Delhi Technological University

GREEN ENERGY TECHNOLOGY

PE 308

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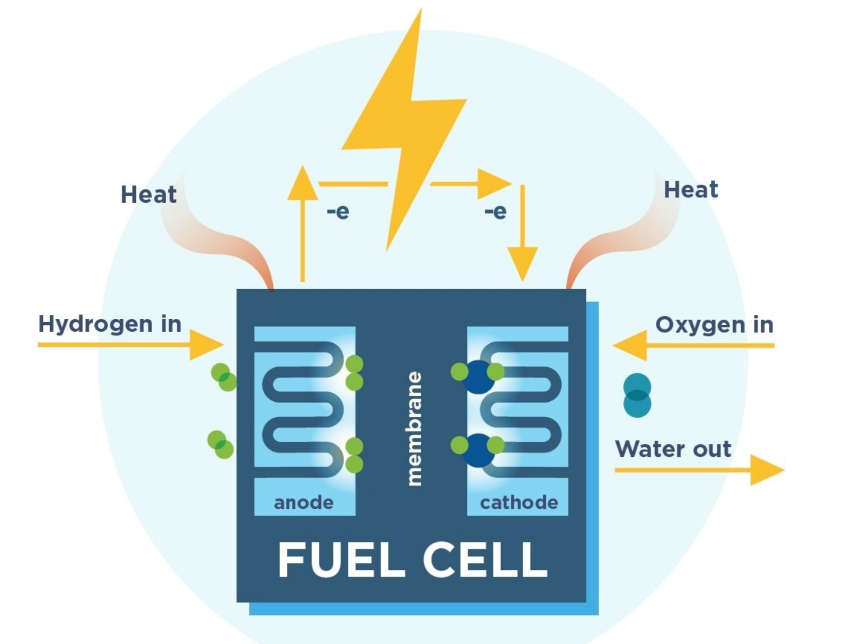
Case Study :

Hydrogen Energy for transportation full and its applications

Introduction

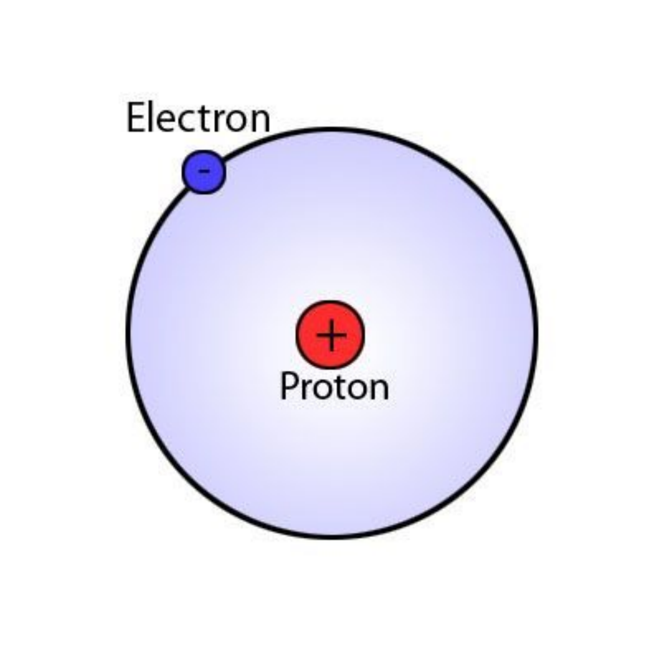


- **Fuel** is any material that stores energy that can later be extracted to perform mechanical work in a controlled manner.
- Hydrogen fuel is an eco-friendly fuel which uses electrochemical cells, or combustion in internal engines, to power vehicles and electric devices. It is also used in the propulsion of spacecraft
- Potentially can be mass produced and commercialized for passenger vehicles and aircraft.

Status of Hydrogen Today

- Although hydrogen is the most abundant element in the universe, it does not naturally exist in its elemental form on Earth.
- Pure hydrogen must be produced from other hydrogen-containing compounds such as fossil fuels, biomass, or water.
- Current leading technology for producing hydrogen in large quantities is steam reforming of methane gas.
- Engine that burns pure hydrogen produces almost no pollution.

