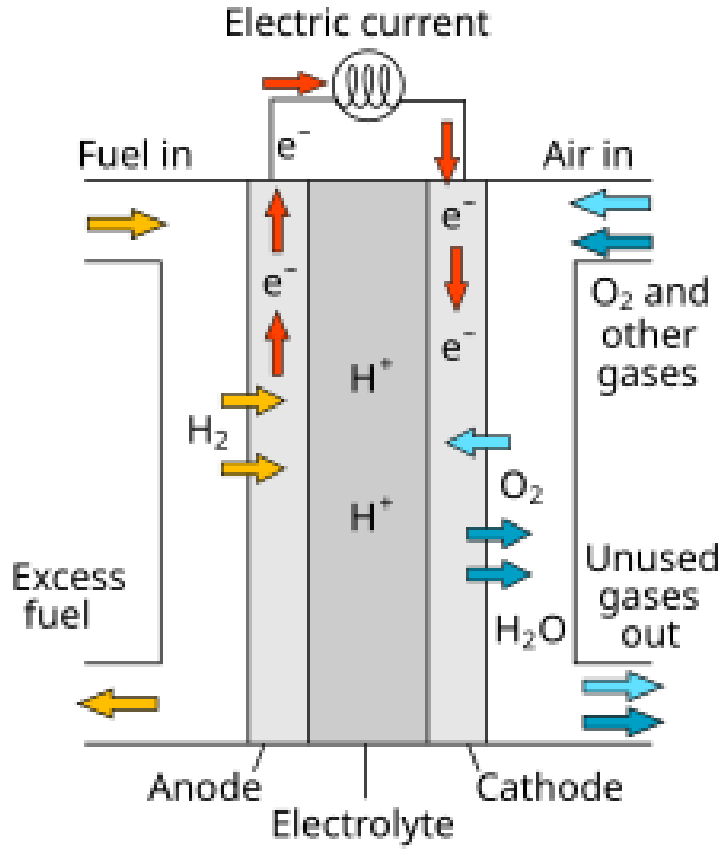
$$H_2 \rightarrow 2H^+ + 2e\text{-}$$

Cathode (reduction):

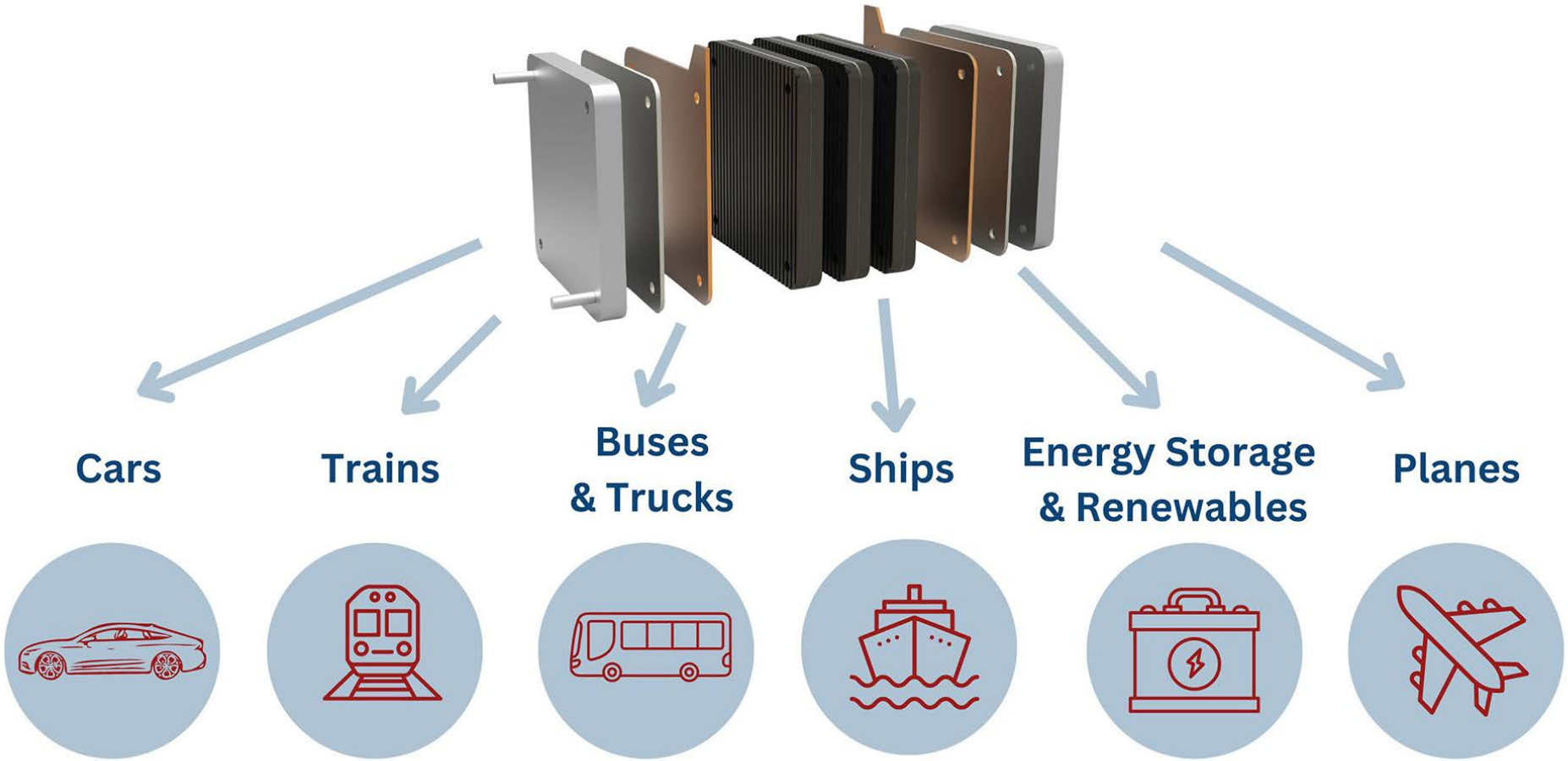
$$(1/2)O_2 + 2H^+ + 2e\text{-} \rightarrow H_2O$$

