



מכון
NSTDA

ENTEC
a member of NSTDA

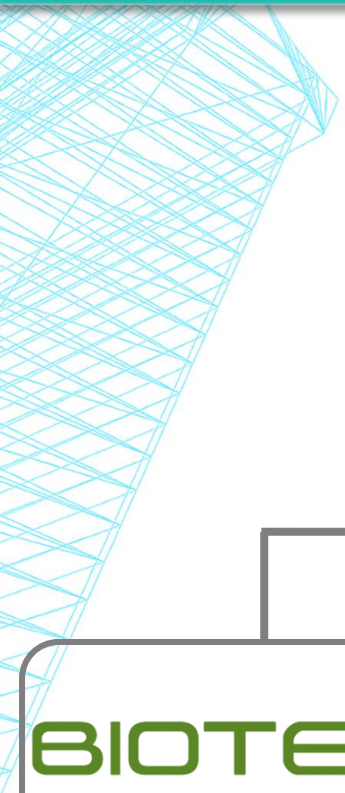
Hydrogen Nuclear Synergy: Pathway to Net Zero

How H₂ and SMR has been planned and conducted in response to decarbonization trend

Visarn Lilavivat Ph.D.

Renewable Energy and Energy Efficiency Research Team
Energy Innovation Research Group
National Energy Technology Center (ENTEC)

Organization Establishment of ENTEC



Establishment: Approved by Thai Cabinet on June 9, 2020





strategy

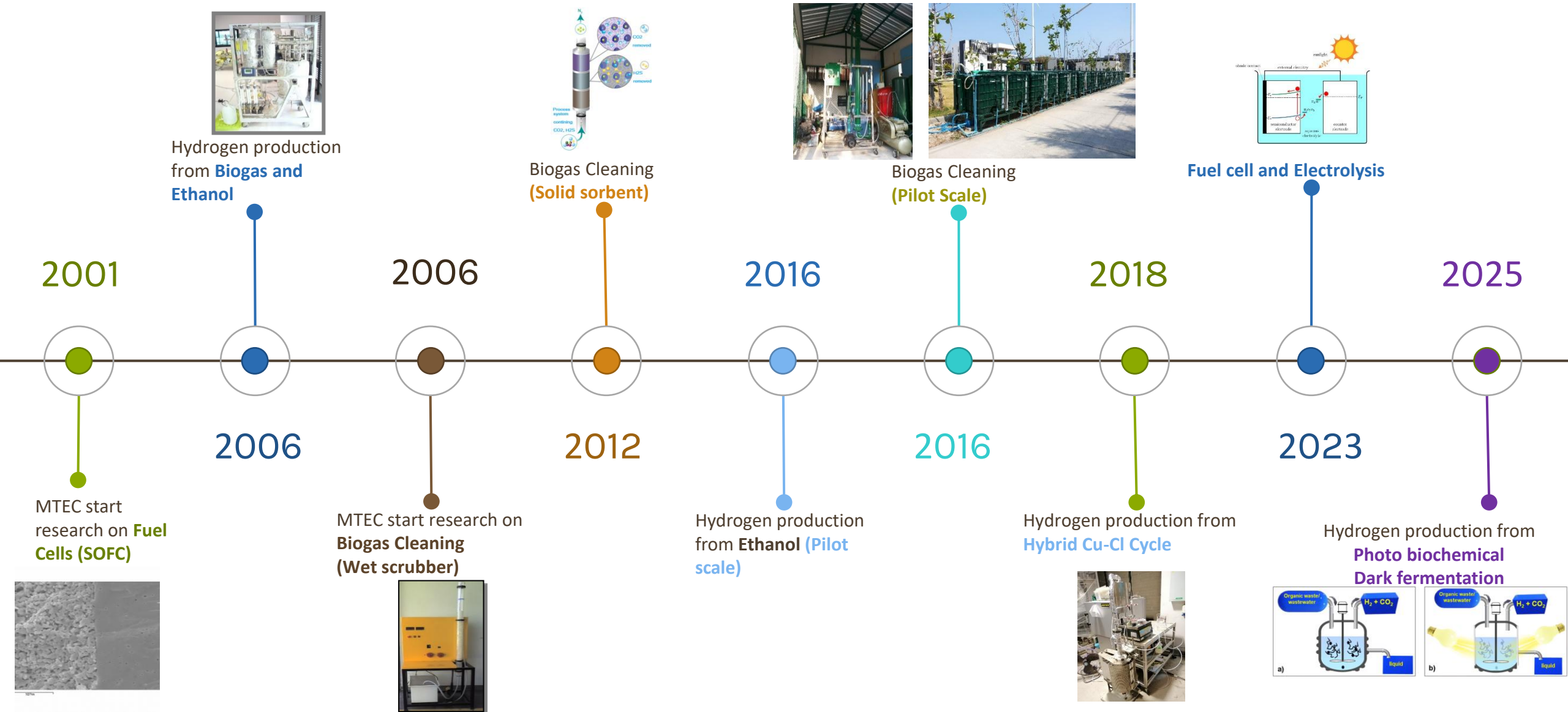
Conduct research, create and comprehend knowledge in supporting Thailand National Energy Plan

Generate and transfer high-quality energy technology knowhow to relevant stakeholders to generate impact

Collaborate w/ both public and private partners on energy tech. R&D

Integrate major resources to prevent redundancy and for high efficiency

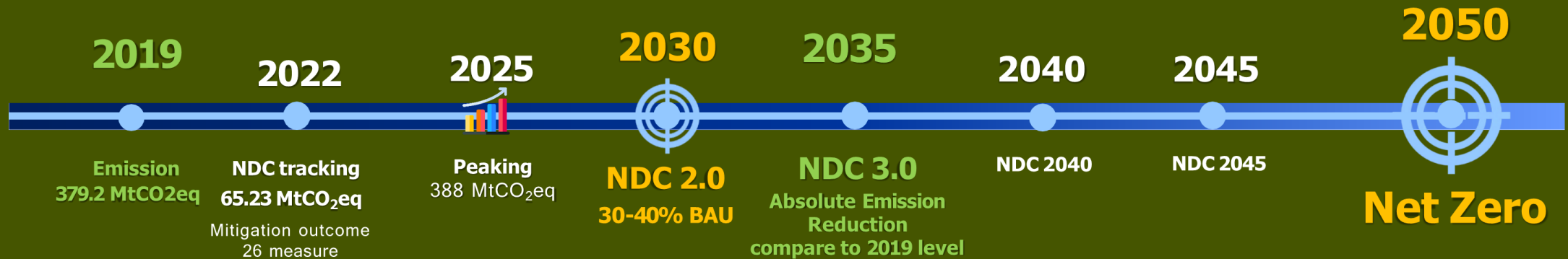
Hydrogen research in ENTEC



Thailand Net Zero Target



Roadmap to Net Zero Emissions 2050 : Thailand



NDC 2.0 (2nd Update NDC 2030)

