RMI
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Green Hydrogen Briefing

April 27th 2022

What I'll cover today

- Hydrogen 101
- Cost
- U.S. policy landscape
- Green Hydrogen Catapult

“Hydrogen 101”

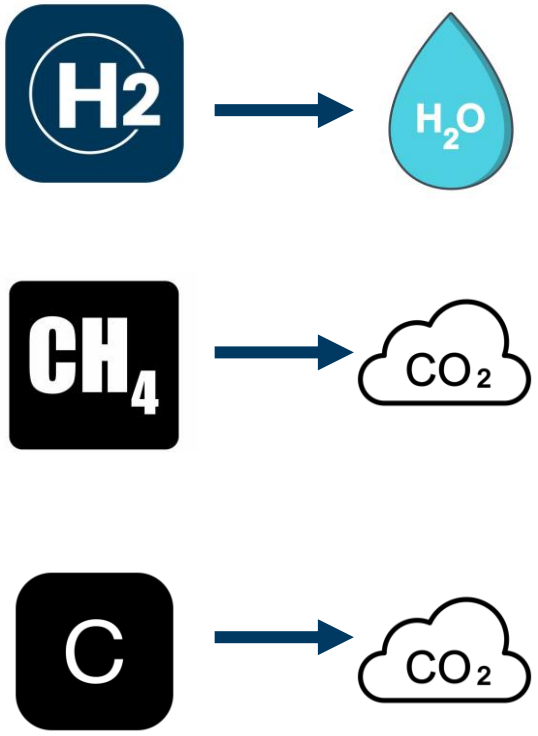
What is hydrogen?

A molecule…

Similar to fossil fuels…

- Combustion produces high temperatures
- It is energy dense
- It can be involved in chemical reactions

Unlike fossil fuels…



Giving it a unique role in net zero

- As a fuel where high temperatures are needed
- As a fuel where high energy density is needed
- As a chemical feedstock

What role will hydrogen play in achieving net zero?

1. Replace hydrogen in existing end uses

Fertilizer | Refining | Chemicals

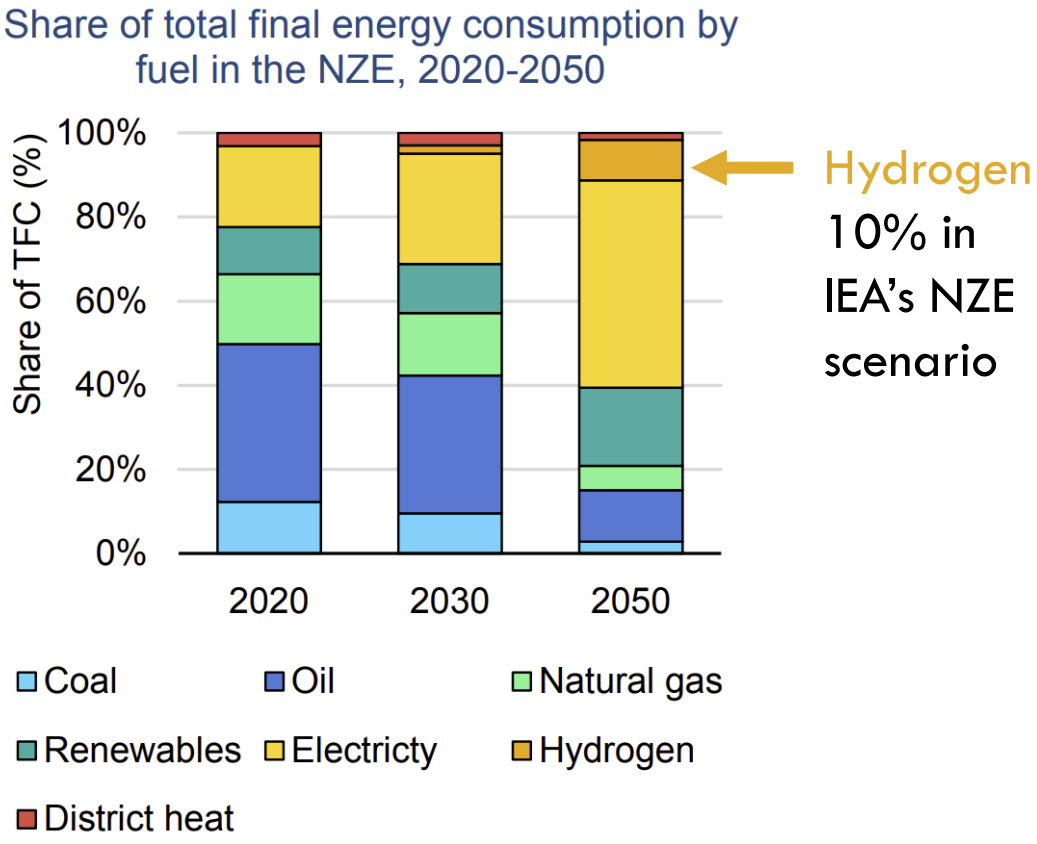
10 MMT H_2/yr → ~100 MMT CO_2/yr
(2% of total US emissions)

