

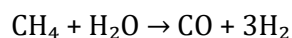
Hydrogen Properties, Production, Storage, and Safety

1. Introduction – Hydrogen as an Energy Carrier

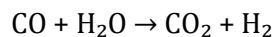
Hydrogen is the lightest element with high gravimetric energy density (120 MJ/kg), nearly three times gasoline. Its low volumetric density, however, makes storage and transport challenging. Hydrogen is vital for fuel cells. Carrier such as for electricity , industry , building and transport.

2. Hydrogen Production – Steam Methane Reforming (SMR)

SMR is the dominant method (~70% of global H₂). It reacts CH₄ with steam:



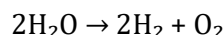
Followed by water-gas shift:



SMR is efficient but CO₂ intensive, unless combined with carbon capture.


3. Hydrogen Production – Electrolysis of Water

Electrolysis splits water into hydrogen and oxygen using electricity:



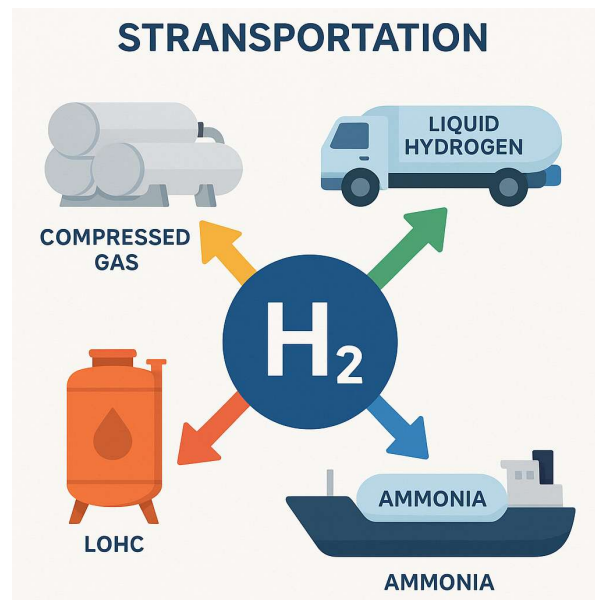
If powered by renewable electricity, electrolysis produces 'green hydrogen'. Alkaline, PEM, and solid oxide electrolysis cells (SOECs) are under development.

4. Hydrogen Production – Biomass Gasification

Biomass gasification converts organic matter into syngas (H₂ + CO). This renewable pathway reduces net CO₂ emissions and utilizes agricultural waste. Challenges: feedstock variability and  **Compressed Gas** → Stored in high-pressure cylinders (350–700 bar). Common for small-scale and vehicle refueling.

1. **Liquid Hydrogen** → Stored at cryogenic temperatures (–253 °C) in insulated tanks. Higher density, used for trucks and aerospace.
2. **LOHC (Liquid Organic Hydrogen Carriers)** → Hydrogen bound in liquid compounds, making storage and transport safer at ambient conditions.
1. **Ammonia (NH₃)** → Used as a hydrogen carrier since it is easier to liquefy and transport by ship; hydrogen is released at destination.

efficiency.



5. Hydrogen Storage & Transportati

6. Safety Considerations

Hydrogen has a wide flammability range (4–75%) and invisible flames. Safety requires leak detection sensors, ventilation, and robust standards (ISO, SAE).

7. Case Study & Conclusion

Case: Germany's National Hydrogen Strategy invests €9B in electrolysis and hydrogen transport.

Conclusion: Hydrogen production and safe storage are essential for the hydrogen economy.

Figure: Energy density comparison of hydrogen vs conventional fuels.

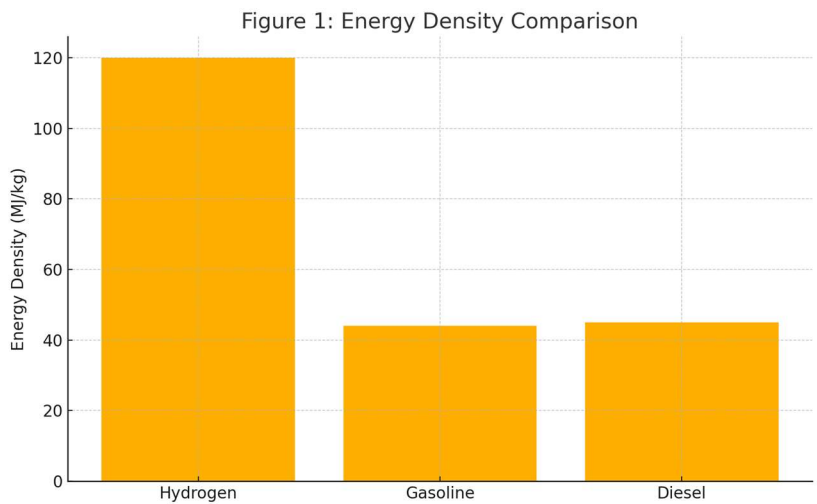


Figure 2: Share of hydrogen production methods globally.

