U.S. DEPARTMENT OF ENERGY

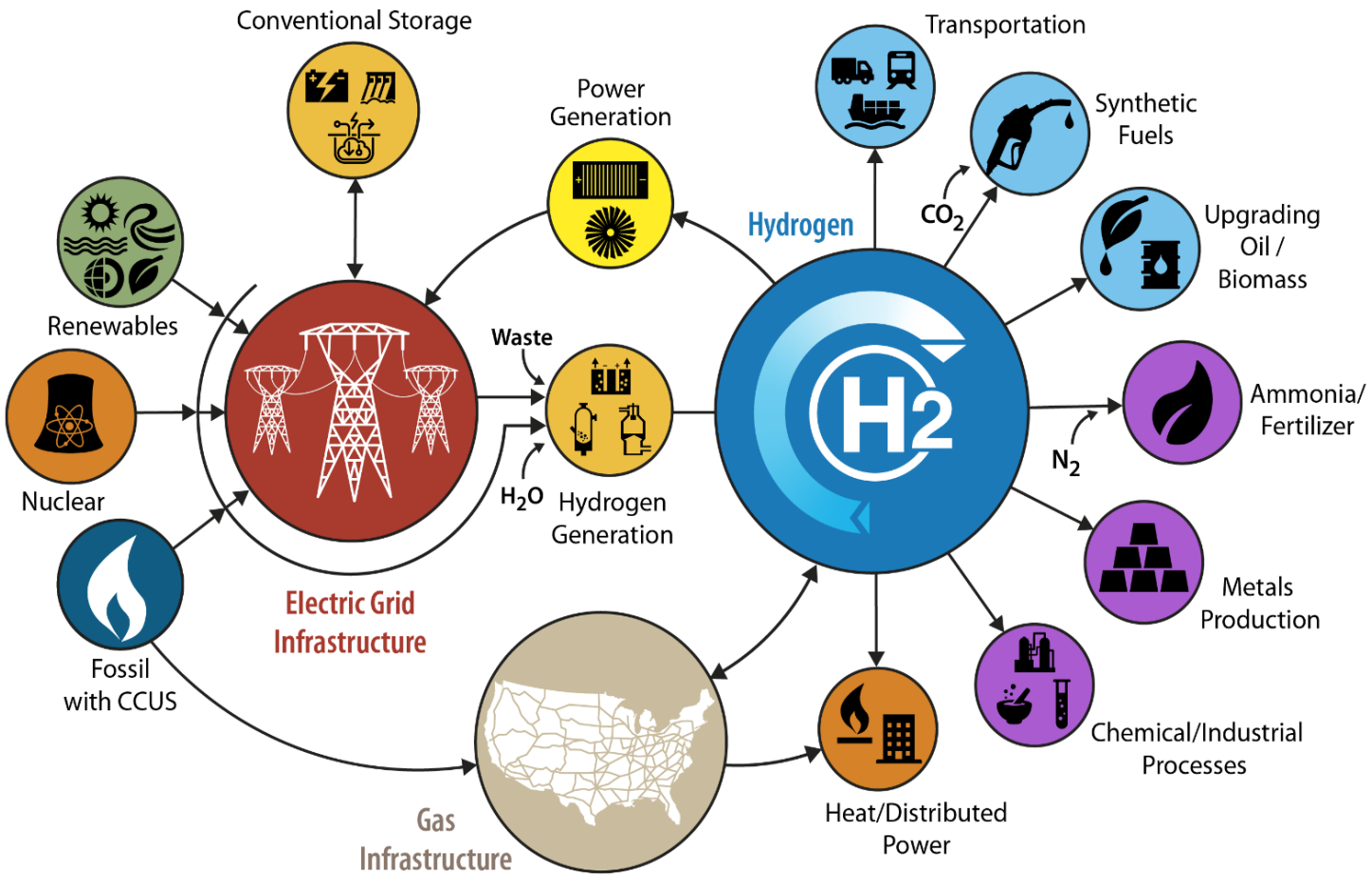
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office Perspectives on Hydrogen Energy Storage