Overall reaction:

$$2H_2 + O_2 \rightarrow 2H_2O + \text{electricity} + \text{heat}$$

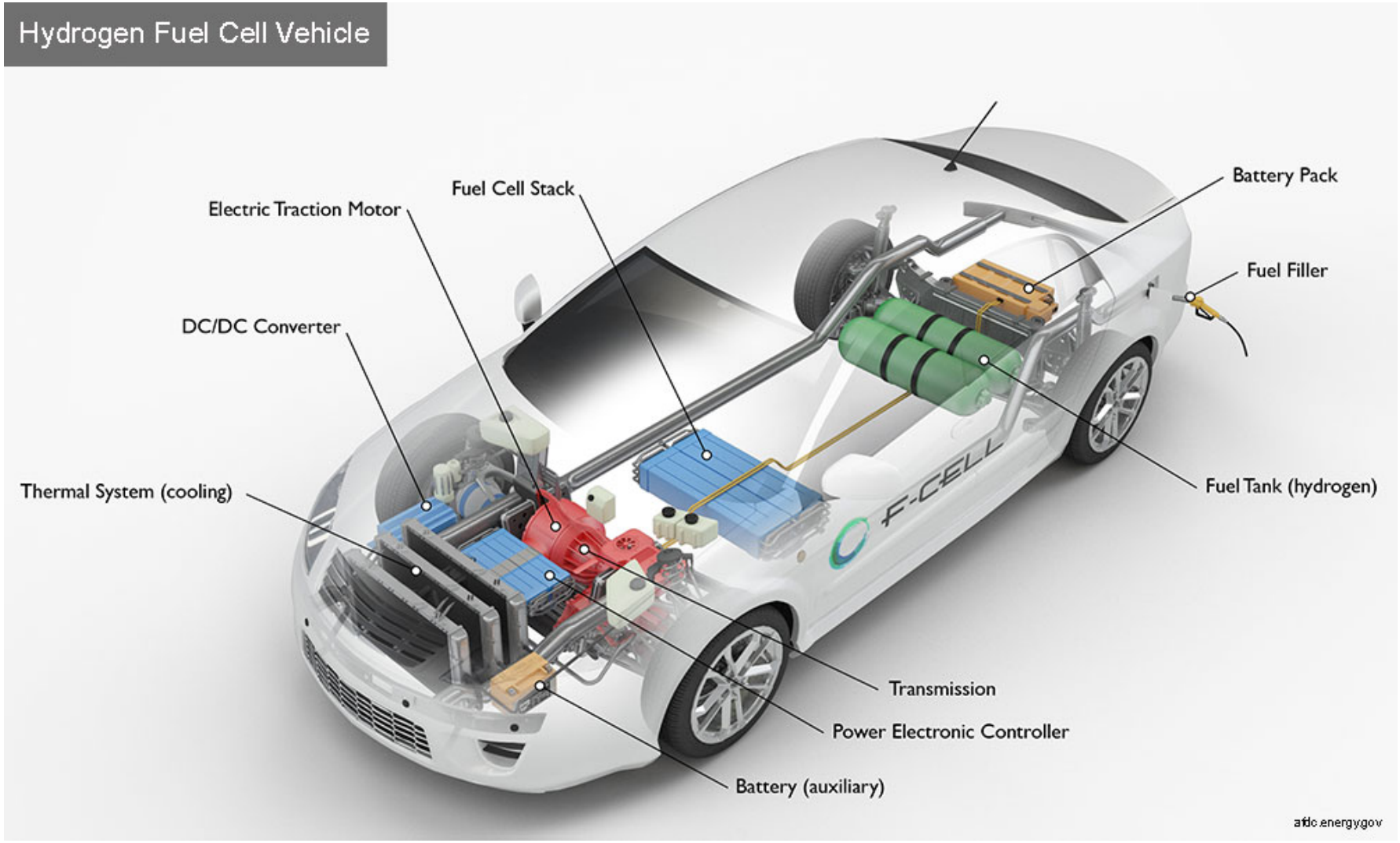


Fuel Cell: Application



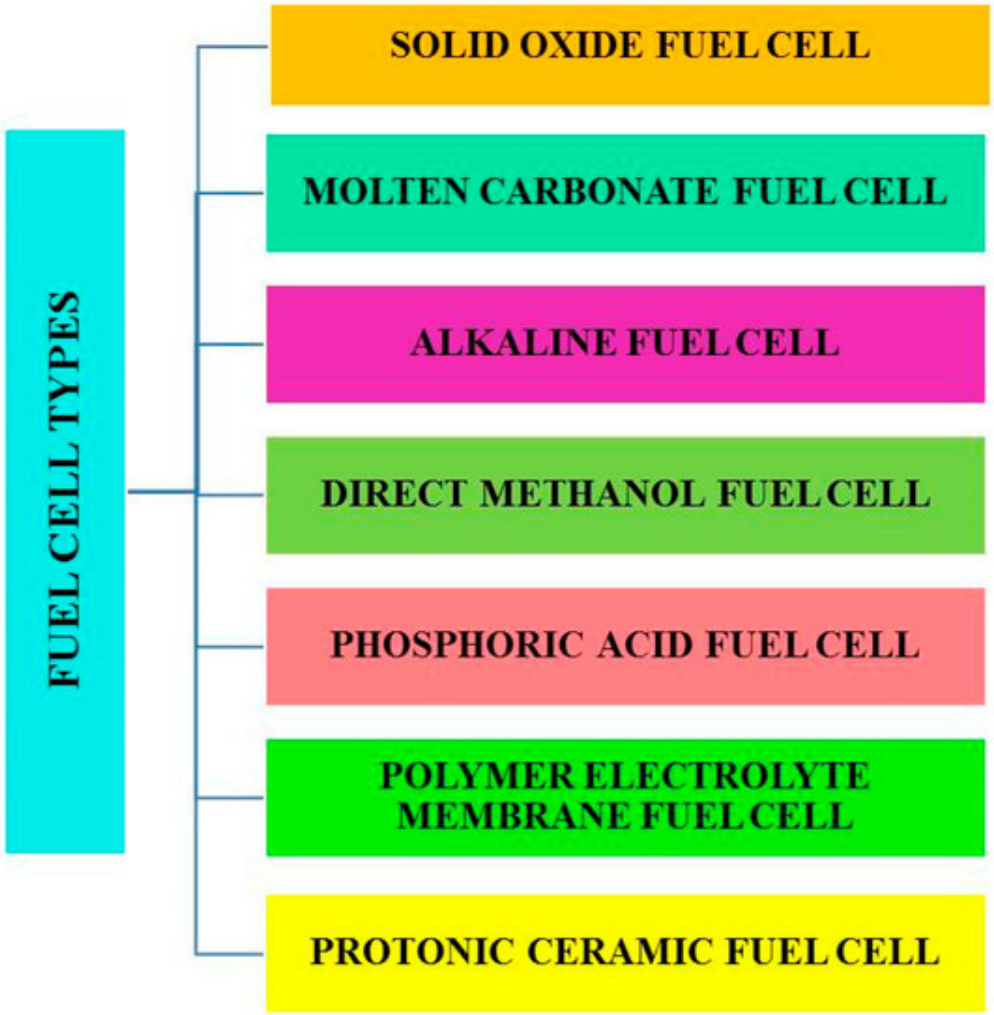
https://www.innovationnewsnetwork.com/graphite-hydrogen-fuel-cell-technologies/26736/

