Hydrogen Energy Storage

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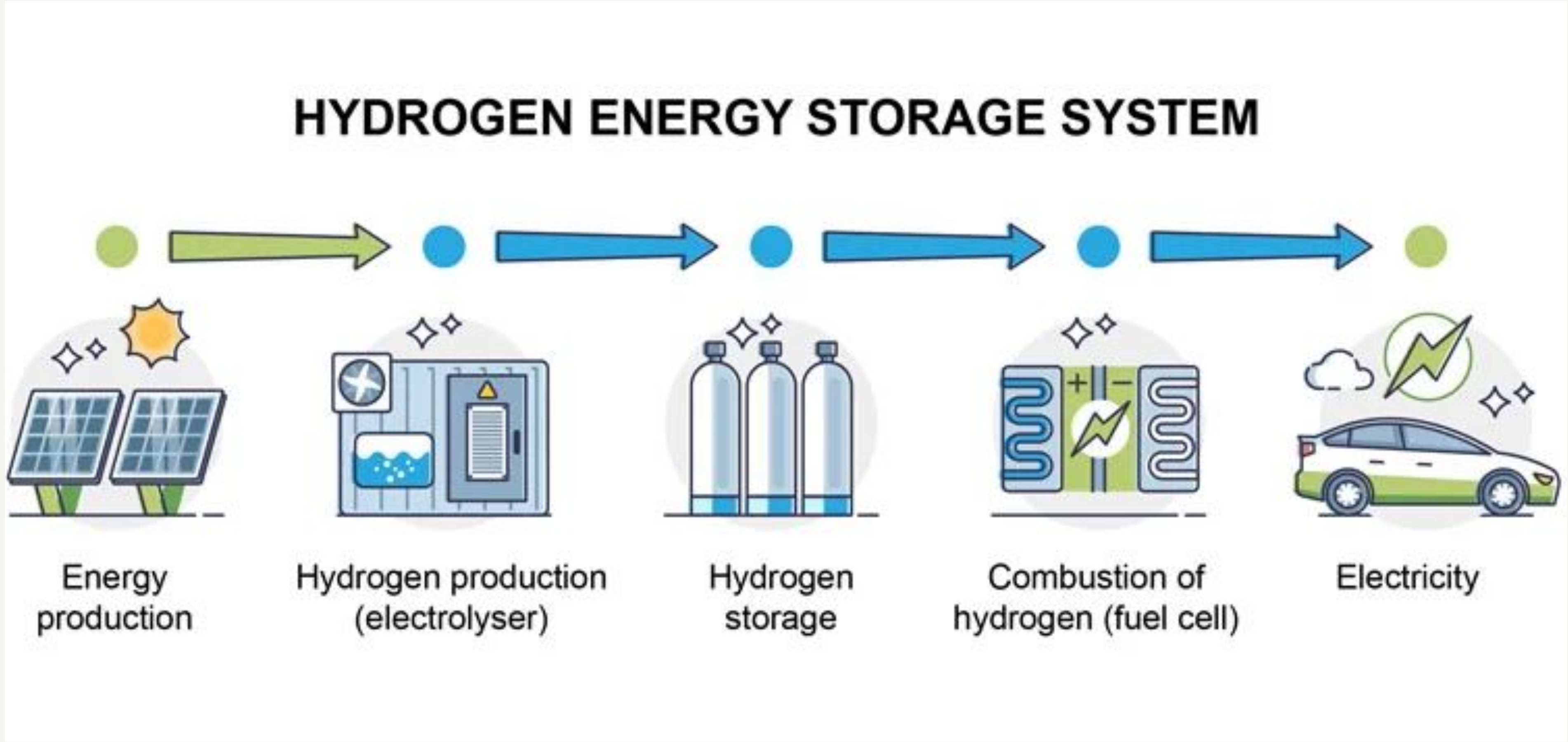
AGENDA

- Introduction
- Advantages & Disavdantages
- Comparison with other storage methods
- How it works
- Future prospects

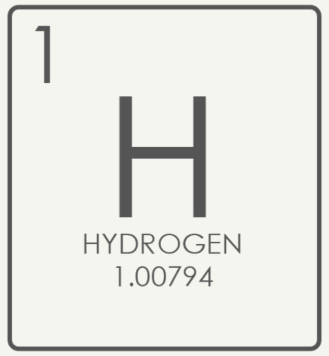
Introduction

Hydrogen energy storage is another form of chemical energy storage in which electrical power is converted into hydrogen. This energy can then be released again by using the gas as fuel in a combustion engine or a fuel cell.