Neha Rustagi
Hydrogen and Fuel Cell Technologies Office

"Big" Energy Storage: Priorities and Pathways to Long Duration Energy Storage
March 8, 2021

H2@Scale: Enabling affordable, reliable, clean, and secure energy



- Hydrogen can address specific applications across sectors that are hard to decarbonize
- Today: 10MMT H_2 in the U.S.
- Economic Potential: 2 to 4x more[1]

Strategies

- Scale up technologies in key sectors
- Continue R&D to reduce cost and improve performance, reliability $1 to $2/kg H_2
- Address enablers: harmonization of codes, standards, safety, global supply chain, workforce development, sustainable markets

Source: U.S. DOE Hydrogen and Fuel Cell Technologies Office, https://www.energy.gov/eere/fuelcells/h2scale

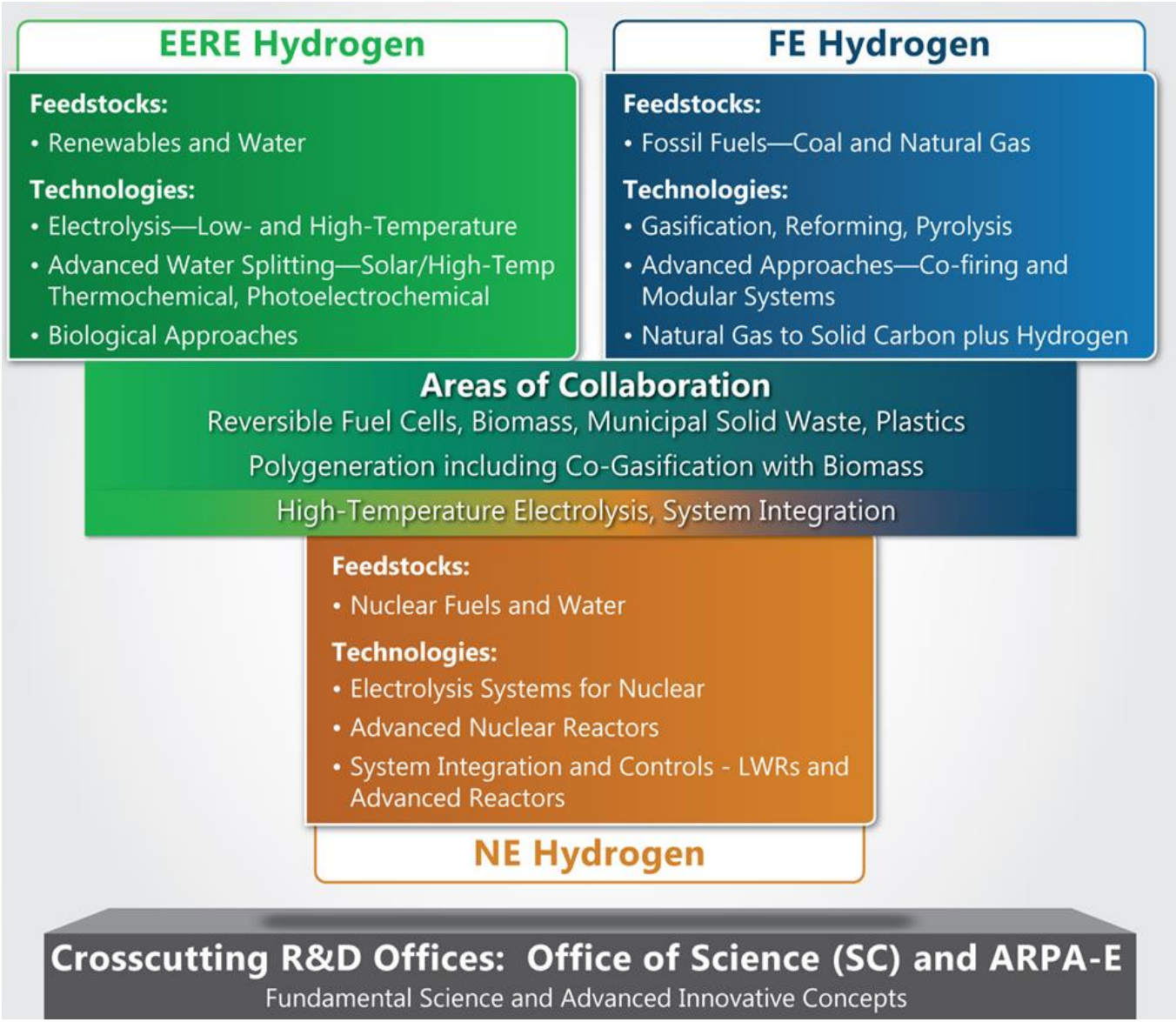
1. https://www.nrel.gov/docs/fy21osti/77610.pdf