Fuel Cell: Application

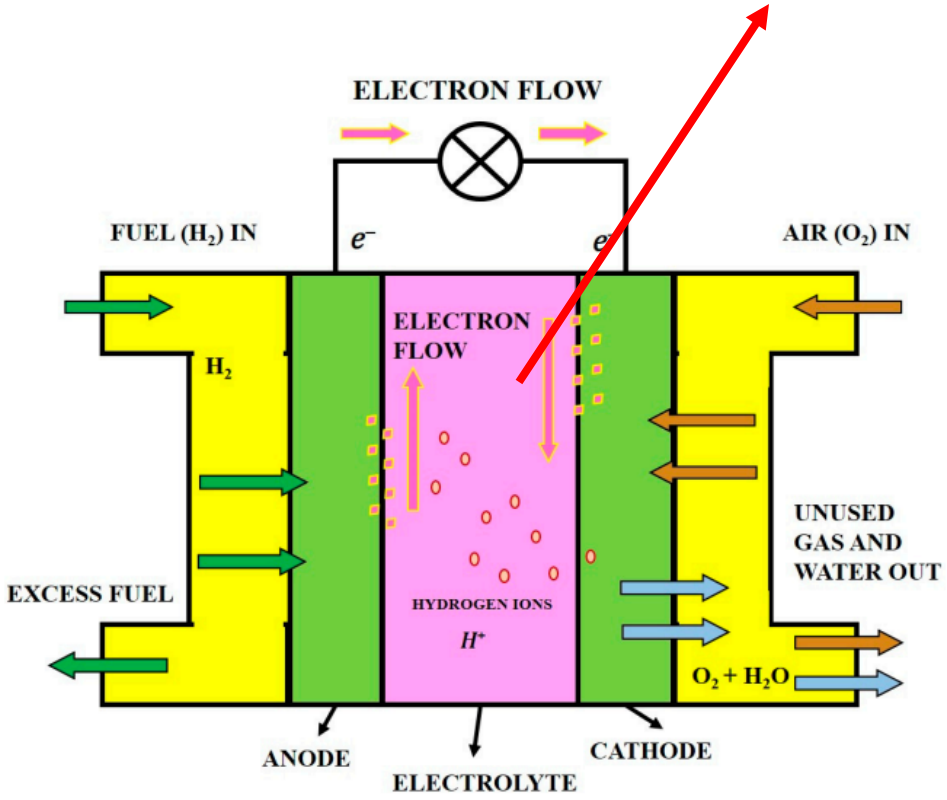


https://diyguru.org/insights/article/fuel-cell-electric-vehicle/

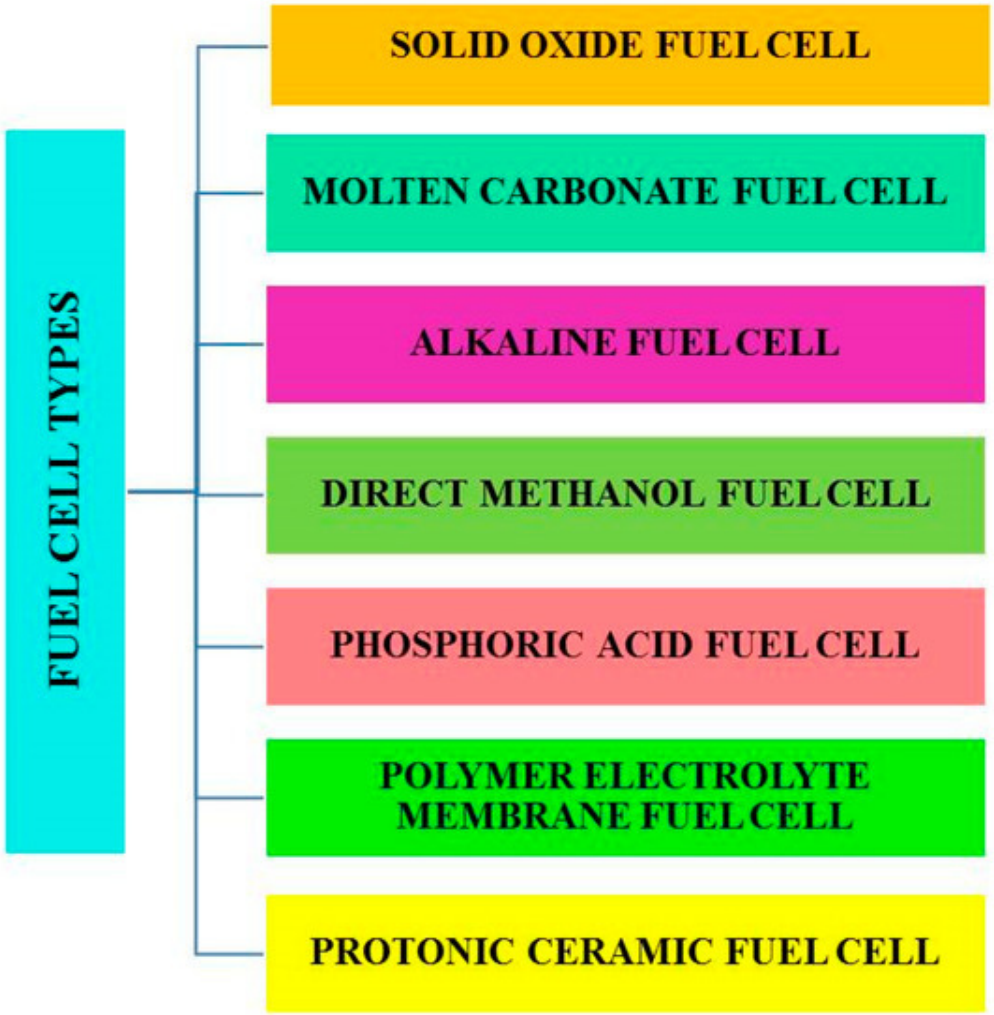
Fuel Cell: Types



uses a **solid ceramic electrolyte**
-commonly yttria-stabilized zirconia, YSZ



Fuel Cell: Types



→ uses a **molten carbonate salt mixture as the electrolyte**

Operating temperature: ~ 600-700 °C.