2. Replace fossil fuels in heavy industry & transport

Steel | Shipping | Trucking | Aviation

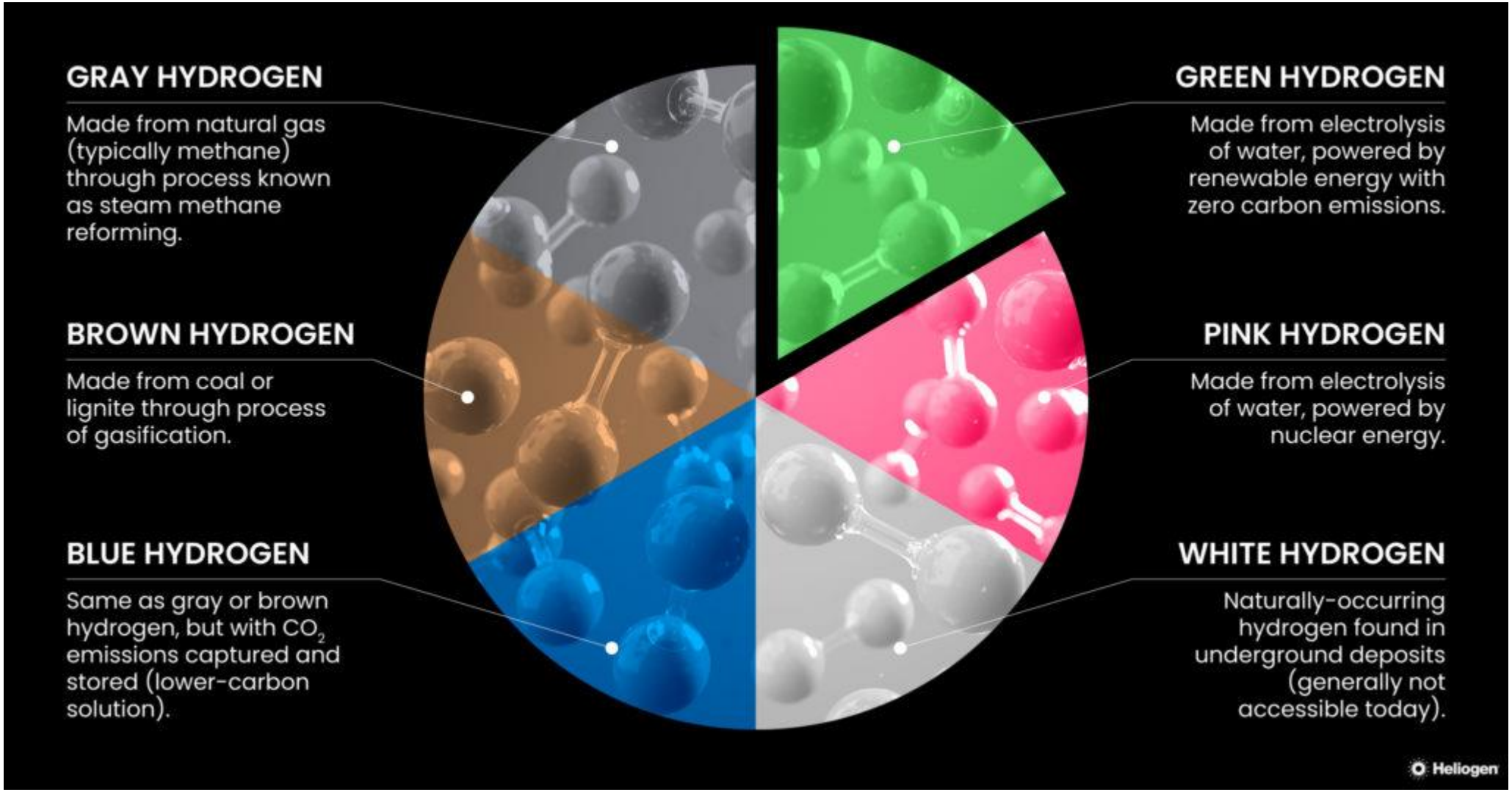
200-300 MMT CO_2/yr
(4-6% of total US emissions)