Properties of Hydrogen



- Atomic Number : 1
- Atomic Weight : 1.0079
- Melting Point: -259°C
- Boiling Point: - 253°C
- Max boiling point: -240°C (at 14 bar)
- Vapour Density: 0.08376 kg/m^3 (at 20 °C, 1 atm)
- Specific Gravity : 0.0696
- Flashpoint : –253 °C
- Valence: 1
- Hydrogen is a colourless, odourless, combustible gas.

Combustive Properties of Hydrogen

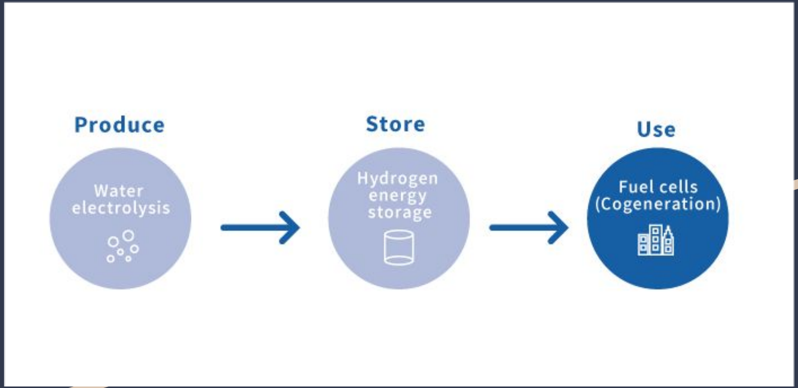
The properties that contribute to its use as a combustible fuel are its:

- Wide range of flammability : 4% to 75% at 25°C
- low ignition energy   : 0.02 mJ
- small quenching distance : 0.064 cm
- High auto ignition temperature : 585 °C
- High octane number: 130
- High flame speed
- High diffusivity and Very low density
- Hydrogen flames are very pale blue and are almost invisible in daylight due to the absence of soot

Higher calorific value (kJ/kg)

Alcohol, 96%	30,000
Anthracite	32,500 - 34,000
Bituminous	17,000 - 23,250
Butane	49,510
Carbon	**34,080**
Gasoline	47,300
Charcoal	29,600
Coke	28,000 - 31,000
Diesel	**44,800**
Lignite	16,300
Methane	**55,530**
Oils, vegetable	39,000 - 48,000
Peat	13,800 - 20,500
Petrol	**48,000**
Propane	50,350
Sulphur	9,200
Wood (dry)	**14,400 - 17,400**

