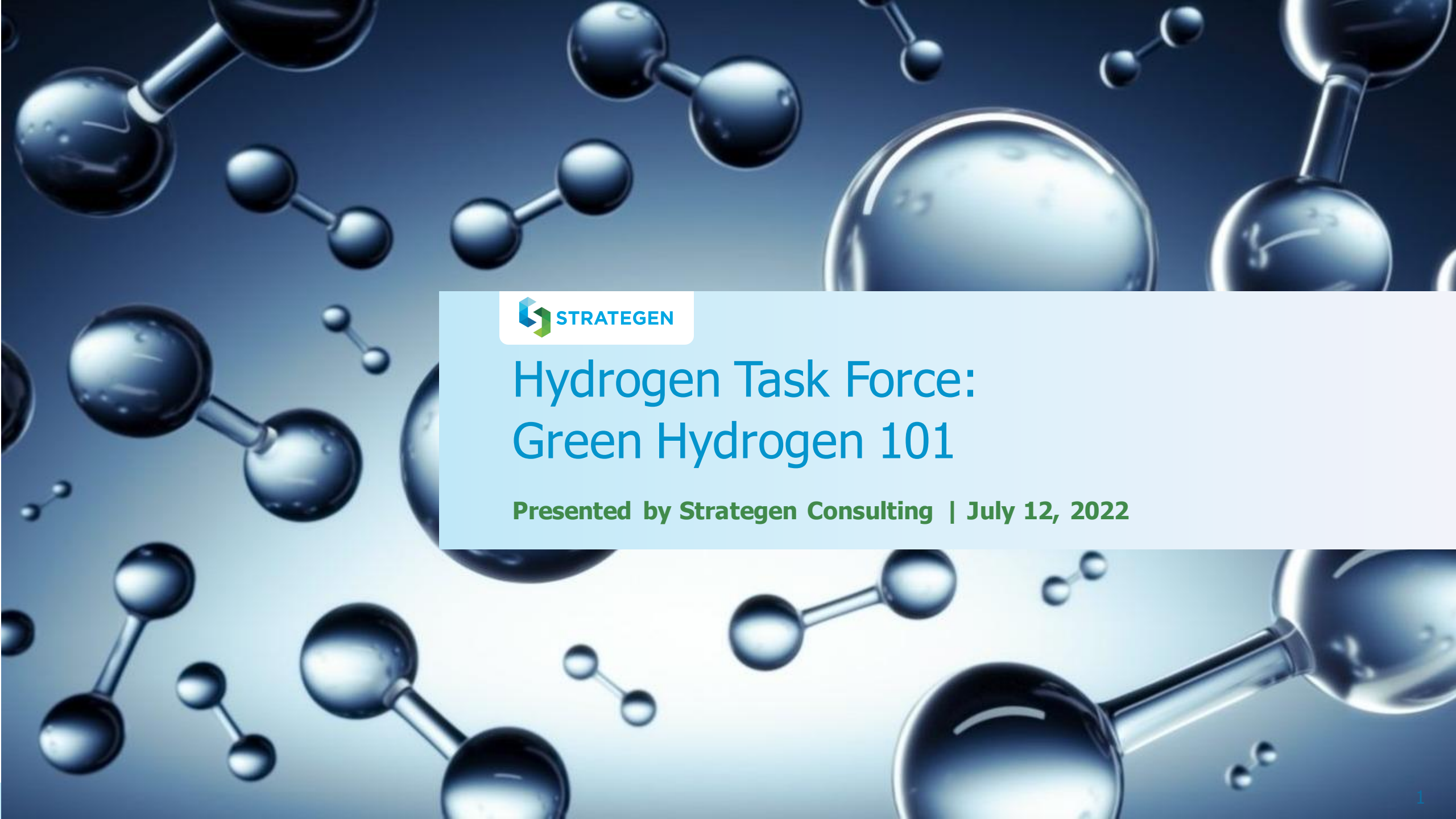

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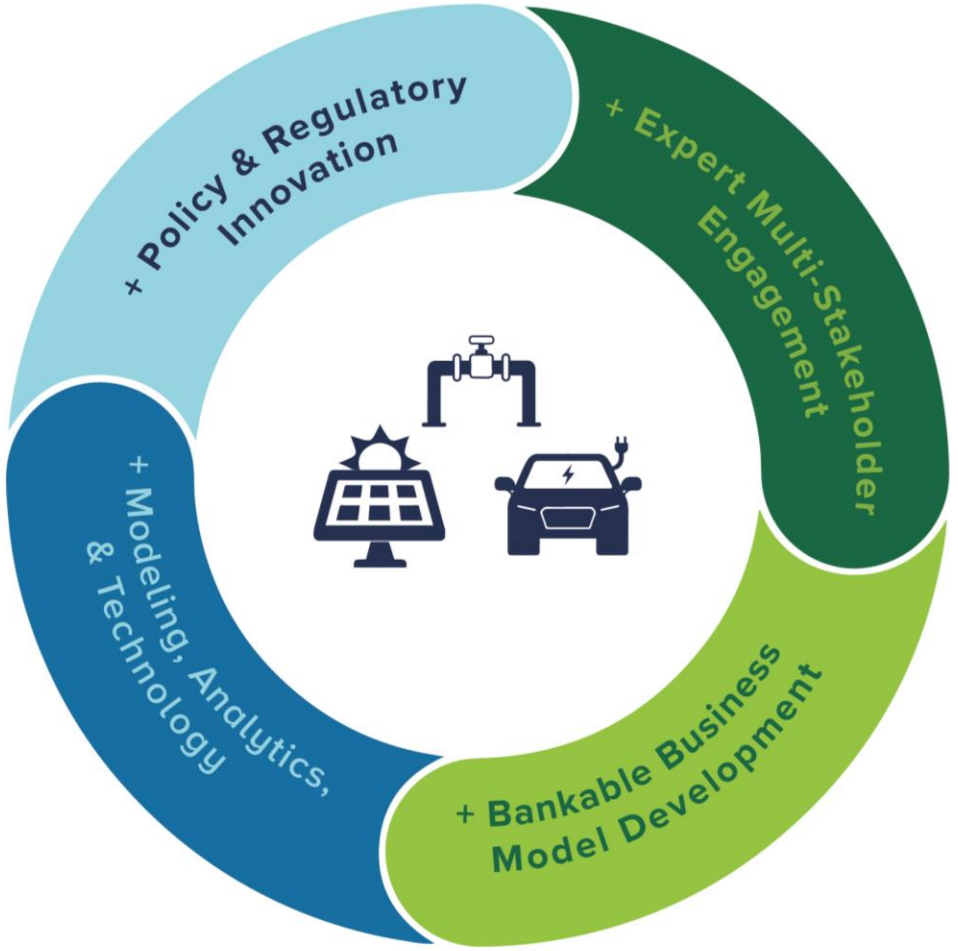
Hydrogen Task Force: Green Hydrogen 101