cathode (reduction reaction):

$$O_2 + 2CO_2 + 4e^- \rightarrow 2CO_3^{2-}$$

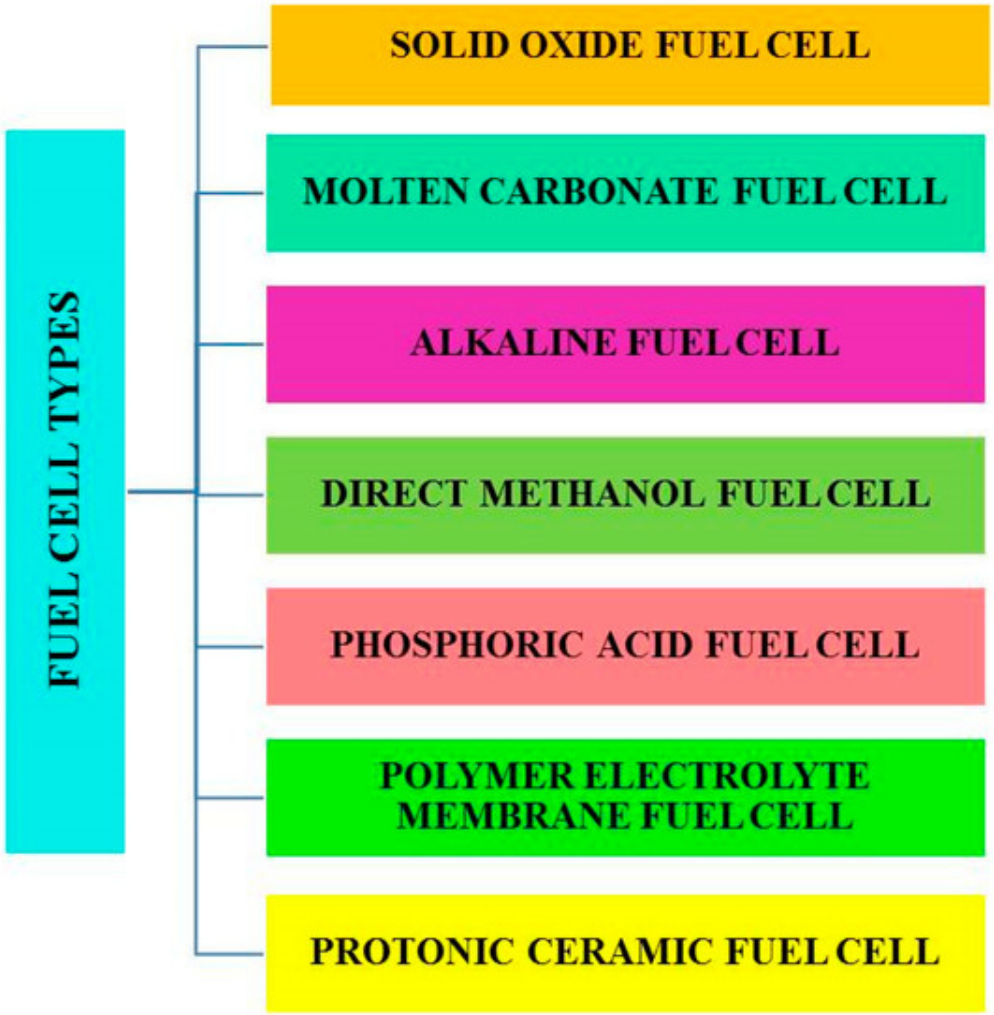
anode (oxidation of fuel, e.g., hydrogen):

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

Overall Reaction

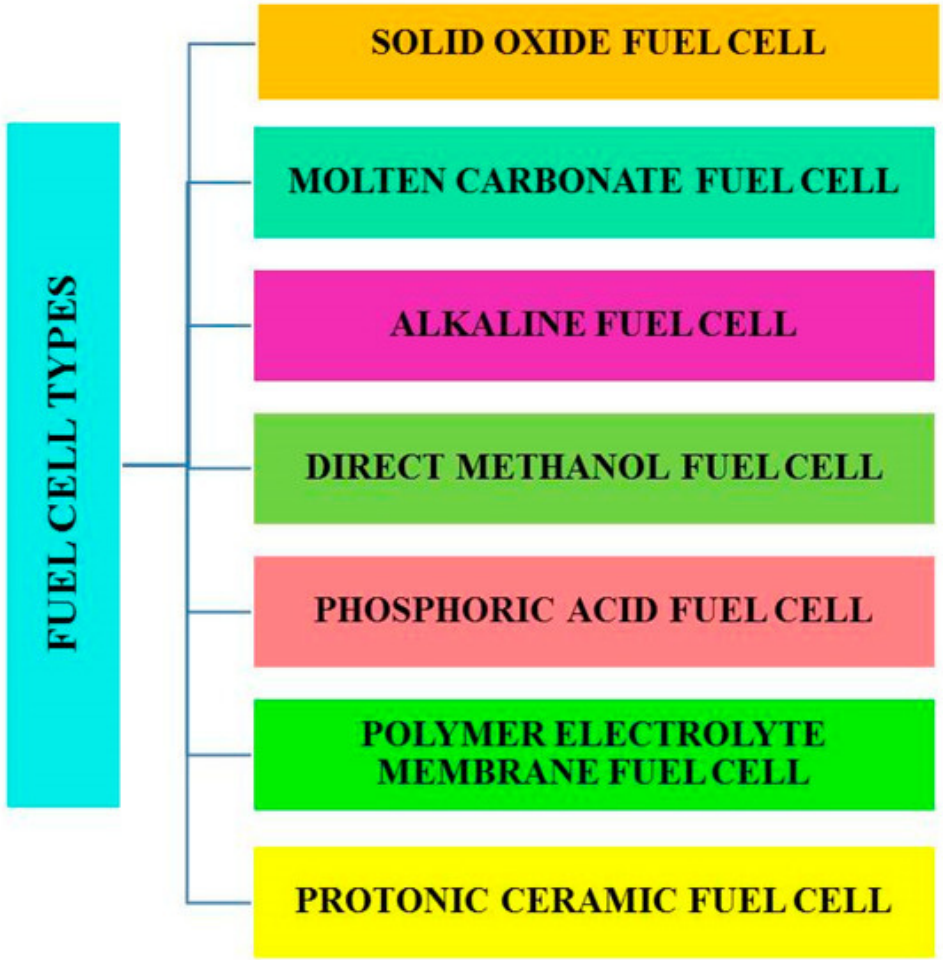
$$H_2 + (1/2)O_2 + CO_2 \rightarrow H_2O + CO_2 + \text{electricity} + \text{heat}$$