Key Program Targets and Key R&D Office Activities

Examples of Key DOE Hydrogen Program Targets

DOE targets are application-specific and developed with stakeholder input to enable competitiveness with incumbent and emerging technologies. These targets guide the R&D community and inform the Program's portfolio of activities. Examples include:

- $2/kg for hydrogen production and $2/kg for delivery and dispensing for transportation applications
- $1/kg hydrogen for industrial and stationary power generation applications
- Fuel cell system cost of $80/kW with 25,000-hour durability for long-haul heavy-duty trucks
- On-board vehicular hydrogen storage at $8/kWh, 2.2 kWh/kg, and 1.7kWh/l
- Electrolyzer capital cost of $300/kW, 80,000 hour durability, and 65% system efficiency
- Fuel cell system cost of $900/kW and 40,000 hour durability for fuel-flexible stationary high-temperature fuel cells



Snapshot of Hydrogen and Fuel Cell Applications in the U.S.

Examples of Applications

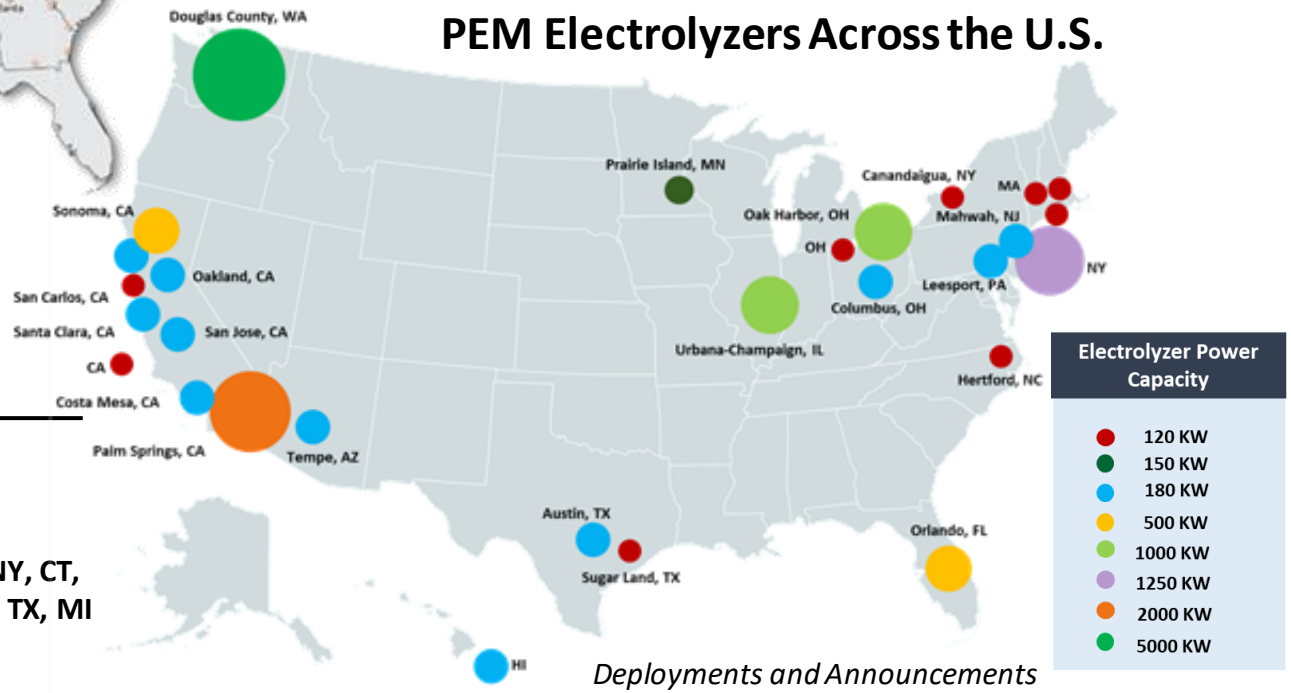
- **>500MW** — Backup Power
- **>35,000** — Forklifts
- **>14 MW** — PEM* Electrolyzers
- **>60** — Fuel Cell Buses
- **>45** — H_2 Retail Stations
- **>9,000** — Fuel Cell Cars