Presented by Strategen Consulting | July 12, 2022

Strategen is a mission-driven consulting company focused on enabling a clean and just energy transition.

We advise and empower leading organizations to design innovative, practical solutions that capture the promise of a clean energy future, strengthen resilience and adaptability, and are equitable, collaborative, and impactful



Strategen's Green Hydrogen Expertise

Nick Connell

Policy Director

- On behalf of the California Energy Storage Alliance (CESA) Strategen has evaluated hydrogen as resource for balancing and storing renewable energy.
- Since 2019, Strategen has been responsible for the founding, staffing and daily operations of the Green Hydrogen Coalition (GHC), a 501(c)(3) nonprofit dedicated to facilitating policies and practices to advance green hydrogen production and use at scale. Strategen's support for the GHC has included the development of a hydrogen hub strategy for the Los Angeles basin, HyDeal Los Angeles.
- Strategen has also facilitated the convening of the Western Green Hydrogen Initiative (WGHI), a collaborative effort of state energy officials and policymakers to discuss opportunities for green hydrogen to support regional energy, economic, and environmental needs.
- Strategen is supporting a range of public and private sector clients on their green hydrogen commercialization and regulatory strategies, including assessments of electrolytic hydrogen offtake opportunities across the US and evaluation of hydrogen pipeline opportunities and relevant policy.

Client & Work Examples

GREEN HYDROGEN COALITION

LA DWP

IPA Intermountain Power Agency

QUI TRANSTULIT SUSTINET

pennsylvania DEPARTMENT OF ENVIRONMENTAL PROTECTION

DMME Virginia Department of Mines Minerals and Energy

NRDC

Learning Objectives

1. Form an understanding of hydrogen including production, storage, and use
2. Identify the green hydrogen end-user ecosystem
3. Understand current policy and regulatory activities driving clean and green hydrogen momentum

Interest in green hydrogen is skyrocketing

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Air Products Plans $5 Billion Green Fuel Plant in Saudi Arabia

Air Products signed an accord with Saudi-based ACWA Power International and the kingdom's planned futuristic city of Neom to develop a $5 billion hydrogen-based ammonia plant powered by renewable energy

Bloomberg Green

CNN BUSINESS

Toyota is pushing ahead with hydrogen-powered cars

Doubling down on its bet that fuel cells will help secure Toyota's future as the industry comes under enormous

gtm: A Wood Mackenzie Business

Coalition Aims for 25GW of Green Hydrogen by 2026

Seven firms join forces for fiftyfold scale-up of global hydrogen production capacity.

reNEWS.BIZ

Vestas backs world's first commercial green ammonia plant

TechCrunch

GM and Honda partner to mass produce hydrogen fuel cells in Michigan

Enel teams up on US green hydrogen project

2000

2022

BBC

New hydrogen buses hit the road

Three buses powered by H_2 are to be introduced on routes in central London as part of a two-year trial

The New York Times

Hydrogen cars join EV models in showrooms

Hydrogen-powered flight

Is the time now ripe for planes to run on hydrogen?

The Economist

PHYS.ORG

European nations plan to use more hydrogen for energy needs

Energy officials from 25 countries pledged Tuesday to increase research into hydrogen technology and accelerate its everyday use to power factories, drive cars and heat homes.

RTO Insider

Initiative Seeks to Fuel Use of Green Hydrogen in West

The push to develop green hydrogen got a boost with the announcement of a new program to hasten its development for use in the Western Interconnection

Lancaster, CA Becomes the First Hydrogen City in the US

CISION PR Newswire

riviera

Hydrogen and fuel cells will future-proof shipping

Future Proof Shipping is taking a pioneering step by retrofitting a vessel to run on hydrogen fuel cell propulsion