Hydrogen is vital for net zero, but is only one piece of the puzzle



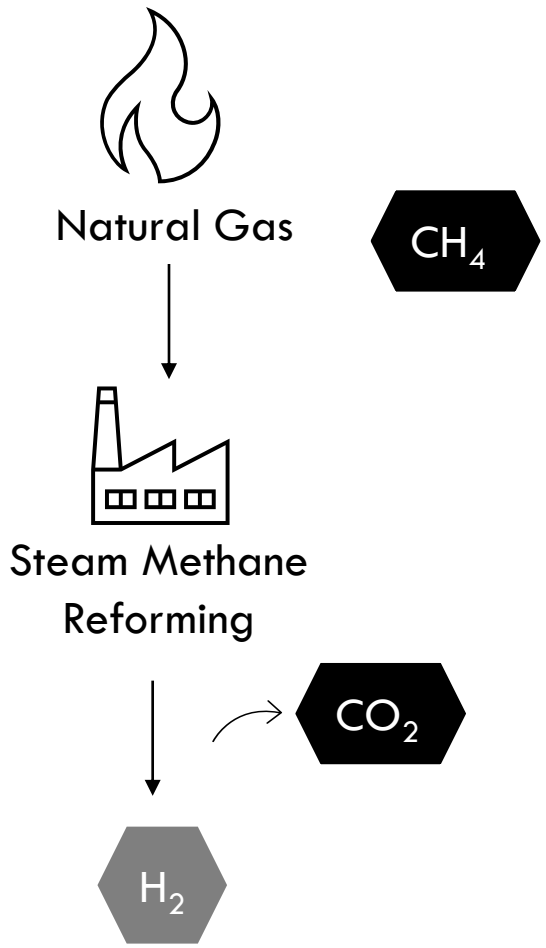
Source: IEA, Global Hydrogen Review 2021, link

How is hydrogen produced?