*Polymer electrolyte membrane

Hydrogen Produced

- 10 million metric tons produced annually
- More than 1,600 miles of H_2 pipeline
- World's largest H_2 storage cavern

PEM Electrolyzers Across the U.S.



Deployments and Announcements

* Polymer electrolyte membrane

Hydrogen Stations Plans Across States

California

200 Stations Planned
CAFCP Goal

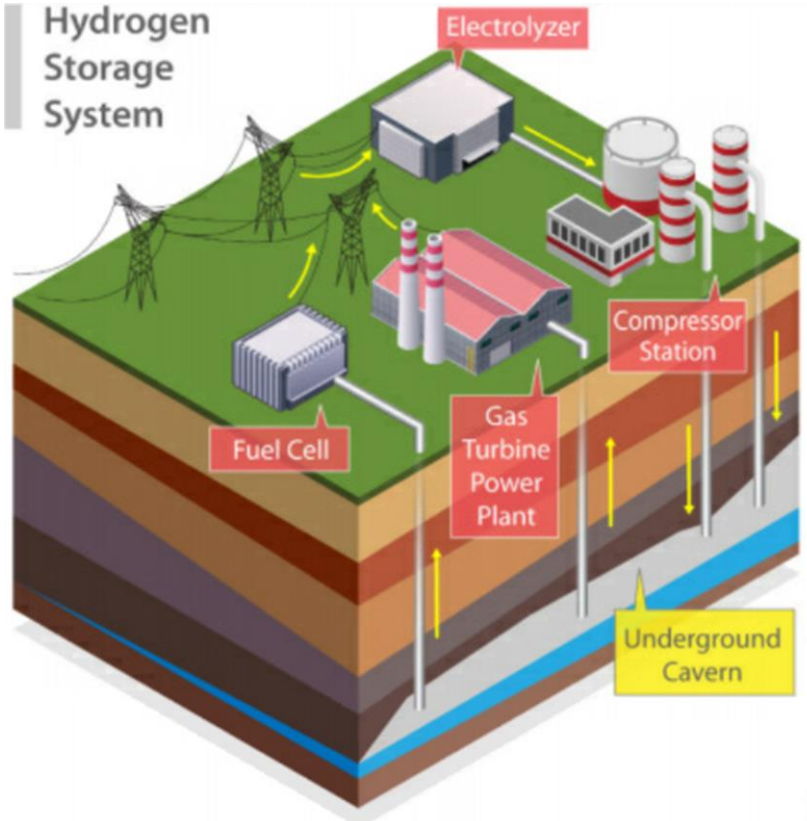