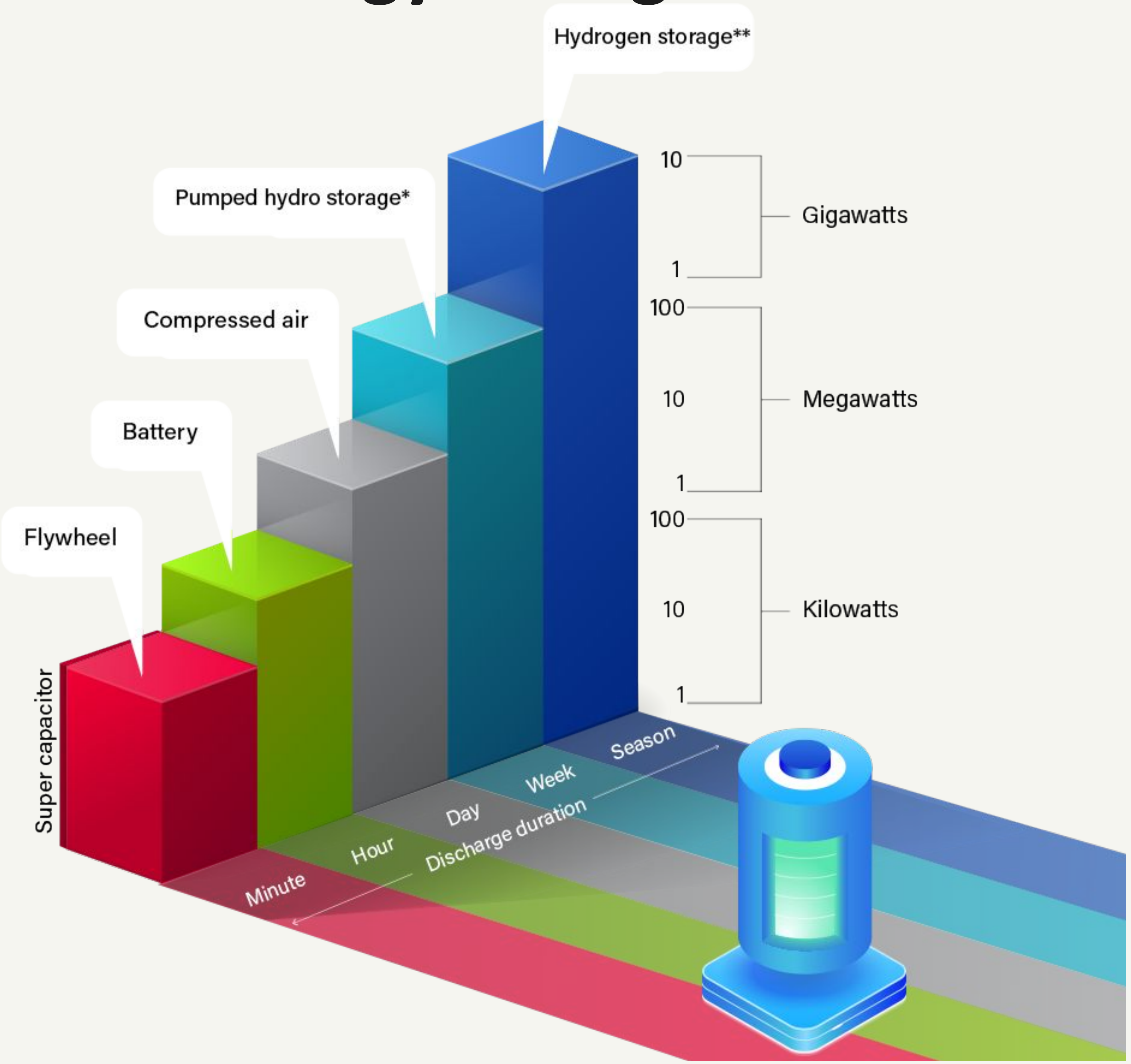


4 ways storing renewable hydrogen:

- Geological hydrogen storage
- Liquified hydrogen
- Compressed hydrogen storage
- Materials-based storage



Comparison of hydrogen storage with other energy storage sources



Best material to store hydrogen energy is gas cylinders at pressures of 350, 700 or 900 bars. Hydrogen storage tank materials are steel, aluminum, carbon fiber, epoxy resins or tough

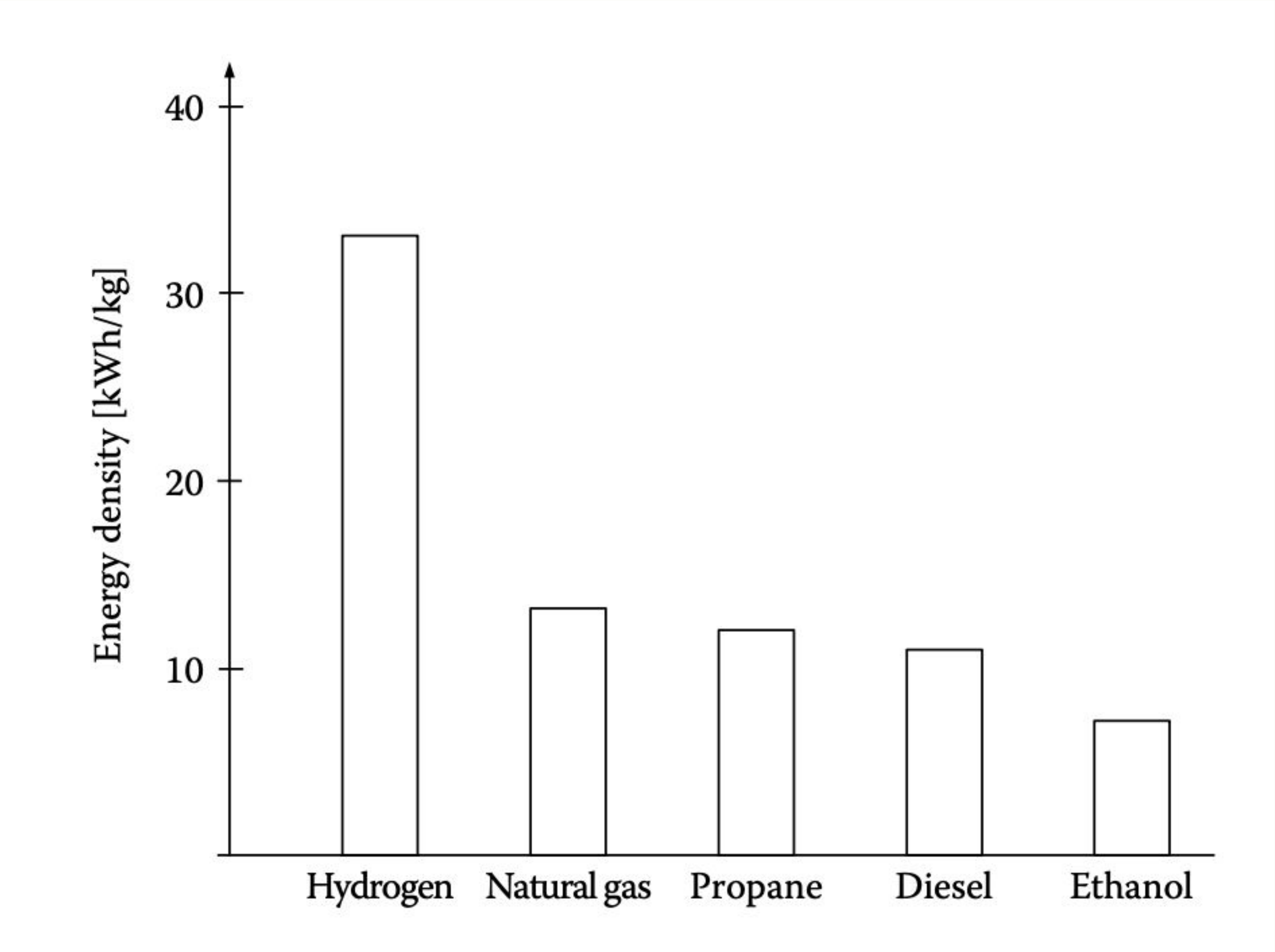
Advantages

- High energy density
- Scalability
- Long-term storage
- Environmentally friendly

