RAMAIAH
Institute of Technology

UNIT V
Green Energy

Unit-5 (9 hours)

Green Energy: Introduction, Fuel cells: Classification of fuel cells – H2; Operating principles, Zero energy Concepts. Benefits of hydrogen energy, hydrogen production technologies (electrolysis method only), hydrogen energy storage, applications of hydrogen energy, problem associated with hydrogen energy.

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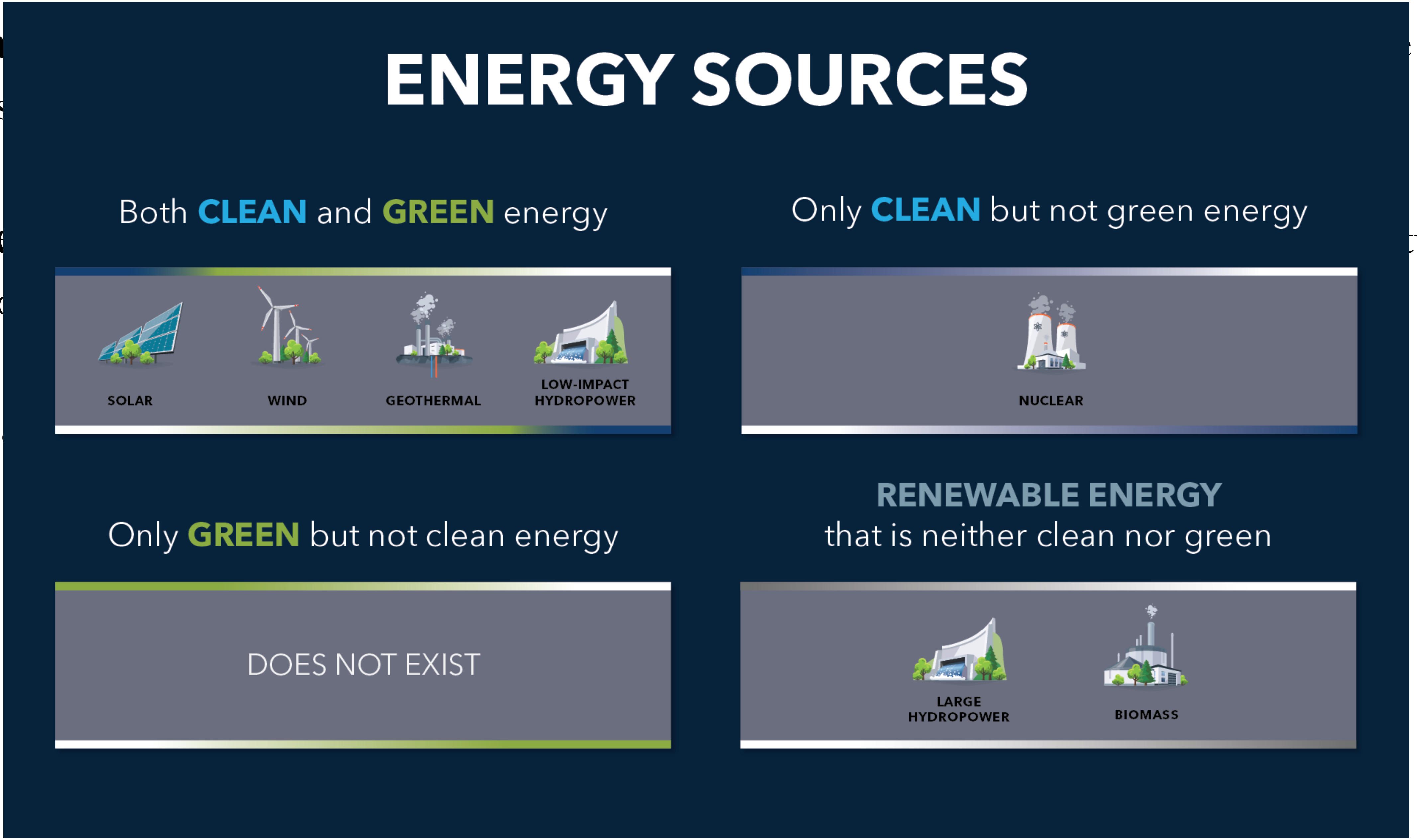


