Hydrogen Production from Renewable Energy

Group No.7

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Need for a cleaner fuel

- Today, impending depletion of fossil fuel resources has become a main challenge of humankind.
- To establish an environmentally friendly energy for the future of the world, we should develop carbon-neutral energy systems.
- It was projected that to supply the energy demand of the world and support economic development, and maintain atmospheric carbon dioxide (CO_2) levels at an acceptable level, approximately 10 TW (terawatt) of carbon-neutral power should be generated by the mid-century.
- Hydrogen is one of the most promising alternative energy carriers, which does not exist freely in nature.
- Same as electricity, hydrogen is not a source of energy and it is assumed as a secondary form of energy and will play a great role in the future scenario of energy sectors.

Why Hydrogen?

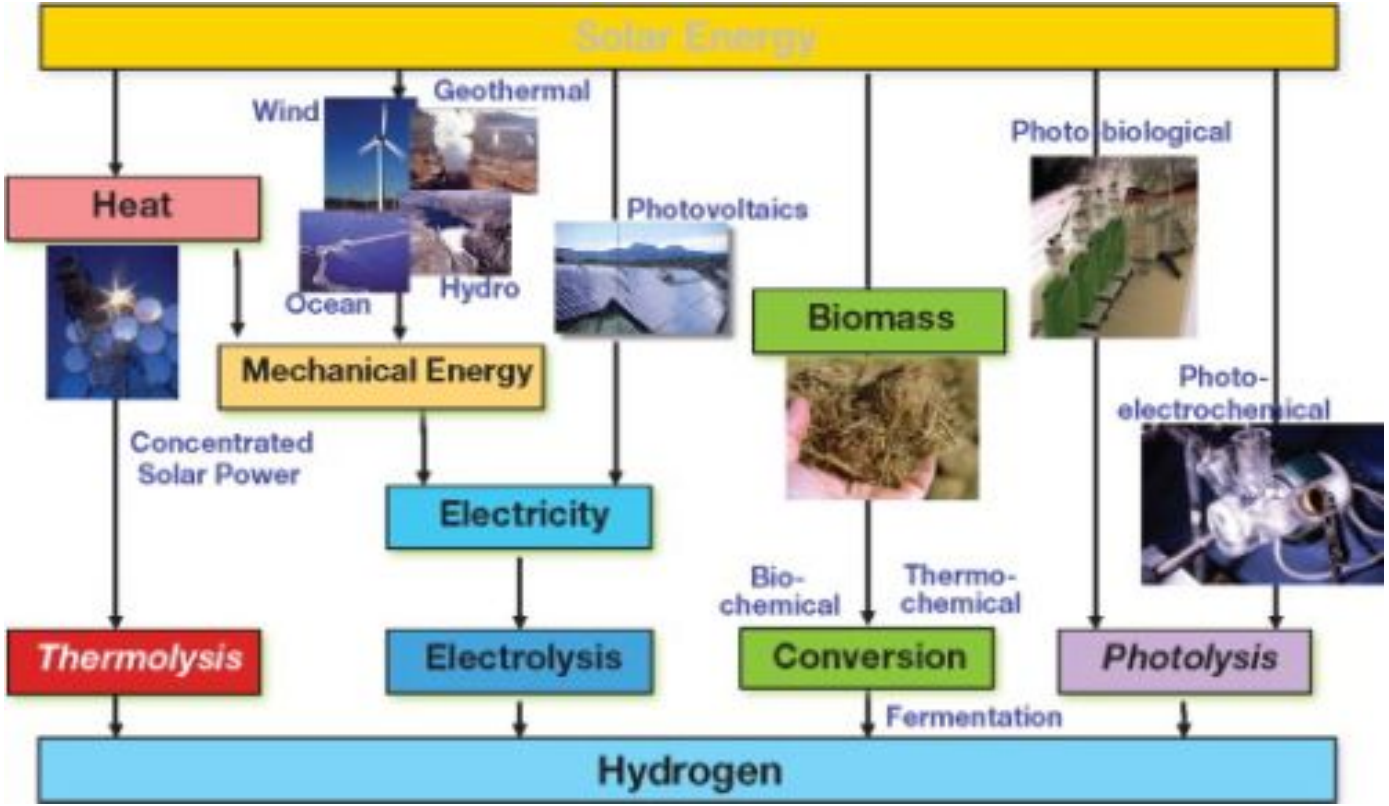
- A clean fuel without toxic emissions.
- Can be easily applied in fuel cells for electricity generation.
- No CO2 emission, only product is water vapour.
- High calorific value.
- Hydrogen fuel cells are very efficient.
- Reduced demand for foreign oil.
- High Reliability.
- Improved environmental quality.
- Hydrogen as a fuel for automobiles poses some advantages such as rapid burning speed, no toxic emission and a high effective octane number.