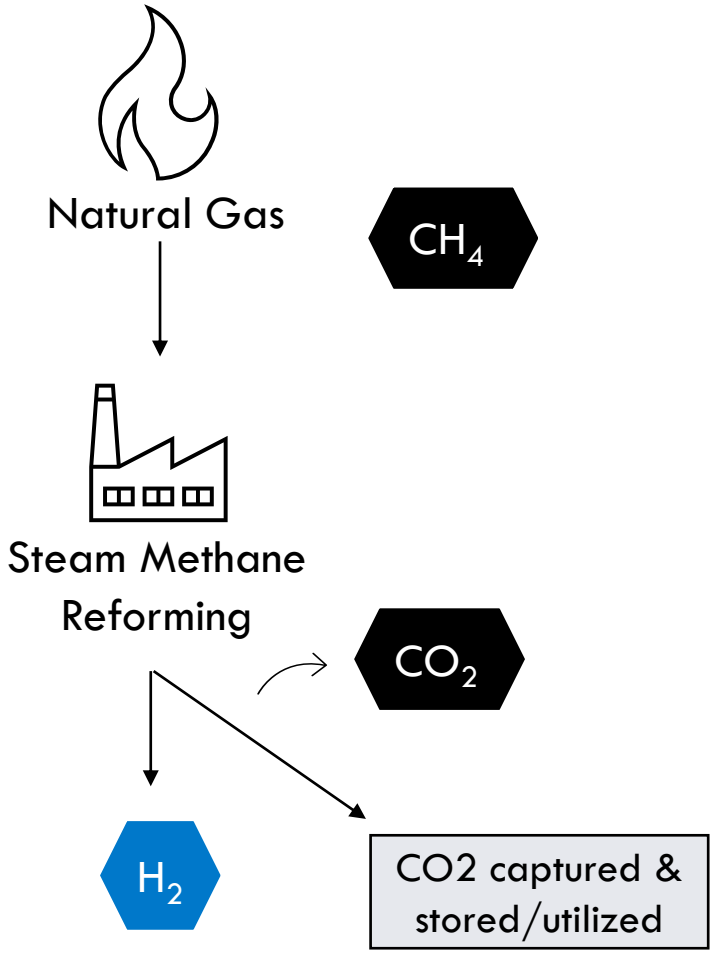
Source: Heliogen, link

Grey Hydrogen Pathway



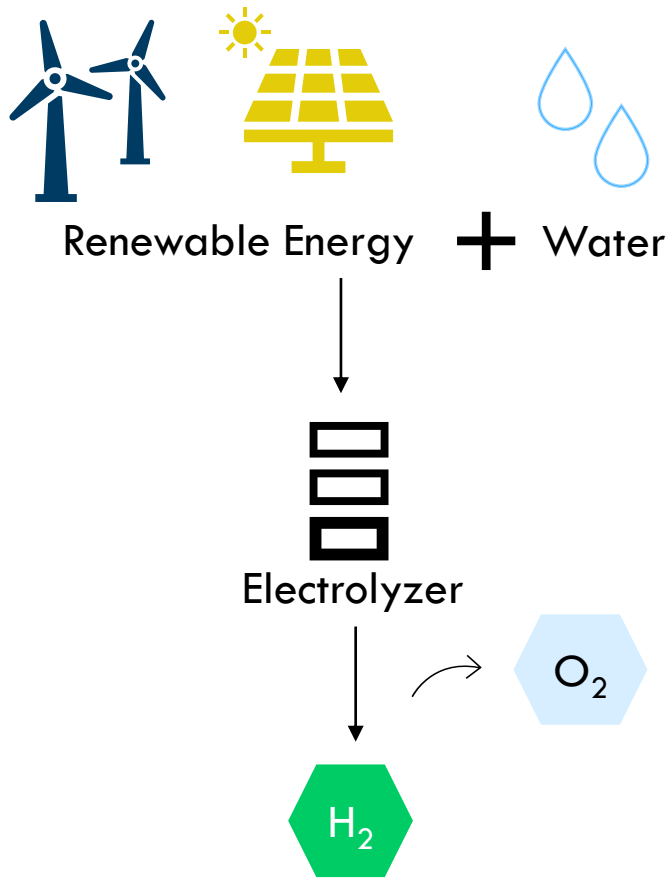
Emissions: ~10-12 $kgCO_2/kgH_2$

Blue Hydrogen Pathway



Emissions: ~2-9 $kgCO_2/kgH_2$

Green Hydrogen Pathway

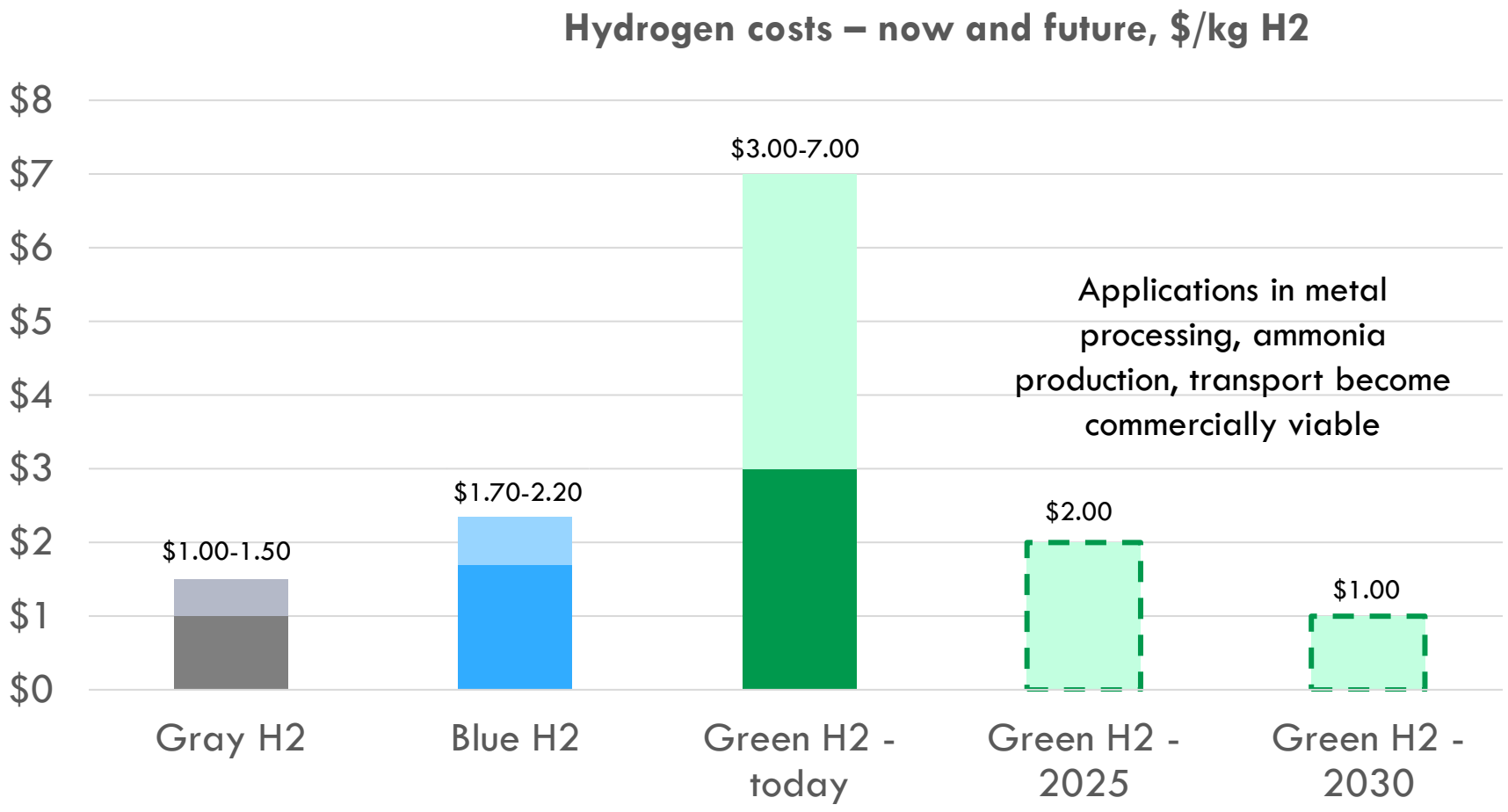


Emissions: 0 $kgCO_2/kgH_2$

Today's approximate values shown, emissions dependent on efficiency of capture, upstream emissions, electricity sourcing.
Capture rate used: 56-95%. Based on RMI analysis, the best blue (95% capture, 0.05% leakage) case still results in ~1.7kgCO2/kgH2 based on a typical grid emissions.

Cost

How much does hydrogen cost?



Source: RMI analysis; RFF analysis, link; DOE Hydrogen Shot; Carbon Brief / BloombergNEF, link

Why are green hydrogen costs expected to drop?