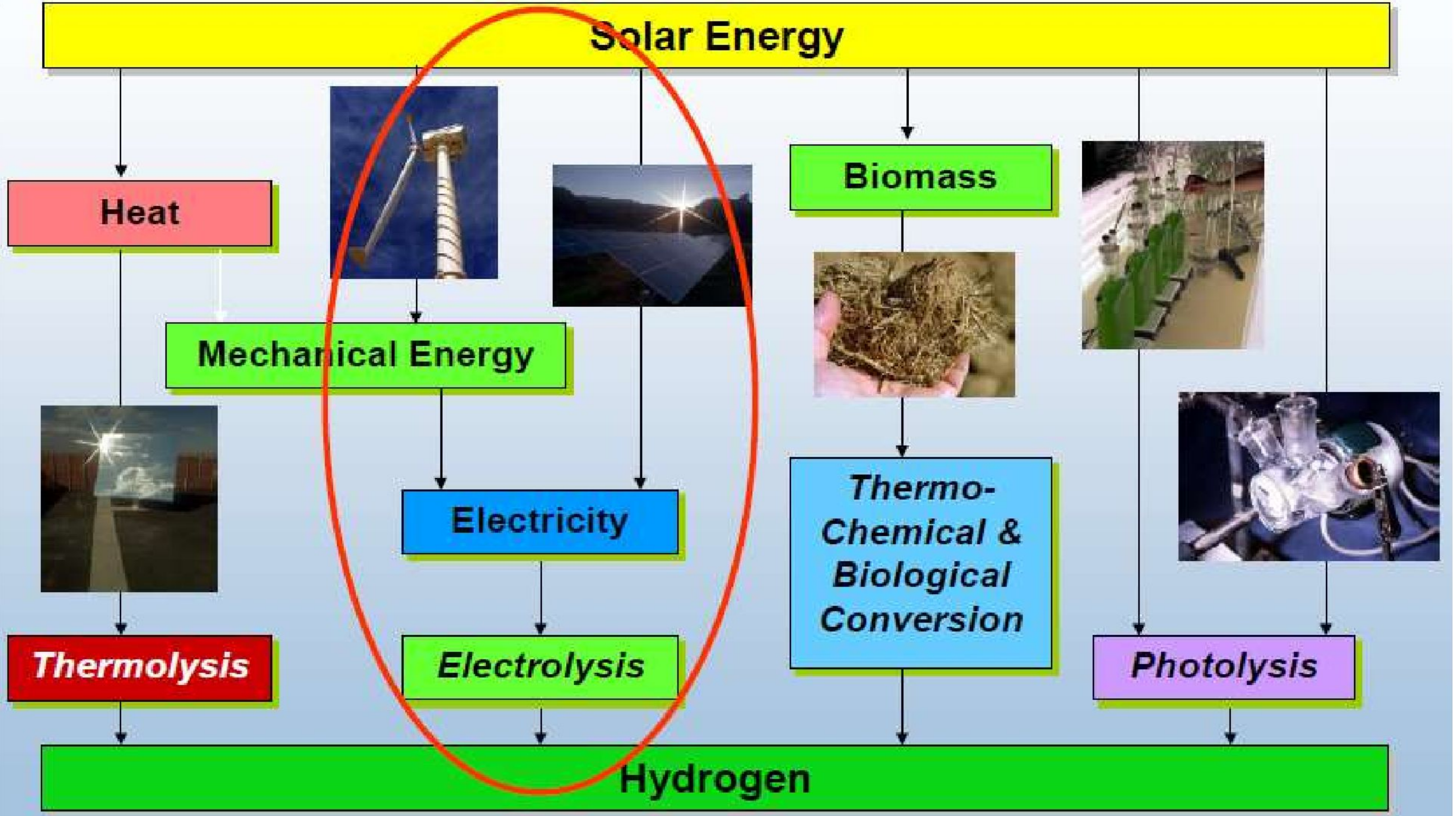
PRODUCING HYDROGEN

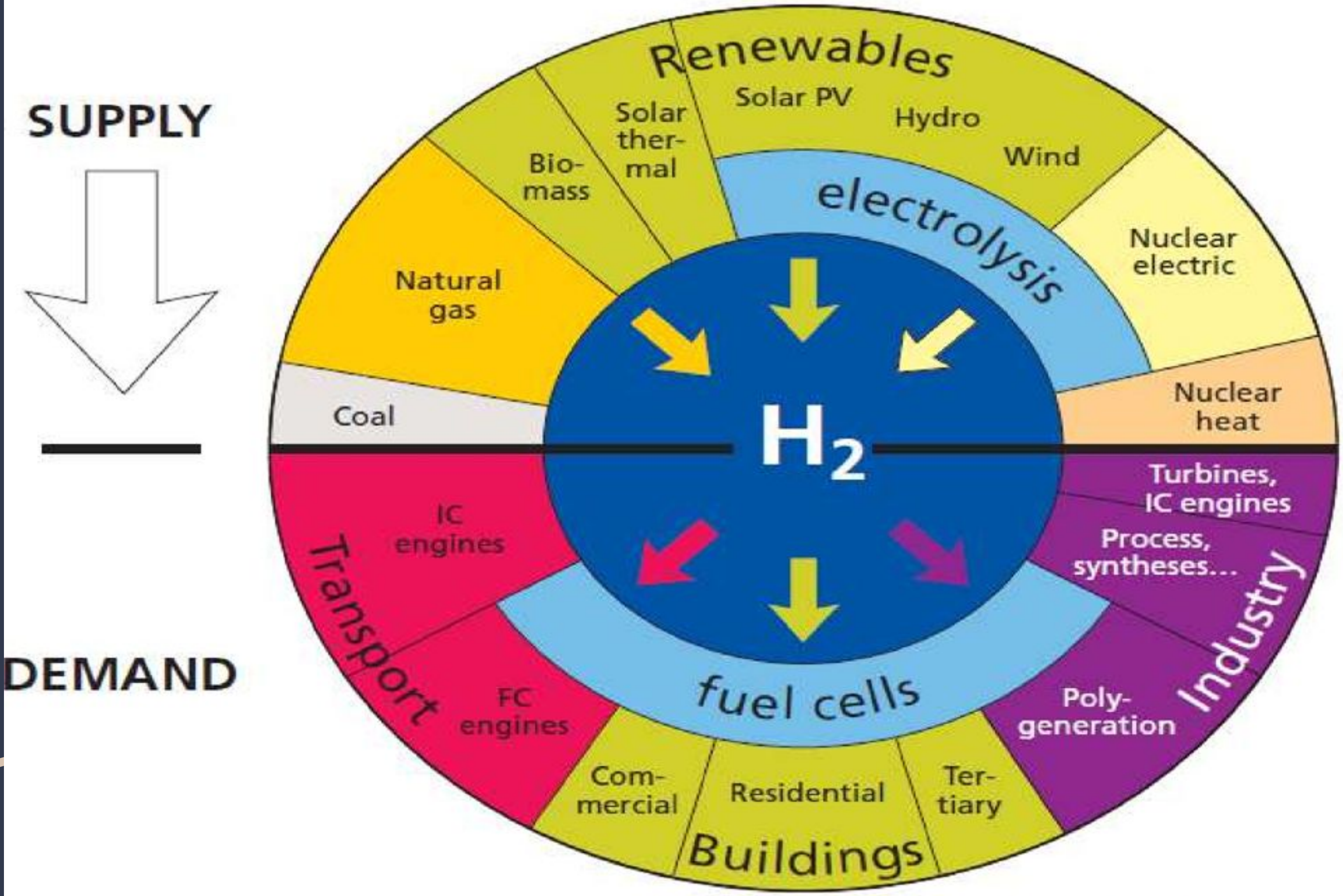


There are more than 200 viable means to produce H_2. Some common methods are;

1. Steam Reforming
2. From Coal
3. Electrolysis
4. Thermolysis
5. Photocatalytic water splitting
6. Fermentative Hydrogen Production
7. Bio-catalysed electrolysis