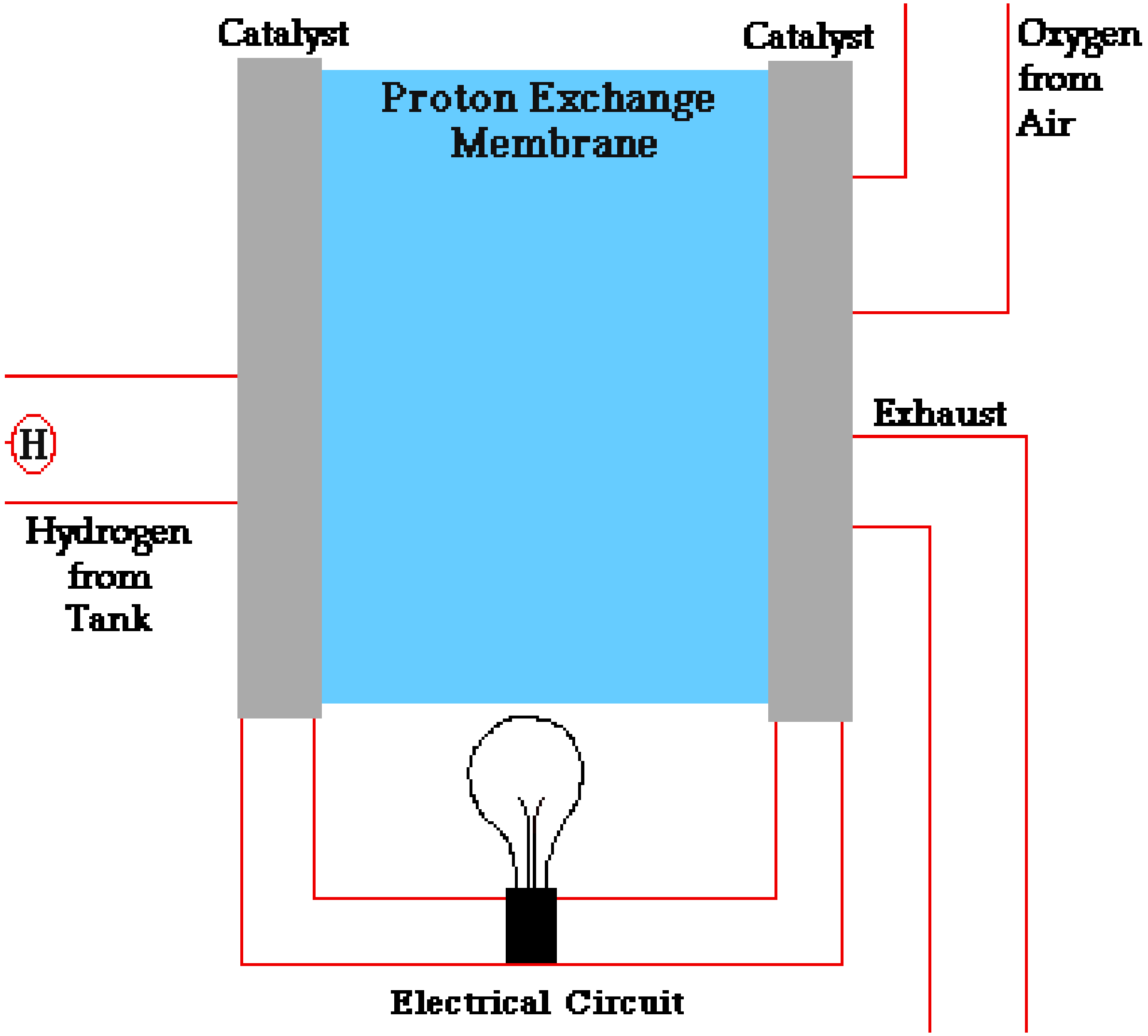
FUEL CELL

- A fuel cell uses the chemical energy of hydrogen or other fuels to cleanly and efficiently produce electricity.

- If hydrogen is the fuel, the only products are electricity, water, and heat.

- Fuel cells are unique in terms of the variety of their potential applications; they can use a wide range of fuels and feedstocks and can provide power for systems as large as a utility power station and as small as a laptop computer.

- One detail of terminology: a single fuel cell generates a tiny amount of direct current (DC) electricity. In practice, many fuel cells are usually assembled into a stack. Cell or stack, the principles are the same.


Catalyst
Catalyst
Oxygen from Air
Proton Exchange Membrane
Exhaust
H
Hydrogen from Tank
Electrical Circuit

There are four basic elements of a PEM Fuel Cell:

- **The anode,** the negative post of the fuel cell, has several jobs. It conducts the electrons that are freed from the hydrogen molecules so that they can be used in an external circuit. It has channels etched into it that disperse the hydrogen gas equally over the surface of the catalyst.

- **The cathode**, the positive post of the fuel cell, has channels etched into it that distribute the oxygen to the surface of the catalyst. It also conducts the electrons back from the external circuit to the catalyst, where they can recombine with the hydrogen ions and oxygen to form water.

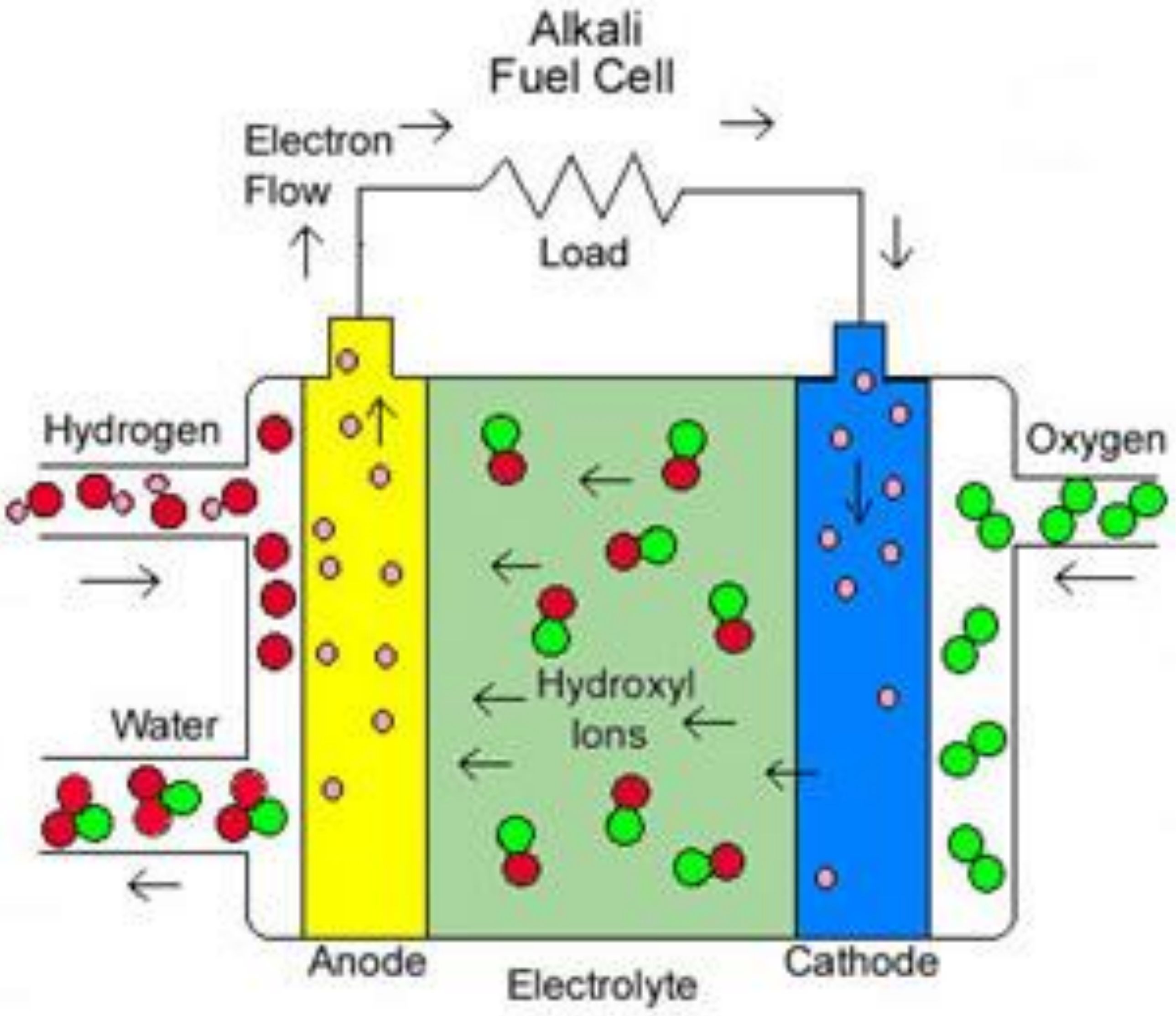
- **The electrolyte** is the proton exchange membrane. This specially treated material, which looks something like ordinary kitchen plastic wrap, only conducts positively charged ions. The membrane blocks electrons. For a PEMFC, the membrane must be hydrated in order to function and remain stable.

