U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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Introduction to the DOE Hydrogen Program

Dr. Ned Stetson (Program Manager),
Hydrogen and Fuel Cell Technologies Office

Advanced Materials for PEM Electrolyzer Virtual Workshop, March 30-31, 2022

Thank You for Joining Us!

Special thanks to the Organizing Team…

HFTO	***National Labs***
James Vickers	*Bryan Pivovar*
Dave Peterson	***The Building People***
McKenzie Hubert	
Anne Marie Esposito	*Stacey Young*

And all Speakers, Panelists, Moderators, & Scribes!

Mike Hickner
Iryna Zenyuk
Kathy Ayers
Corky Mittelsteadt
Nemanja Danilovic
Ton Hurkmans
Debbie Myers
Shaun Alia
DJ Liu
Ahmet Kusoglu
Guido Bender
Alexey Serov

Jacob Spendelow
Tom Zawodzinski
Rod Borup
Julie Forniciari
Ahmed Farghaly
Jake Wrubel
Jason (Keonhag) Lee
Leiming Hu
Elliot Padgett
Eun Joo (Sarah) Park
James Young

H2NEW Hydrogen from Next-generation Electrolyzers of Water
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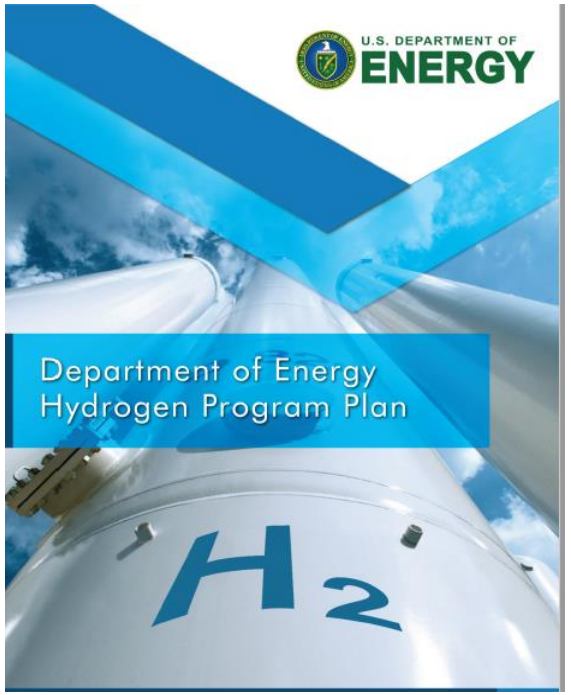
The U.S. DOE Hydrogen Program

Key DOE Hydrogen Authorizations in the Energy Policy Act (2005, 2020) and Infrastructure Investment and Jobs Act (2021)

Hydrogen is one part of a broad portfolio of activities



www.hydrogen.energy.gov

The DOE Hydrogen Program is an agency wide effort, encompassing efforts from across the DOE

EERE – Hydrogen and Fuel Cell Technologies Office – H_2 Program Coordination Lead