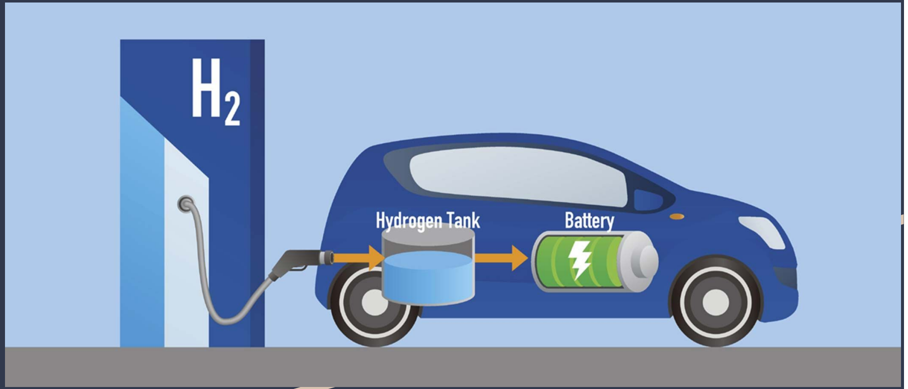
Sustainable Paths to Hydrogen





Size of "sectors" has no connection with current or expected markets.

Storage and delivery



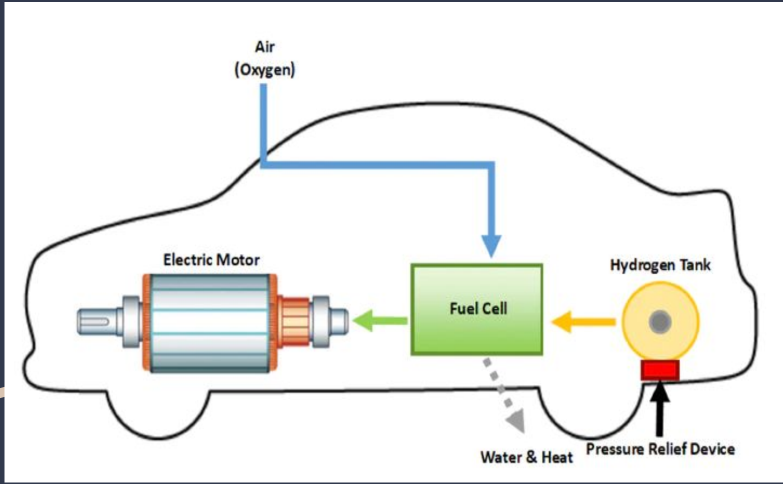
Physical storage: liquefaction , compression, physisorption Chemical storage: metal hydrides, complex hydrides.