30 - 40% + 3%

Energy Transport IPPU Waste Agriculture



Sector	Emission (MtCO ₂ eq)	Percentage
Energy	124.6	22.4%
Transport	45.6	8.2%
IPPU	14	0.3%
Waste	9.1	2.6%
Agriculture	4.1	0.7%

Category	Emission (MtCO ₂ eq)	Percentage
Domestic Implementation	184.8	33.3%
International Support	37.5	6.7%

Article 6.2 (3%)

Total **222** MtCO₂eq

NDC 3.0 (NDC 2035)

60% Compare with 2019

Energy Transport IPPU Waste Agriculture



Sector	Emission (MtCO ₂ eq)
Energy	68.1
Transport	22.6
IPPU	4.2
Waste	6.7
Agriculture	7.6

Category	Emission (MtCO ₂ eq)
Unconditional	76.4
Conditional	32.8

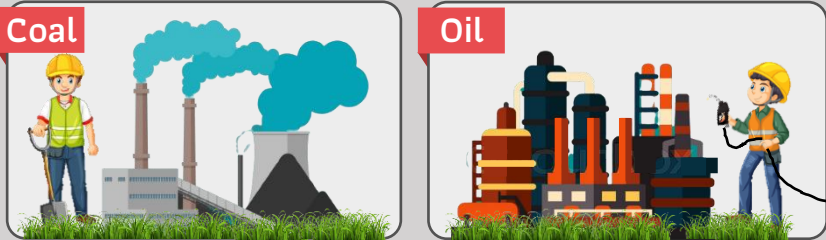
LULUCF -118 MtCO₂eq

Total **152** MtCO₂eq

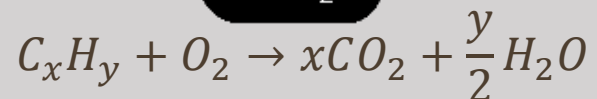
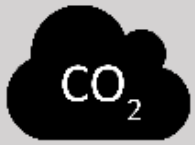
Why Hydrogen



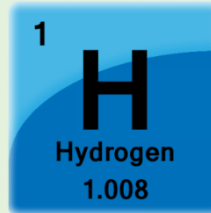
Current State



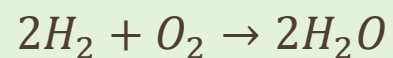
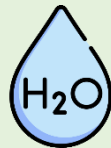
Energy



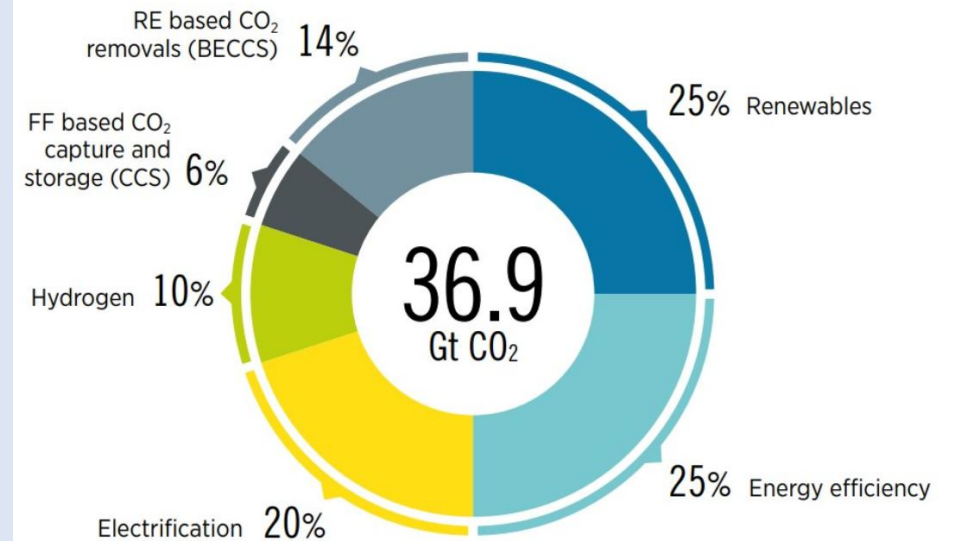
Future State



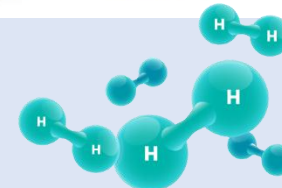
Energy



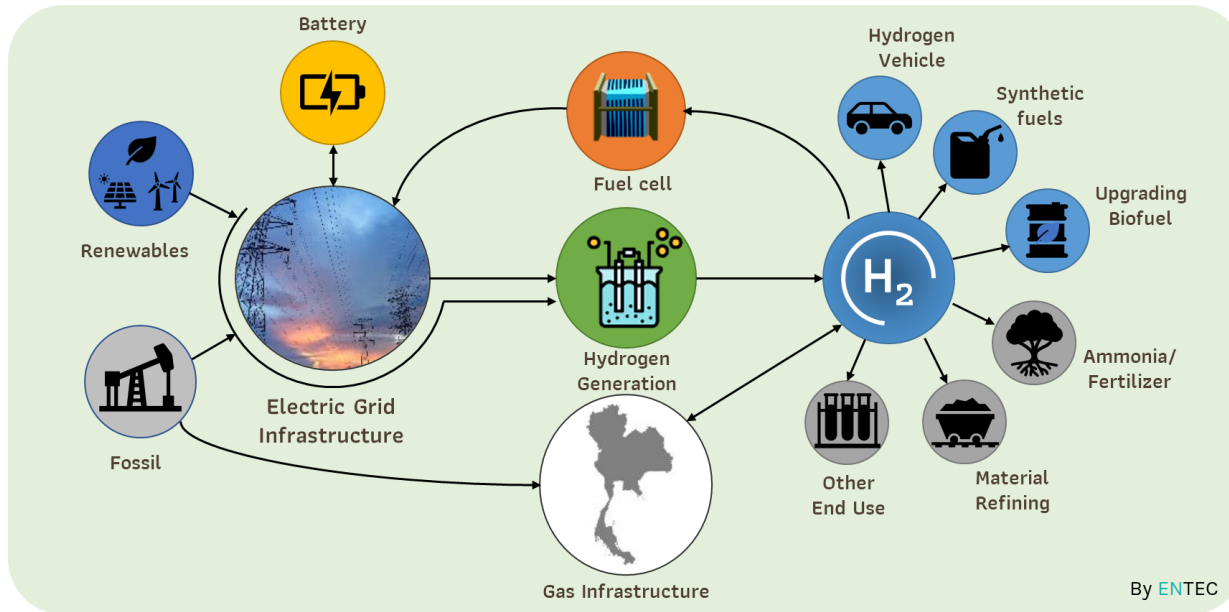
Hydrogen one of six technology for decarbonization