Comparison with other fuels

Fuel	Calorific Value (kJ/kg)
Cow dung cake	6000-8000
Wood	17000-22000
Coal	25000-33000
Petrol	45000
Kerosene	45000
Diesel	45000
Methane	50000
CNG	50000
LPG	55000
Biogas	35000-40000
Hydrogen	150000

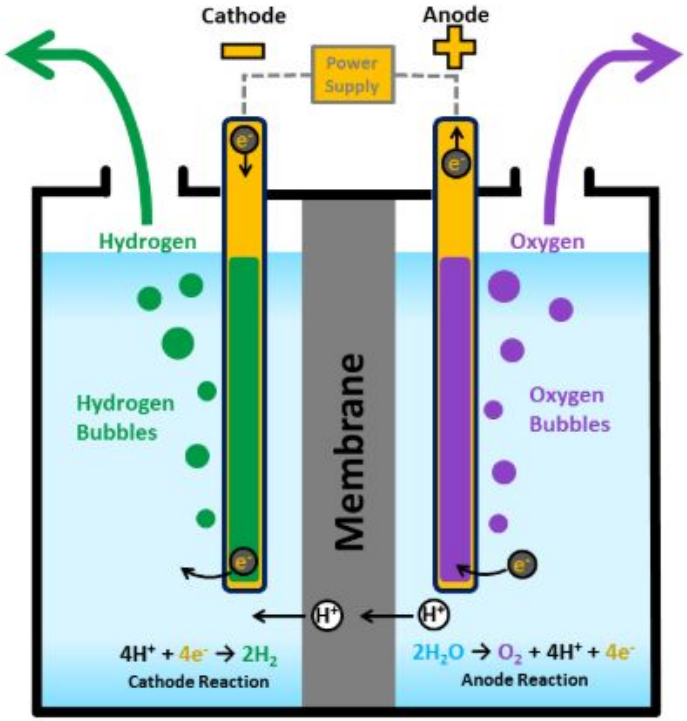
- Energy yield of hydrogen is almost 3 times greater than hydrocarbon fuels.
- The **efficiency** of hydrogen fuel cell (HFC) vehicles is **three times** more than gasoline engines.
- Being a gas at normal pressures and temperatures, hydrogen presents greater storage and **transportation barriers** than exist for the liquid fuels.

Ways of hydrogen production



Electrolysis

- Decomposition of water into **oxygen** and **hydrogen** gas due to the passage of an **electric current.**
- This reaction takes place in a unit called an **electrolyzer**.
- water electrolysis system operates at **70–75%** energy efficiency
- Ideal potential difference of water splitting is **1.23 volts**.
- Electrolysis is a promising option for hydrogen production from renewable resources.