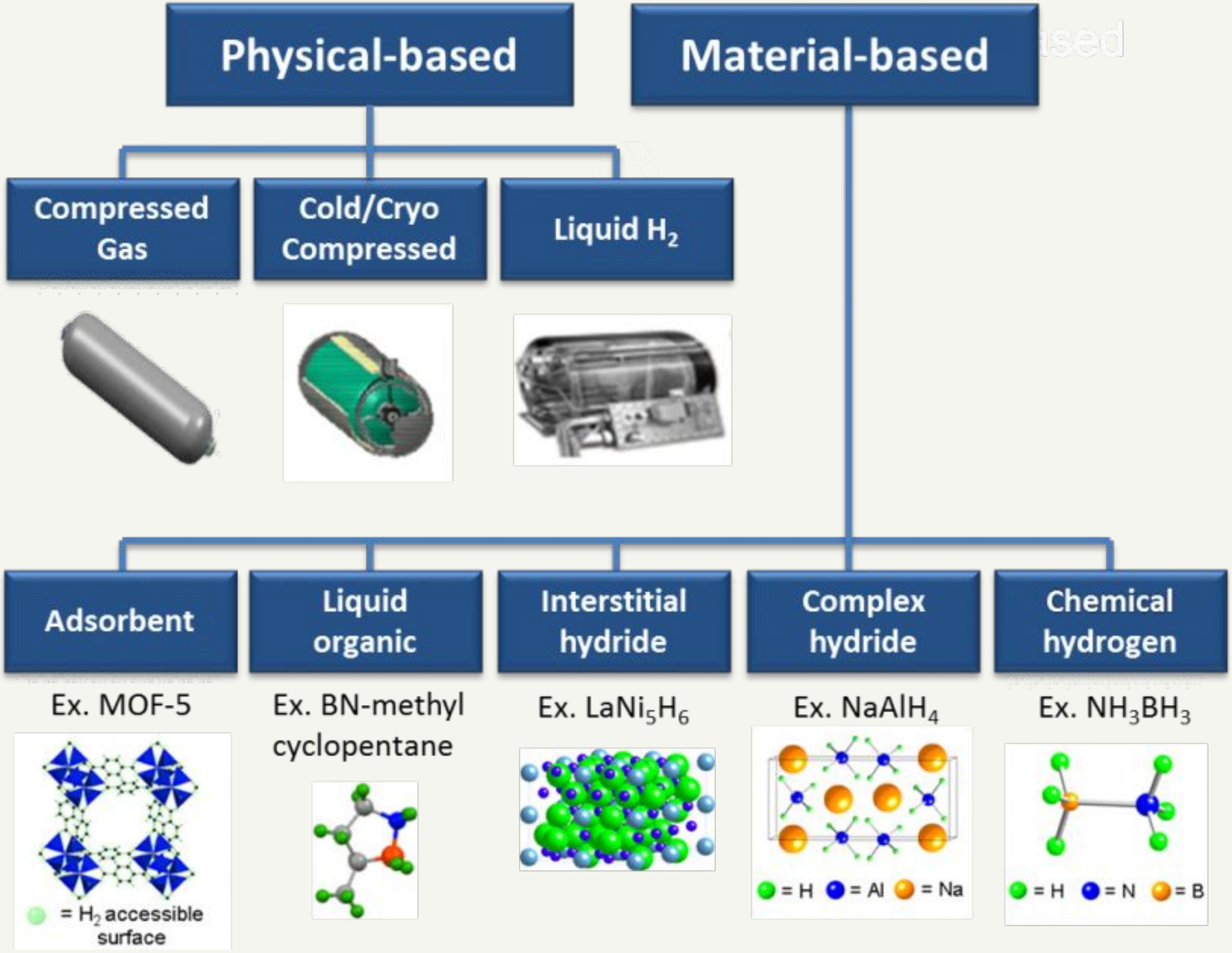
Disadvantages

- Low Efficiency
- High capital costs
- Infrastructure
- Safety concerns
- Energy density by volume