Fuel Cells Power Up: Three Surprising Places Where Hydrogen Energy Is Working

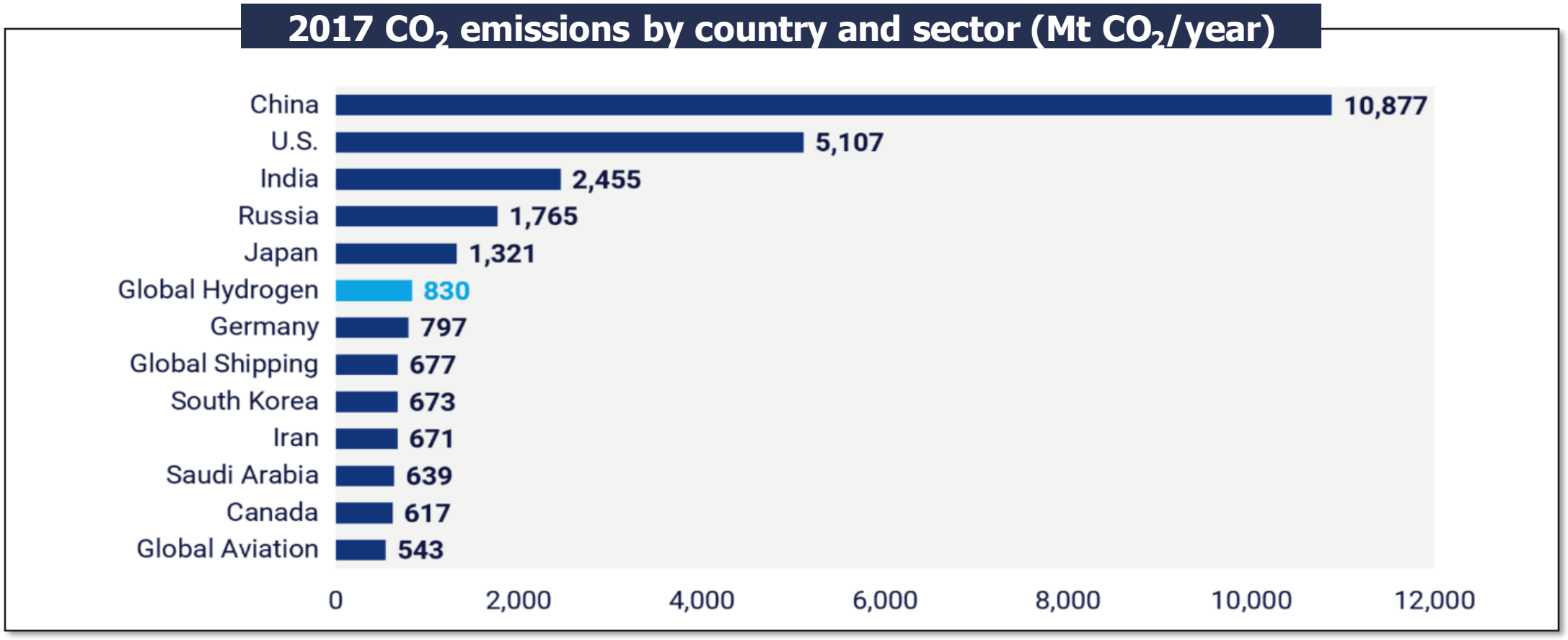
Hydrogen may not be fueling many cars, but it is delivering clean power for warehouses, data centers, and Telcom towers.

UTILITY DIVE

Utility of the Year

NextEra Energy is investing in green hydrogen, solar energy and grid resilience,