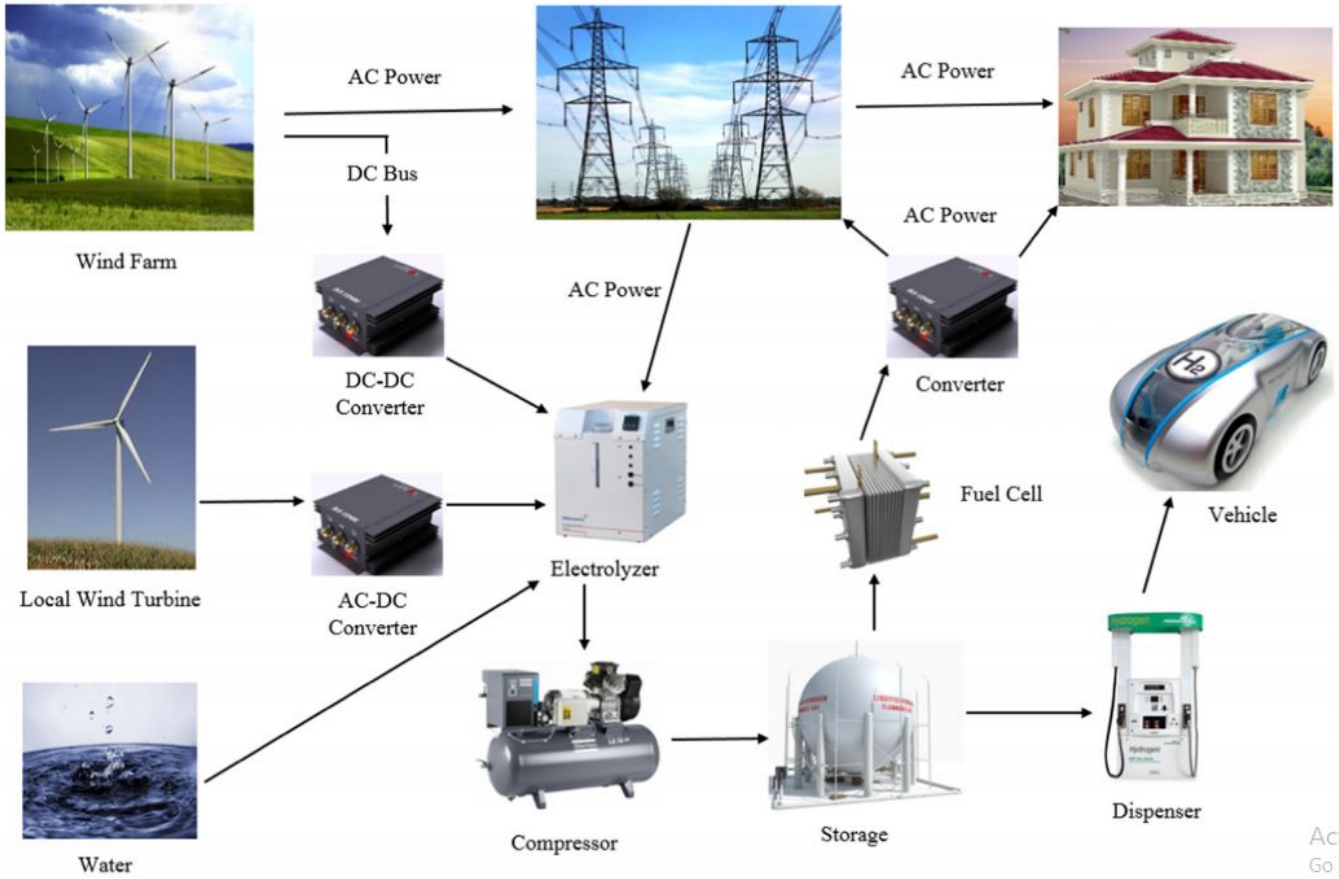
POLYMER ELECTROLYTE MEMBRANE ELECTROLYZERS

Solar to Hydrogen System (SHS)

- In SHS, the PV energy cracks H2O molecules into H2 and O2 which are applied later in Hydrogen Fuel Cells (HFC) to make electricity when the sun is not shining.
- The infrastructure of first SHS was made in **El Segundo, California** in **1995**. A complex of advanced PV cell and electrolyzer generated about 50–70 m3 hydrogen per day.
- Efficiency of SHS is approximately **8–14%** for commercial silicon-based solar cells.SHS has great potential to increase the efficiency up to 25–30%.

$$\eta_{SHS} = \eta_{PV} * \eta_{ELECTROLYSER}$$

Integrated system of electricity/hydrogen generation from wind power.