Source: IRENA

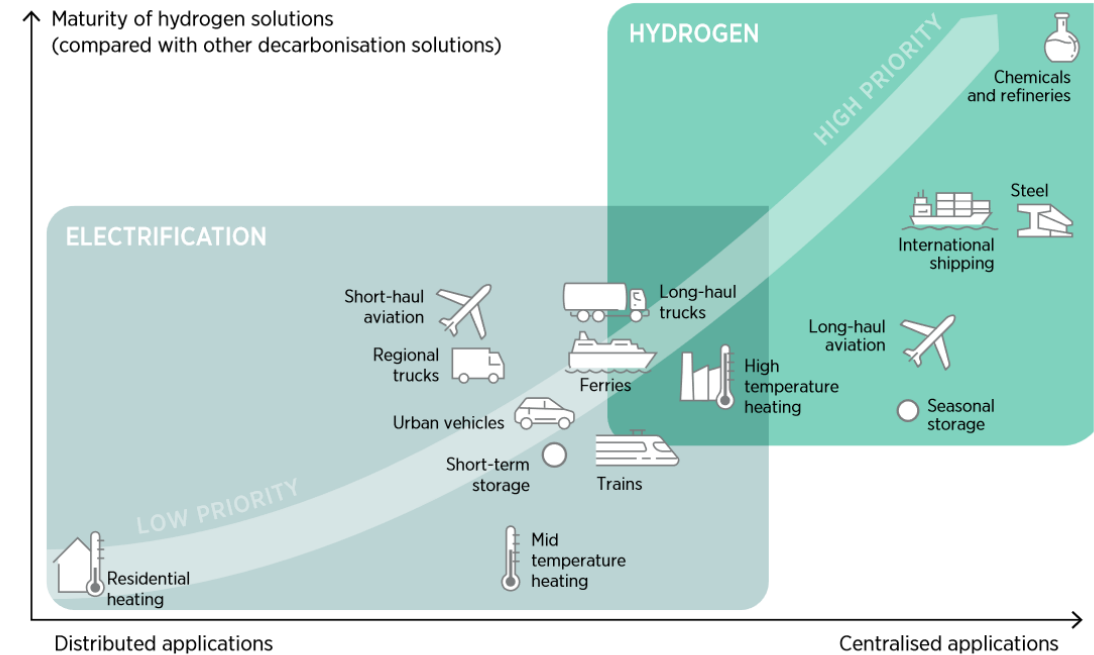


Hydrogen for decarbonization

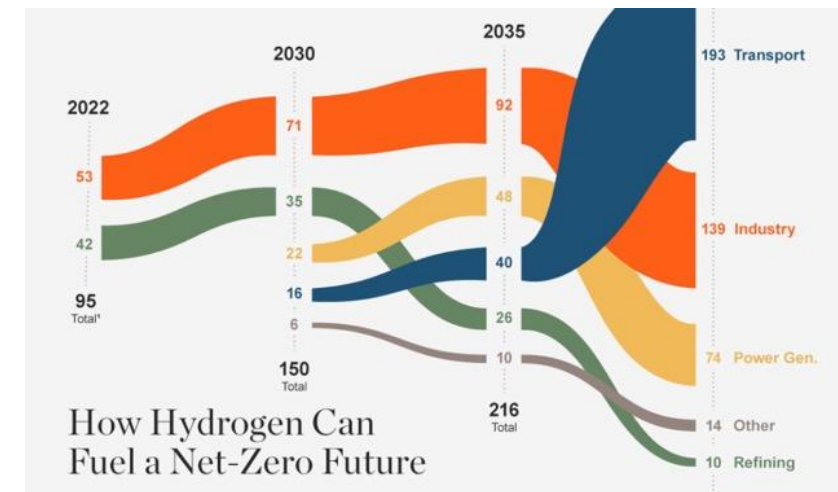


The benefits of using **Hydrogen** for decarbonization

- Decarbonizing Heavy Industries
- Flexibility in Energy Systems
- Potential for Large-Scale Decarbonization
- Versatility in Applications
- Potential for Carbon Capture and Utilization
- Support for Net-Zero Goals



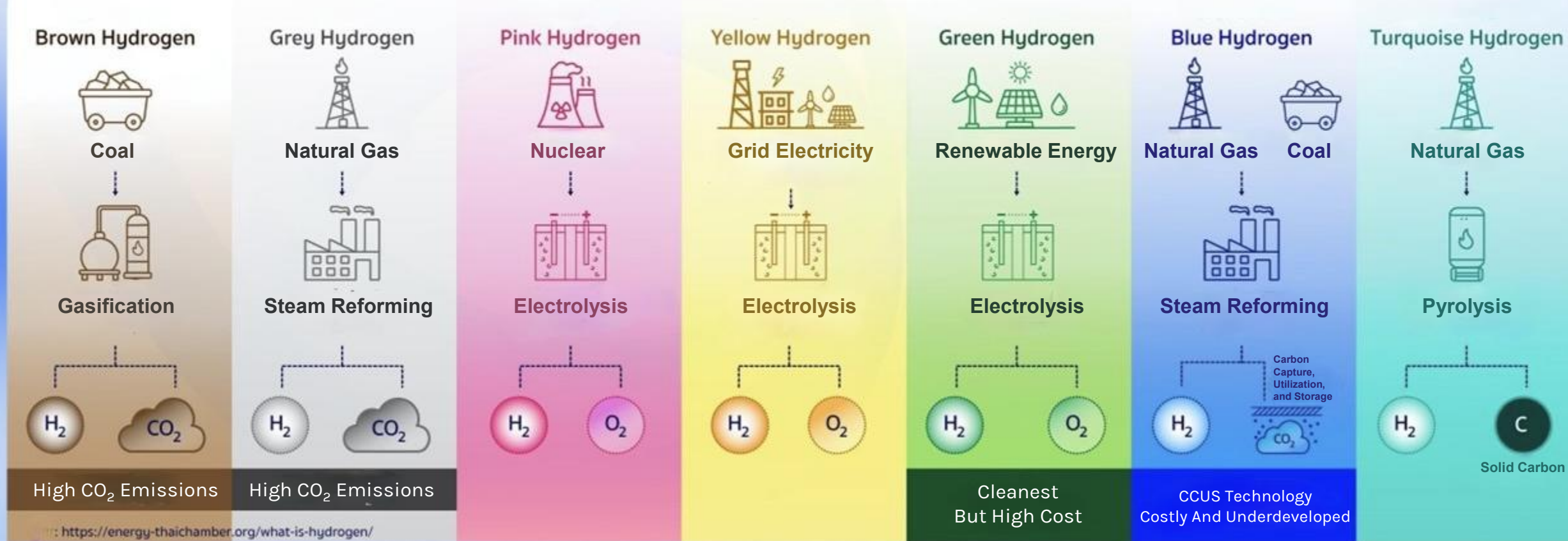
Source: IRENA (2022e).