Suppliers currently transport hydrogen by pipeline or over roadways using tube trailers or cryogenic liquid hydrogen tankers.

For a given volume, hydrogen contains a smaller amount of useable energy than other fuels such as natural gas and gasoline.

Because of its low volumetric energy density, hydrogen is comparatively more costly to transport and store.

Hydrogen internal combustion engine (HICE)

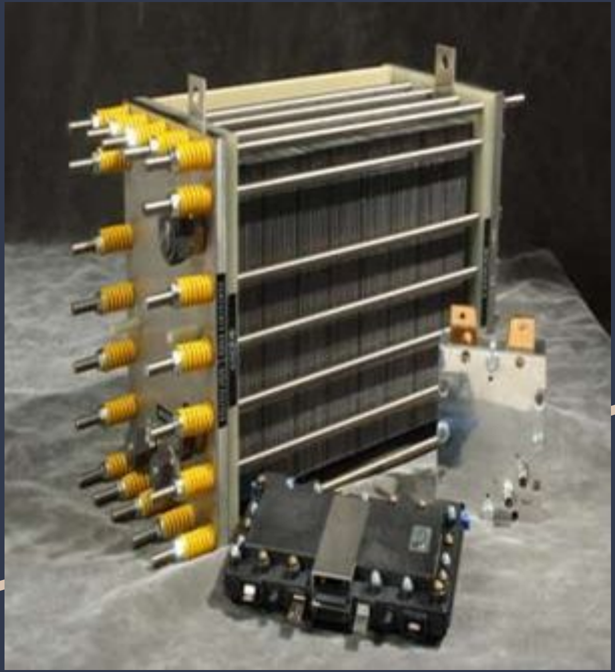


- Small number of vehicles use HICE
- In general, getting an internal combustion engine to run on hydrogen is not difficult but it is a challenge to run well.
- H2 + O2 + N2 => H2O + N2 +NOx