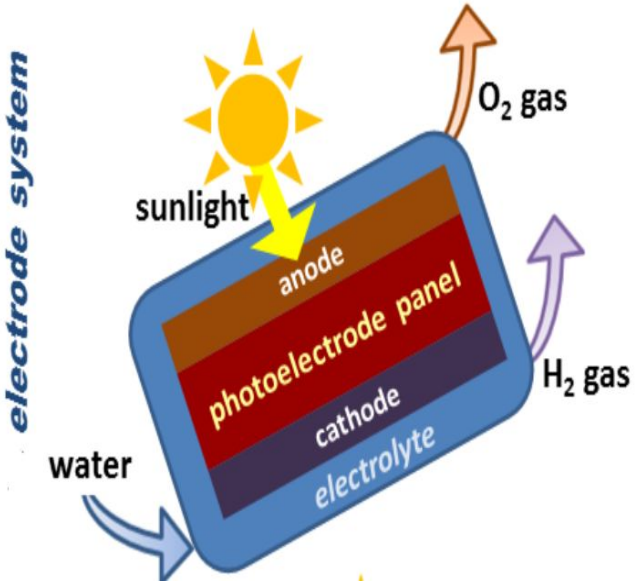


Hydrogen from photolysis

Direct solar water splitting, or photolytic, processes use light energy to split water into hydrogen and oxygen. 2 types are there -

(1) Photoelectrochemical (PEC)

- Use of **semiconductor materials** to convert solar energy directly to chemical energy in the form of hydrogen.
- Semiconductor is **immersed in a water-based electrolyte**, where sunlight energizes the water-splitting process.