Fuel Cell: Types



→ uses **alkaline electrolyte (usually potassium hydroxide, KOH).**
Operating temperature: ~ 60-200 °C.

Fuel Cell: Types



Direct Methanol Fuel Cell (DMFC) is a type of proton exchange membrane (PEM) fuel cell that directly uses methanol (CH_3OH) as the fuel instead of hydrogen gas

anode (oxidation of fuel, e.g., hydrogen):

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

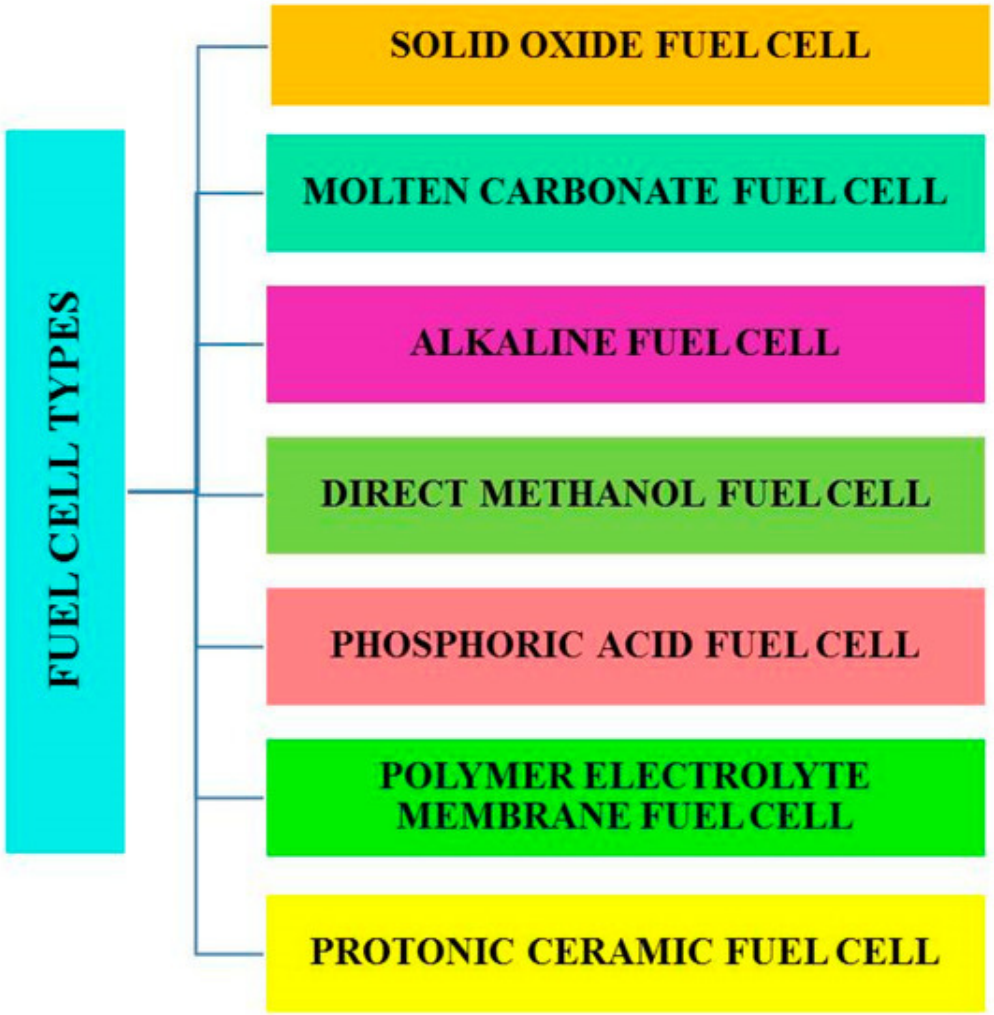
cathode (reduction reaction):