- **The catalyst** is a special material that facilitates the reaction of oxygen and hydrogen. It is usually made of platinum nanoparticles very thinly coated onto carbon paper or cloth. The catalyst is rough and porous so that the maximum surface area of the platinum can be exposed to the hydrogen or oxygen. The platinum-coated side of the catalyst faces the PEM.

Types of fuel cells

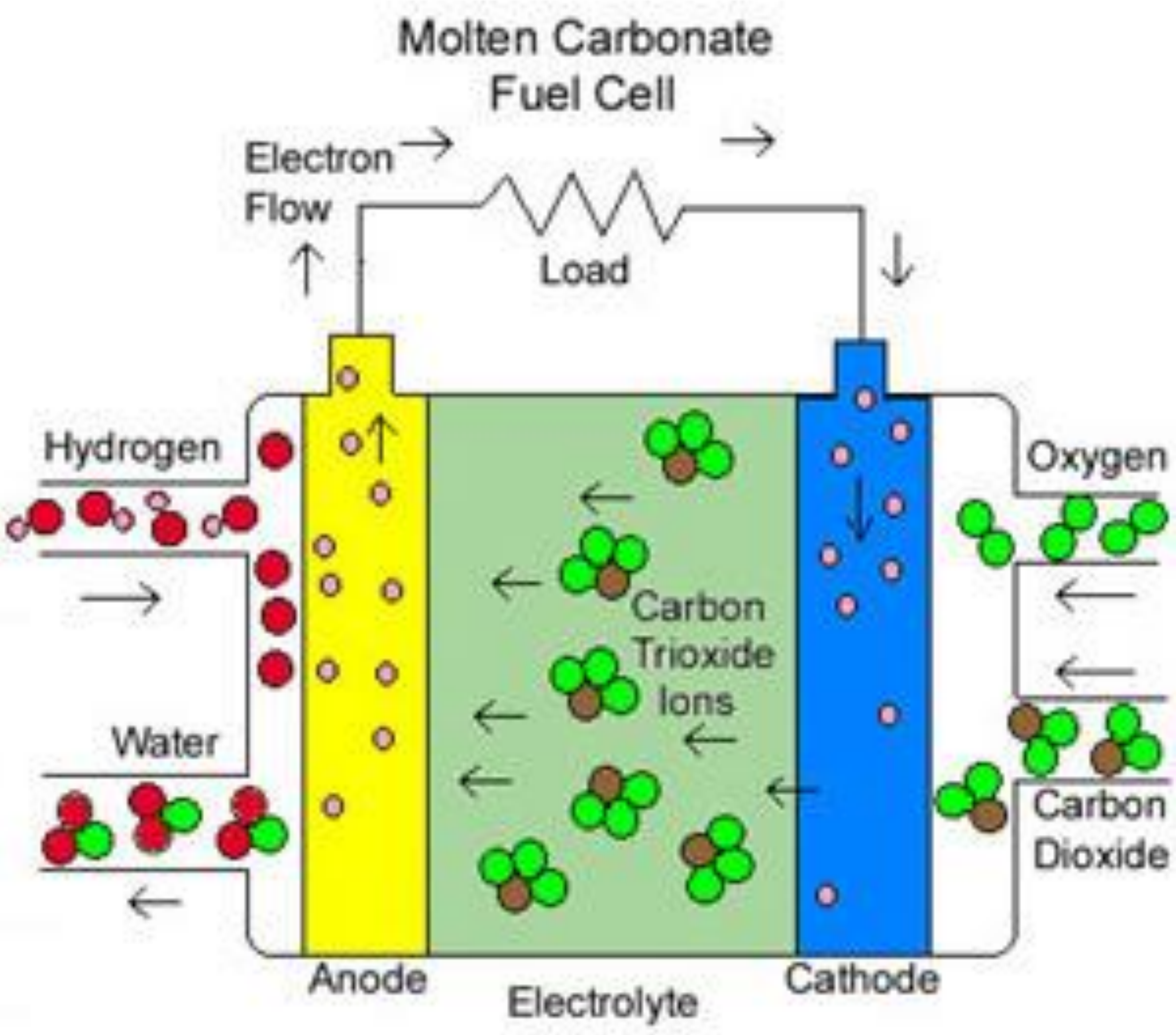
- Polymer electrolyte membrane fuel cells. ...
- Direct methanol fuel cells. ...
- **Alkaline fuel cells. ...**
- **Phosphoric acid fuel cells**. ...
- **Molten carbonate fuel cells**. ...
- **Solid oxide fuel cells**. ...
- Reversible fuel cells

Alkali fuel cells



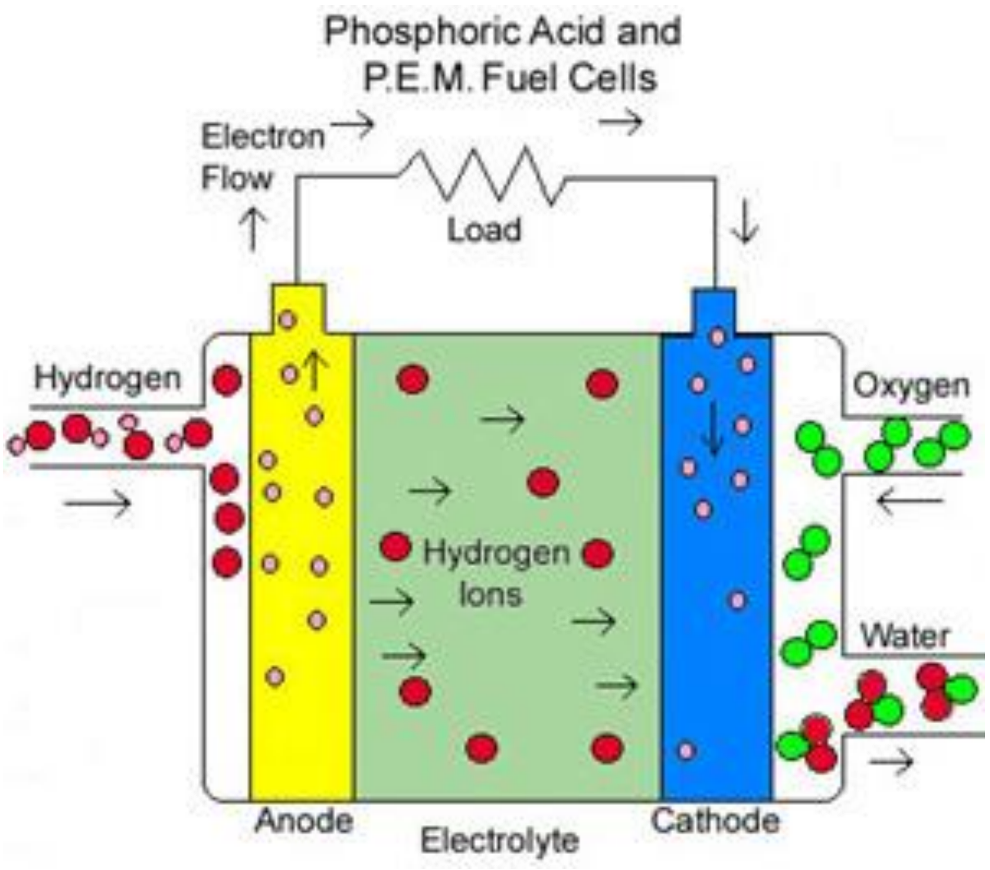
- Potassium hydroxide as electrolyte
- Efficiency is about 70 percent, and operating temperature is 150 to 200 degrees C.
- Cell output ranges from 300 watts (W) to 5 kilowatts (kW).
- Alkali cells were used in Apollo spacecraft to provide both electricity and drinking water