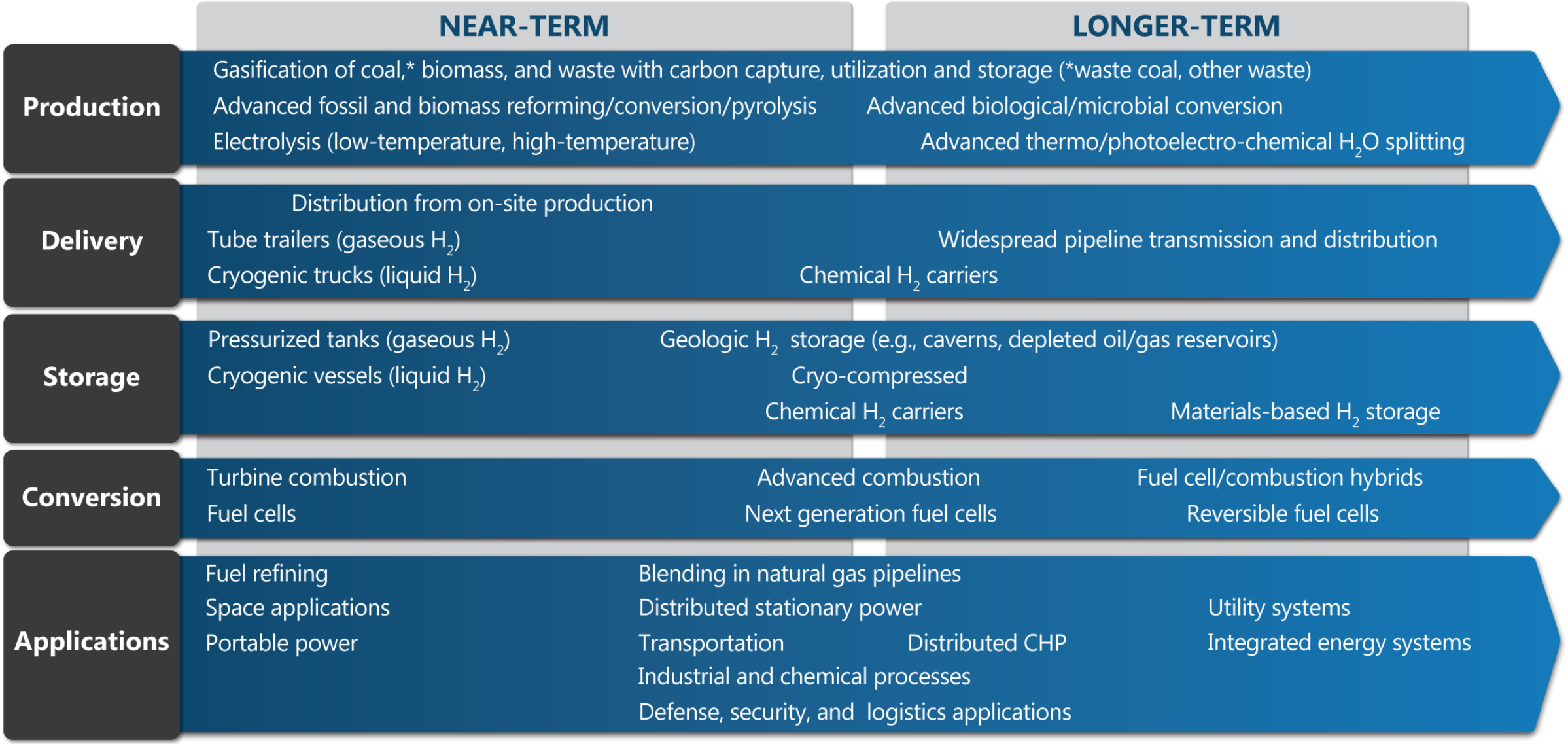
Office of Energy Efficiency and Renewable Energy
Office of Fossil Energy and Carbon Management
Office of Nuclear Energy
Office of Electricity
Office of Science
Office of Clean Energy Demonstrations
Advanced Research Projects Agency – Energy
Office of Technology Transition
Loan Program Office

Priorities

1. **Low-cost, clean hydrogen**
2. **Low-cost, efficient, safe hydrogen delivery and storage**
3. **Enable end-use applications at scale for impact**

Workforce development, safety, codes, standards, and Environmental Justice priorities