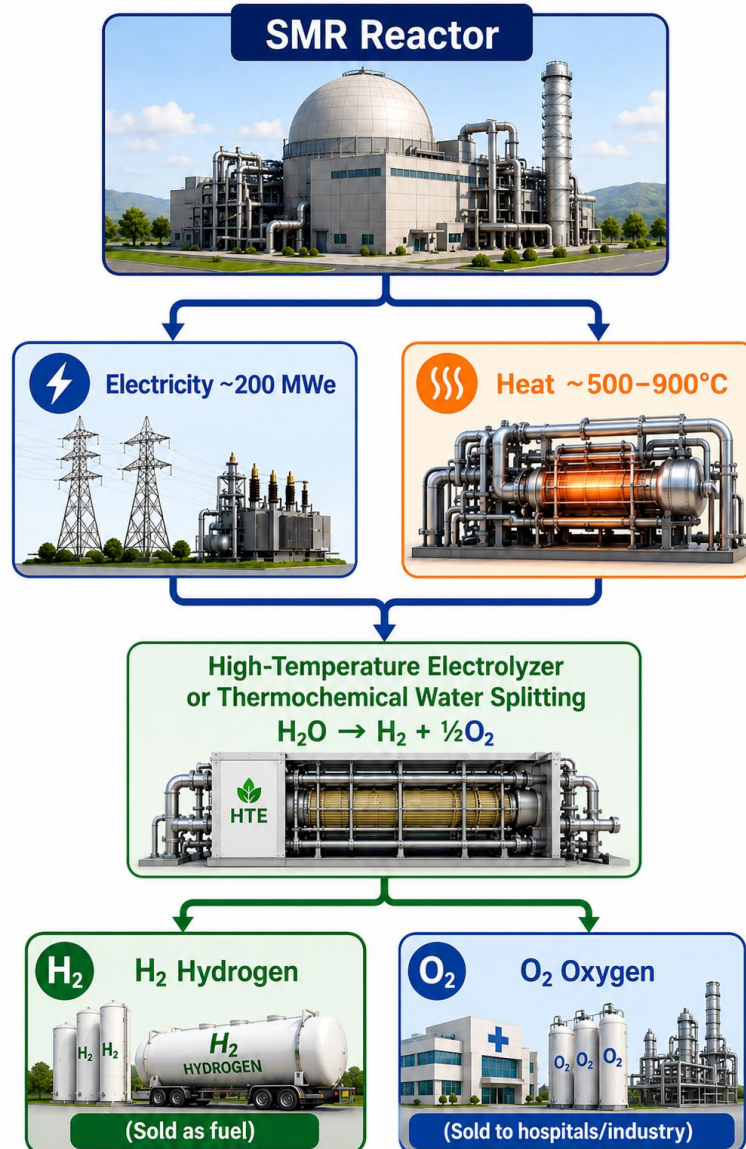
Color of Hydrogen



Classified by feedstock, production process, products, and environmental impacts



SMR to Hydrogen



Low-Temp Electrolysis

LWR-SMR: Ready to use

- Alkaline / PEM Electrolysis
- Temperature 50-90°C
- Uses electricity from SMR
- Efficiency ~ 50%
- TRL: 9 (commercially)

HTSE / SOEC

★ Highest efficiency

- High-Temperature Steam Electrolysis
- Temperature >700°C (uses waste heat)
- Overall efficiency >50%
- Best paired with HTGR-SMR
- TRL: 5-7 (scaling up)

Thermochemical S-I Cycle

Future technology (Gen IV)

- Sulfur-Iodine Thermochemical Process
- Temperature >850°C
- Does not use electricity
- Heat only
- Highest theoretical efficiency
- TRL: 3-5 (research stage)

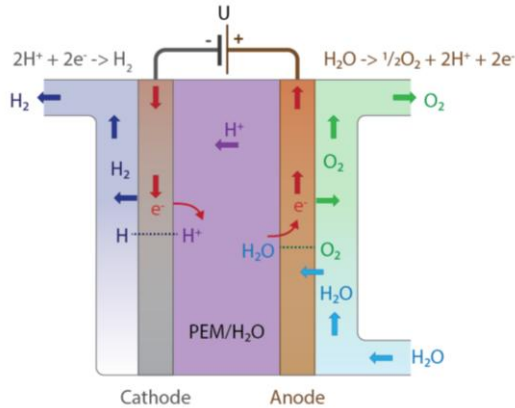
Electrolysis Technology



Comparison of 4 electrolysis

Electrolysis	Advantages	Disadvantages	Challenge
PEM	- Commercialized technology - Operates higher current densities - High purity of the gases - Compact system design - Quick response	- Cost of the cell components - Noble metal electrocatalysts - Acidic electrolyte	Past two centuries, water electrolysis is a well-known technology for green hydrogen production. However, globally only 4% of hydrogen (65 million tons) can be produced from water electrolysis due to economic issues with most of this hydrogen being produced as a by-product from the Chlor-alkali industry
AEL	- Well established Technology - Commercialized for industrial applications - Noble metal-free electrocatalysts - Relatively low cost - Long-term stability	- Limited current densities - Crossover of the gasses - High concentrated (5M KOH) liquid electrolyte	
SOEC	- High working temperature - High efficiency	- Limited stability - Under development	
AEM	- Noble metal-free electrocatalysts - Low concentrated (1M KOH) liquid electrolyte	- Limited stability - Under development	

Low-Temp Electrolysis



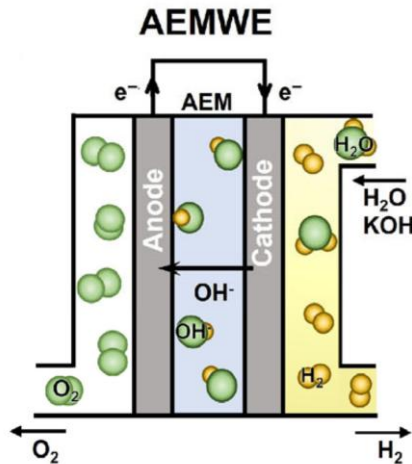
Proton Exchange Membrane Electrolysis (PEM)

Anode: $\text{H}_2\text{O} \rightarrow \frac{1}{2}\text{O}_2 + 2\text{H}^+ + 2\text{e}^-$

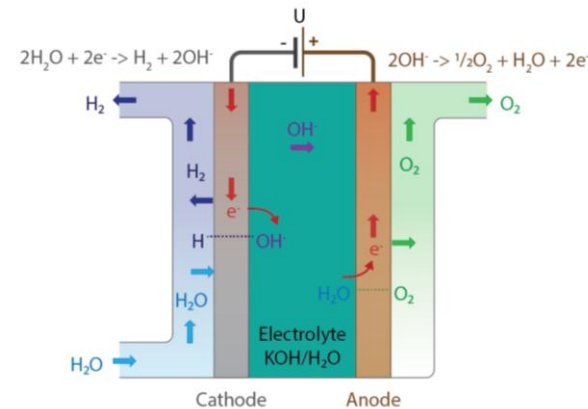
Cathode: $2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2$