$$(3/2)O_2 + 6H^+ + 6e- \rightarrow 3H_2O$$

Overall Reaction

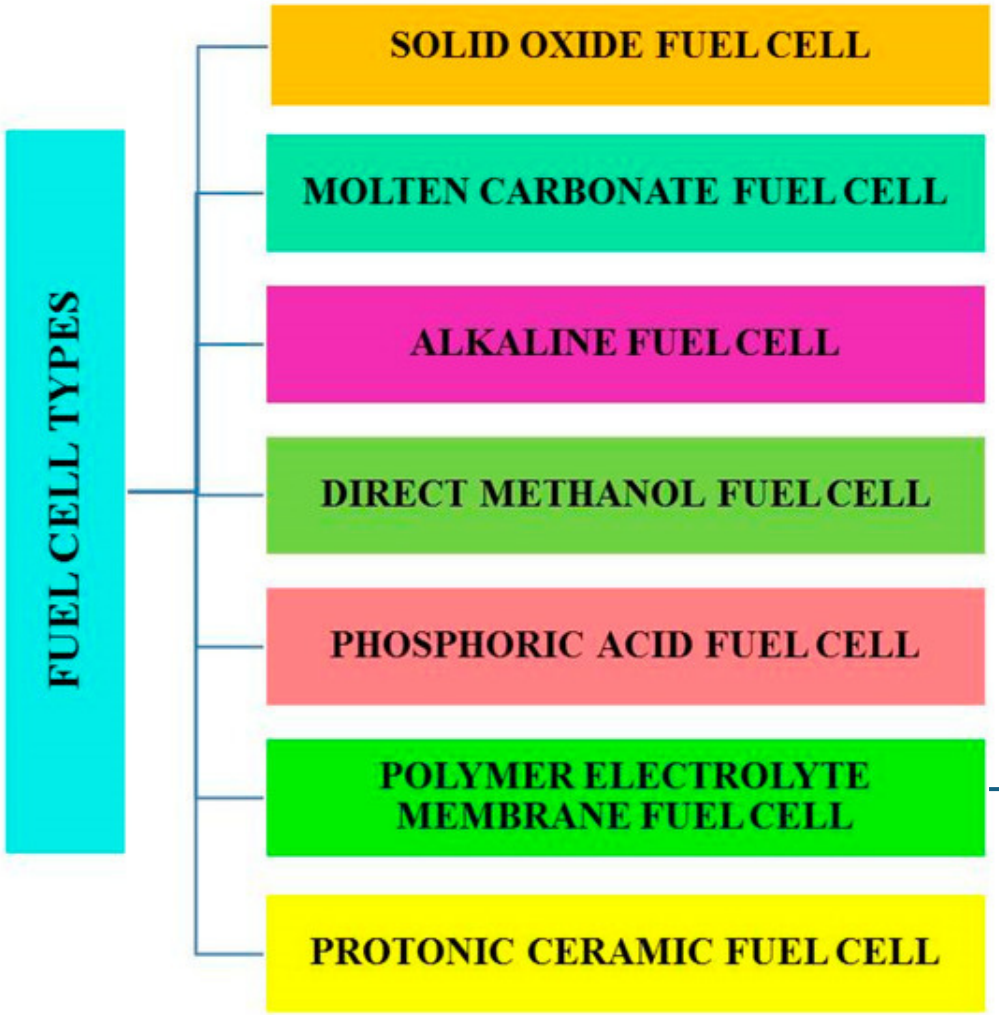
$$CH_3OH + (3/2)O_2 \rightarrow CO_2 + 2H_2O + \text{electricity} + \text{heat}$$

Fuel Cell: Types



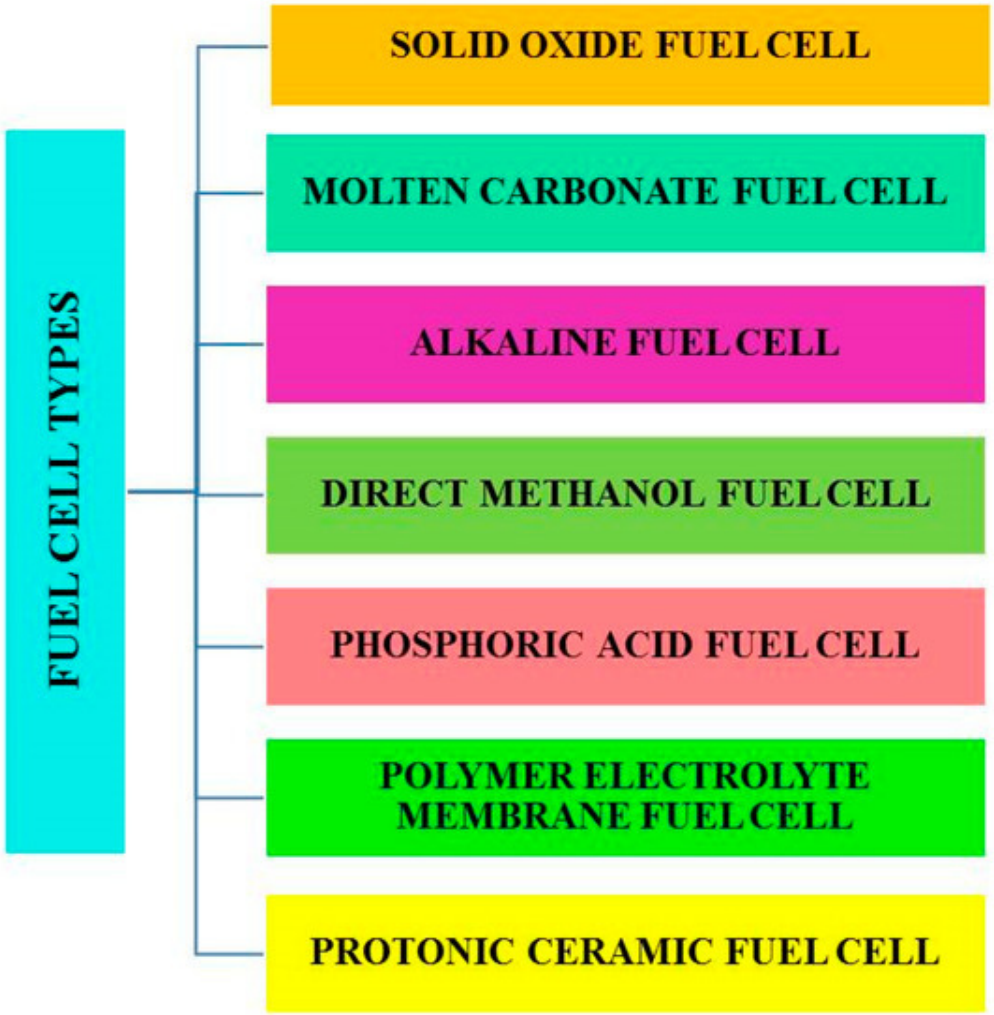
→ uses **liquid phosphoric acid (H_3PO_4) as the electrolyte.**
Operating temperature: ~ 150-220 °C.