Global (gray/brown) hydrogen production accounts for 832 Mt CO_2/year…more than the emissions of Germany



Source: Wood Mackenzie, 2019. "The Future of Green Hydrogen"

Green Hydrogen can decarbonize today's global hydrogen commodity markets

Today's Global Hydrogen Value Chains

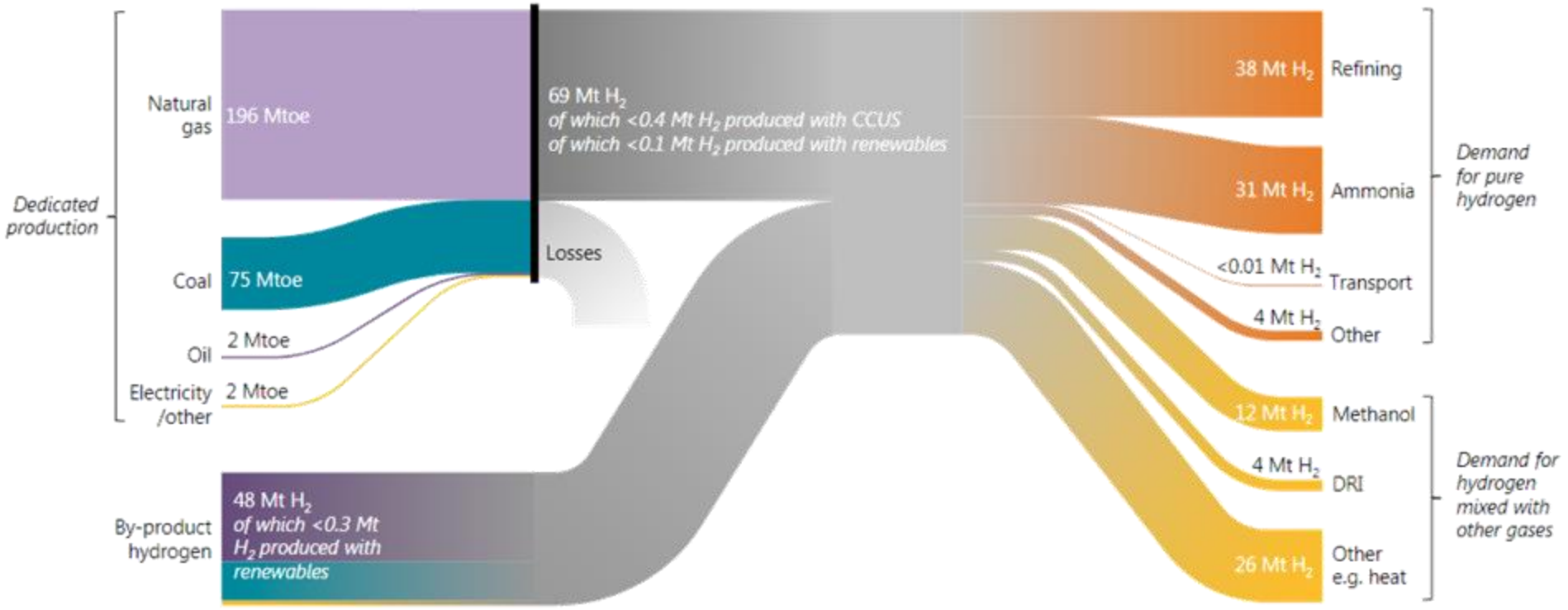
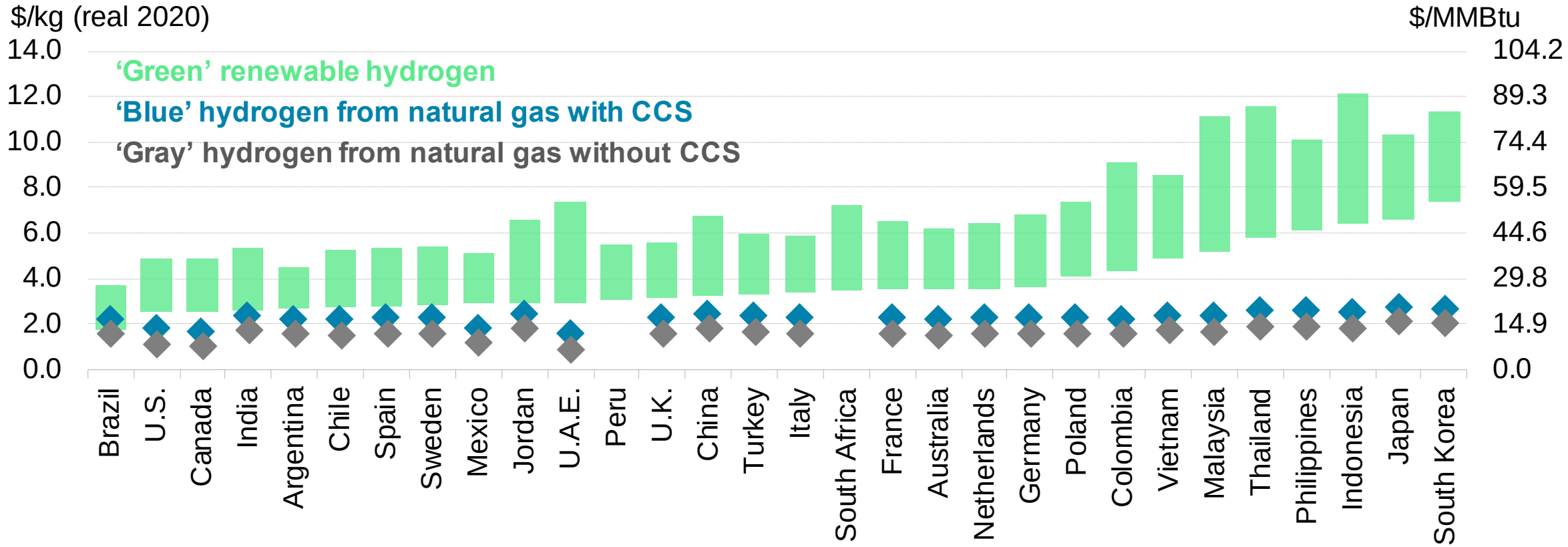