Energy densities of important energy vectors

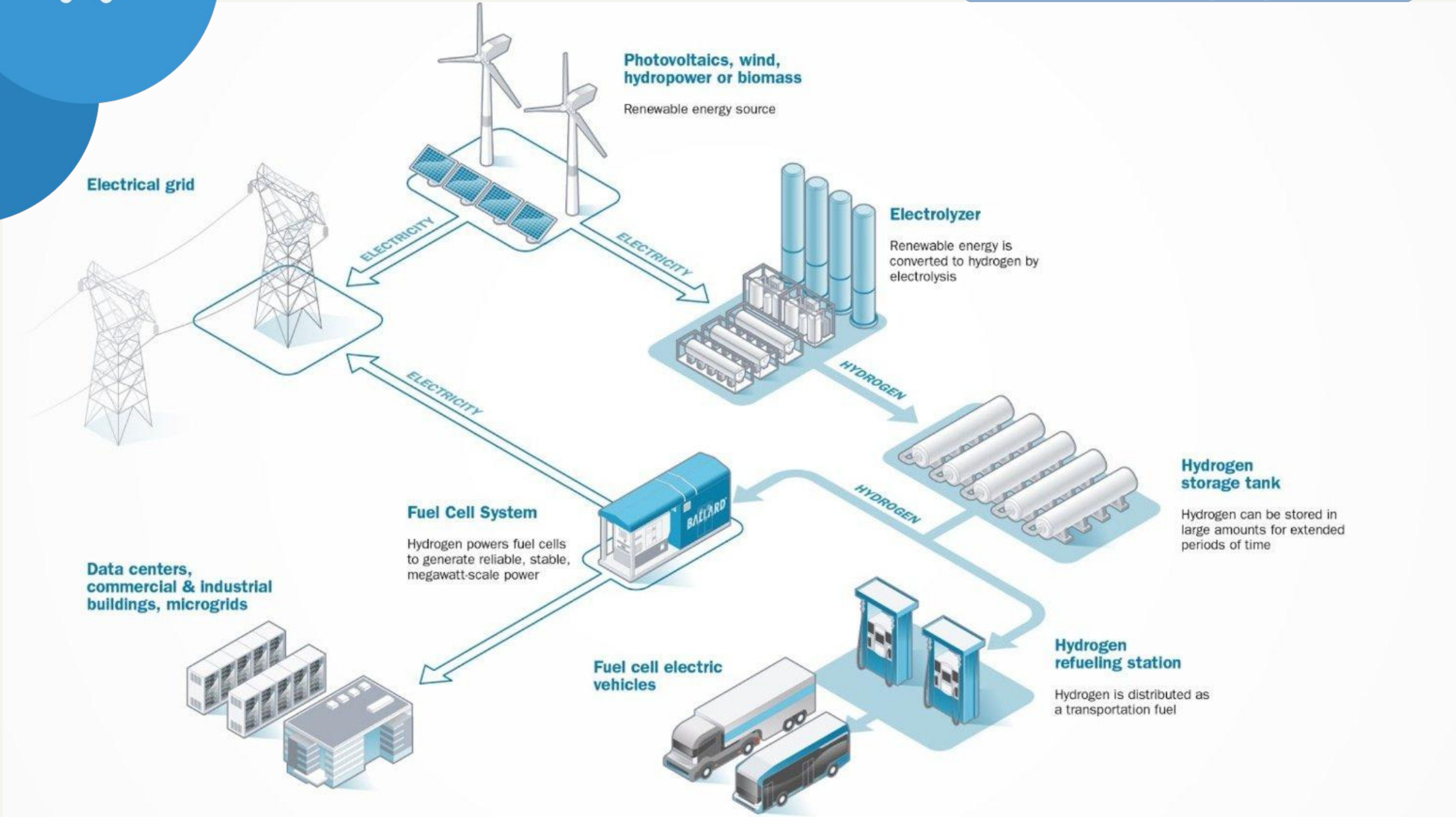


How is hydrogen stored?

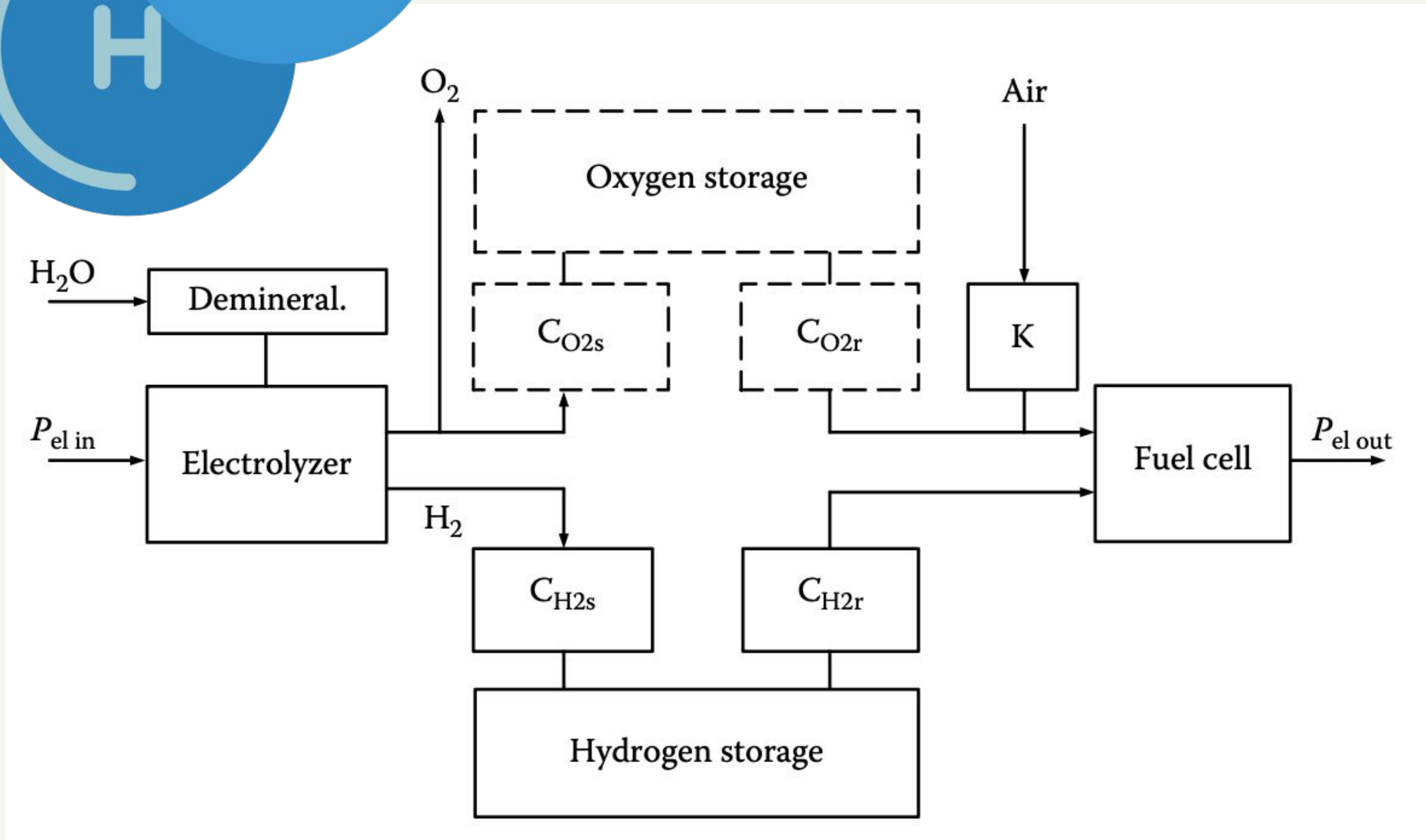


- Storage of hydrogen as compressed gas (350–700 bar)
- Storage of hydrogen in Cold/Cryo compressed form
- Storage of hydrogen in its liquid phase (−253°C/-423°F)
- Storage of hydrogen in a solid form