Northeast

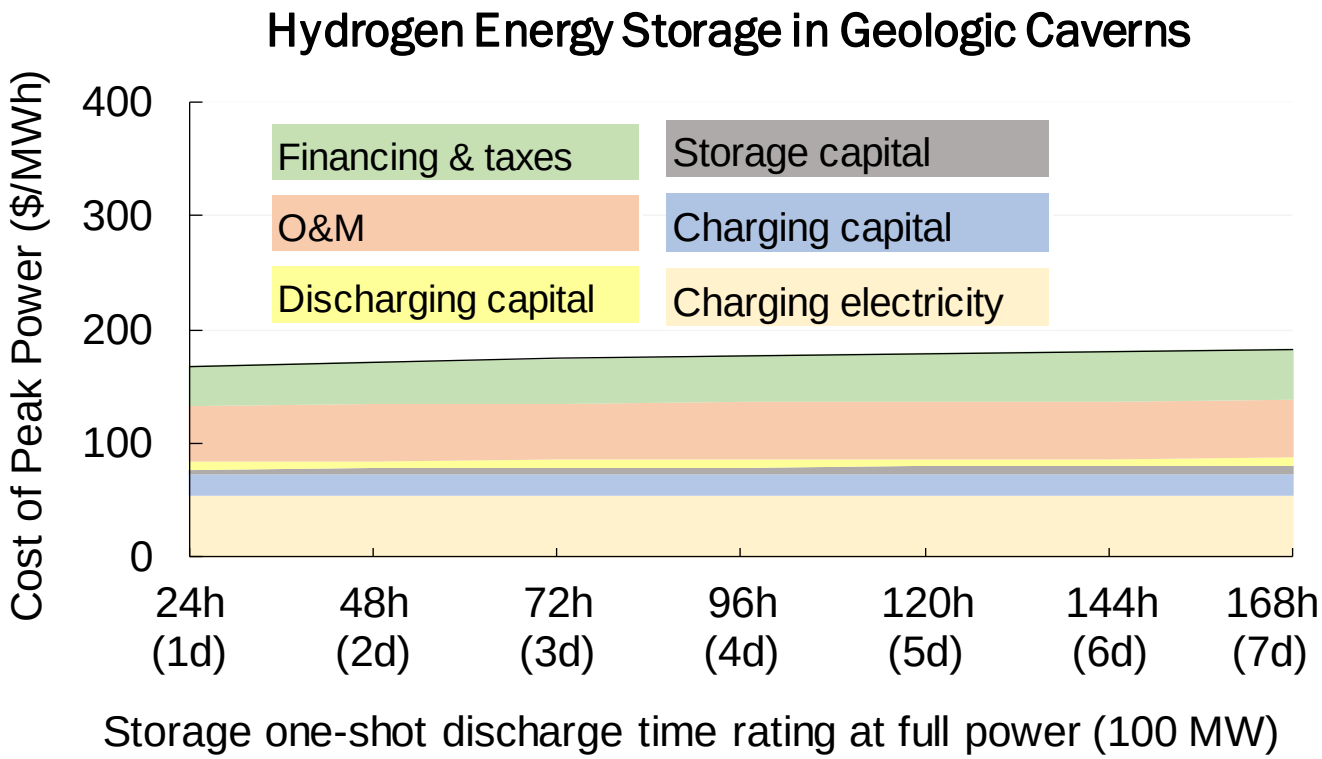
12 – 20
Stations Planned

HI, OH, SC, NY, CT, MA, CO, UT, TX, MI

And Others

Overview of Hydrogen Energy Storage Technologies





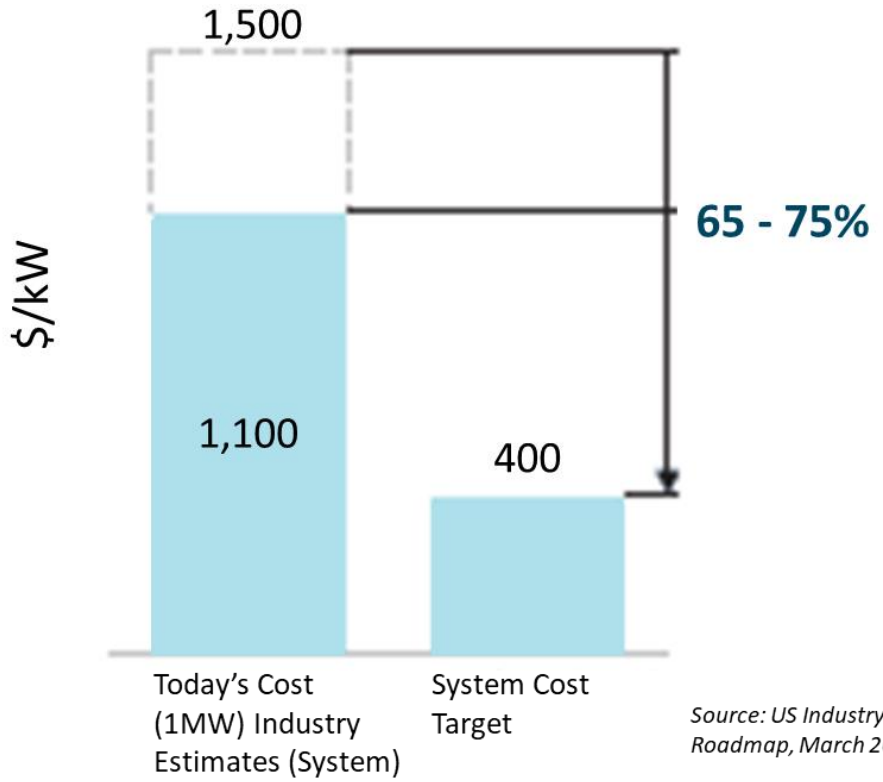
Hydrogen energy storage involves use of an electrolyzer, bulk storage (e.g. cavern or underground pipe), and fuel cell or turbine.