BMW Hydrogen 7

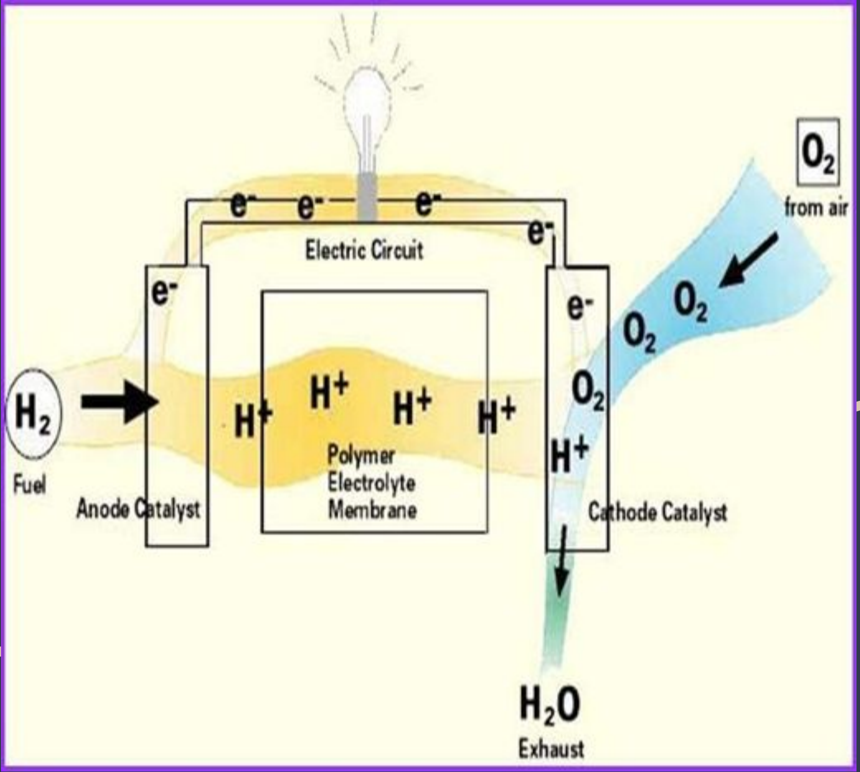
Hydrogen-Powered 1965 Cobra

Fuel cells



- Fuel cells now in development will provide a new way to produce power, also significantly improve energy conversion efficiency, especially in transportation applications.
- Fuel cells are electrochemical devices like batteries that convert the chemical energy of a fuel directly and very efficiently into electricity (DC) and heat, thus doing away with combustion.
- Unlike a battery, a fuel cell does not run down or require recharging. It will produce energy in the form of electricity and heat as long as fuel is supplied.
- Since conversion of the fuel to energy takes place via an electrochemical process, not combustion .It is a clean, quiet and highly efficient process- two to three times more efficient than fuel burning.

Fuel cell :



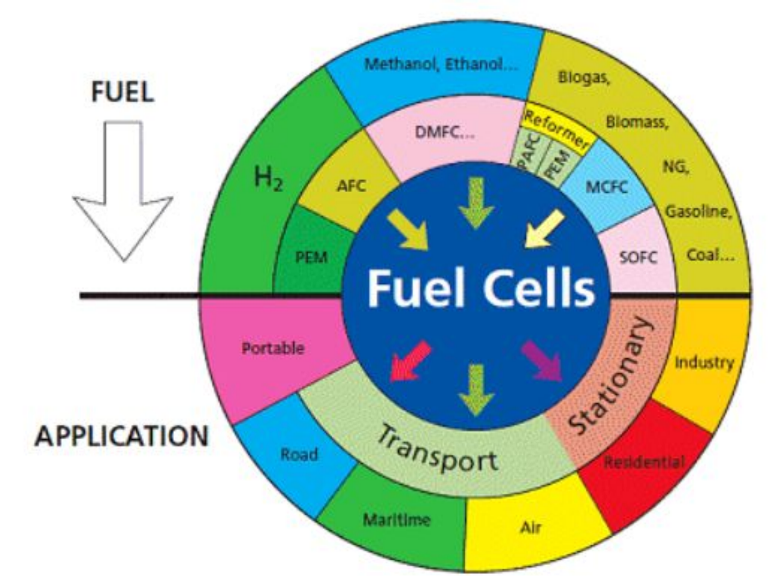
A fuel cell consists of two electrodes sandwiched around an electrolyte. Oxygen passes over one electrode and hydrogen over the other, Spurred by a catalyst, hydrogen oxidizes into hydrogen protons and give up its electrons to the electrode, which thereby becomes the anode. This buildup of negative charge then follows the path of least resistance via the external circuit to the cathode. flow of electrons through a circuit that creates electricity.

As the electrical current begins to flow, hydrogen protons pass through the membrane from the anode to the cathode, react with oxygen at the cathode to form water. Heat emanates from this union