Total reaction: $\text{H}_2\text{O} \rightarrow \text{H}_2 + \frac{1}{2}\text{O}_2$

Low-temperature electrolysis splits water into hydrogen and oxygen using electricity at operational ranges below 80–100 °C. It is the most mature and market-dominant technology for hydrogen production, utilizing established configurations like Proton Exchange Membrane (**PEM**), Alkaline Water Electrolysis (**AWE**), and Anion Exchange Membrane (**AEM**)



Anion Exchange Membrane Electrolyzer (AEM)



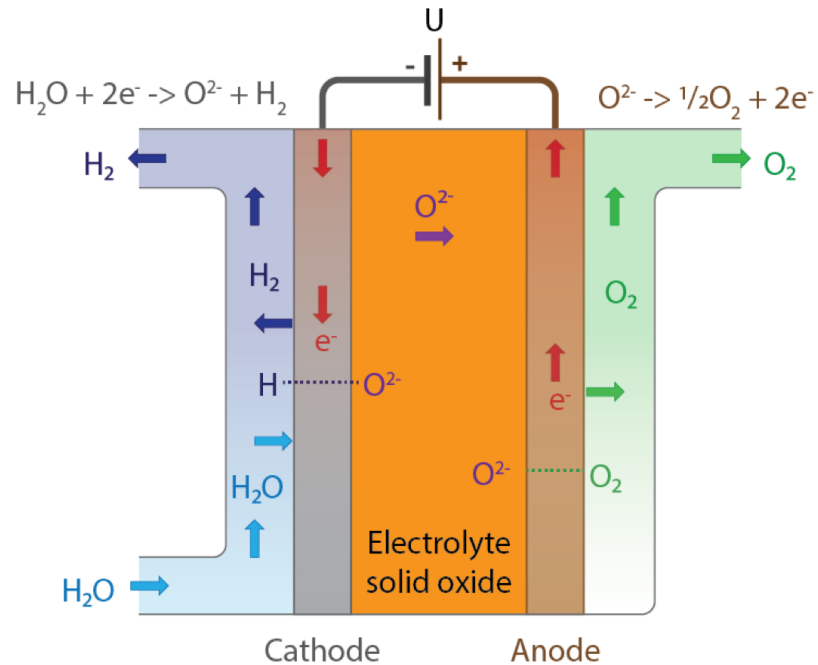
Alkaline Electrolyzer (AWE)

Anode: $2\text{OH}^- \rightarrow \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} + 2\text{e}^-$

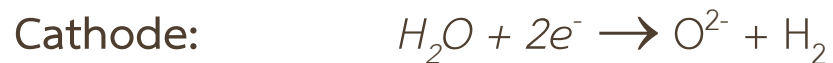
Cathode: $2\text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{H}_2 + 2\text{OH}^-$

Total reaction: $\text{H}_2\text{O} \rightarrow \text{H}_2 + \frac{1}{2}\text{O}_2$

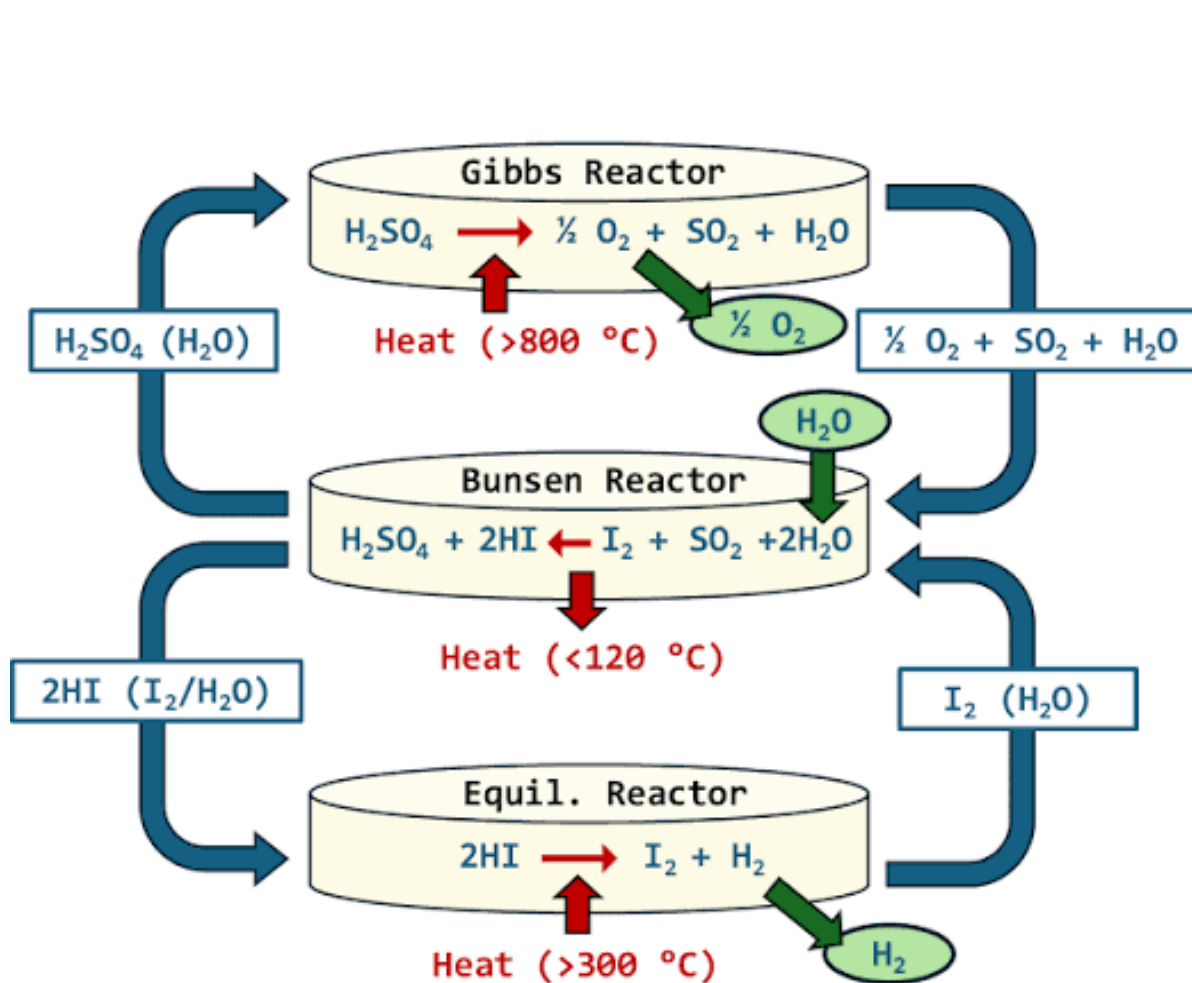
Solid Oxide Electrolysis Cell (SOEC)