Hydrogen Program Areas of Focus across Multiple Offices



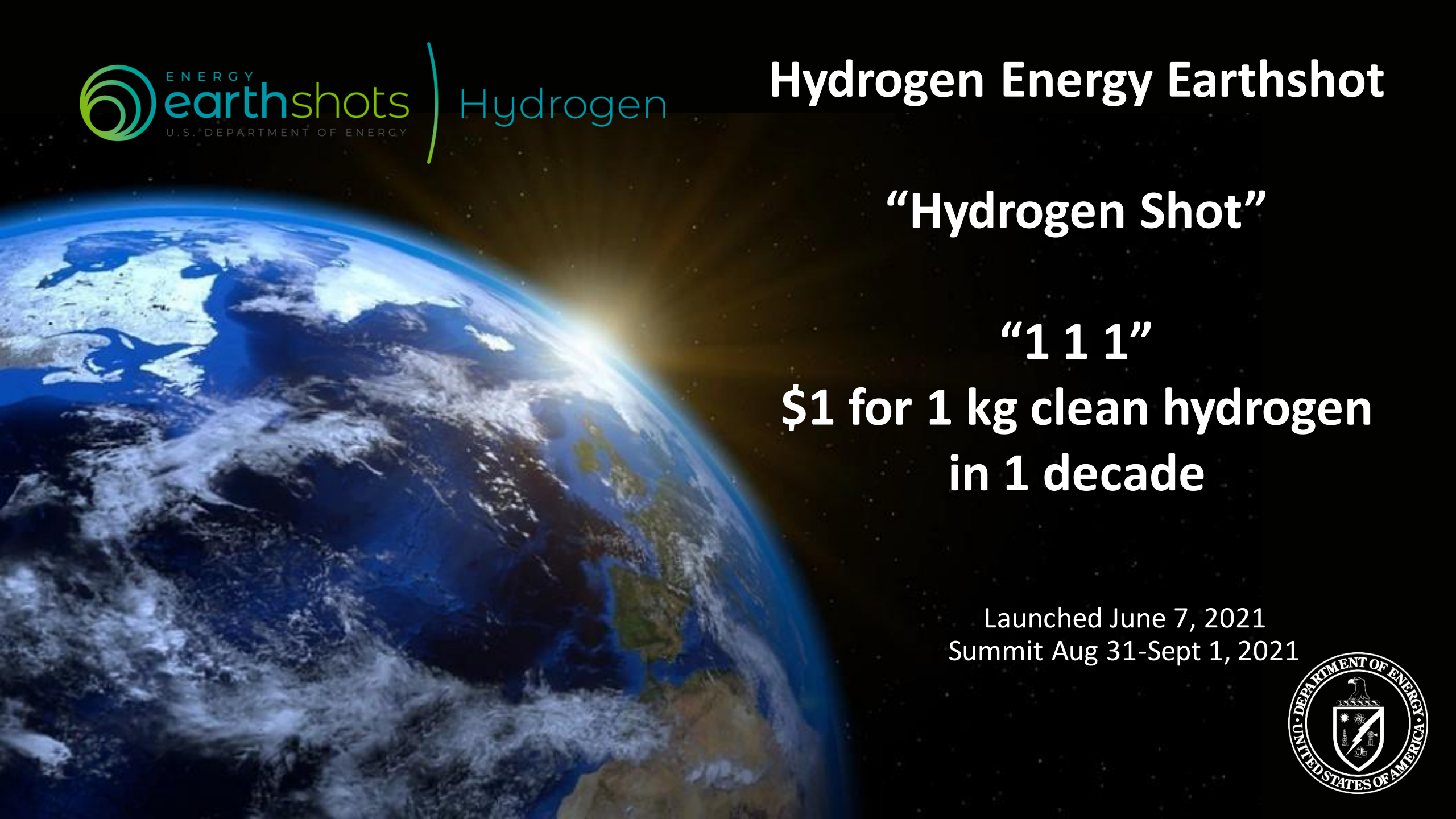
President Biden and Energy Secretary Granholm at Climate Summit

"…I've asked the Secretary of Energy to speed the development of critical technologies to tackle the climate crisis. No single technology is the answer on its own because every sector requires innovation to meet this moment."

President Joseph R. Biden
April 23, 2021

Launch of Hydrogen Energy Earthshot
First of the Energy Earthshots
June 7, 2021
at DOE Hydrogen Program Annual Merit Review

Secretary Jennifer Granholm
June 7, 2021



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Hydrogen Energy Earthshot

"Hydrogen Shot"

"1 1 1"
$1 for 1 kg clean hydrogen in 1 decade

Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

Bipartisan Infrastructure Law - Hydrogen Highlights

- **Includes $9.5B for clean hydrogen:**
  - $8B for at least four regional clean hydrogen hubs
  - $1B for electrolysis research, development, demonstration, commercialization, and deployment
  - $500M for clean hydrogen technology manufacturing and recycling R&D