Anode Reaction: $H \longrightarrow 2H^+ + 2e^-$

Cathode Reaction: $\frac{1}{2}O_2 + 2H^+ + 2e^- \longrightarrow H_2O$

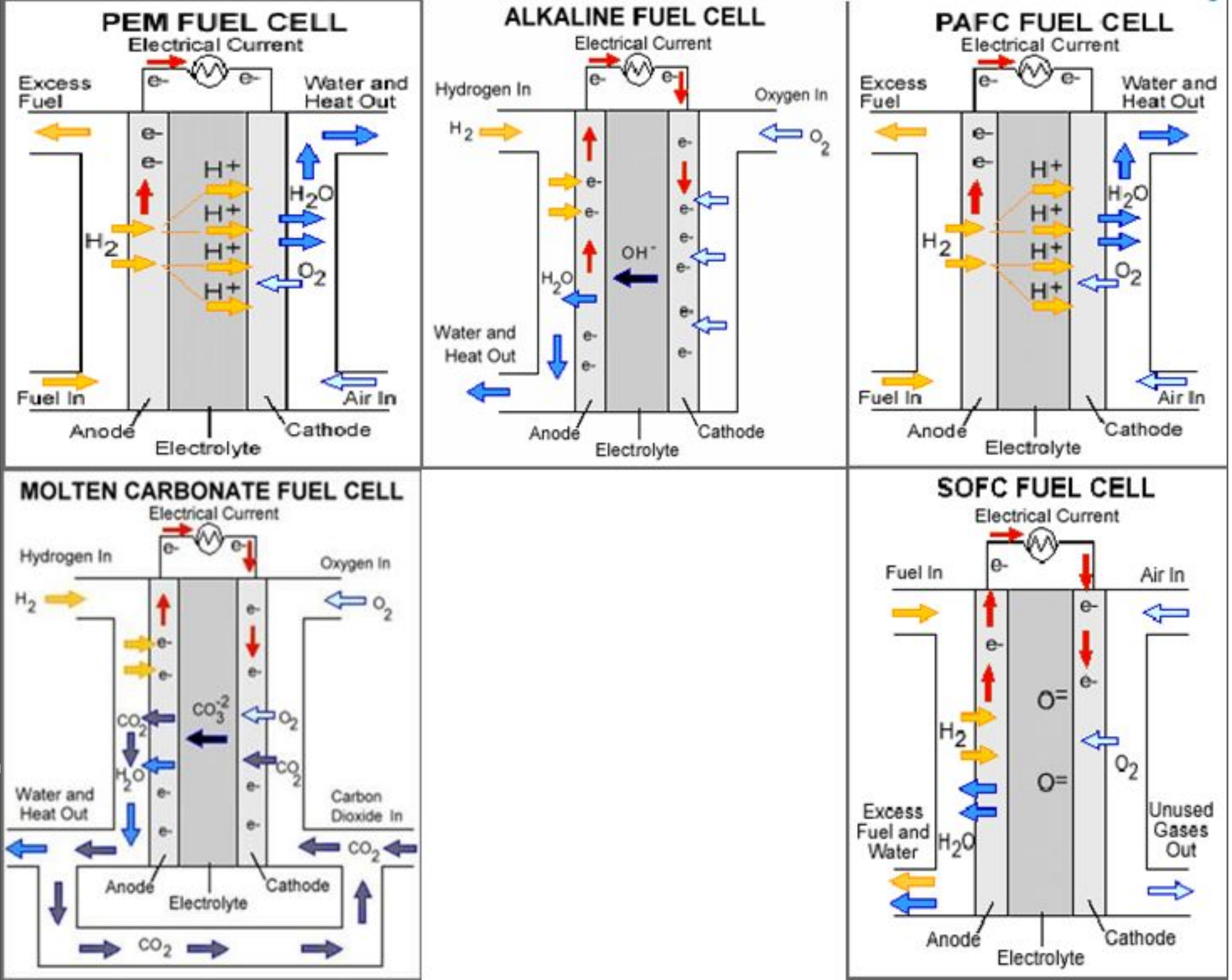
Types of fuel cells



In general all fuel cells have the same basic configuration - an electrolyte and two electrodes.

Different types of fuel cells are classified by the kind of electrolyte used The type of electrolyte used determines the kind of chemical reactions that take place and the temperature range of operation

- ❖ Polymer Electrolyte Membrane (PEM) : Perfluorosulfonic acid
- ❖ Alkaline (AFC) : Aqueous solution of potassium hydroxide soaked in a matrix
- ❖ Phosphoric Acid (PAFC) : Phosphoric acid soaked in a matrix
- ❖ Molten Carbonate (MCFC) : Solution of lithium, sodium, and/ or potassium carbonates, soaked in a matrix
- ❖ Solid Oxide (SOFC) : Yttria stabilized zirconia


PEM FUEL CELL
Electrical Current
Excess Fuel
Water and Heat Out
H+
H2O
H2
O2
Fuel In
Air In
Anode
Electrolyte
Cathode
ALKALINE FUEL CELL
Electrical Current
Hydrogen In
Oxygen In
H2
O2
OH-
H2O
Water and Heat Out
Anode
Electrolyte
Cathode
PAFC FUEL CELL
Electrical Current
Excess Fuel
Water and Heat Out
H+
H2O
H2
O2
Fuel In
Air In
Anode
Electrolyte
Cathode
MOLTEN CARBONATE FUEL CELL
Electrical Current
Hydrogen In
Oxygen In
H2
O2
CO3-2
CO2
H2O
Water and Heat Out
Carbon Dioxide In
Anode
Electrolyte
Cathode
SOFC FUEL CELL
Electrical Current
Fuel In
Air In
O=
H2
O2
Excess Fuel and Water
H2O
Unused Gases Out
Anode
Electrolyte
Cathode

