HYDROGEN ENERGY

HYDROGEN

- Hydrogen is the most abundant element in the universe, about 75% by mass of the universe is made up of hydrogen; however, in the earth's atmosphere the quantity of hydrogen is very small.
- While highly combustible and energy-dense, hydrogen only naturally occurs on earth in compounds formed with other elements such as with oxygen to form water and carbon to form hydrocarbons. These hydrocarbons are found in fossil fuels among other resources.
- Combusted hydrogen primarily emits water vapor, thus hydrogen is viewed as a key method to reduce greenhouse gas emissions.
- It is richest in terms of energy per unit mass because of its high diffusivity.

Hydrogen colours codes

- Hydrogen itself is a colourless gas but there are around nine colour codes to identify hydrogen. The colours codes of hydrogen refer to the source or the process used to make hydrogen. These codes are: green, blue, grey, brown or black, turquoise, purple, pink, red and white.

Colour						
Type	Black/Brown Hydrogen	Grey Hydrogen	Blue Hydrogen	Turquise Hydrogen	Pink Hydrogen	Green Hydrogen
Process	Coal Gasification	Methane Reformation	Coal Gasification &Methane Reformation with CCUS	Pyrolysis	Electrolysis	Electrolysis/ Biomass Gasification
Source	Coal	Natural Gas	Fossil Fuel	Methane	Nuclear Energy	Renewable Energy

'Green hydrogen' is pure hydrogen produced using renewable energy sources such as wind or solar power.

- **GREEN HYDROGEN is derived from renewable energy sources. The electrolysis process used to produce *it relies solely on electricity generated from renewable sources like solar, wind, or hydroelectric power.***
- During its production the only by product is water vapor, making it a sustainable energy source with minimal environmental impact.
- The versatility of green hydrogen extends to various sectors. It can be used as a clean transportation fuel, powering fuel cell electric vehicles and eliminating harmful tailpipe emissions.
- Green hydrogen can be employed in power generation, providing a sustainable alternative to fossil fuels.

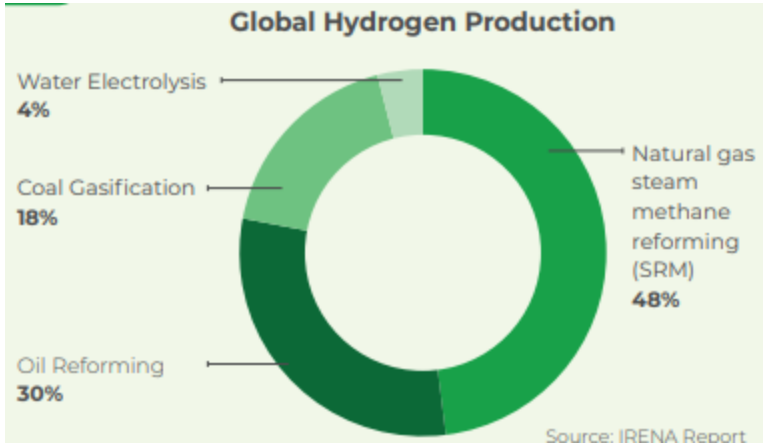
HYDROGEN PRODUCTION IN INDIA

- **National Green Hydrogen Mission**: Launched in January 2023 with an allocation of ₹19,744 crore, this mission aims to establish a **green hydrogen** production capacity of 5 million metric tons (MMT) per annum by 2030. Ministry of New and Renewable Energy
- India's hydrogen production primarily consists of **grey hydrogen, which is produced from fossil fuels**, accounting for approximately 7 million metric tons (MMT) annually. However, this production is largely tied to industrial applications like ammonia synthesis, petroleum refining, **using processes that emit significant amounts of carbon dioxide.**
- India's production of **green hydrogen, made through electrolysis of water powered by renewable energy**, is still in its nascent stage, estimated to be below 0.1 MMT annually, as green hydrogen production projects are just beginning to scale up.

Hydrogen production

To produce hydrogen, it must be separated from the other elements in the molecules where it occurs. Hydrogen can be produced from many different sources in different ways to use as a fuel.