Molten Carbonate fuel cells (MCFC)



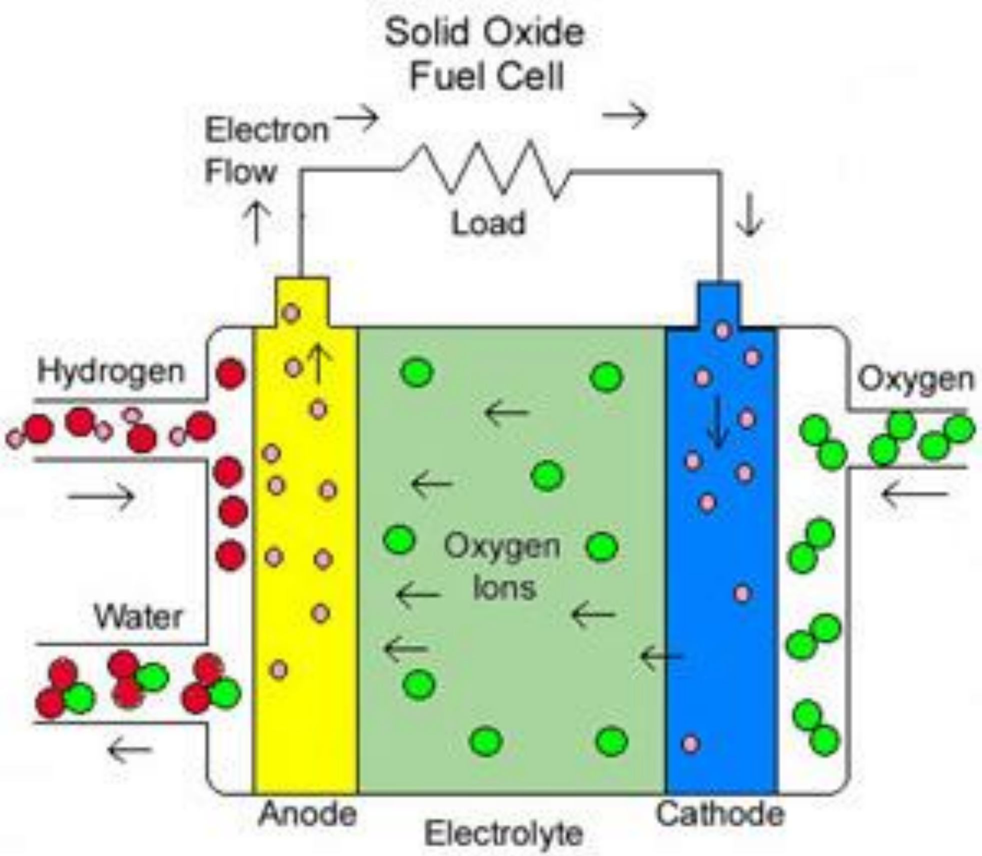
- like sodium or magnesium Carbonates uses as electrolyte
- Efficiency ranges from 60 to 80 percent, and operating temperature is about 650 degrees C (1,200 degrees F).
- Units with output up to 2 megawatts (MW) have been constructed, and designs exist for units up to 100 MW

Phosphoric Acid fuel cells (PAFC)



- Phosphoric acid as the electrolyte
- Efficiency ranges from 40 to 80 percent, and operating temperature is between 150 to 200 degrees C (about 300 to 400 degrees F).
- Existing phosphoric acid cells have outputs up to 200 kW, and 11 MW units have been tested.

Solid Oxide fuel cells (SOFC)



- use a hard, ceramic compound of metal (like calcium or zirconium) oxides (chemically, O2) as electrolyte.

- Efficiency is about 60 percent, and

- operating temperatures are about 1,000 degrees C (about 1,800 degrees F).
- Cells output is up to 100 kW.

Type of Fuel Cell	Application	Advantages	Limitations	Status
Proton Exchange Membrane	Cars, buses, portable power supplies, medium to large-scale stationary power generation.	Compact design; relatively long operating life; adapted by major automakers; offers quick start-up, low temperature operation, operates at 50% efficiency.	High manufacturing costs, needs pure hydrogen; heavy auxiliary equipment and complex heat and water management.	Most widely developed; experimental production.
Alkaline	Space (NASA), terrestrial transport (German submarines).	Low manufacturing and operation costs; does not need heavy compressor, fast cathode kinetics.	Large size; needs pure hydrogen and oxygen; use of corrosive liquid electrolyte.	First generation technology; gains interest due to low operating cost.
Molten Carbonate	Large-scale power generation.	Highly efficient; utilizes heat for co-generation.	Electrolyte instability; limited service life.	Well developed; semi-commercial.
Phosphoric Acid	Medium to large-scale power generation.	Commercially available; lenient to fuels; heat for co-generation.	Low efficiency, limited service life, expensive catalyst.	Mature but faces competition from PEM.
Solid Oxide	Medium to large-scale power generation.	High efficiency, lenient to fuels, takes natural gas directly, no reformer needed. Operates at 60% efficiency; co-generation.	High operating temp; exotic metals, high manufacturing costs, oxidation issues; low specific power.	Least developed. Breakthroughs in cell material and stack design sets off new research.
Direct Methanol (DMFC)	Suitable for portable, mobile and stationary applications.	Compact design, no compressor or humidification needed; feeds directly	Complex stack structure, slow load response, operates at	Laboratory prototypes.