Image from "The Future of Hydrogen: Seizing today's opportunities" report prepared by IEA for the G20, Japan. Mtoe=million tons of oil equivalent. Mt=million tons

But today >99% of hydrogen is made from fossil fuels

Today, making H_2 from renewables more expensive than producing it from fossil fuels

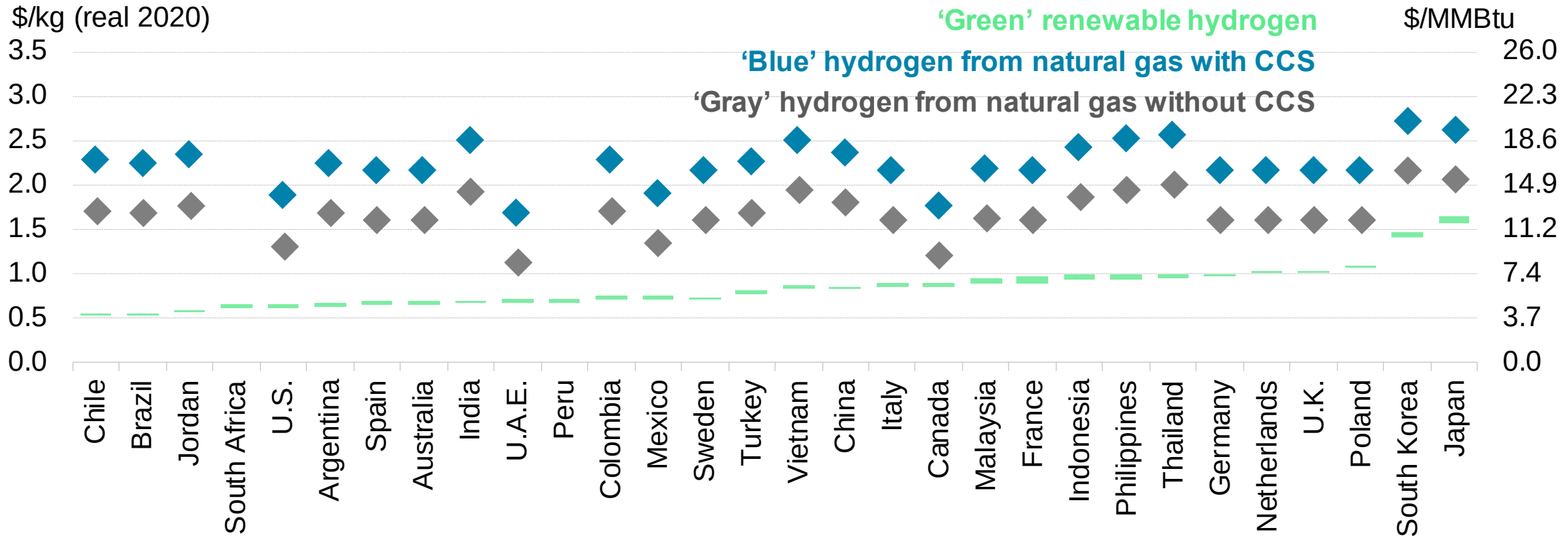
Hydrogen production costs, 2021



Source: BloombergNEF. Note: CCS = carbon capture and storage. Renewable $LCOH_2$ range reflects a diversity of electrolyzer type, Chinese alkaline (low) to PEM (high). The electricity powering the electrolyzer is either PV or onshore wind, whichever is cheaper. Assumes equal CCS costs in all countries.