ELECTRICAL STORAGE SYSTEM BASED ON HYDROGEN

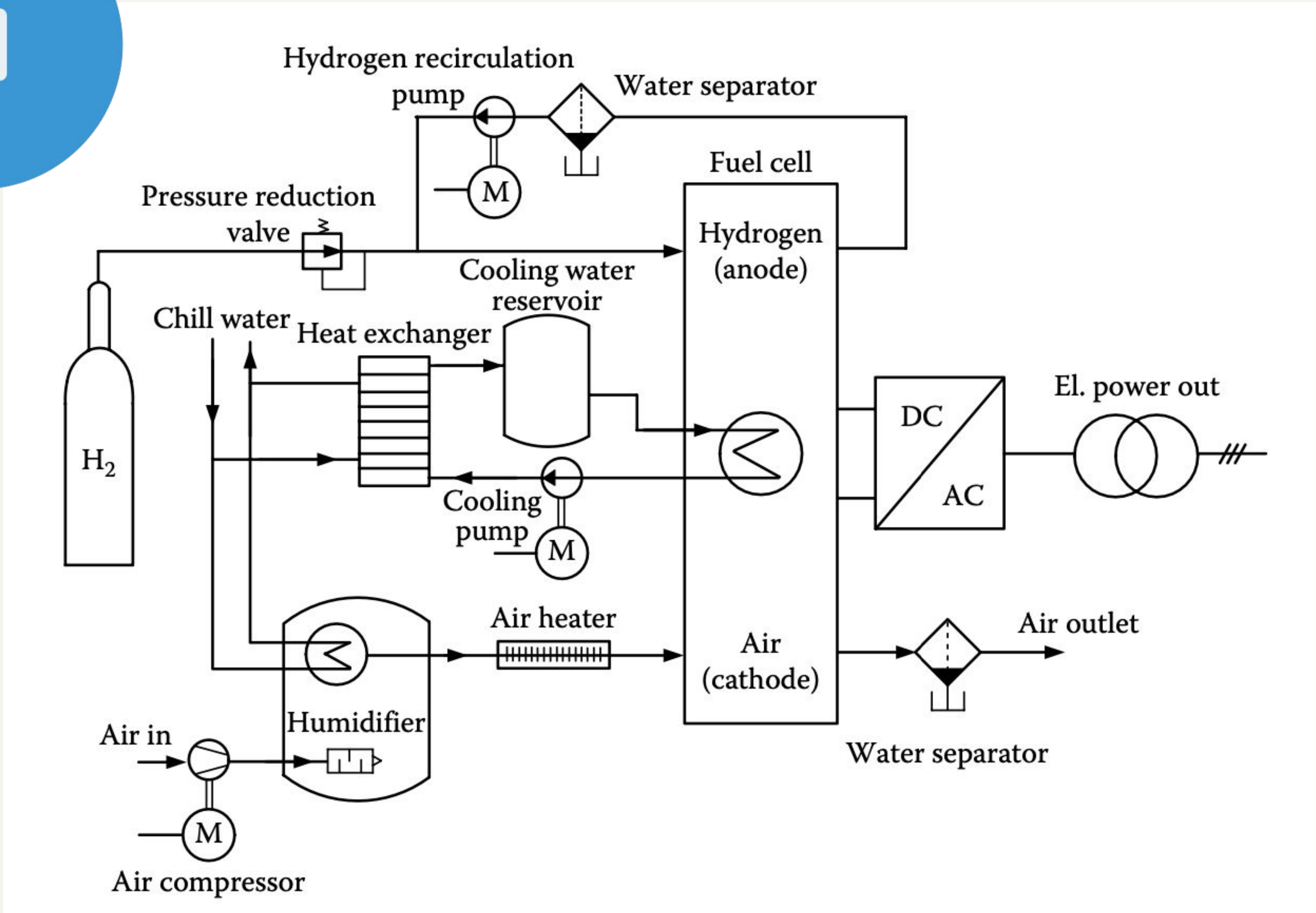


ELECTROLYZER, HYDROGEN STORAGE, AND THE FUEL CELL



- An air compressor is represented (K).
- CO2s, CO2r are the conditioning blocks represented for the case of using stored oxygen
- The conditioning devices for the storage process (CH2s, CO2s) are generally compressors or liquefiers, while the recovery conditioning devices (CH2r, CO2r) are simple relieve valves.
- In the case of solid storage of hydrogen in the form of metal hydrides, the conditioning processes are more complex.

FUEL CELL SYSTEM



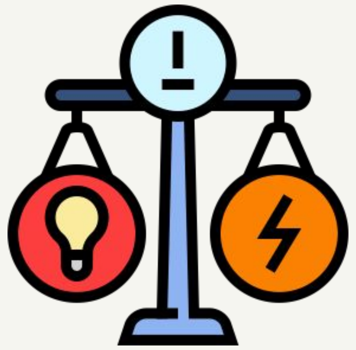
HYDROGEN FUTURE :

HYDROGEN POTENTIAL IN ENERGY STORAGE AND GRID BALANCING

ENERGY AND SEASONAL STORAGE

- During times of surplus renewable energy production, such as windy or sunny periods, the excess electricity can be used to power electrolyzers and produce hydrogen. This renewable hydrogen can be stored in large quantities, providing a valuable energy storage medium.
- One of the notable advantages of hydrogen is its potential for long-term or seasonal energy storage. Unlike batteries, which have limited storage capacity and discharge durations, hydrogen can be stored for extended periods without significant energy losses.

GRID BALANCING AND RENEWABLE INTEGRATION



The integration of intermittent renewable energy sources, such as wind and solar, into the grid presents challenges in maintaining grid stability and balancing supply and demand. Hydrogen can serve as a flexible energy carrier to support grid balancing efforts. Excess renewable energy can be used to produce hydrogen, which can then be stored and injected into the grid during peak demand periods or when renewable energy generation is low.