Uses:

- ❖ Stationary power generation
- ❖ Residential
- ❖ Transportation – No pollution
- ❖ Portable power – Miniature Fuel Cells

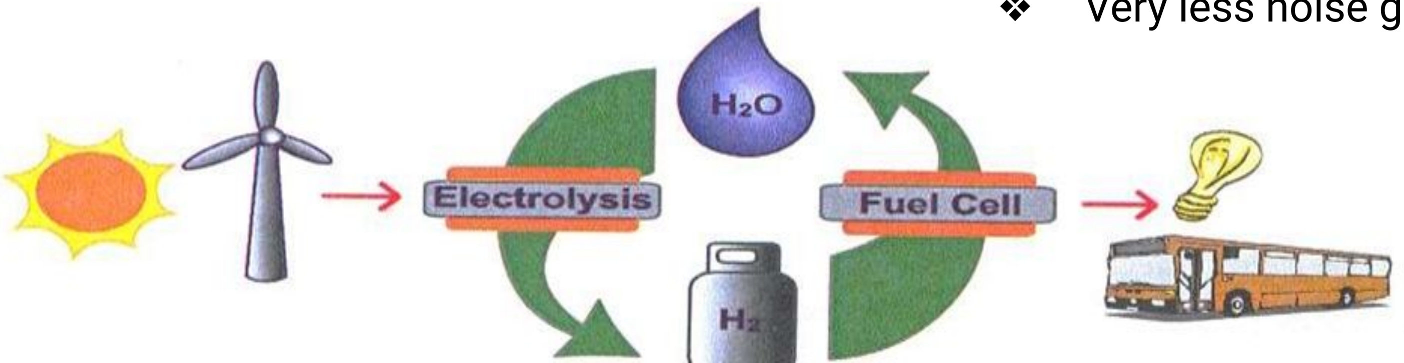
Examples
Campervans, boats, lighting, small personal electronics
Fuel cell electric vehicles, trucks, and buses, forklift trucks
Large stationary combined heat and power, uninterruptible power supplies

Why hydrogen and fuel cells ?

- ❖ Physical Security
- ❖ Reliability
- ❖ Efficiency
- ❖ Environmental

Benefits:

- ❖ No dependence on foreign oil
- ❖ Zero to near-zero levels of harmful emissions .
- ❖ Fuel Cell vehicles can be up to 3 times more efficient than internal combustion engines.
- ❖ Very less noise generated .



Safety implications :

- Colourless and odourless (mixtures will poison fuel cell)
- Extremely reactive with oxygen and other oxidizers
- Low ignition energy (1:10::H2:Petrol)
- High flame temperature(around 2273 K)
- Invisible flame in daylight conditions(pale blue)
- Negative Joule-Thomson coefficient; leaking gas warms and may spontaneously ignite
- Small molecular size promotes leaks and diffusion
- Very wide flammability limits in air mixtures
- Can diffuse into or react with certain metals, embrittling them
- The cryogenic liquid at 20K is even colder than frozen nitrogen, oxygen or argon

Challenges :

- **Infrastructure:** Refuelling, large-scale manufacturing processes and support infrastructures, such as trained personnel, are not yet available for fuel cell systems.
- Hydrogen has to be stored on-board vehicles, at hydrogen production sites, refuelling stations and stationary power sites which requires several precautions
- The size and weight of current fuel cell systems must be reduced to attain market acceptance, especially with automobiles
- Use in fuel cells requires catalysts, which usually require a component metal (most often platinum). Platinum is extremely rare, expensive and environmentally unsound to produce.

Reference :

- Atomic weights of the elements 2009 (IUPAC Technical Report)
- Michael E. Wieser 1* and Tyler B. Coplen 2
- 1 Department of Physics and Astronomy, University of Calgary, Calgary, Canada 2 U.S. Geological Survey, Reston, VA, USA
- L. Zhou. Progress and problems in hydrogen storage methods . / Renewable and Sustainable Energy Reviews 9 (2005) 395–408
- K. Harrison, R. Remick, A. Hoskin, G. Martin. Hydrogen Production: Fundamentals and
- Case Study Summaries Presented at the World Hydrogen Energy Conference. (May 2010)
- Energy, Economics, and the Environment. Cases and Materials Second Edition.

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