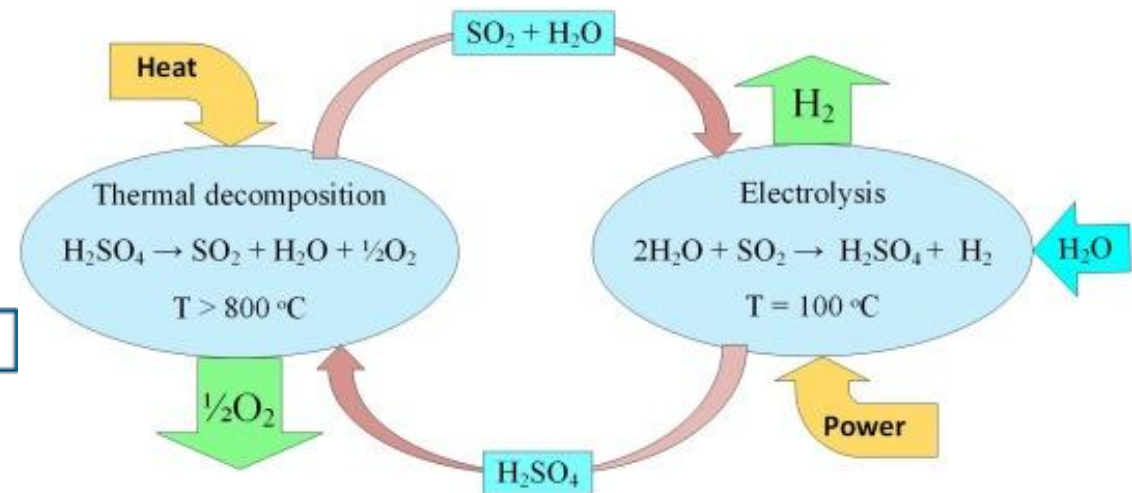
- **SOEC** is an advanced ceramic device that splits water steam into hydrogen and oxygen using electricity and high heat.
- Operating at extreme temperatures **(500°C to 1,000°C)**, it achieves higher efficiency than standard low-temperature water splitters.