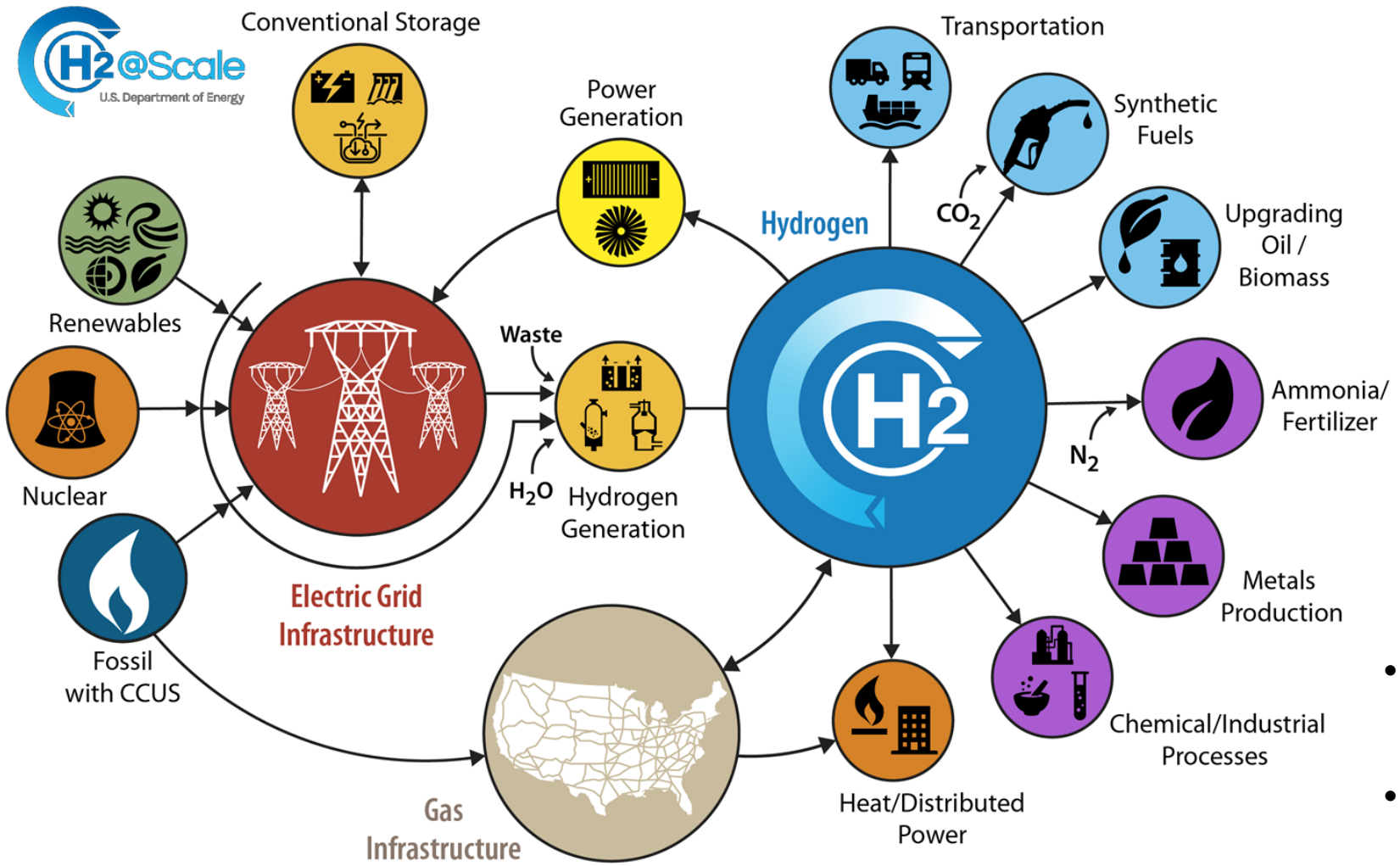
President Biden Signs the Bipartisan Infrastructure Bill on November 15, 2021.
Photo Credit: Kenny Holston/Getty Images

- **Aligns with Hydrogen Shot priorities by directing work to reduce the cost of clean hydrogen to $2 per kilogram by 2026**
- **Requires developing a National Hydrogen Strategy and Roadmap and Clean H_2 Standard**

Gathering stakeholder input for program planning

- Recent workshops and experts' meetings
  - Power and Control Electronics for Hydrogen Technologies – Dec. 2-3, 2021
  - Advanced Liquid Alkaline Water Electrolysis - January 26-27, 2022
  - Bulk Storage of Gaseous Hydrogen – February 10-11, 2022
  - Liquid Hydrogen Technologies – February 22-23, 2022
  - High-Temperature Electrolyzer Manufacturing - March 8-9, 2022
  - Advanced Materials for PEM Electrolyzers – March 30-31, 2022
- Request for Information
  - DE-FOA-0002698 RFI on Clean Hydrogen Manufacturing, Recycling, and Electrolysis
    - Official close date: yesterday March 29th, however responses will still be accepted
- Stay tuned for additional events, especially on manufacturing and recycling needs