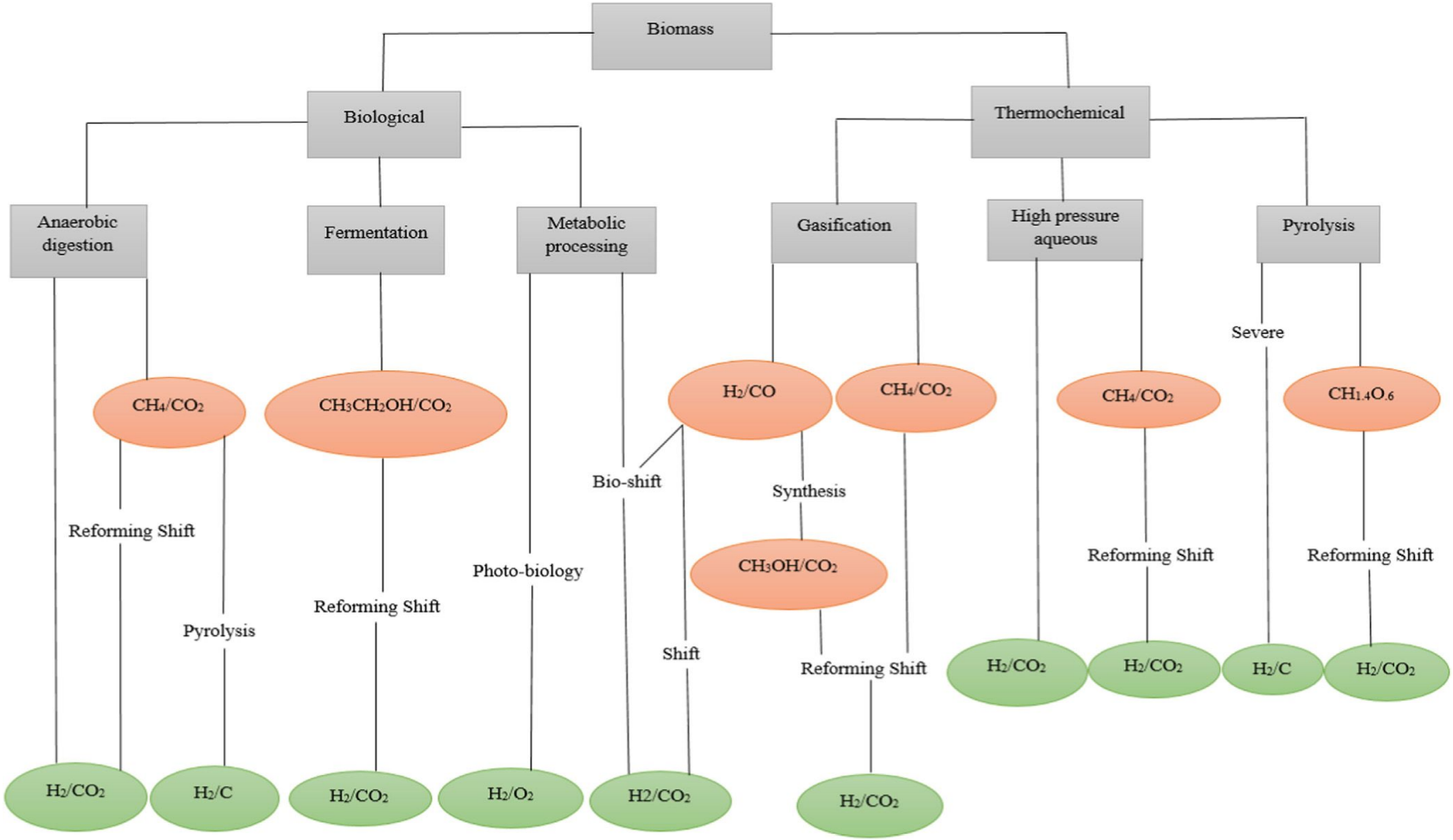


(2) Photobiological

- Use of microorganisms such as **green microalgae or cyanobacteria and sunlight** to turn water, and sometimes organic matter, into hydrogen.
- **Hydrogen ions** can be combined through **direct or indirect routes** and released as hydrogen gas
- Algae and bacteria could be grown in **water that cannot be used for drinking or for agriculture**, and could potentially even use **wastewater**.
- **Low rates of hydrogen production**, **inhibition of hydrogen production** reaction because of oxygen produced are some challenges faced.
- Some **photosynthetic microbes** use sunlight to break down organic matter, releasing hydrogen called as **photo-fermentative process**.

Hydrogen from biomass

- ➔ Wood, agricultural crops, the waste of agricultural byproducts, animal waste, municipal solid waste(MSW), waste from food processing, aquatic plants and algae are the most important sources of biomass.
- ➔ Biomass **restores degraded lands**,**increasing biodiversity, soil fertility and water retention**.
- ➔ **Availability, diversity and the low prices of biomass feedstock, elimination of CO2 capture and storage(CCS) as well as sulfur removal system** are the most promising characteristics of biomass based hydrogen production process.
- ➔ Bioenergy contributes in **mitigation of poverty in developing countries and supplies required energy at all times** without complicated energy conversion instrument and expensive process.


Biomass
Biological
Thermochemical
Anaerobic digestion
Fermentation
Metabolic processing
Gasification
High pressure aqueous
Pyrolysis
CH4/CO2
CH3CH2OH/CO2
H2/CO
CH4/CO2
CH4/CO2
CH1.4O.6
Severe
Reforming Shift
Pyrolysis
Reforming Shift
Photo-biology
Bio-shift
Synthesis
Reforming Shift
Reforming Shift
Reforming Shift
CH3OH/CO2
Shift
Reforming Shift
H2/CO2
H2/C
H2/CO2
H2/O2
H2/CO2
H2/CO2
H2/CO2
H2/CO2
H2/C
H2/CO2