Thermochemical

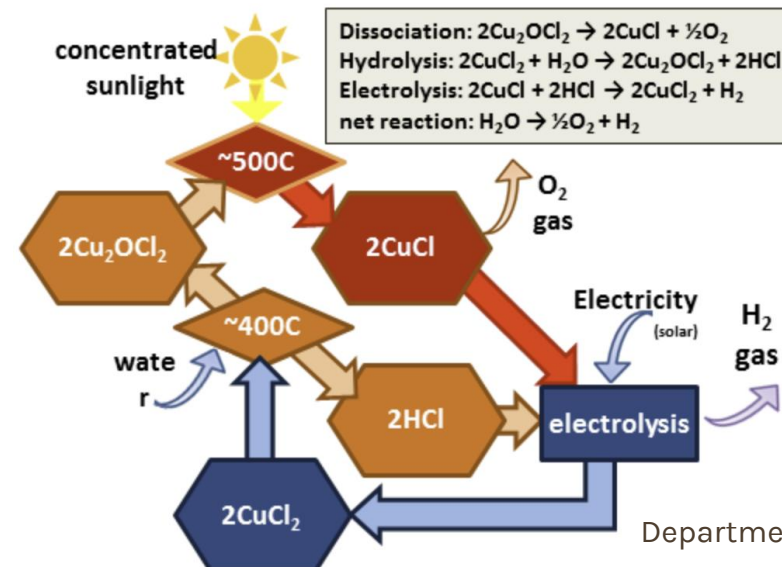


Stanford University



ScienceDirect.com

copper chloride hybrid cycle

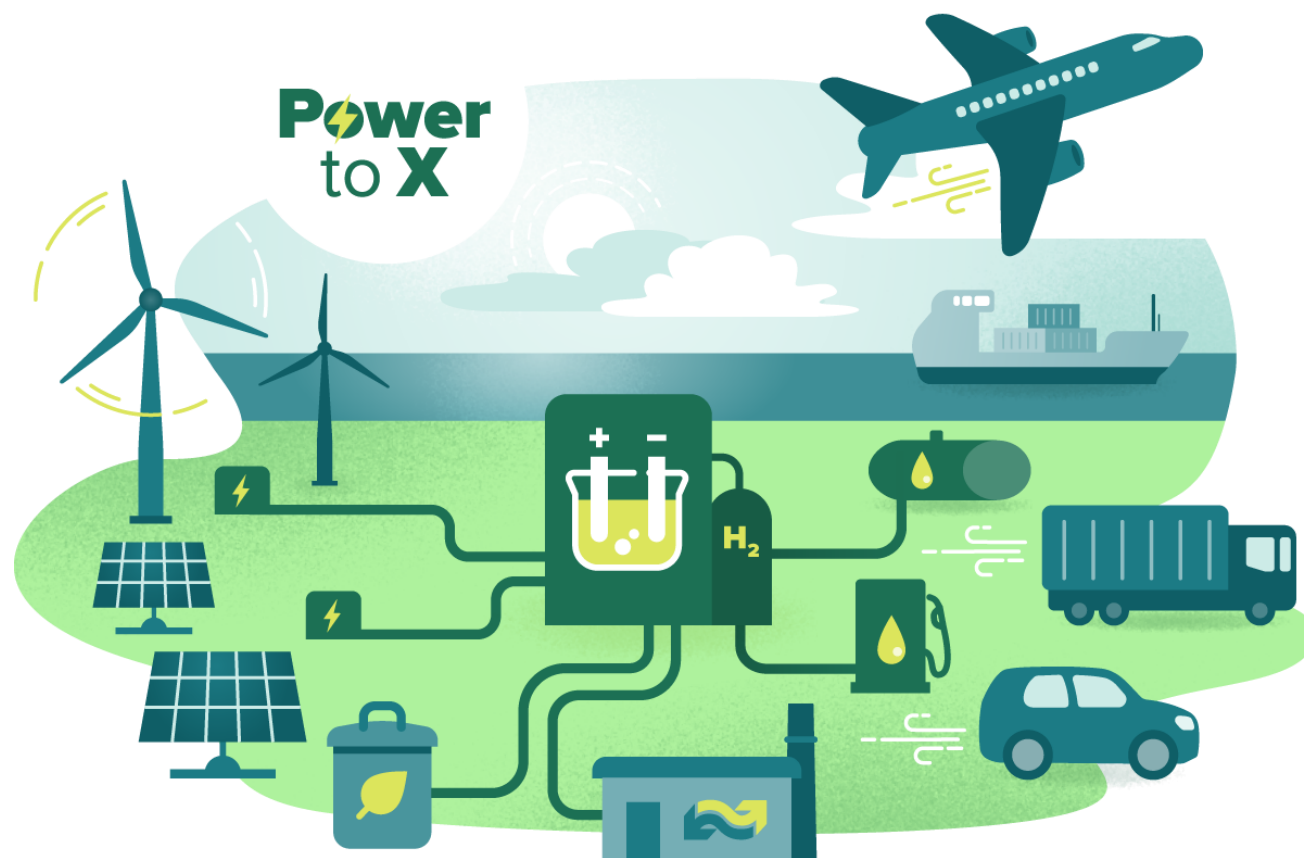


Department of Energy

Driving the H2 Economy with SMR

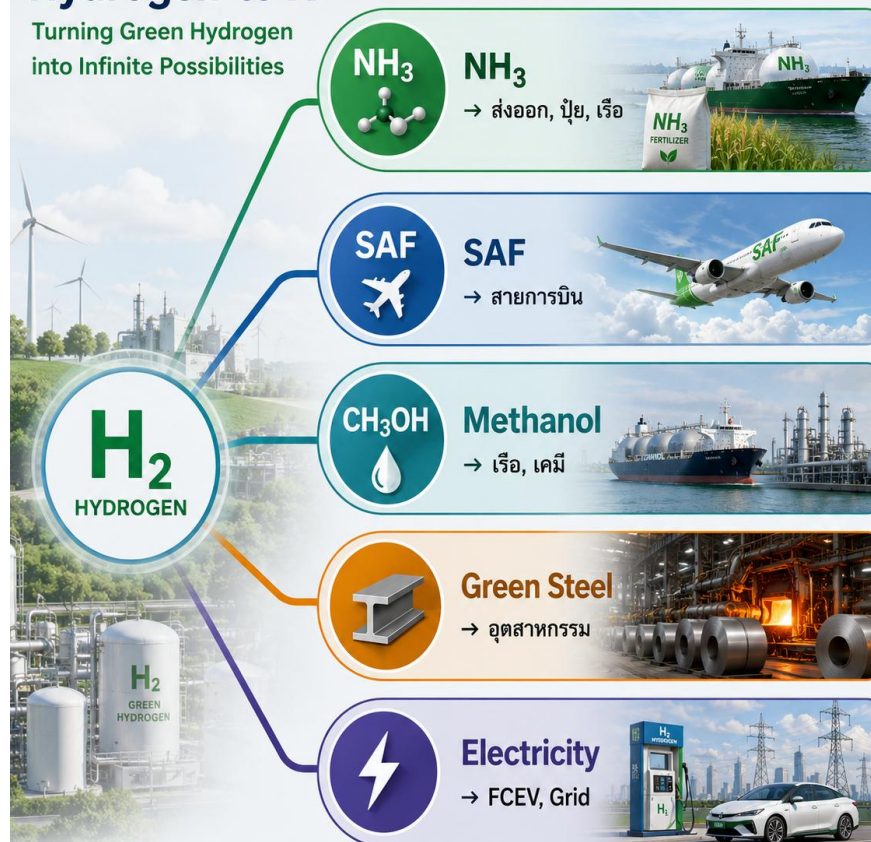


ENTEC
a member of NSTDA

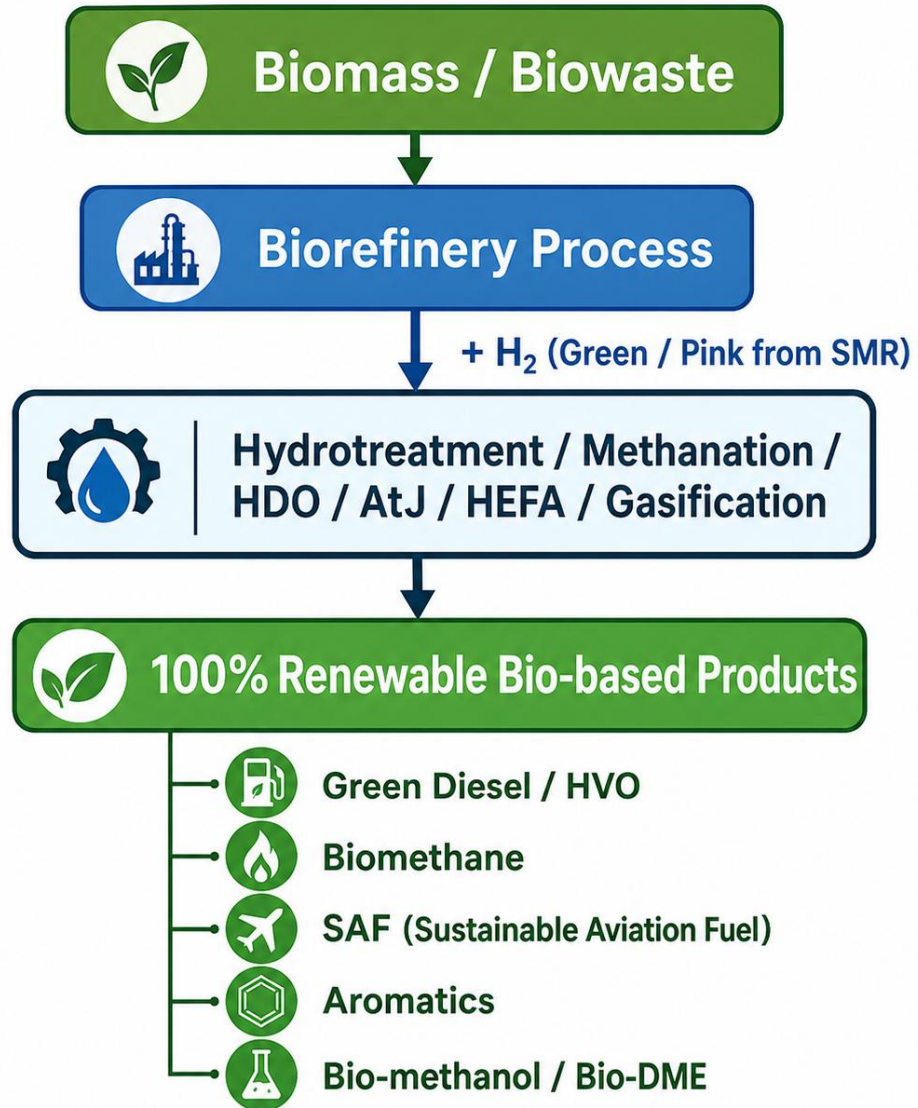


Hydrogen-to-X

Turning Green Hydrogen
into Infinite Possibilities



Hydrogen in Biorefinery



Using hydrogen in a biorefinery makes bio-based products truly 100% renewable, especially for sites located near the plant, where an SMR can serve as a stable and cost-competitive source of pink hydrogen for these processes.