There is global consensus that green hydrogen will be lowest cost in the future – even lower cost than hydrogen produced from fossil fuels

Hydrogen production costs, 2050



Source: BloombergNEF. Note: CCS = carbon capture and storage. Renewable $LCOH_2$ range reflects a diversity of electrolyzer type, Chinese alkaline (low) to PEM (high). The electricity powering the electrolyzer is either PV or onshore wind, whichever is cheaper. Assumes equal CCS costs in all countries.

The hydrogen supply chain is composed of four key elements

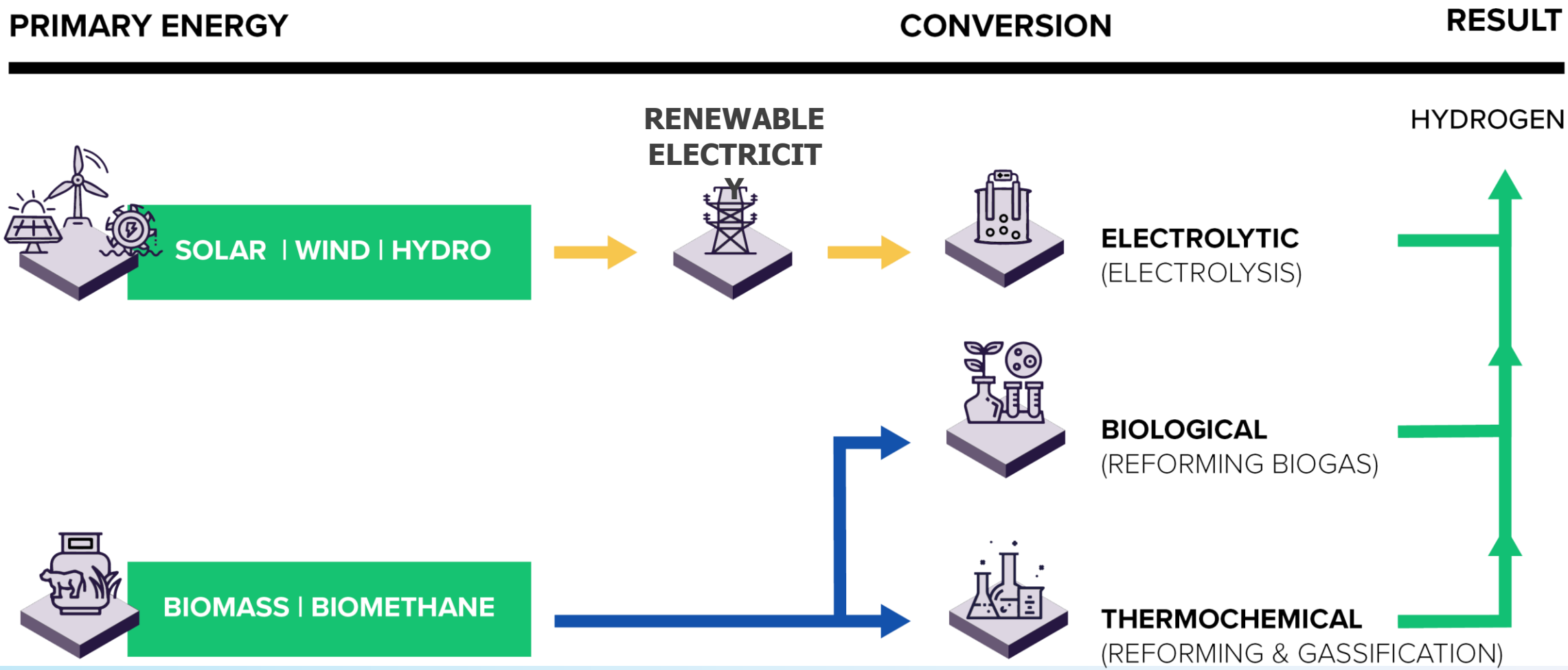
Production

Transportation

Storage

Offtake

There are many ways to make green hydrogen such as electrolysis, steam methane reforming of biogas, and thermal conversion of biomass



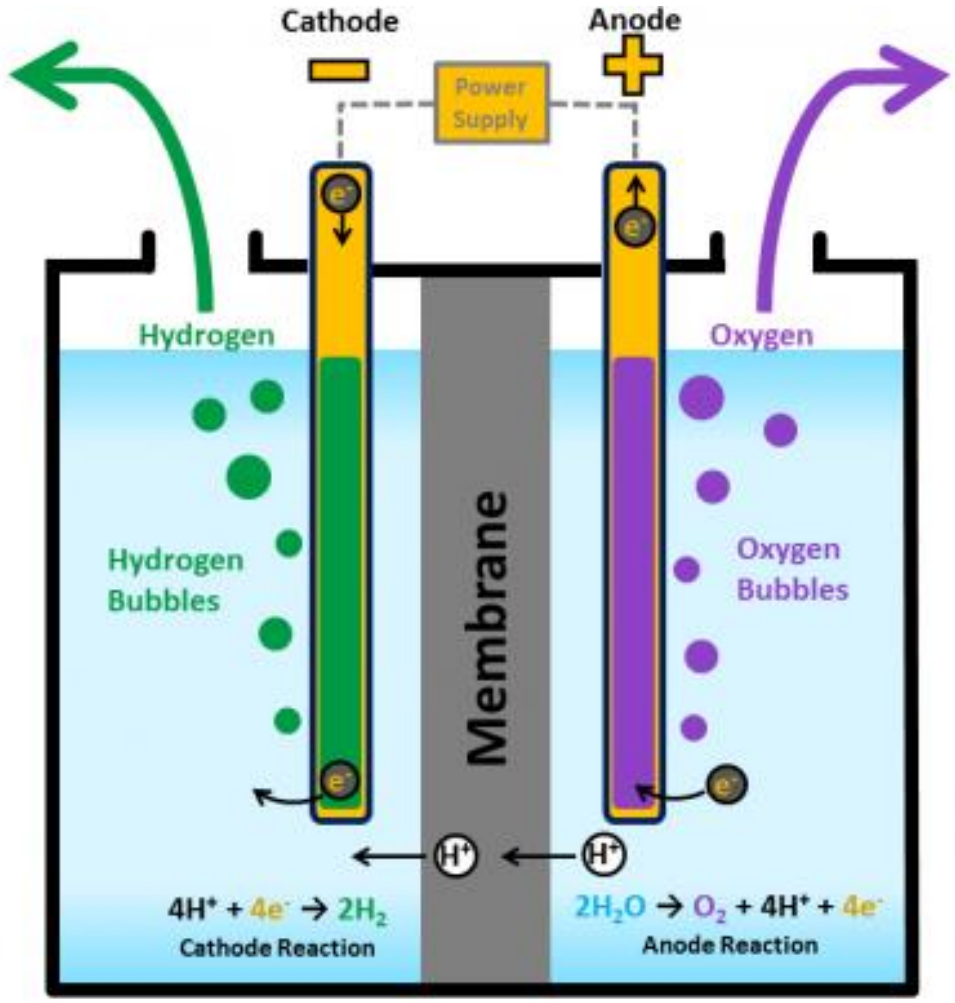
Electrolyzers – what they are, how they work