Hydrogen energy storage is competitive at long durations due to the low cost of each additional hour. Value proposition can be enhanced through RD&D that improves efficiency and reduces capital cost.

Source of Images: (Left) "The Four Phases of Storage Deployment: A Framework for the Expanding Role of Storage in the U.S. Power System.". 2021. NREL. https://www.nrel.gov/docs/fy21osti/77480.pdf, and (right) Hunter, et. al., in press. 2021. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3720769

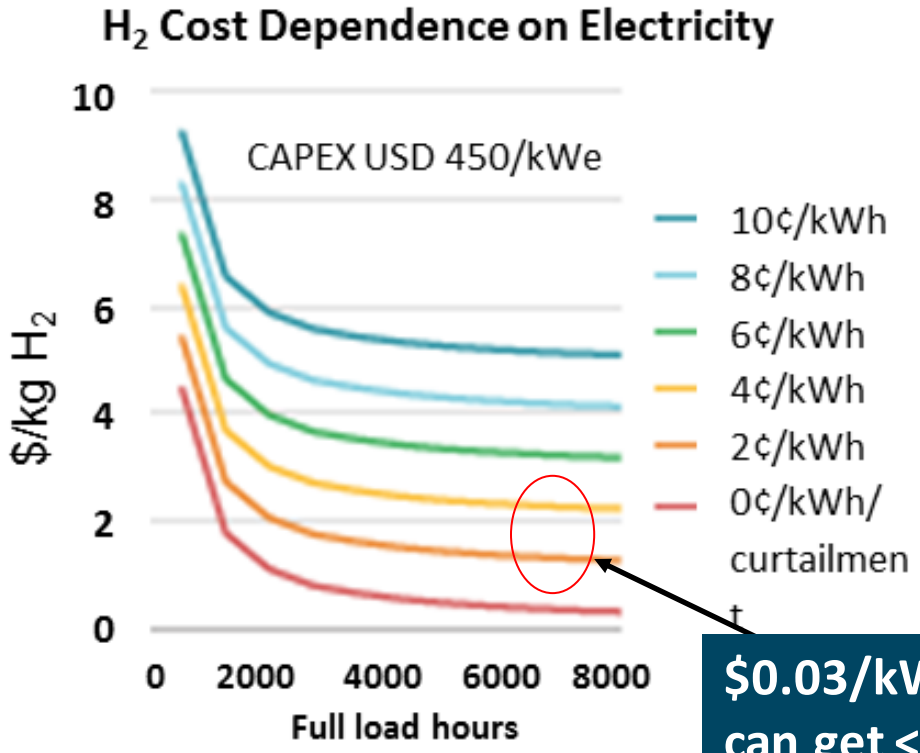
Electrolysis Cost – Recent Independent Analyses

Today's Polymer Electrolyte Membrane (PEM) electrolyzers require 65 75% cost reduction