1. Production of hydrogen from hydrocarbons
   a) Steam Methane Reforming
   b) Partial Oxidation of Hydrocarbons (oil reforming)
2. Production of hydrogen by Coal Gasification
3. Hydrogen Production from Electrolysis of Water

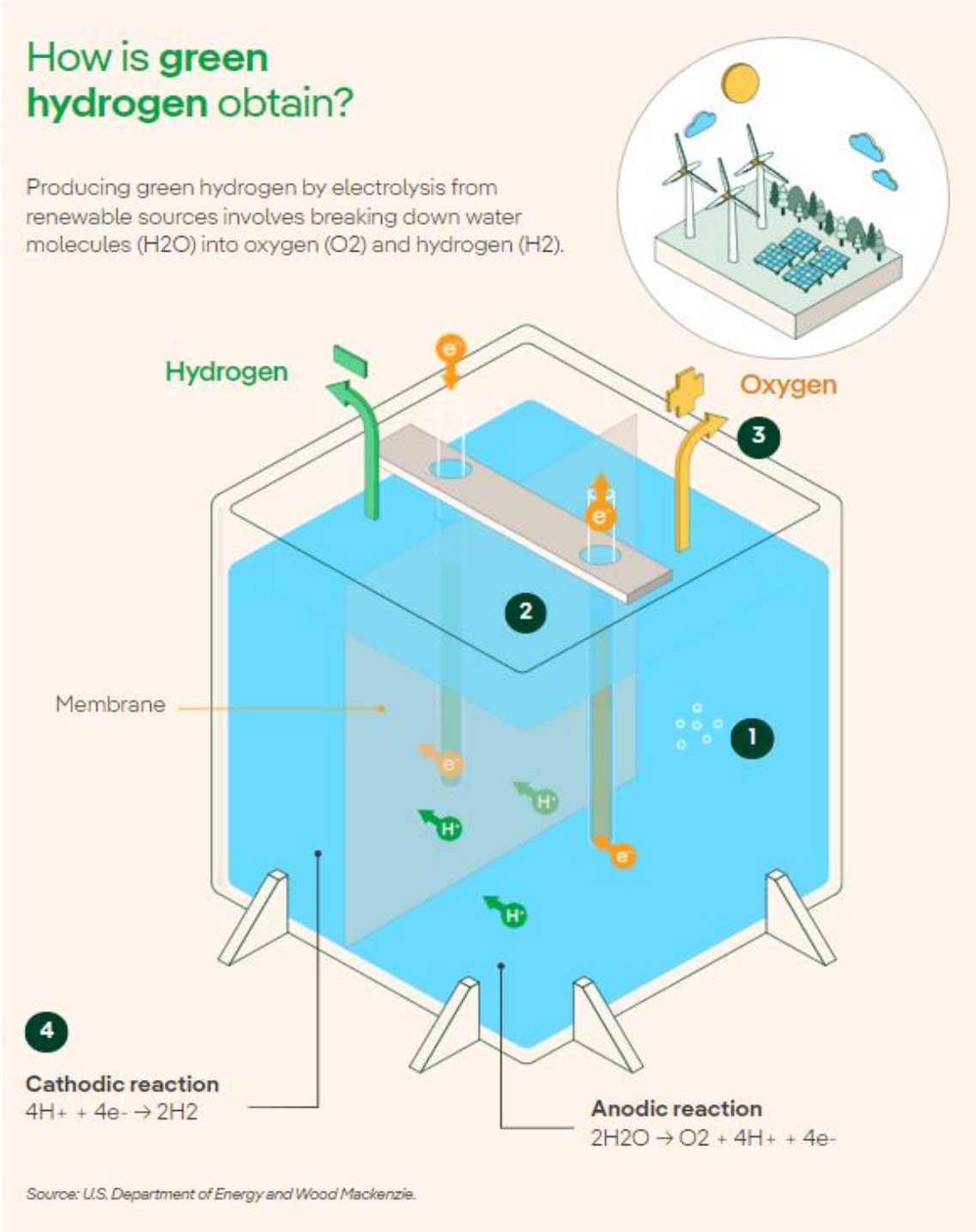


https://www.youtube.com/watch?v=Kv8WT3-7ZHE&t=1s

Electrolysis

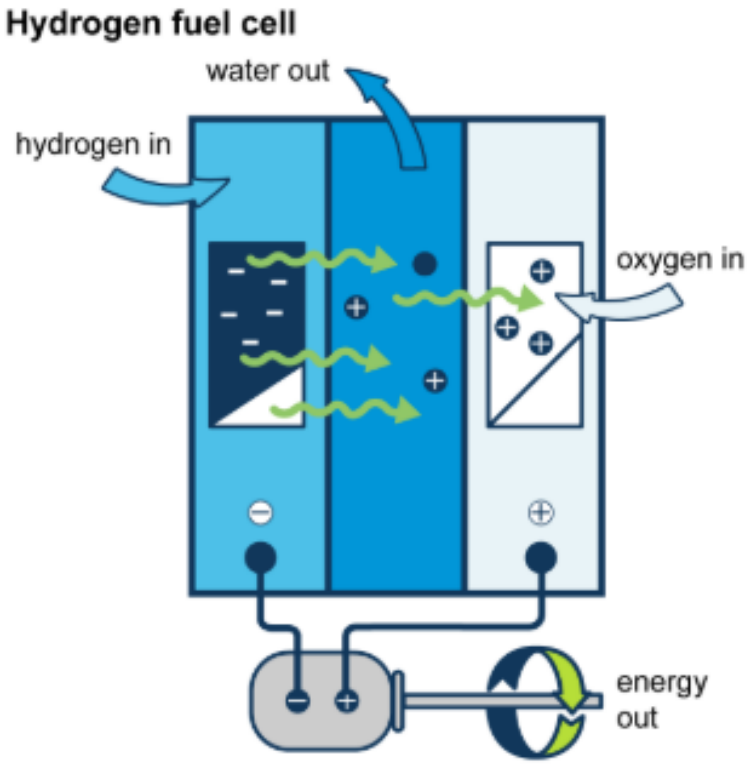
It is a process that splits hydrogen from water using an electric current.