A Commercially Available & Widely Used Flexible Load

- Can provide ancillary services (e.g., regulation, Volt/VAR support)
- Sizes range from 10's of KW to 10's MW (today)

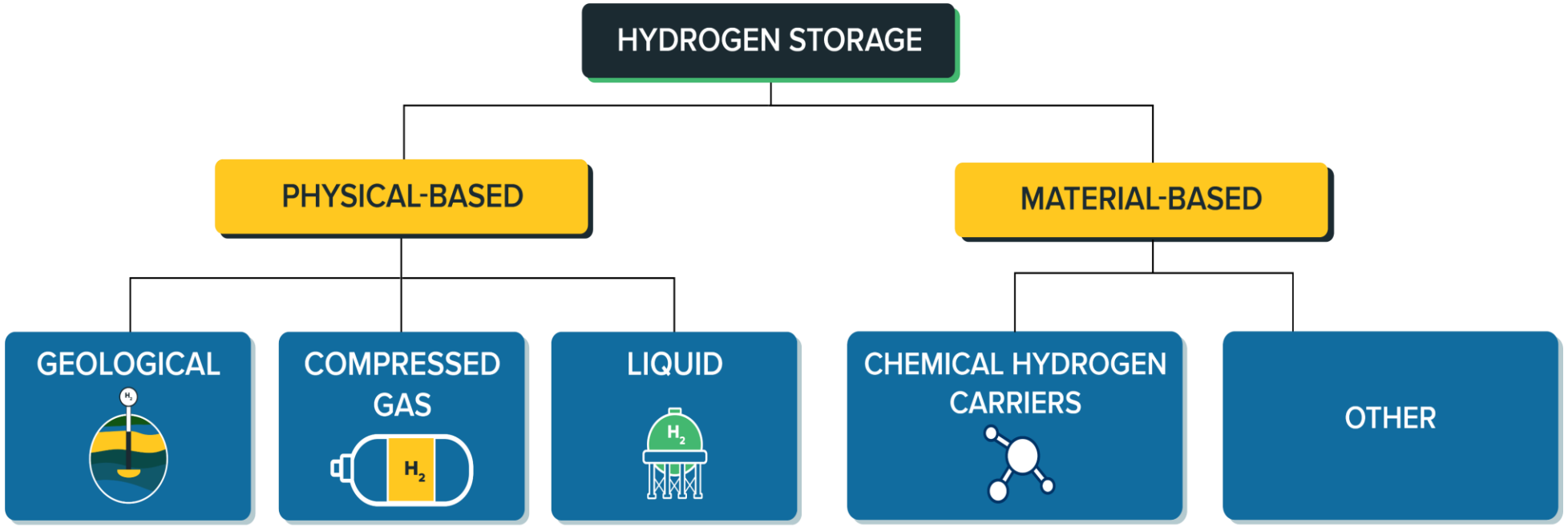
Various Types of Electrolyzers

- Alkaline
- Proton Exchange Membrane (PEM)
- Solid Oxide

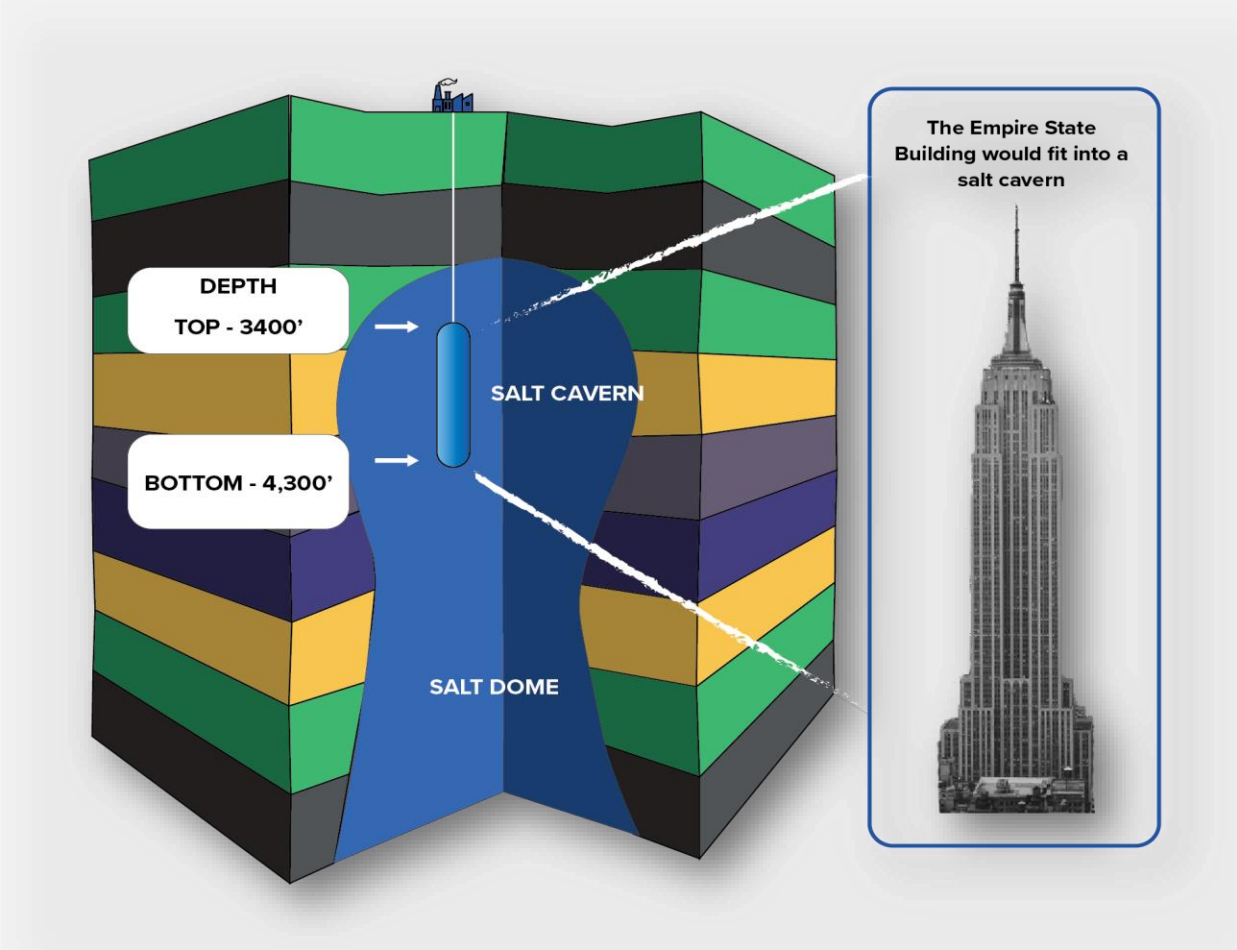


Source: U.S. DOE, 2020

Once hydrogen gas is produced, it must be stored. Hydrogen can be stored using different methods, with each having tradeoffs related to application, location, scale, and cost.



Hydrogen storage in underground salt caverns: Intermountain Power Project conversion (Delta, Utah)



- 1 cavern = 5,512 tons of H_2 (operational limit)
- This is equivalent to:
  - 200,000 hydrogen buses
  - 1,000,000 fuel cell cars
  - 14,000 tube trailers used for delivery
  - 150,000 MWhs of energy storage
- Over 100 caverns can be constructed in the IPP salt dome
- Storing H_2 in salt caverns is already done commercially around the world
- There are three operational H2 salt caverns in the US today

Once the hydrogen is stored, hydrogen can be transported via…

Dedicated hydrogen pipelines or Hydrogen blended in natural gas pipelines

Roads using hydrogen trailers or liquid tankers

Shipping overseas in tube skids or a high-efficiency liquid storage container

Green hydrogen is a solution that can eliminate fossil fuels for end uses where there are no alternate solutions

Agriculture

Industrial Applications

Heavy Duty Trucking

Maritime Shipping

Aviation

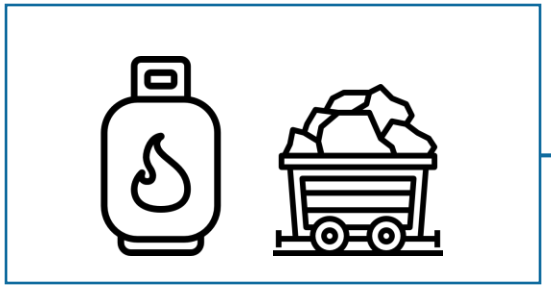
Clean Power

Mining

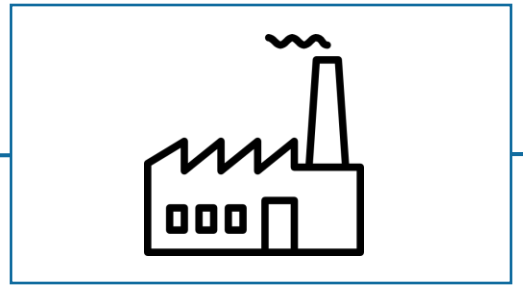
Long Duration Energy Storage

Green hydrogen can repurpose the energy system we've relied upon for the last century