H2@Scale: Enabler for Deep Decarbonization across Sectors and Jobs



Key Opportunities

- **Industry and Chemicals**
  Steel, ammonia, cement, syn fuels (e.g., aviation), exports
- **Transportation**
  Trucks, marine, buses, etc.
- **Power and Energy Storage**
  Long duration storage, NG blending, turbines, fuel cells

U.S. Snapshot

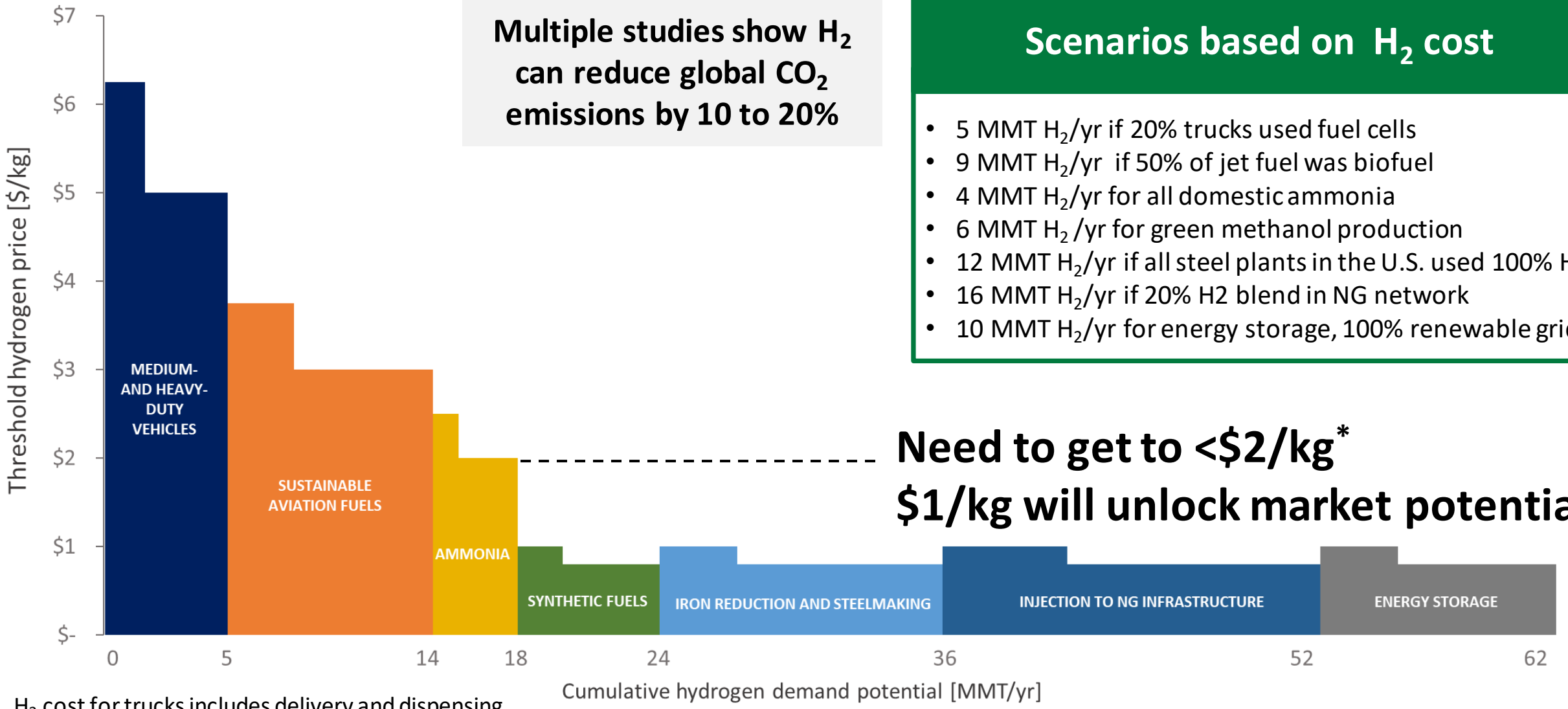
- 10 MMT of H_2/yr produced today with scenarios for 2-5X growth.
- +10 MMT clean H_2 could require ~ double today's solar or wind deployment
- Potential for 700K jobs, $140B by 2030