Advantages of Fuel Cells

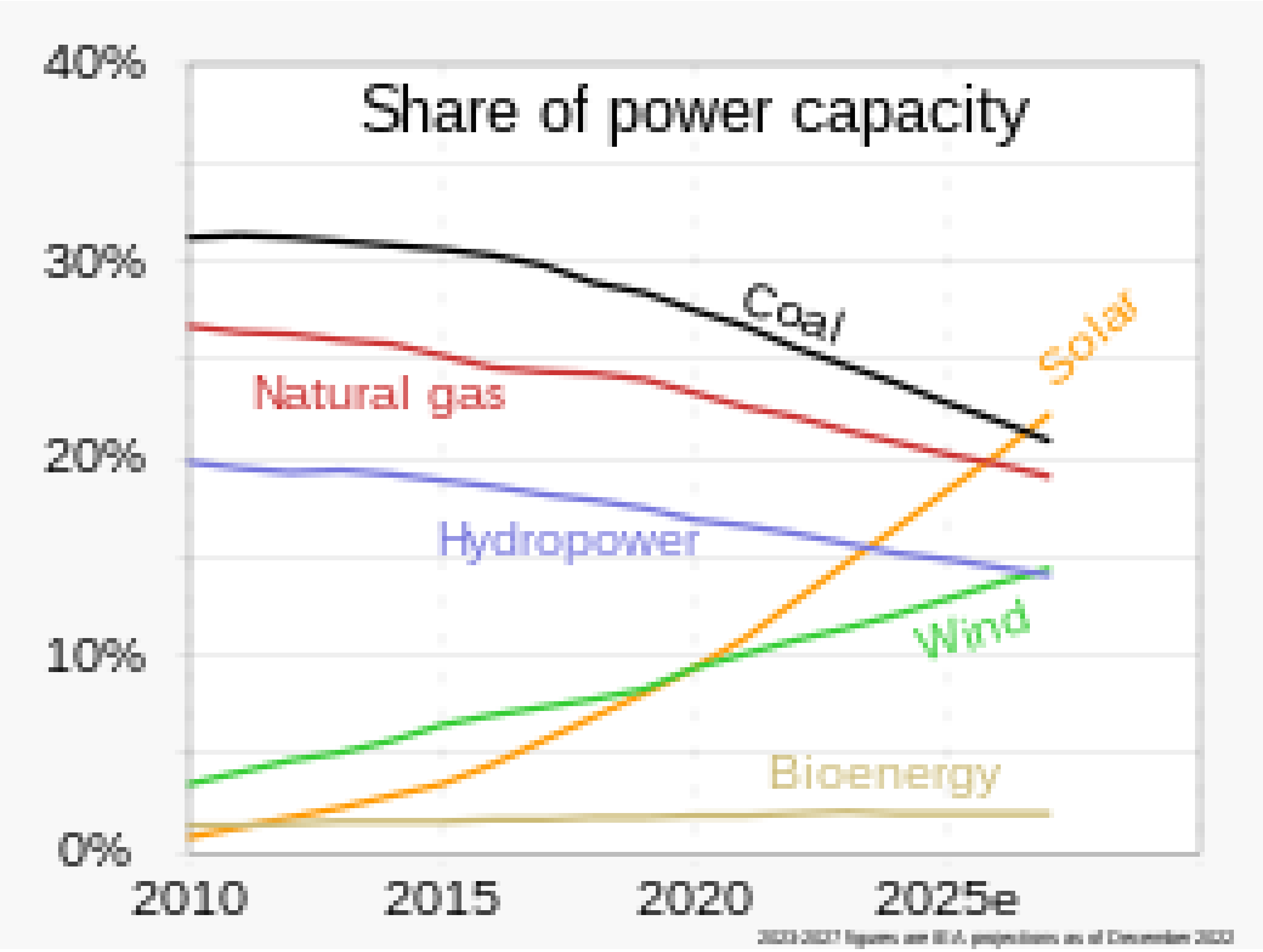
1. **High efficiency of energy conversion (approaching 70%) from chemical energy to electrical energy.**
2. **Low noise pollution & low thermal pollution.**
3. **Fuel cell power can reduce expensive transmission lines & minimize transmission loses for a disturbed system.**
4. **Designing is modular, therefore the parts are exchangeable hence low maintenance cost.**
5. **Fuel cells are less polluting. The chemical process involved in it is clean. It does not produce polluting exhaust. Mostly the byproducts are water & waste heat, which are environmentally acceptable when hydrogen & air are used as reactants.**

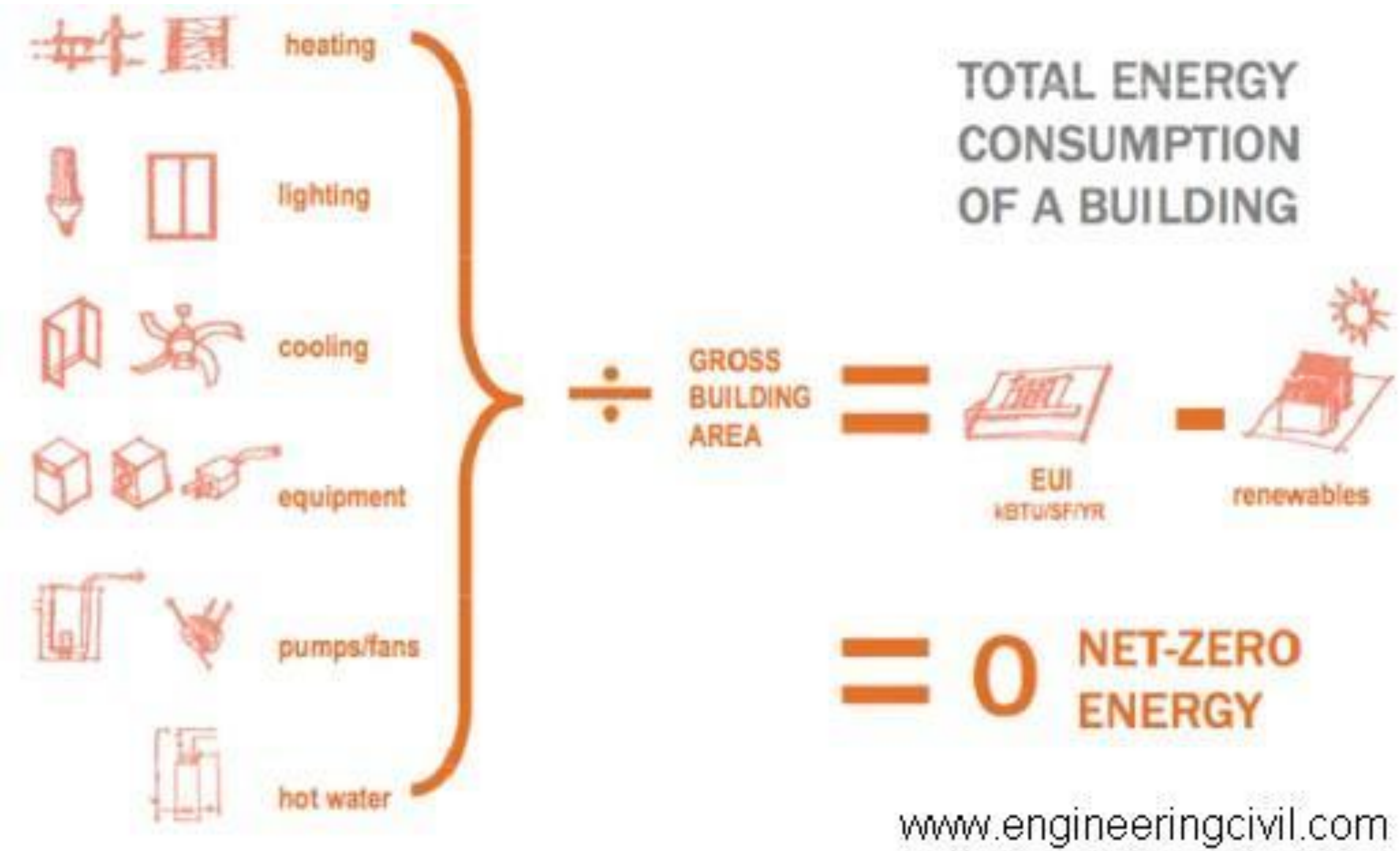
Disadvantages of Fuel Cells:

1. **High initial cost.**
2. **Life times of the cells are not accurately known.**
3. **Large weight and volume of gas fuel storage system.**
4. **High cost of pure hydrogen.**
5. **Hydrogen can be stored in lesser volume by liquefaction but liquefaction itself require 30% of the stored energy.**
6. **Lack of infrastructure for distributing hydrogen.**

Zero energy Concepts

A Zero Energy Building (ZEB), also known as a Net Zero Energy (NZE) building, is a building with net zero energy consumption, meaning the total amount of energy used by the building on an annual basis is equal to the amount of renewable energy created on the site

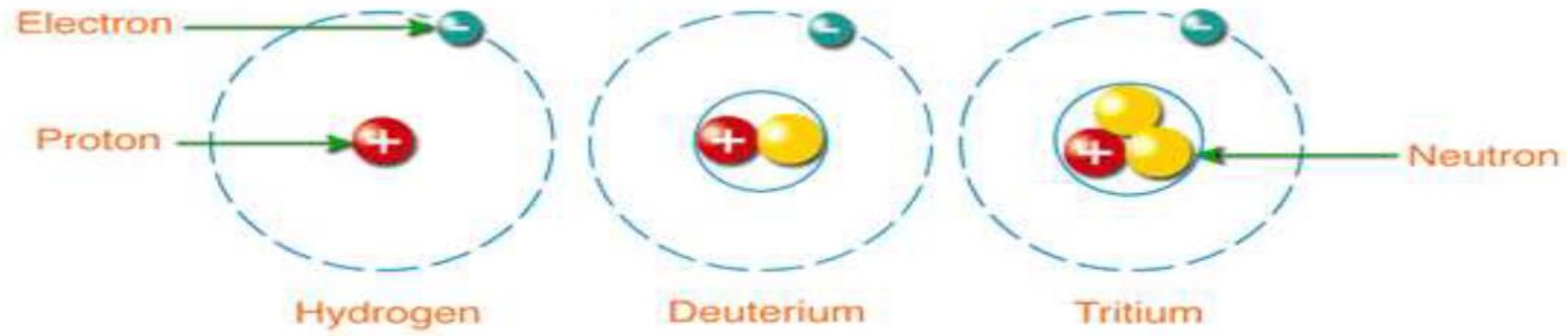



heating
lighting
cooling
equipment
pumps/fans
hot water
TOTAL ENERGY CONSUMPTION OF A BUILDING
GROSS BUILDING AREA
EUI
kBTU/SF/YR
renewables
= 0 NET-ZERO ENERGY
www.engineeringcivil.com

Hydrogen energy

- Hydrogen is most abundant element in luminous universe
- It rarely found in earth as H2
- Largest reservoir of hydrogen in the world
- Hydrogen as renewable energy with very good prospect
- Producing the Hydrogen

Hydrogen isotopes..



Hydrogen
Deuterium : known as heavy water if bounding with O
Tritium : radioactive matter

Physical Properties..

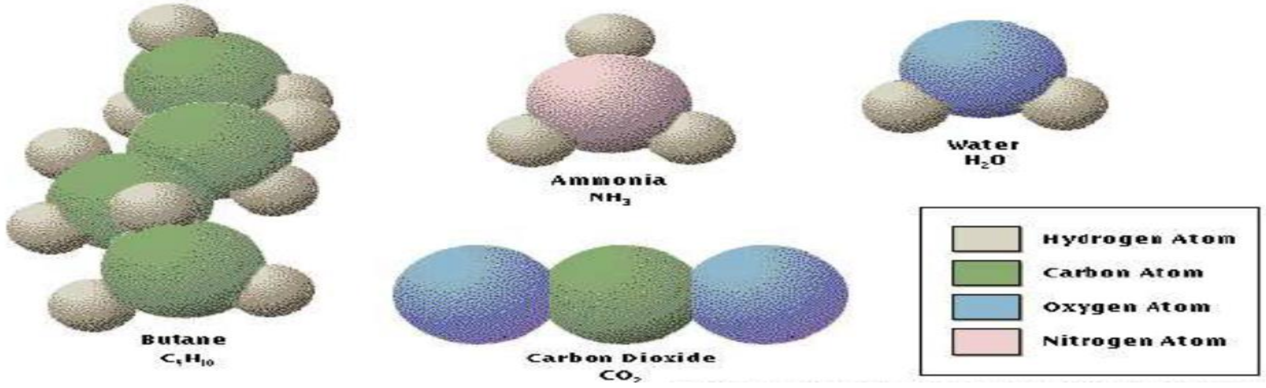
- Second lowest boiling point (-272.78 C)
- Density ; 0.08375 kg/m3
- Specific volume : 11.940 m3/kg
- Follow the ideal gas law behavior
- At high pressure, its behavior added by compressibility factor, measured directly
- It can diffuse through material

Chemical Properties

- Burns with air and form H2O
- HHV : 285.83 kj/mol
- LHV : 241.82 kj/mol
- Lowest energy density

Chemical property..