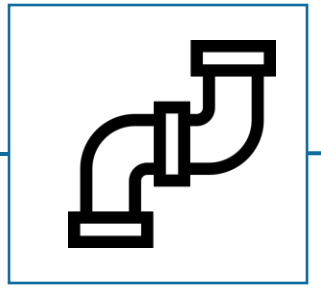
Status Quo



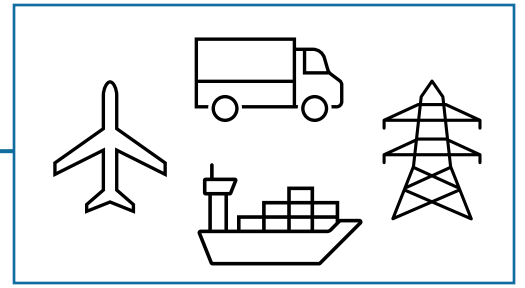
Fossil fuel feedstocks



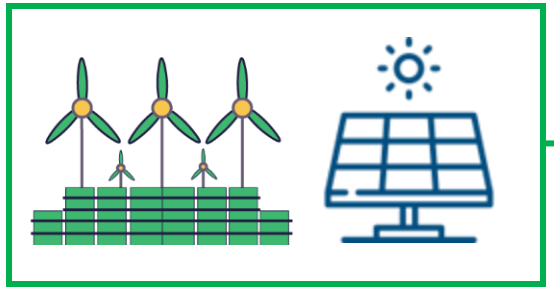
Oil refining and natural gas processing



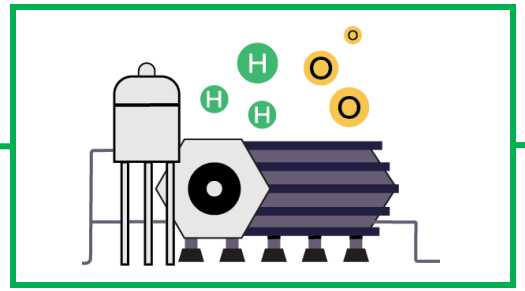
Pipeline Transport



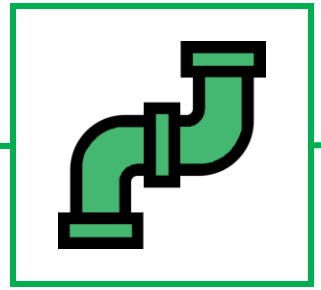
Clean Energy Ecosystem



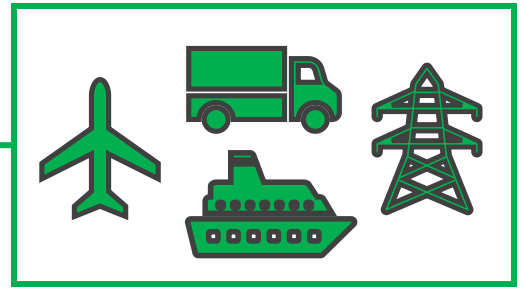
Renewable energy feedstocks and sources



Production of green hydrogen



Repurpose Pipeline Transport

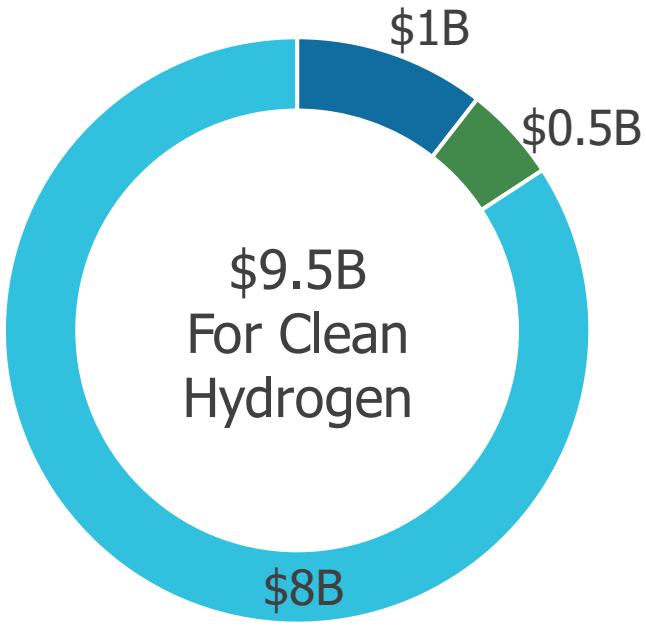


What are the barriers to a realizing a green hydrogen economy?

Infrastructure and Economies of Scale

Cost of Green Hydrogen

Hydrogen Highlights in the Infrastructure Investment and Jobs Act



- Electrolysis research, development, and demonstration
- Clean hydrogen Technology manufacturing and recycling R&D
- Regional clean hydrogen hubs (at least 4)

Other Hydrogen Provisions

- Directs work to reduce the cost of clean hydrogen to $2 per kilogram by 2026
- Requires developing a National Hydrogen Strategy and Roadmap

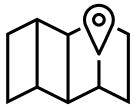
Coordinated policy and regulatory drivers are informing and driving public and private sector investment.

Definitions

Some States and provinces are defining renewable hydrogen eligibility in similar ways.

Technology agnostic definitions are the most prominent.

Specification focuses on feedstock type (i.e., must be renewable or must be non-fossil fuel).



Roadmaps

Roadmaps and strategic plans for renewable hydrogen are emerging in some States and Provinces.

Some state agencies and utilities are also discussing renewable hydrogen for long-term reliability planning needs

Market Development

Approx. 42 public and private renewable hydrogen activities have been identified. This includes research studies, pilots, demonstrations, and full-scale deployment.

Some topics include production, pipeline injection and distribution, power generation, and LDES.

Increasingly, the proliferation of differing hydrogen shades is overly complicating the discussion

Key questions for a sustainable carbon-intensity framework

- Does it support non-fossil fuel feedstock diversity?
- Is it based on a quantifiable methodology?
- What is the hydrogen production CO2e threshold?
- Does it consider the lifecycle impacts?
- Does it support technology-neutrality?
- How will it be certified?

From complexity
(hydrogen colors)

To one indicator based on CI
(e.g., kgCO2e/kgH2, gCO2e/MJ…)

- **A carbon intensity framework is a technology-neutral approach** to assessing the GHGs associated with hydrogen production. It opens the debate about competition between various hydrogen production routes that meet the required carbon intensity at the least cost.
- A carbon intensity framework can adopt a **threshold** and **certification scheme** to rigorously account for GHGs arising both at the site of production and upstream of production.

Key Takeaways

1. The components required for green hydrogen production, storage, and delivery are well understood and available today.
2. Green hydrogen is a commercially available solution to eliminate fossil fuels for end uses where there are no alternate solutions such as aviation, high temperature industrial processes, heavy-duty trucking, long duration and seasonal energy storage.
3. Today, making H_2 from renewables more expensive than producing it from fossil fuels, but there is global consensus that green hydrogen will be lowest cost in the future – even lower cost than hydrogen produced from fossil fuels. Scale & infrastructure can accelerate the realization of this low-cost green hydrogen economy.
4. In order to attract investment capital and accelerate progress, it is crucial to reduce regulatory uncertainty and clarify access to benefit pathways.

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Thank you!

Questions?

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