FUTURE PROSPECTS

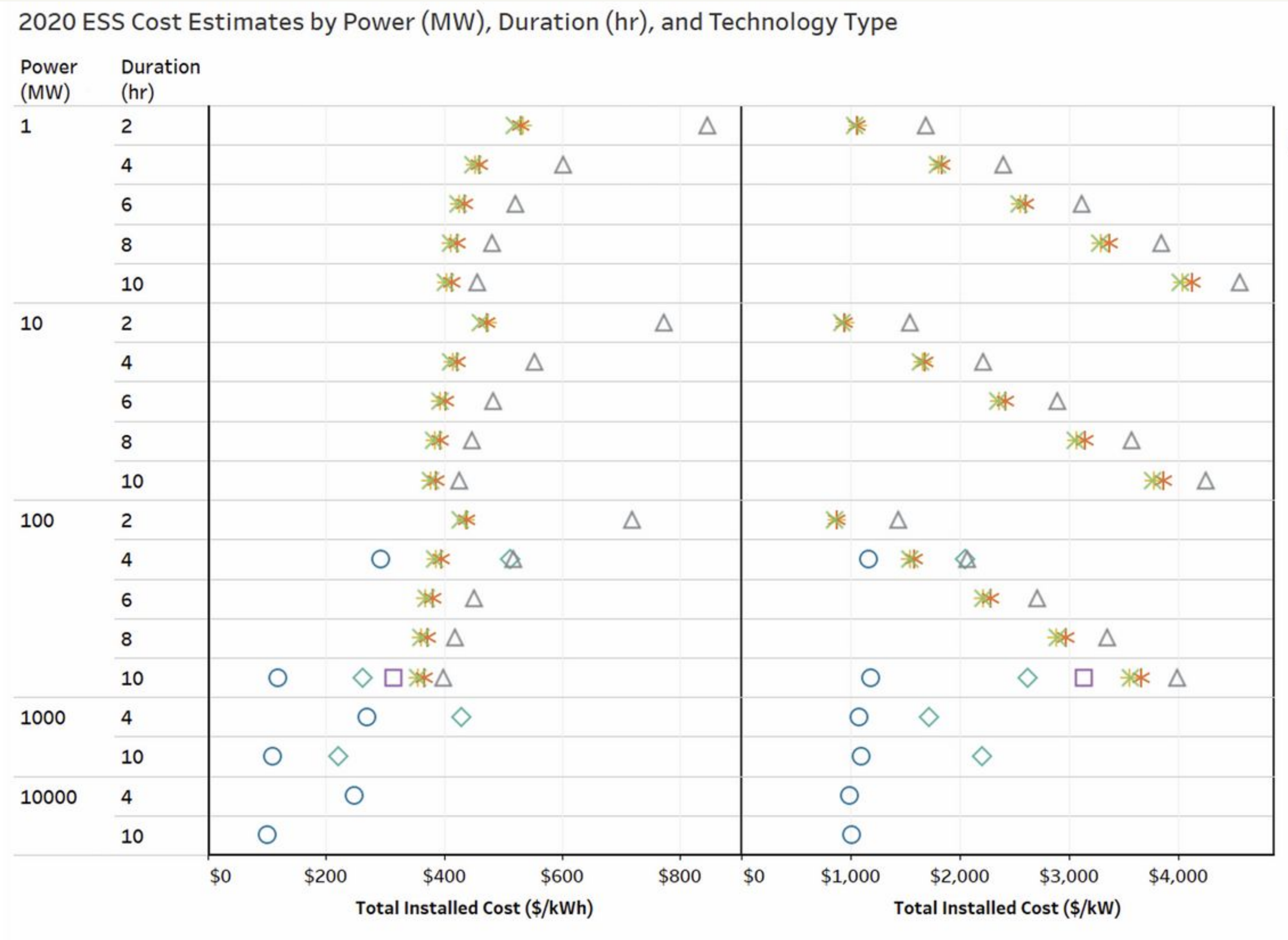
To date, 17 governments have released hydrogen strategies, and 20 governments are working on it

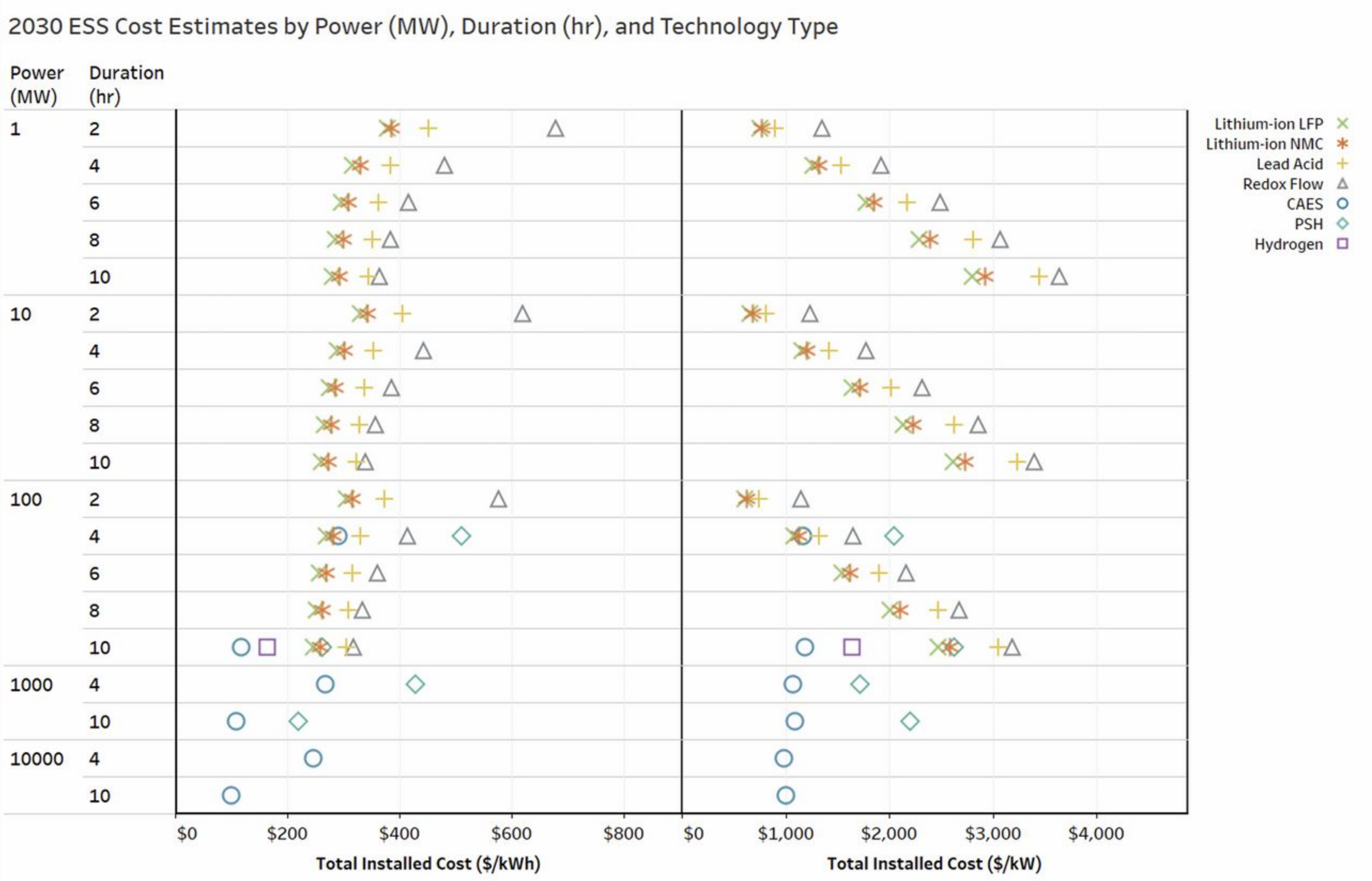
Currently, cost per kg of producing hydrogen from renewables is USD 3–8, estimated to decline further to USD 1.3 by 2030