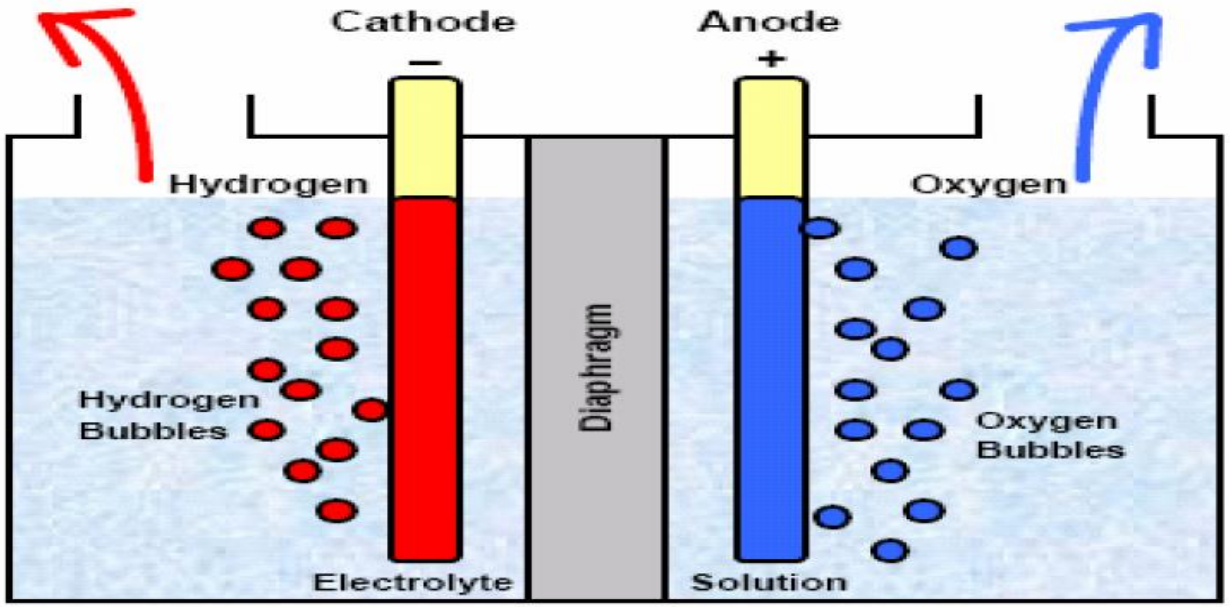
- It can reacting with almost all organic or chemical elements..



On the basis of source use and energy source hydrogen production are following type-

1. Electrolysis or electrolytic production
2. Thermo – Chemical Methods.
3. Thermo chemical cyclic process.
4. Fossil Fuel Methods
5. Solar energy methods.

1. **Electrolysis or electrolytic production**- In electrolysis water spit in to H2 and O2 when electric current pass through in this process two type of electrolyzer used



Standard Electrolysis

2. Thermo – Chemical Methods.

A sequential chemical reaction series can be devised in which hydrogen and oxygen are produced, water is consumed and all other intermediates are recycled. The operation is called as thermo chemical cycle.

It is so called because energy is supplied as heat at one or more of the chemical stage, and hydrogen and oxygen are produced separately in different stages.

Several workers have proposed many multistep reaction sequence that thermally decompose water at lower temperatures.

$2CrCL2 + 2HCL \longrightarrow 2CrCl3 + H2$
$2CrCL3\ 2CrCL2 + Cl2 \longrightarrow H2O + Cl2\ 2HCL + \frac{1}{2}(O2)$

As can be seen, in this reaction sequences, only water is split, all other materials are completely recycled.

3.Thermo chemical cyclic process.

Electrochemical Thermal Sulfur Cycle

$$H_2SO_4 \longrightarrow H_2O + \frac{1}{2}(O_2) + SO_2$$
$$2H_2O + SO_2 \longrightarrow H_2 + H_2SO_4$$

1. It is clear by summing reaction that overall process decomposes water into hydrogen and oxygen and involves only sulphur oxides as recycling intermediates.
2. Although electrical power is required in the electrolyzer, much smaller quantities than those necessary for conventional electrolysis.

4. Fossil fuel

It is popular method of hydrogen production through which about 94% hydrogen is produced by following different processes-

1.Steam reforming of gas
2.Partial oxidation of heavier hydro carbon.
3.Coal gasification
4.Pyrolysis
5.Biomass gasification

$$CO + H_2O = CO_2 + H_2 + 1440\ KJ/KG$$

To remove the CO, the mixture is submitted to the water gas shift reaction with steam. The CO is therefore converted into CO_2 with the formation of additional hydrogen and energy.

5. Solar energy methods.

1.Bio photolysis and

2.Photo Electrolysis.

Bio photolysis:

This method utilizes living systems (or material derived from such systems) to split water into its constituents hydrogen and oxygen.

In normal photosynthesis in green plants the green plants the green pigment chlorophyll takes of the energy from sunlight and in a complex series of reactions breaks up water molecules into oxygen gas, hydrogen ions and electrons.

Photo Electrolysis:

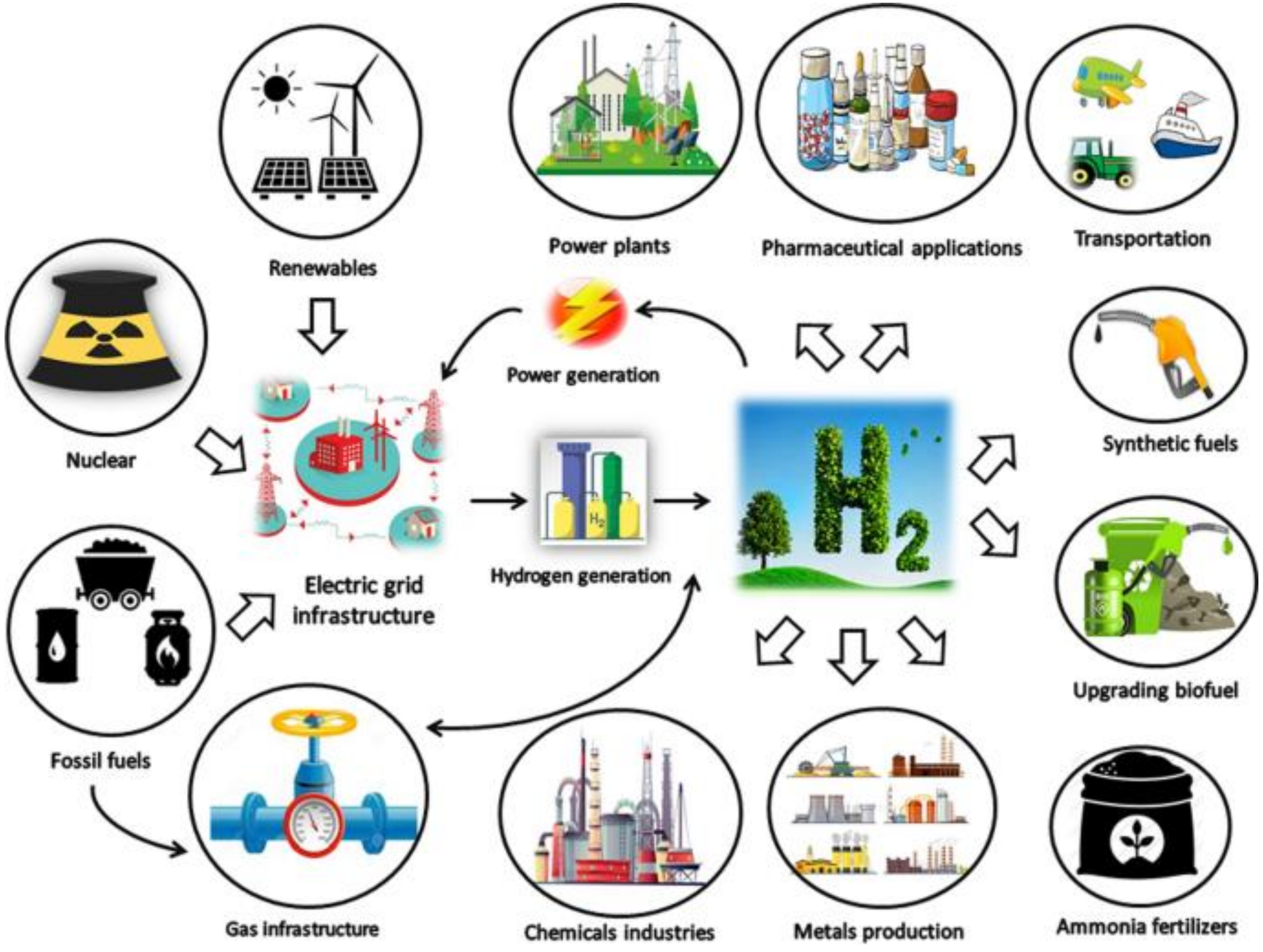
In photosynthesis , a current is generated by exposing on or both electrodes to the sunlight. Hydrogen and Oxygen gases are liberated at the respective electrodes by the decomposition of the water , just as an ordinary electrolysis.

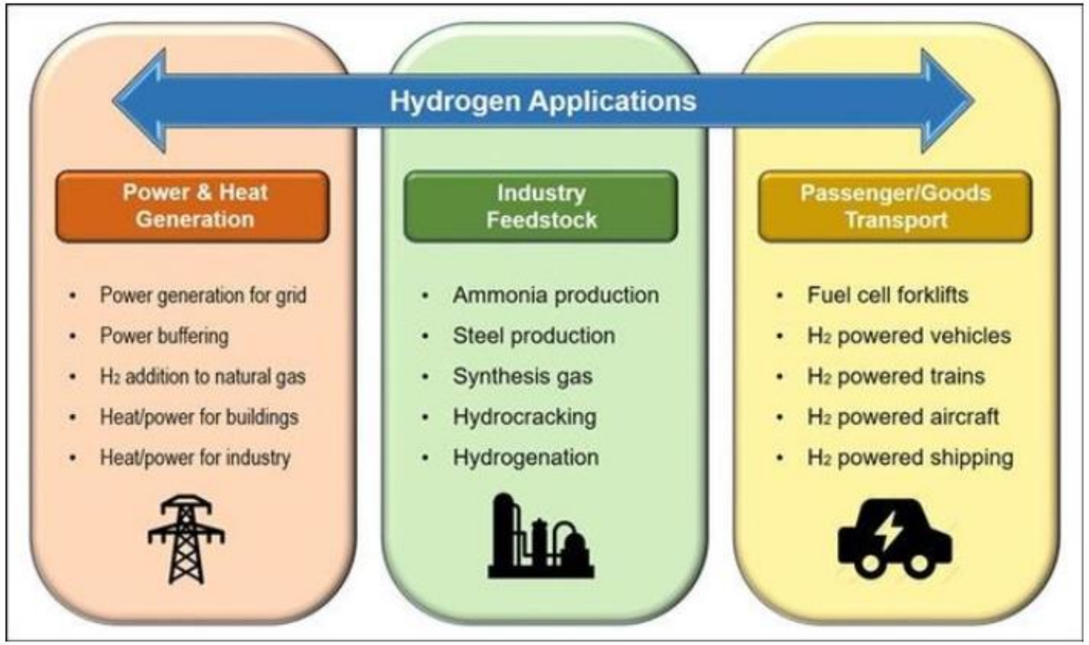
Atleast one of the electrodes in the photosynthesis is usually a semiconductor; a catalyst may be included to facilitate the electrode processes.

Application of Hydrogen Gas in the following ways:

1. For residential uses
2. For industrial uses
3. For as an alternative transport fuel
4. For as an alternative fuel for aircraft.
5. For electric power generation (Utilities)

Application of Hydrogen Gas in the following ways





Advantages

1. Hydrogen is colourless & odourless and non polluting , yielding pure water vapour as exhaust when combusted in air .
2. Hydrogen is the lightest chemical element and has the best energy to weight ratio of any fuel.
3. Hydrogen can be produced anywhere , it can be produced domestically from the decomposition of water .

Disadvantages

1. Hydrogen is difficult to handle , store , and transport .it requires heavy , cumbersome tanks when stored the gas .
2. It is impossible to obtain hydrogen gas without expanding energy in the process.
3. Other than some volcanic emanations , hydrogen does not exist in it pure form in environment.

TODAYS FLIP CLASS ROOM ACTIVITY

Activity 3: PROBLEMS/CHALLENGES ASSOCIATED WITH HYDROGEN ENERGY

PROBLEM/CHALLENGES ASSOCIATED WITH HYDROGEN ENERGY

1. **Hydrogen Extraction**
2. **Investment is Required**
3. **Cost of Raw Materials-**platinum and iridium
4. **Regulatory Issues**
5. **Overall Cost**
6. **Hydrogen Storage**
7. **Infrastructure**
8. **Highly Flammable**

CONCLUSION / SUMMARY

- The advantages of hydrogen fuel cells as one of the best renewable energy sources are evident, however there are still a number of challenges to overcome to realise the full potential of hydrogen as a key enabler for a future decarbonised energy system.

- On the positive side, hydrogen fuel cells could offer a fully renewable and clean power source for stationary and mobile applications in the near future.

- To achieve this there is the need to scale up decarbonised hydrogen production and fuel cell manufacture, and develop the required regulatory framework to clearly define commercial deployment models. Further technological advances to lower the associated costs of extraction, storage and transportation are envisaged, along with further investment in the infrastructure to support it.

- Hydrogen could become the best solution for the future of our energy requirements but this will require political will and investment to achieve. However, as fossil fuels run out hydrogen could be a key solution for our global energy needs.