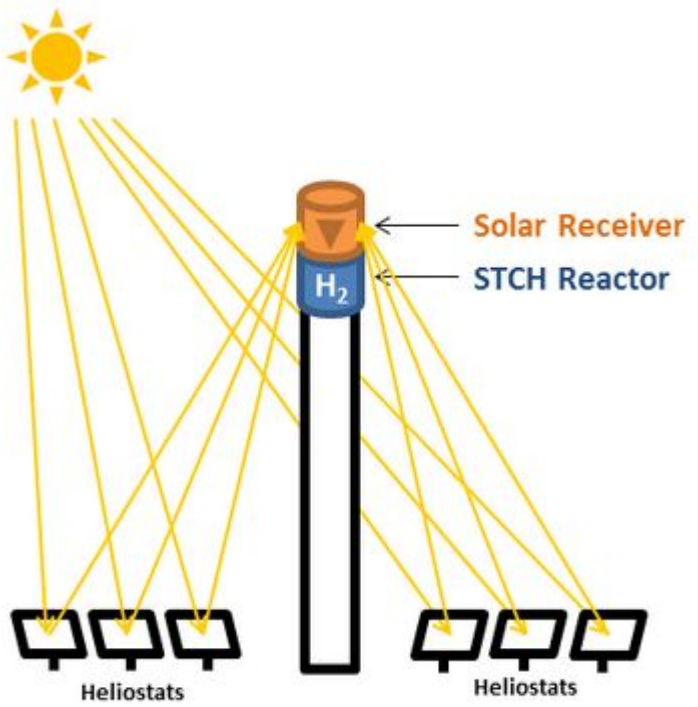
Hydrogen from thermolysis

Thermochemical water splitting **uses high temperatures (500°–2,000°C)** to produce hydrogen and oxygen from water —

(1) From **concentrated solar power onto a reactor tower** using a field of mirror "heliostats" or

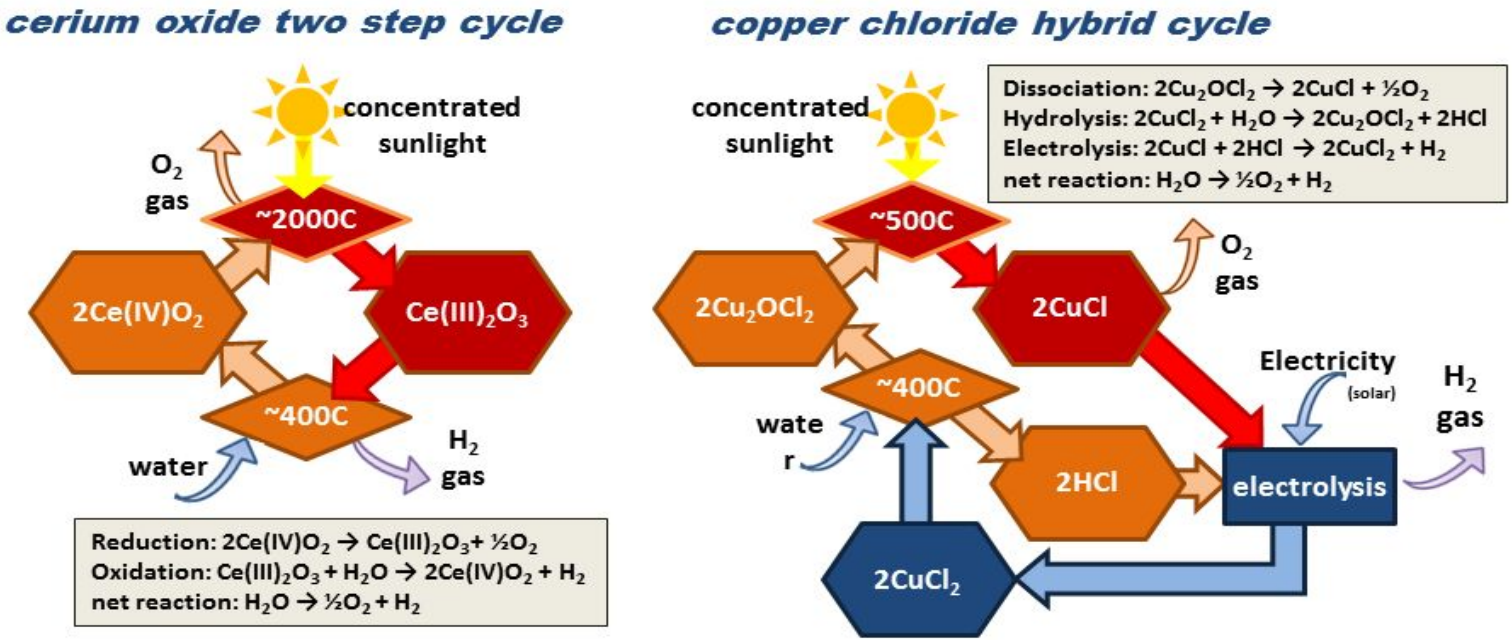
(2) From the **waste heat of nuclear power reactions**—and **chemical reactions**.