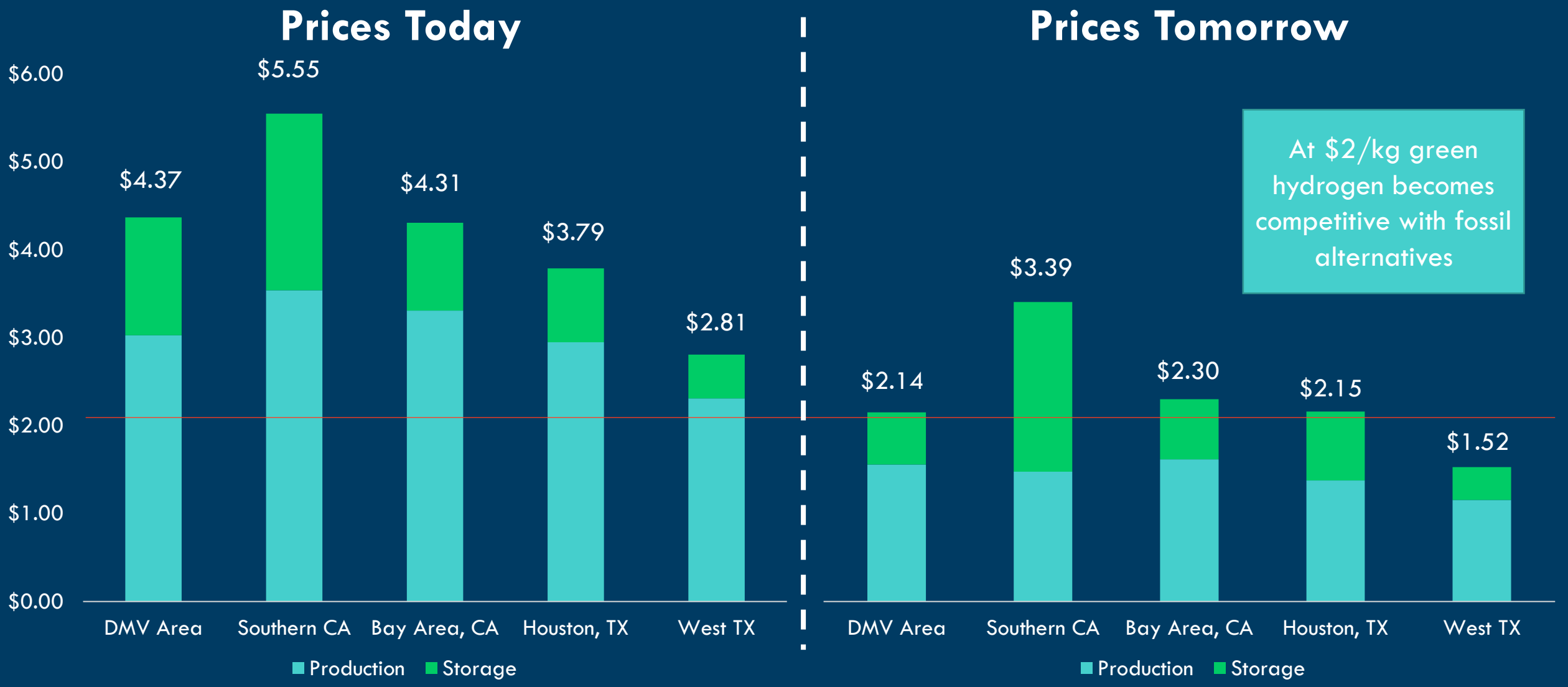
Today

- Renewables and electrolyzer are two Capex drivers
- Electrolyzers need high utilization due to Capex of ~$700/KW
- Combined wind and solar generation to improve renewable energy system availability

Tomorrow

- Improved manufacturing and system design drives electrolyzer Capex down to $200/KW
- Electrolyzer operation moves to capture generation, making utilization less critical
- Shift to use the least cost generation resource more heavily