Source: US Industry H2 Roadmap, March 2020

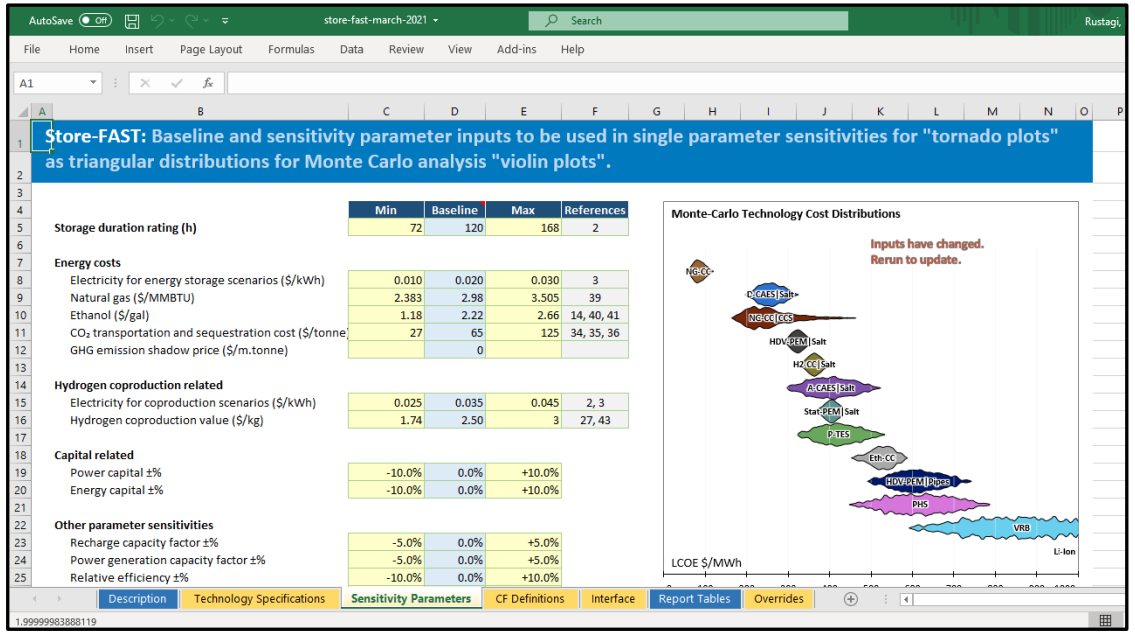
$2/kg H2 is achievable at about $0.03/kWh electricity cost and high utilization