The **chemicals** used in the process are **reused within each cycle**, creating a closed loop that consumes only water and produces hydrogen and oxygen.



Central receiver/reactor tower with heliostats

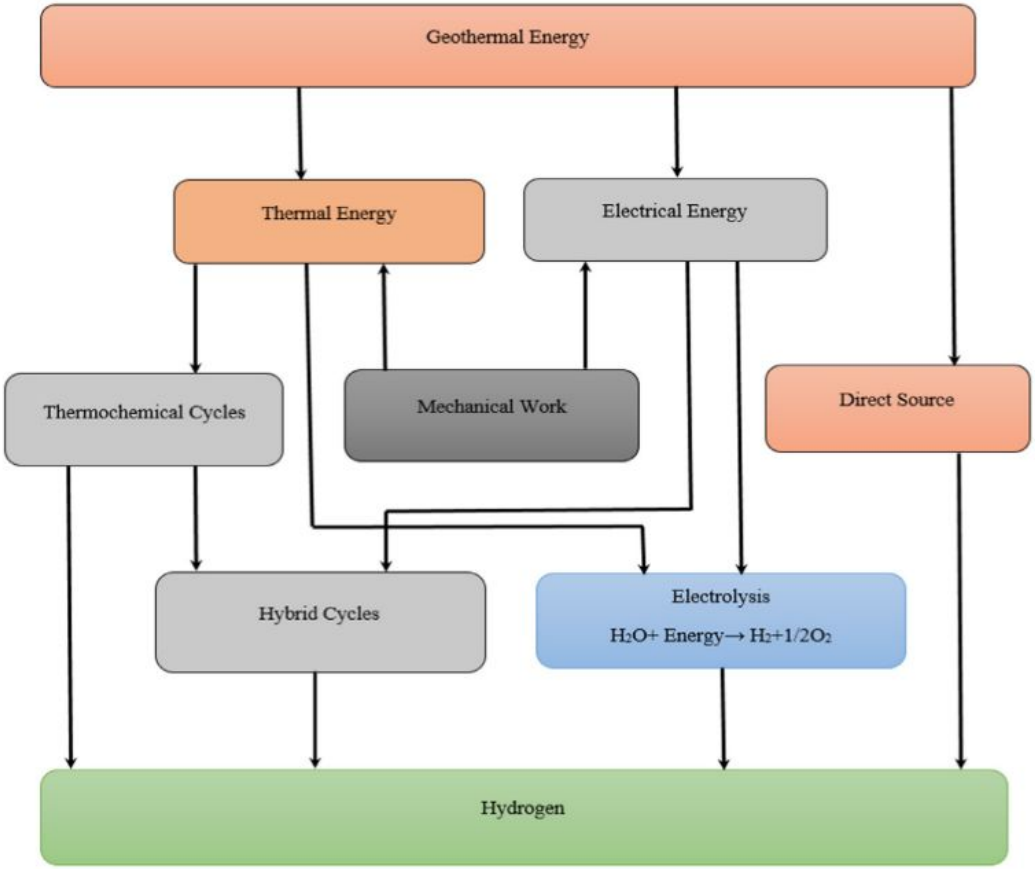
Two examples of thermochemical water splitting cycles, the "direct" two-step cerium oxide thermal cycle and the "hybrid" copper chloride cycle



