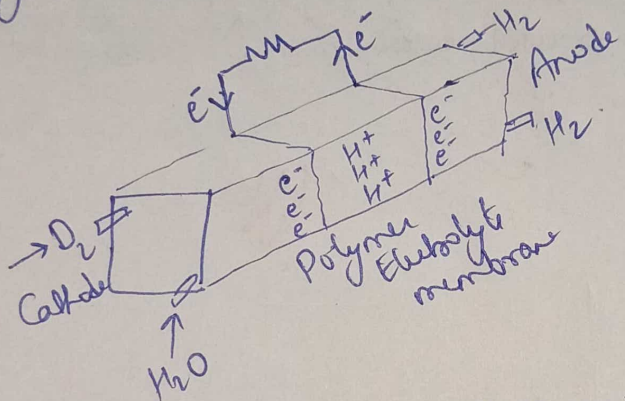
Fuel cell :- device that converts chemical energy to electrical energy from a chemical reaction with oxygen or another oxidizing agent.

2 electrode → anode (+ve) & cathode (-ve). Reaction take place in electrode

Every fuel has electrolyte which carry charged particle from one electrode to other, and catalyst which speed the reactions at electrolyte.

Hydrogen is most common fuel. (Hydrocarbon like natural gas and alcohol like methanol are used sometimes).



→ typical cell produce 0.6V to 0.7V

Working principle :- Composed of anode cathode & electrolyte membrane

→ Hydrogen pass through anode. Oxygen through cathode
→ catalyst split hydrogen into electron & proton at anode sit.
→ Proton pass through porous electrolyte membrane, while electron are forced through circuit generating electric current
→ At cathode proton & electron combine to form water & oxygen
→ As there is no moving part so it is silent & light reliable

Components :-

1) Anode
2) Cathode
3) Electrolyte
4) Catalyst

Battery Cell	Fuel Cell
→ Store energy in form of chemical energy	→ Cannot store energy. It convert chemical to electrical.
→ Reactants are inside cell itself.	→ Reactants are supplied continously
→ Chemical reaction product remain inside the cell itself.	→ removed from cell.
→ Rechargable	→ Not rechargable
→ Less efficiency	→ High
→ Less expensive	→ High
→ Supply energy for limited period of time.	→ Long period of time
Eg. Lithium ion battery	Eg. hydrogen oxygen fuel cell.

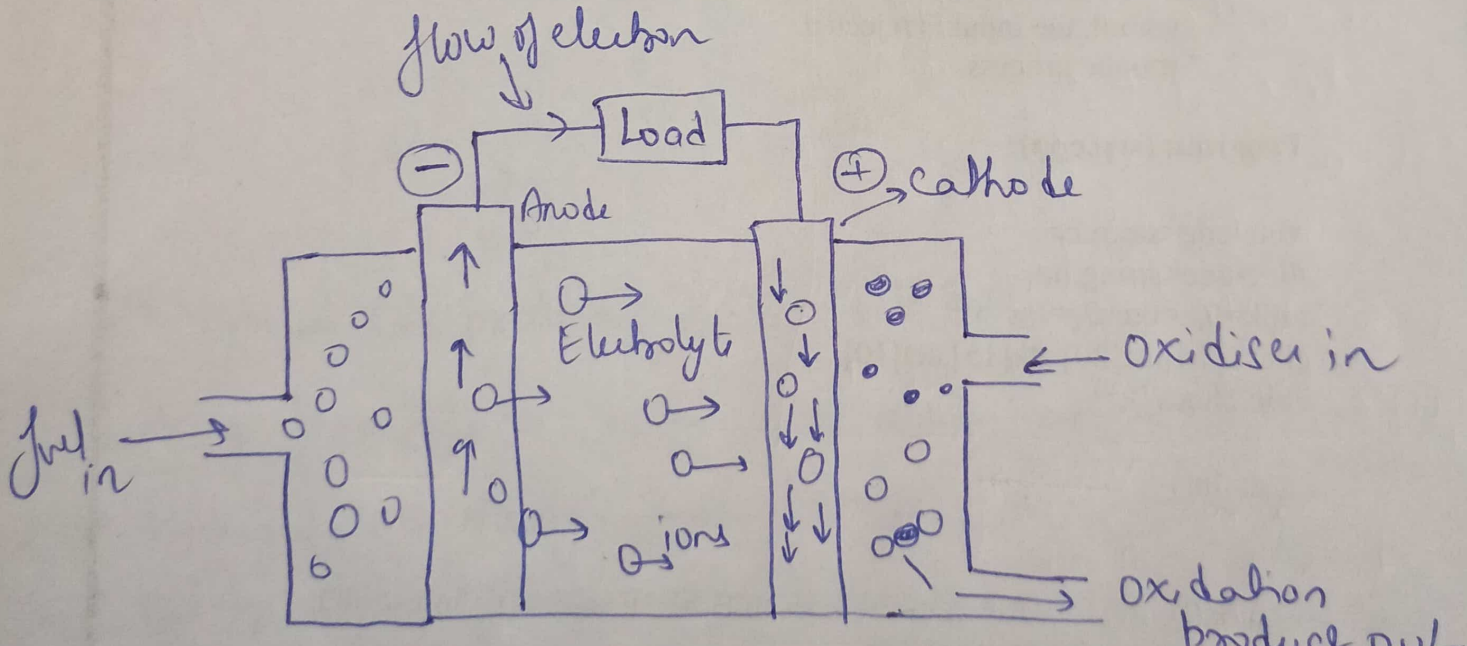


Diagram for working

Type of Fuel cell :-

1) Polymer Electrolyte Membrane (PEM) Fuel cell
2) Phosphoric Acid Fuel Cell
3) Solid Oxide fuel cell
4) Alkaline fuel cell
5) Molten Carbonate fuel cell.