Analysis of Potential Market Demand Scenarios

Multiple studies show H_2 can reduce global CO_2 emissions by 10 to 20%

Scenarios based on H_2 cost

- 5 MMT H_2/yr if 20% trucks used fuel cells
- 9 MMT H_2/yr if 50% of jet fuel was biofuel
- 4 MMT H_2/yr for all domestic ammonia
- 6 MMT H_2 /yr for green methanol production
- 12 MMT H_2/yr if all steel plants in the U.S. used 100% H_2
- 16 MMT H_2/yr if 20% H2 blend in NG network
- 10 MMT H_2/yr for energy storage, 100% renewable grid



**Need to get to <$2/kg*
$1/kg will unlock market potential**

H_2 cost for trucks includes delivery and dispensing

* H_2 could compete at $1 to $2/kg higher cost with a carbon price

Results based on preliminary analysis

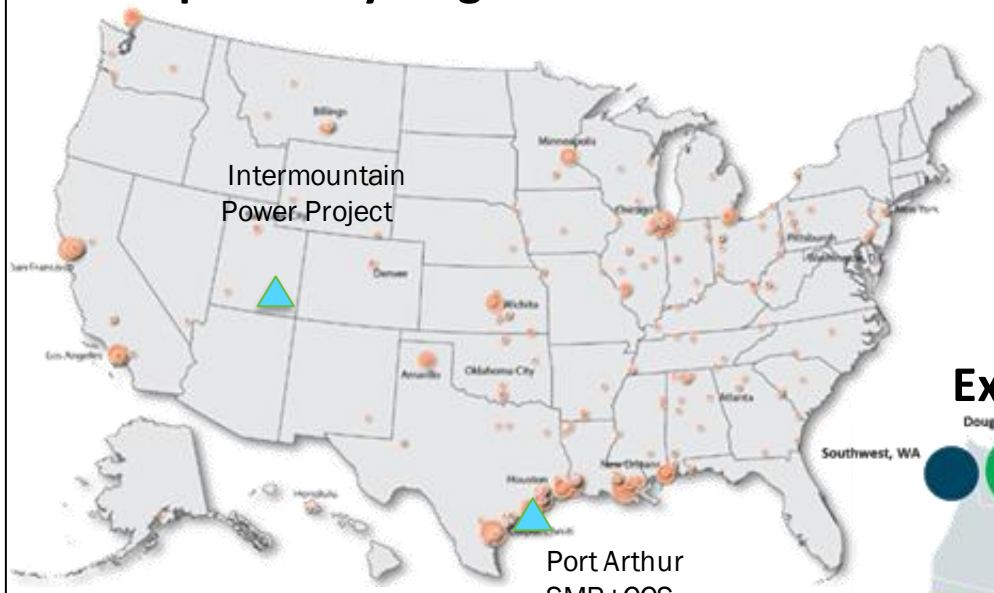
Snapshot of Hydrogen and Fuel Cells in the U.S.

Deployment Examples
March 2022 Snapshot

- **>500MW** Backup Power
- **>50,000** Forklifts
- **>172 MW** PEM* Electrolyzers
- **>75** Fuel Cell Buses
- **>50** H_2 Retail Stations
- **>12,500** Fuel Cell Cars