On a large, commercial scale, the process may be referred to as power-to-gas, where *power* is electricity and hydrogen is *gas*. Electrolysis itself does not produce any byproducts or emissions other than hydrogen and oxygen.



Hydrogen fuel cells produce electricity

- Hydrogen fuel cells produce electricity by combining hydrogen and oxygen atoms. The hydrogen reacts with oxygen across an electrochemical cell—similar to a battery—to produce electricity, water, and small amounts of heat.
- Fuel cell power plants provide electricity for individual facilities and have potential applications in microgrids and for remote locations that are not connected to electric power grids. Several vehicle manufacturers have developed fuel cells for powering vehicles.



Advantages of Green Hydrogen Energy

- **Inexhaustible, and Renewable resource**
- **Sustainable and pollution free :** green hydrogen does not emit polluting gases either during combustion or during production.
- **Storable:** hydrogen is easy to store, which allows it to be used subsequently for other purposes and at times other than immediately after its production.
- **Hydrogen fuel cells** provide backup power and grid integration of renewables.
- **Versatile:** green hydrogen can be transformed into electricity or synthetic gas and used for commercial, industrial or mobility purposes.

Challenges of the green hydrogen market

High hydrogen production, storage, and transportation costs

- Despite being one of the most plentiful elements, hydrogen is frequently found in combination with other elements, making its extraction from nature more difficult.
- The cost of hydrogen will also vary considerably depending on the production method
- Black hydrogen, is now one of the least expensive types of hydrogen, but it also produces the highest CO_2 emissions, as seen in Table 1. Similarly, gray hydrogen is currently one of the most common ways to produce hydrogen. Blue hydrogen has greatly decreased CO_2 emissions as a result of the use of CCUS carbon storage technology.
- The green hydrogen production guarantees zero emissions in the production process and is crucial to achieving the global Net Zero goals. Currently, the cost of producing green hydrogen is four times more expensive than gray hydrogen and more than two times higher than blue hydrogen.

Table 1 Production costs for different types of hydrogen

	Black Hydrogen	**Gray Hydrogen**	**Blue Hydrogen**	**Green Hydrogen**
Production price ($/kg)	0.95 – 1.90 (2020) [1]	1.27 – 2.37 (2020) [1]	4 – 5 (2022) [2]	5.5 – 9.5 (2022) [3]

Hydrogen conversion cost (compression and liquefaction)

- The hydrogen is compressed, liquefied (Hydrogen can be liquefied by cooling it to below −253ºC), or converted into ammonia (NH_3) once it is created to be transported to the end-user or to be stored. The cost of hydrogen to the end user will rise as a result of this process.

Hydrogen transportation cost

- Transporting hydrogen to end-users after conversion will also drive up the cost of hydrogen, which includes the investment expenses for transportation infrastructure, such as trucks, ships, or pipeline systems.
- The cost of transporting hydrogen can be decreased by using liquefied hydrogen rather than compressed hydrogen because it can be transported in greater quantities per vehicle.
- Another potential alternative is to transport hydrogen through pipelines, but this will need a substantial initial investment in the pipelines.

Safety and storage

- Hydrogen is inherently flammable in air and has a lower energy density than gasoline or natural gas. Hydrogen may easily leak into the air through the smallest gaps in pipes.
- Hydrogen can also brittle steel in pipes and other equipment.

Hydrogen projects' impacts on water supply and land use

- **Green hydrogen projects will require significant amounts of renewable energy** and water as inputs for electrolyzers. This will likely put pressure on land allocation and water supplies.
- **Large supply of input water for hydrogen production is essential**, which may not be possible in in drought-prone areas. For producing 1 kg of hydrogen, about 9 liters of water input is required.
- It is to be ensured that production of green hydrogen from water should not affect the supply of water for other essential purposes, such as water for residential areas or agricultural consumption.
- **Land used for green hydrogen production projects:** The electrolysis plants donot take up too much space, renewable energy systems that provide power inputs to electrolyzers require significant amounts of land, leading to changes in land use, affecting social and ecosystem factors.