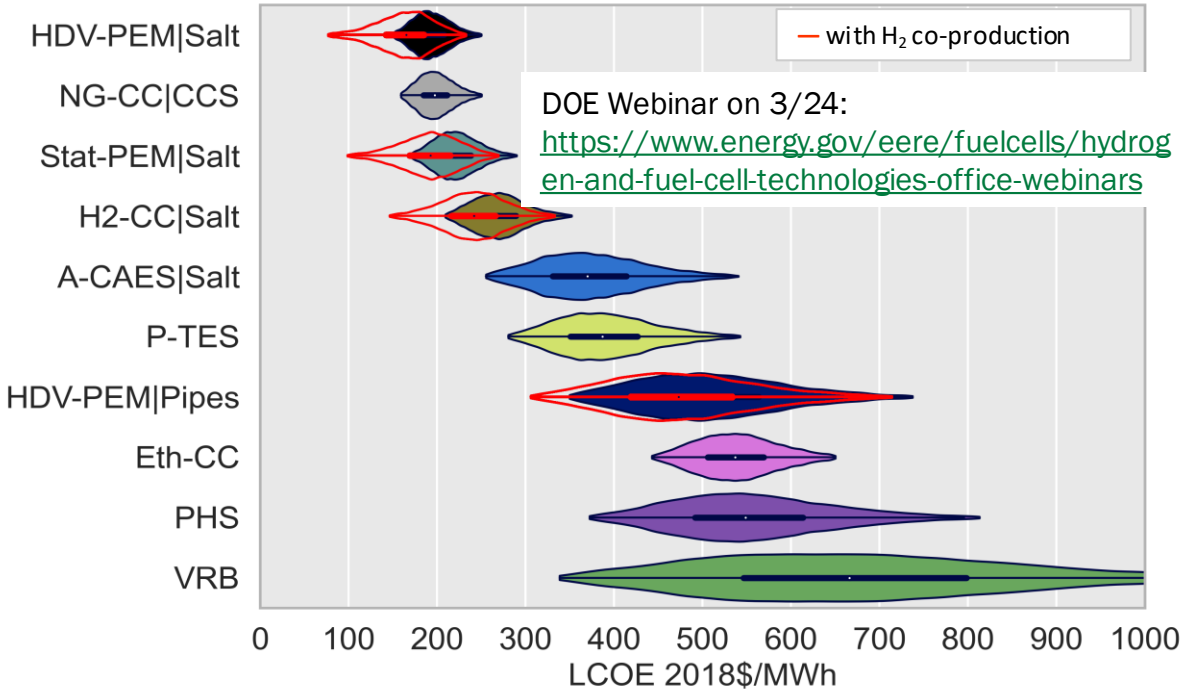
Source: IEA Hydrogen Future Report 2019

Today's hydrogen cost from PEM electrolyzers: ~ $5 to $6/kg at $0.05 to $0.07/kWh

Techno-Economic Analysis of Long Duration Energy Storage



	Min	Baseline	Max	References
Storage duration rating (h)	72	120	168	2
Energy costs				
Electricity for energy storage scenarios ($/kWh)	0.010	0.020	0.030	3
Natural gas ($/MMBTU)	2.383	2.98	3.505	39
Ethanol ($/gal)	1.18	2.22	2.66	14, 40, 41
CO_2 transportation and sequestration cost ($/tonne)	27	65	125	34, 35, 36
GHG emission shadow price ($/m.tonne)		0		
Hydrogen coproduction related				
Electricity for coproduction scenarios ($/kWh)	0.025	0.035	0.045	2, 3
Hydrogen coproduction value ($/kg)	1.74	2.50	3	27, 43
Capital related				
Power capital ±%	-10.0%	0.0%	+10.0%	
Energy capital ±%	-10.0%	0.0%	+10.0%	
Other parameter sensitivities				
Recharge capacity factor ±%	-5.0%	0.0%	+5.0%	
Power generation capacity factor ±%	-5.0%	0.0%	+5.0%	
Relative efficiency ±%	-10.0%	0.0%	+10.0%	



The StoreFAST model simulates levelized cost of energy storage given user inputs of technology cost and electricity price.[1]

Hydrogen energy storage is competitive at long durations. Co-production of hydrogen for other regional markets can enhance value proposition by 10-40%.[2]

Key Assumptions:

- Wholesale renewable electricity: 2¢/kWh
- 120 hours of energy storage
- Future technology costs, assuming economies of scale

1. Model developed by the National Renewable Energy Laboratory and available at https://www.nrel.gov/storage/storefast.html *Currently under beta testing*
2. Hunter, et al. 2021. in press. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3720769

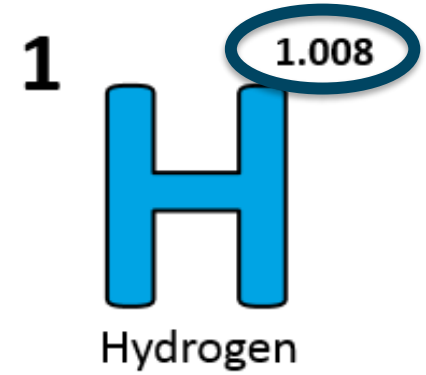
Resources and Events

Save the Date

Week of June 7, 2021
Annual Merit Review and Peer Evaluation Meeting (AMR) for the DOE Hydrogen and Fuel Cells Program

Oct 8 - Hydrogen and Fuel Cells Day

(Held on its very own atomic weight-day)



Resources

INCREASE YOUR H2IQ

Join Monthly
H2IQ Hour Webinars

Download
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energy.gov/eere/fuelcells/fuel-cell-technologies-office-webinars

energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

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Additional Information

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