Countries that have adopted hydrogen strategy have committed to an investment of USD 337 billion to produce low-carbon hydrogen

Electrolysis capacity expected to rise up to 90 GW by 2030

Solid Oxide Electrolyzer Cells, Methane Pyrolysis, Anion Exchange Membranes, and Electrified Steam Methane Reforming amongst the promising H2 production technologies



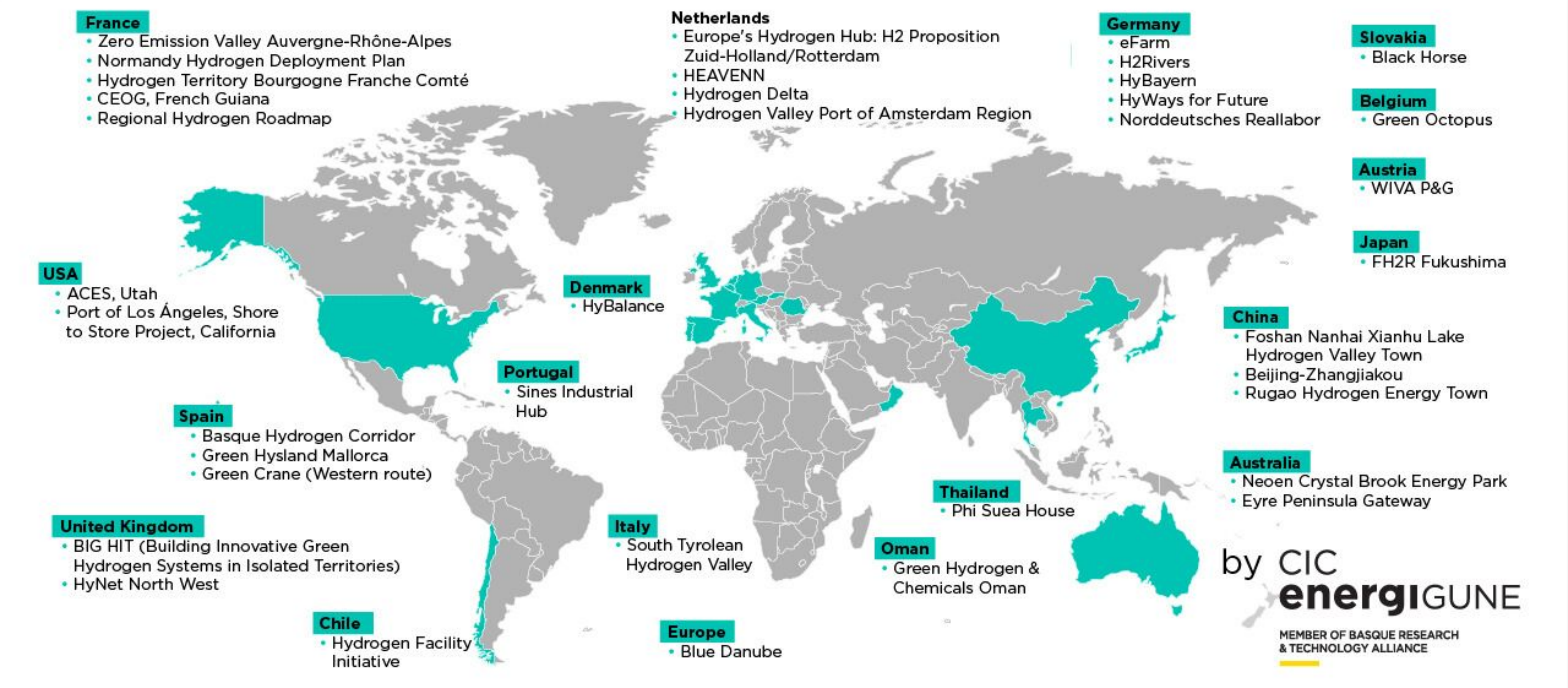


FUTURE PROSPECTS

Technology (Round-Trip Efficiency, Lifetime)	Year	Power capacity cost ($ kW^{-1})			Energy capacity cost ($ kWh^{-1})		
		Min	Ref.	Max	Min	Ref.	Max
Hydrogen (40%, 18 years)	2025	1,507	3,013	4,520	1.8	3.7	5.5
	2050	650	1,300	1,950	0.5	1.0	1.5
CAES (60%, 30 years)	2025	434	817	984	9.1	34.9	80.8
	2050	415	755	947	8.9	31.0	81.6
PHS (80%, 55 years)	2025	573	1,156	1,819	17.4	50.3	101.8
	2050	573	1,164	2,807	17.3	50.9	97.4