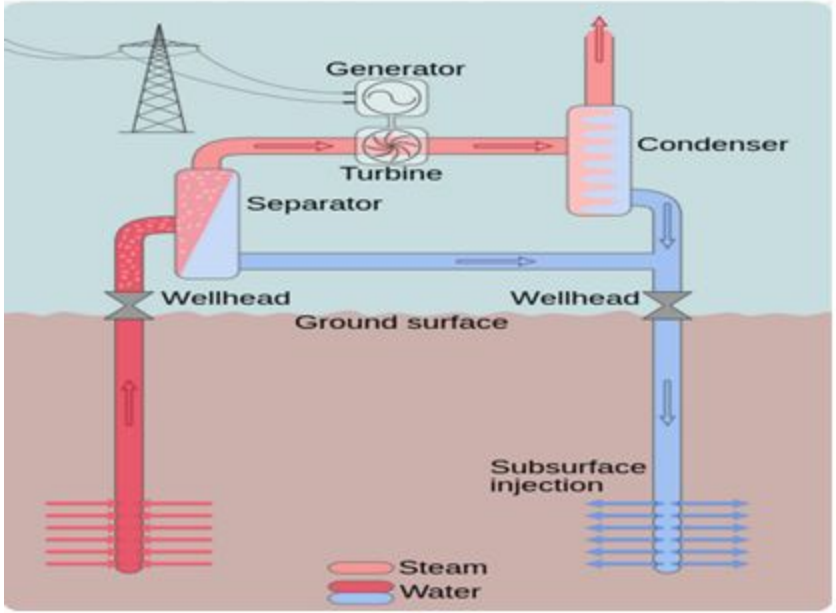
Hydrogen production from geothermal energy

- Geothermal could be an attractive option for hydrogen production due to its relatively **low cost** and **high availability**.
- Geothermal energy is obtained in the form of heat or electricity,which can be applied to generate hydrogen by **hybrid cycles** or **electrolysis**.
- More than 100 various thermochemical cycles have been proposed for hydrogen production.
- Br–Ca–Fe cycle and sulphur–iodine(S–I) cycle as the most promising high-temperature cycles and copper–chloride (Cu–Cl) as the best lower-temperature cycle.
- Hydrogen production from geothermal energy has been implemented in Hachijo Island in Japan as well as Iceland.

Pathway of geothermal-based hydrogen production process



Geothermal plants for Hydrogen production



Schematic of Geothermal Power Plant

Wairakei geothermal facilities, Taupo/ New Zealand

Production cost comparison

Process	Cost of hydrogen ($US per kg)
Natural gas reforming	1.03
Natural gas $+CO_2$ capture	1.22
Coal gasification	0.96
Coal $+CO_2$ capture	1.03
Wind electrolysis	6.64
Biomass gasification	4.63
Biomass pyrolysis	3.8
Nuclear thermal splitting of water	1.63
Gasoline (for reference)	0.93

Drawbacks of Hydrogen fuel

- Being a gas at normal pressures and temperatures, hydrogen presents **greater storage and transportation barriers** than those exist for the liquid fuels.
- **The unavailability in nature and the expensive production process of hydrogen** are the other hurdles that make hydrogen gas an uneconomic fuel.
- Moreover,the **small size of hydrogen molecules** causes **hydrogen to be leaked from the vessel**.
- If significant amounts of Hydrogen escape to the environment, free radicals of hydrogen can be constituted due to ultraviolet radiation,which leads to **ozone depletion**.

Conclusion

- The future energy scenario of the world as well as global warming phenomena lead the energy mix of the world to the renewable energy resources.In this regard, hydrogen has been introduced as **a promising energy carrier** for clean development.
- Currently, hydrogen production from **nonrenewable resources is dominant** in the world.For each ton of hydrogen production from coal, approximately 5 tons of carbon in the form of CO2 is released.
- In wind and solar power plants, hydrogen could be employed as an **intermediate energy carrier**.
- Biomass conversion, photolysis and thermolysis are **more appropriate methods** based on **sustainable energy sources**, methods that **do not employ electricity as an intermediate step.**