- SMRs deliver both electricity and high-temperature heat, fully matching the PtX chain
- No intermittency → electrolyzers run at full load → lower unit cost
- Ideal for industrial hubs needing large, continuous volumes of H₂

Hydrogen as Clean Energy

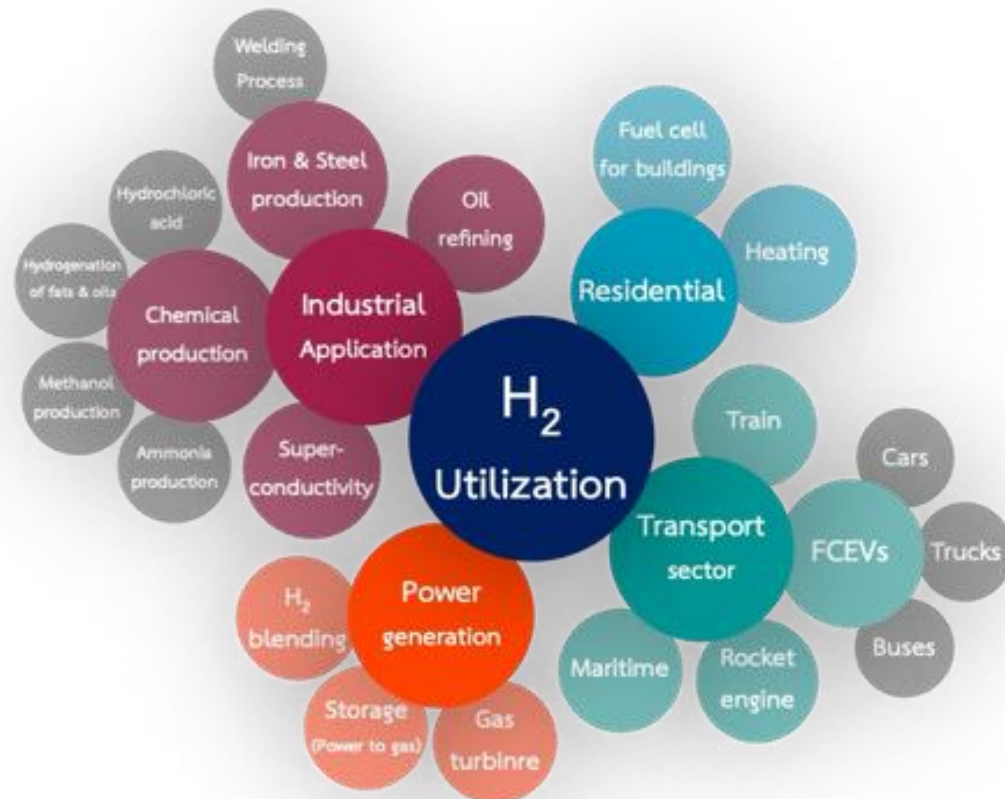


Hydrogen is widely recognized as a clean energy carrier due to its ability to diversify energy sources, store excess renewable energy for future use, and deliver high energy content per unit mass—surpassing even petroleum.

Fuel	Energy content (MJ/kg)
Hydrogen	120
Liquefied natural gas	54.4
Propane	49.6
Aviation gasoline	46.8
Automotive gasoline	46.4
Automotive diesel	45.6
Ethanol	29.6
Methanol	19.7
Coke	27
Wood (dry)	16.2
Bagasse	9.6

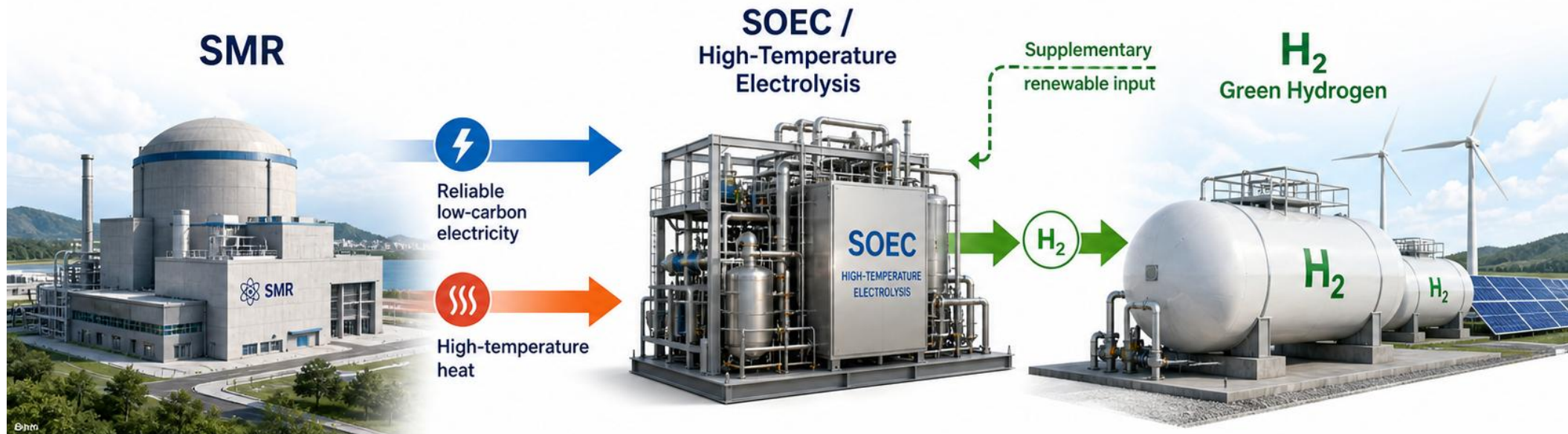
Dutta, S. (2014). A review on production, storage of hydrogen and its utilization as an energy resource. *Journal of Industrial and Engineering Chemistry*, 20(4), 1148-1156.

Hydrogen is getting further recognition worldwide as an exclusive energy solution and a potential fuel as it offers carbon-free solutions. Moreover, it is noted that existing fuel storage and transportation infrastructure that is used for other chemical fuels can also be employed for hydrogen storage and transportation.



Amin, M., Shah, H. H., Bashir, B., Iqbal, M. A., Shah, U. H., & Ali, M. U. (2023). Environmental assessment of hydrogen utilization in various applications and alternative renewable sources for hydrogen production: A review. *Energies*, 16(11), 4348.

Hydrogen–Nuclear Synergy



1



SMRs provide stable, low-carbon baseload electricity and heat for electrolyzers.

2



SOEC uses nuclear waste heat to improve hydrogen-production efficiency.

3



Stable nuclear output reduces the variability of renewable-powered green hydrogen.

4



Thailand's SMR feasibility studies create an opportunity to integrate nuclear and hydrogen policy.

Key Takeaways



- Pink hydrogen from SMRs uses SMR heat and electricity to split water via electrolysis or a thermochemical cycle
- With an SMR load factor above 90%, energy is produced 24/7/365 regardless of weather, solving green H₂ weaknesses in continuity, cost, and land use
- Pink hydrogen can be applied to
 - ✈ SAF (Sustainable Aviation Fuel)
 - 🌱 Green Ammonia
 - ⚡ Seasonal Energy Storage
- Pink H₂ does not compete with green H₂ — the two complement each other in the future clean energy system
- SMR nuclear is the key to making the hydrogen economy real at industrial scale

National ENERGY Technology Center



ENTEC
a member of **NSTDA**



National Energy Technology Center [ENTEC]
National Science and Technology Development Agency
Email: info@entec.or.th