Green hydrogen costs



Today assumes $700/kW electrolyzer capex, $800/kW solar capex, $1000/kW wind capex, and $516/kg hydrogen storage capex
Tomorrow assumes $200/kW electrolyzer capex, $500/kW solar capex, $800/kW wind capex, and $516/kg hydrogen storage capex

U.S. Policy Landscape

U.S. federal policy landscape

Oppor-tunity unlocked

Bipartisan Infrastructure Law

- 4+ hydrogen hubs **($8bn)**
- RD&D **($1.5bn)**
- National strategy; clean hydrogen definition

Reconciliation

- Production incentive of $3/kg for cleanest hydrogen; bringing renewable 'green' close to parity with fossil 'blue' and 'grey'

Sector-based proposals

Support for priority end-use sectors:

- Fertilizer
- Trucking
- Shipping
- H2 Distrib.

Notes

Requirements for:

- Feedstock diversity
- End use diversity
- Geographic diversity
- Max. employment

Tiered incentive:

- <0.45 kgCO2e/kgH2 = $3
- <1.5 = $1.00
- <2.5 = $0.75
- <4 = $0.60
- <6 = $0.45

- $500m for H2 equipment at ports and for shipping
- $1.2b for H2 in industrial end use applications
- $500m in grants/loans for H2 transport/ storage infra.

What's needed next?

The hydrogen economy needs local and state support to be successful

- **Prioritizing end uses** – directing $$ toward high-value long-term uses
- **Integrated planning** – considering system design including feedstocks
- **Permitting** – siting and building necessary infrastructure
- **Safety and handling** – updating regulations for new hydrogen industries
- **Standards/certification** – verifying emissions of hydrogen production

Not exhaustive

U.S. state policy landscape

	Current	In development
States with hydrogen strategies and/or incentives:	• California (LCFS, ZEV targets) • Washington	• California • Colorado • Illinois (stalled) • New Mexico (stalled) • New York
States with interest in H2 hub funding	• Half of U.S. states have announced interest in H2 Hub funding: • AR, AZ, CA, CO, CT, IL, LA, MA, MS, NC, ND, NJ, NM, NY, OH, OK, OR, PA, SC, TX, UT, WA, WV, WY	

Green Hydrogen Catapult

Green Hydrogen Catapult

GHC is a private sector coalition, convened with the support of the UN High-Level Climate Champions and coordinated by RMI. It bring together the world's biggest green hydrogen project developers to drive down the production cost of green hydrogen.

Our members include ACWA Power, Arcelor Mittal, CWP Renewables, Fortescue Future Industries, H2 Green Steel, HyStor, Iberdrola, Mærsk Mc-Kinney Møller Institute for Zero Carbon Shipping, Ørsted, ReNew Power, Snam, and Yara.

Our Mission is to mobilize **80GW of green hydrogen capacity by mid-2026** to catalyze market growth, making possible a future where **green hydrogen is produced well below $2/kg.**

Our Approach is focused on 1) Developing "breakthrough" green hydrogen production solutions that can meet the cost target in many regions of the world, not just the most favorable, 2) Rally coordinated action in key sector supply chains 3) Equip policy makers with insights, targets, and policy options to drive down costs to stimulate market formation.

Taking action now is critical to meet out global climate targets. **Scaling Giga-Watts requires a whole system approach** that begins with designing-in the future, the GHC is helping to lead the way.

GHC areas of focus for 2022

Mobilize GW-scale Projects and Demand

Work with demand sectors to translate commitments to real projects

Hub Demand Aggregation in Key Regions (US, EU, Global South)

- Support operationalization of medium-term targets into near-term procurement
- Aggregate portfolios of projects into hydrogen clusters

Steel

- Domestic green production pathways
- Establish procurement coalitions

Shipping

- Green corridors
- Port infrastructure and value chains
- Book and claim system

Fertilizer

- Switch production assets to green H2
- Demand aggregation via certification and buyer schemes

Supercharge policy

- Support enabling policy to foster demand in select hubs
- Demand stimulation policy blueprints
- Support to develop global Green H2 Standard

Thank you!

Questions or feedback welcome
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