FUTURE PROSPECTS

PROJECTS


France
• Zero Emission Valley Auvergne-Rhône-Alpes
• Normandy Hydrogen Deployment Plan
• Hydrogen Territory Bourgogne Franche Comté
• CEOG, French Guiana
• Regional Hydrogen Roadmap
Netherlands
• Europe's Hydrogen Hub: H2 Proposition Zuid-Holland/Rotterdam
• HEAVENN
• Hydrogen Delta
• Hydrogen Valley Port of Amsterdam Region
Germany
• eFarm
• H2Rivers
• HyBayern
• HyWays for Future
• Norddeutsches Reallabor
Slovakia
• Black Horse
Belgium
• Green Octopus
Austria
• WIVA P&G
Japan
• FH2R Fukushima
USA
• ACES, Utah
• Port of Los Ángeles, Shore to Store Project, California
Denmark
• HyBalance
China
• Foshan Nanhai Xianhu Lake Hydrogen Valley Town
• Beijing-Zhangjiakou
• Rugao Hydrogen Energy Town
Portugal
• Sines Industrial Hub
Spain
• Basque Hydrogen Corridor
• Green Hysland Mallorca
• Green Crane (Western route)
Australia
• Neoen Crystal Brook Energy Park
• Eyre Peninsula Gateway
Thailand
• Phi Suea House
United Kingdom
• BIG HIT (Building Innovative Green Hydrogen Systems in Isolated Territories)
• HyNet North West
Italy
• South Tyrolean Hydrogen Valley
Oman
• Green Hydrogen & Chemicals Oman
Chile
• Hydrogen Facility Initiative
Europe
• Blue Danube
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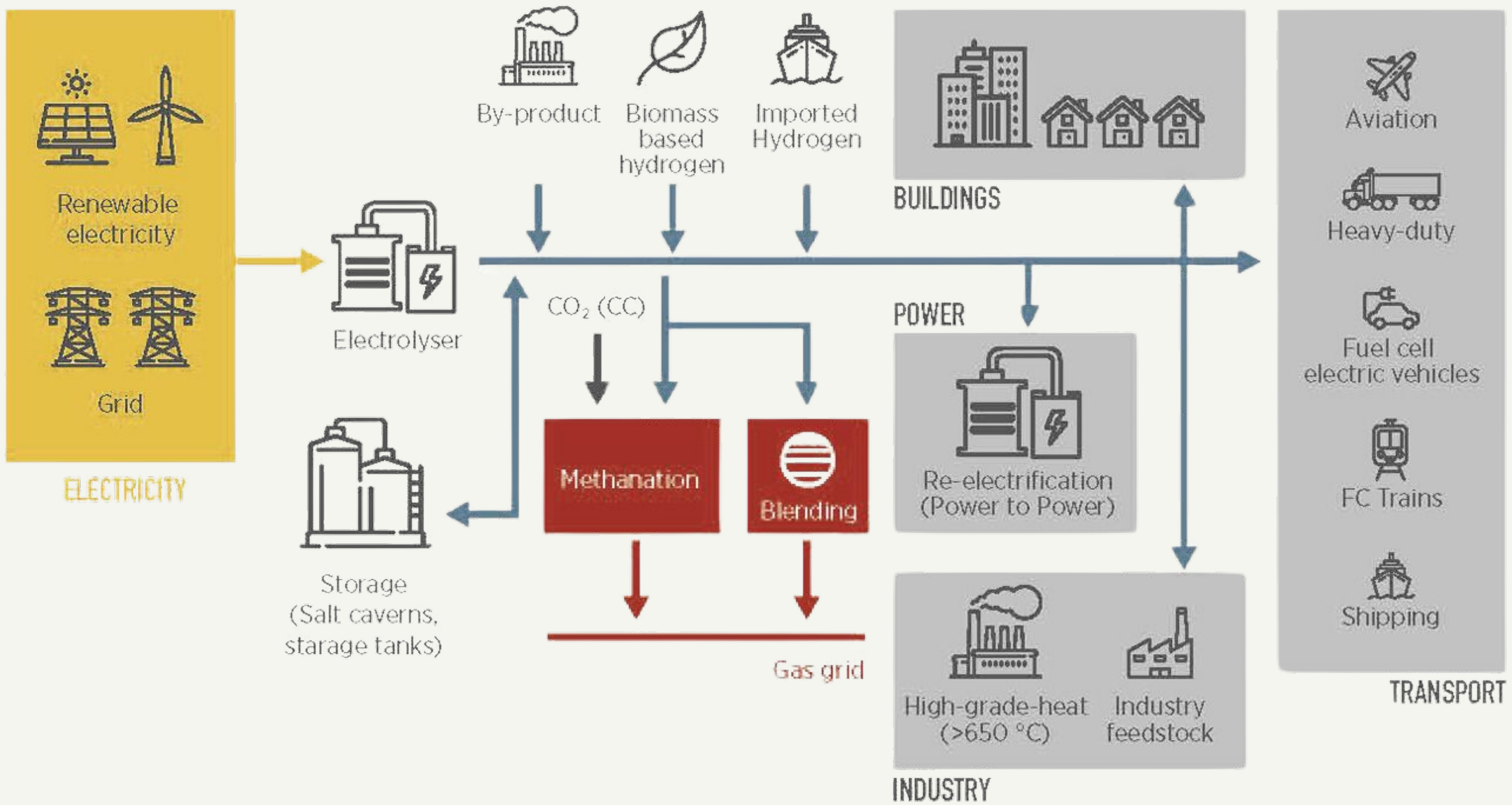
PROJECTS AND INITIATIVES

Project	Country	Annual Production	Power Source	Electrolyser capacity	Cost	Year
HyBalance	Denmark	53 tonnes of green hydrogen	Wind	1.2 MW	15 M€	2018
Dachen Island	China	73 000 normal cubic metres (Nm3) of hydrogen	Wind	N/A	N/A	2022
Eco-Energy World (EEW)	Australia	33 000 tonnes of green hydrogen	Solar & wind	320 MW	N/A	2025/2026
ACES	USA, Utah	N/A	Solar & wind	220 MW	$504.4 million loan	Project stage

- European Clean Hydrogen Alliance
- H2@Scale (United States): H2@Scale is a U.S. Department of Energy initiative
- Hydrogen Energy Supply Chain (Japan):
- HyDeal Ambition
- Gigastack (United Kingdom)
- NorthH2 (Netherlands): NorthH2 is a consortium of companies, including Shell, Gasunie, and Groningen Seaports,



CONCLUSION

Electrolysis-based hydrogen production and storage, including seasonal energy storage capabilities, could improve the operation of the electric grid while integrating a variety of disparate systems, including the transportation, agricultural, industrial, and residential sectors.

QUESTIONS