	Electrolyte used	temp.	Reaction
1)	Polymer membrane	60-140°C	Anode :- $H_2 \rightarrow 2H^+ + 2e^-$ Cathode :- $\frac{1}{2}O_2 + 2H^+ + 2e^- \Rightarrow H_2O$
2)	Phosphoric Acid	180°-200°C	Anode :- $H_2 \rightarrow 2H^+ + 2e^-$ Cathode :- $\frac{1}{2}O^2 + 2H^+ + 2e^- \rightarrow H_2O$
3)	Yittria Stablized Zirconia	1000°C	Anode :- $H_2 + O^{2-} \rightarrow H_2O + 2e^-$ Cathode :- $\frac{1}{2}O_2 + 2e^- \rightarrow O^{2-}$
4)	Potassium Hydroxide	150-200°C	Anode :- $H_2 + 2OH^- \rightarrow H_2O + 2e^-$ Cathode :- $\frac{1}{2}O_2 + H_2O + 2e^- \rightarrow 2OH^-$
5)	Lithium/Pottasium Carbonate	650°C	Anode :- $H_2 + CO_3^{2-} \rightarrow H_2O + CO_2 + 2e^-$ Cathode :- $\frac{1}{2}O_2 + CO_2 + 2e^- \rightarrow CO_3^{2-}$

	Adv	Disadv
1)	High power density & long operating life	Lack of CO tolerance. water & heat management expensive catalyst
2)	Commercially available, market presence, long life	low efficiency, limited lifetime.
3)	high efficiency, high grade waste heat Internal fuel processing	High operating temp. High cost
4)	Inexpensive. CO tolerance, fast kinetics	lack of CO_2 tolerance, Corrosive liquid
5)	high efficiency, high grade waste heat, Internal fuel processing.	undetermined lifetime CO_2 poisoning, electrolyte instability.

Challenges :-

1) Cost
2) Durability & Reliability
3) System Size
4) Air, Thermal & Water management
5) Improved Heat Recovery System

Adv :-

1) Efficiency → Little waste (b/c operate at higher temps).
2) Clean Energy → only water as byproduct.
3) Versatility → variety of application
4) Reliability → no moving parts so less chance of mech. fail.
5) Longevity → long lifetime & less maintainence

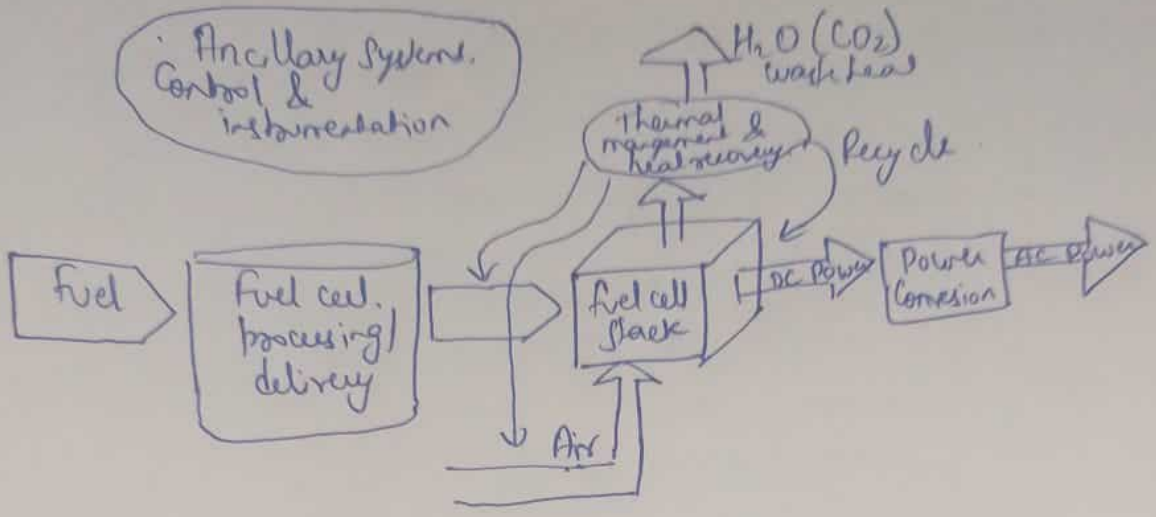
Disadv :-

1) Cost
2) Infrastructure
3) Efficiency
4) Durability
5) Safety.

Criteria for selection of fuel cell :-

1) Combined Heat & Power
2) Production Cost
3) Estimation Cost
4) Pollution
5) Energy supply limit
6) Stack Size
7) Efficiency
8) Working temp.

Fuel cell Power Plant :-



Fuel Cell Stack :-

→ Heart of fuel cell power plant
→ generate electricity in form of direct current (DC) from electrochemical reaction taking place in fuel cell.
→ Single cell produces less than 1V which is insufficient
→ So, they are combined in series to form fuel cell stack
→ Amount of power produced depend on various factor like fuel ~~Size~~ cell type, size, temp. of operation & pressure of gas.

Hydrogen Storage option

Physical (Molecular H_2)
↓
Reversible
↓
Compressed Gas | Hybrid Tanks | Liquid Hydrogen

Chemical Storage (Dissociated) ($H_2 \rightarrow 2H$)

Reversible
↓
Conventional metal hydride | Complex Metal Hydride

Non-Reversible
↓
Reformed fuel | Hydrolyzed fuel | Decomposed fuel