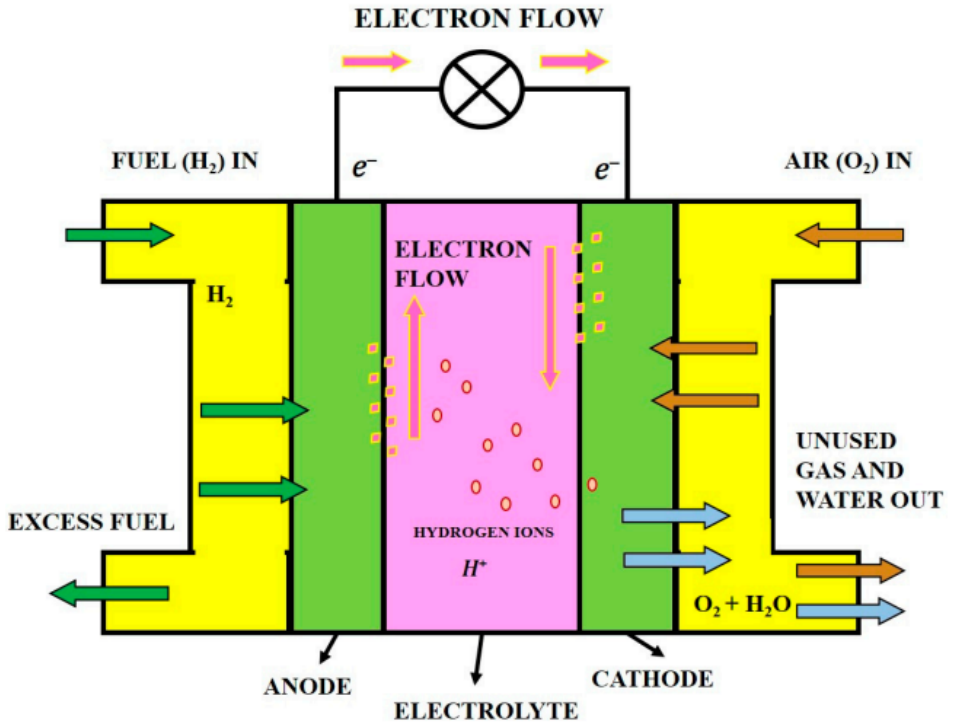
Fuel Cell: Types



- Polymer Electrolyte Membrane Fuel Cell (PEMFC), also called a Proton Exchange Membrane Fuel Cell.
- It is the most common type of low-temperature fuel cell.
- It uses a solid polymer membrane (e.g., Nafion) as the electrolyte and produces electricity by the reaction of hydrogen and oxygen.

Fuel Cell: Types





→ uses a **ceramic electrolyte conducting protons (H^+) instead of oxygen.**

Electric Vehicle

The first EV was built in 1839 by Robert Anderson of Aberdeen, Scotland.

https://www.story-cars.com/1832-1839-robert-anderson-s-electric-carriage

Electric Vehicle

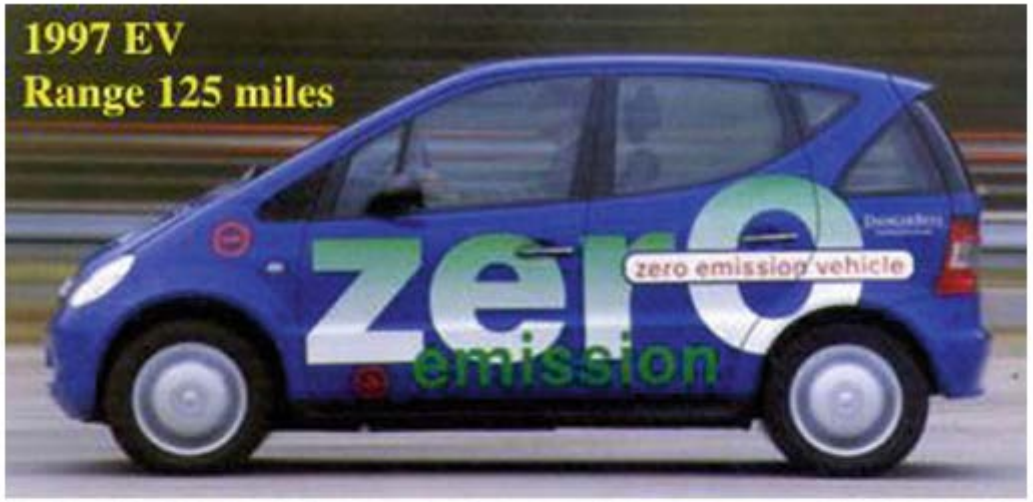
First electrical Taxi: **August 1897 – The London Electrical Cab**

https://www.theengineer.co.uk/content/archive/august-1897-the-london-electrical-cab/

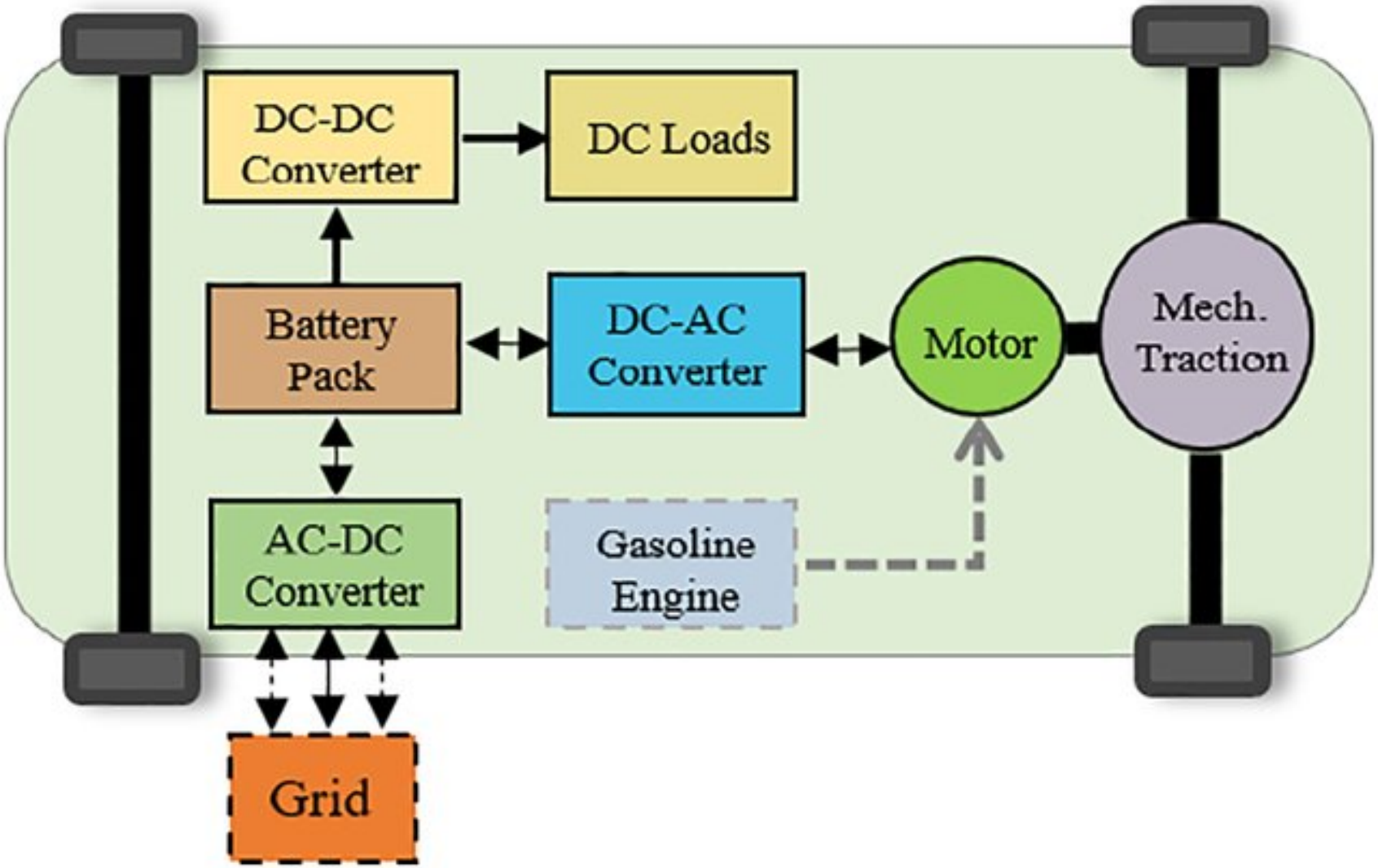
Electric Vehicle

Mercedes-Benz zero-emission class A EV.

The car uses a 40 kW (54 hp) three-phase induction motor developing a rated torque of 155 Nm, which can accelerate the car to 100 km/h in 17 s with a top speed of 120 km/h and a normal usage range of 150 km. Recharging can be made in 6-12 h using normal household sockets. The battery system is sodium/nickel chloride with an energy storage capacity of 100 Wh/kg and a life of over 100,000 km

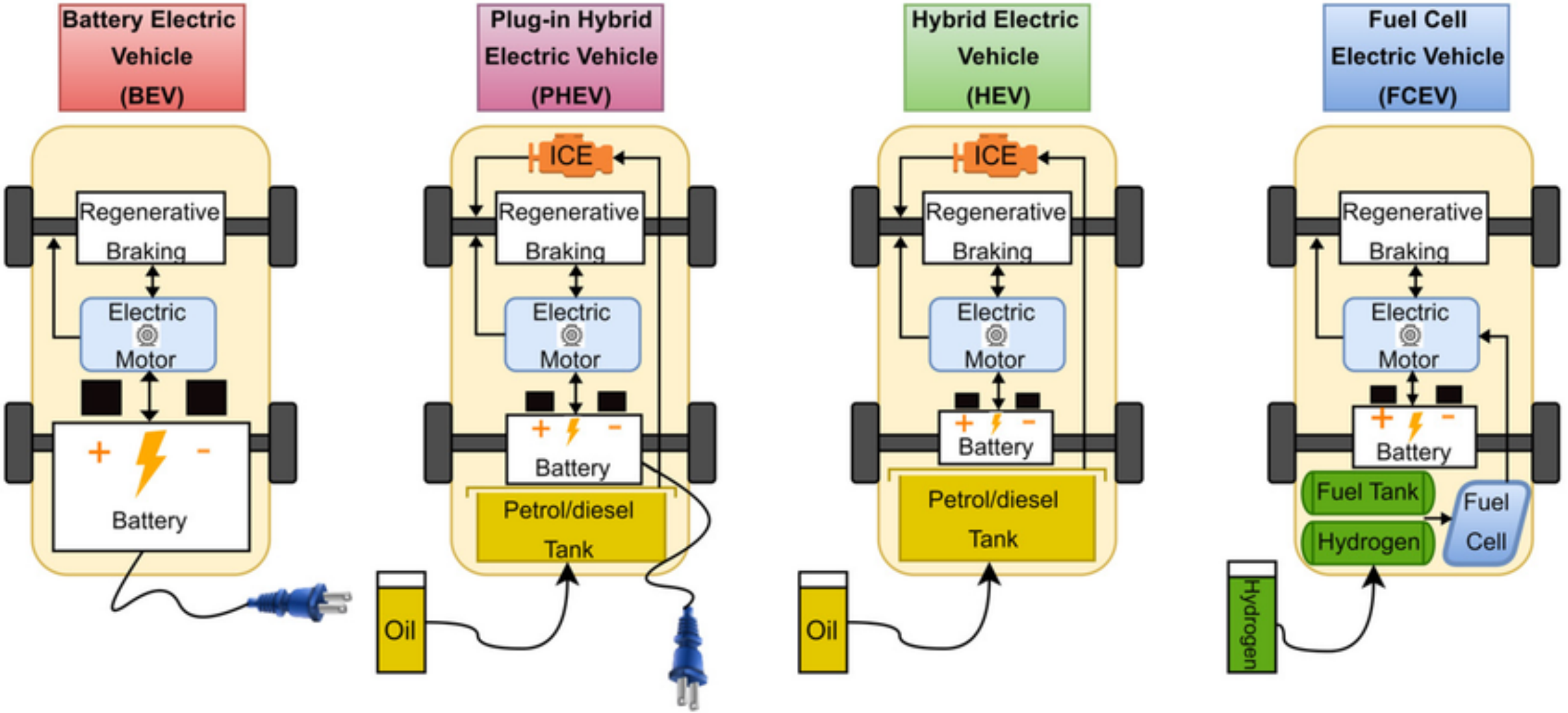


Electric Vehicle: Block Diagram



http://dx.doi.org/10.1049/esi2.12038

Electric Vehicle: Type



http://dx.doi.org/10.3390/en16135204