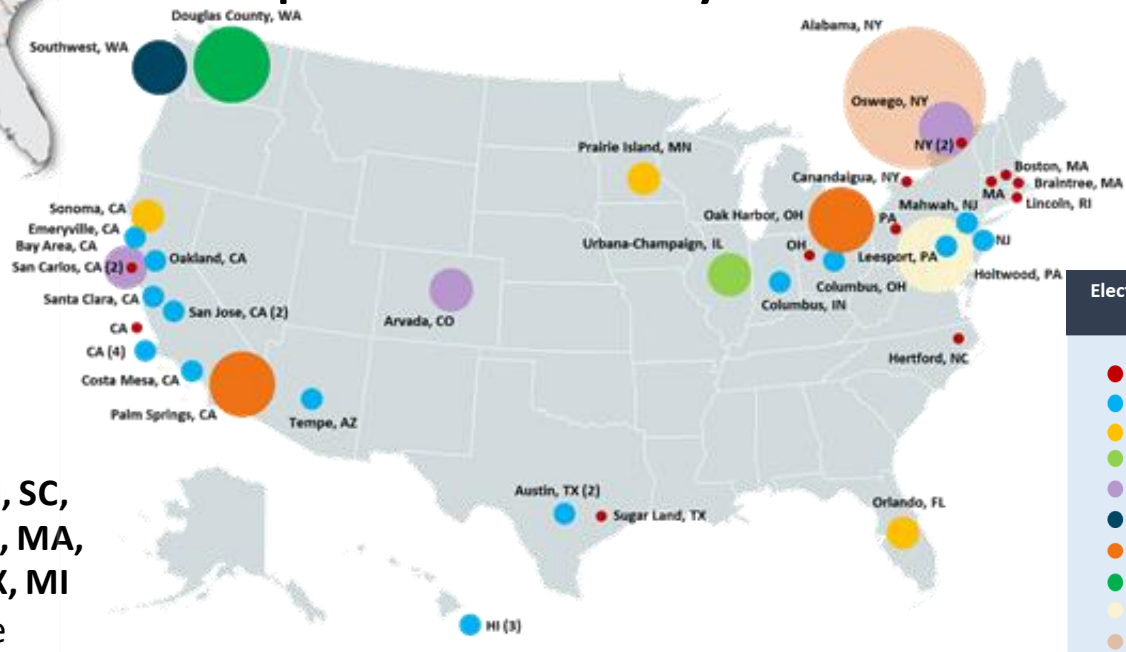
* Polymer electrolyte membrane

Examples of Hydrogen Production Locations



- 10 million metric tons (MMT) H_2/yr
- Over 1,600 miles of H_2 pipelines
- World's largest H_2 storage cavern

Examples of PEM Electrolyzer Installations



Current and under construction installations over 120 kW as of Jun. 2021
** Source: Arjona, et al, DOE HFTO Program Record, June 2021*

Examples of Hydrogen Station Plans

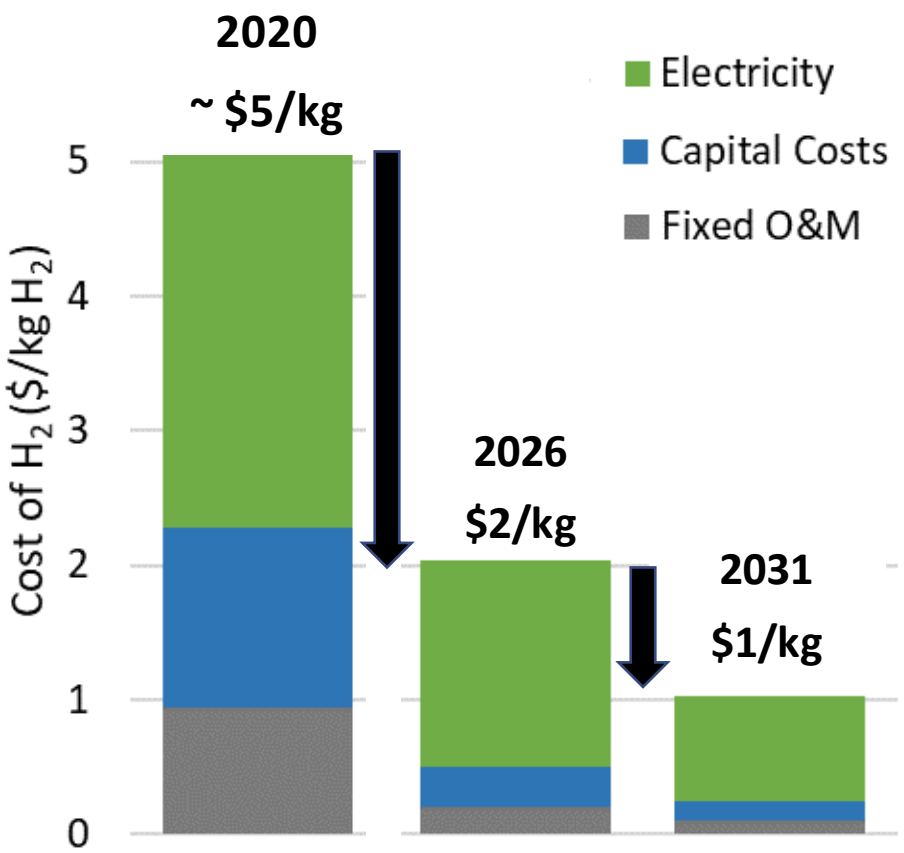
California
200 Stations Planned
California Fuel Cell Partnership Goal

Northeast
12 – 20 Stations Planned

AZ, HI, OH, SC, NJ, NY, CT, MA, CO, UT, TX, MI
And more

Pathways to Reduce the Cost of Electrolytic H_2

Cost Reduction of Clean Electrolytic H_2

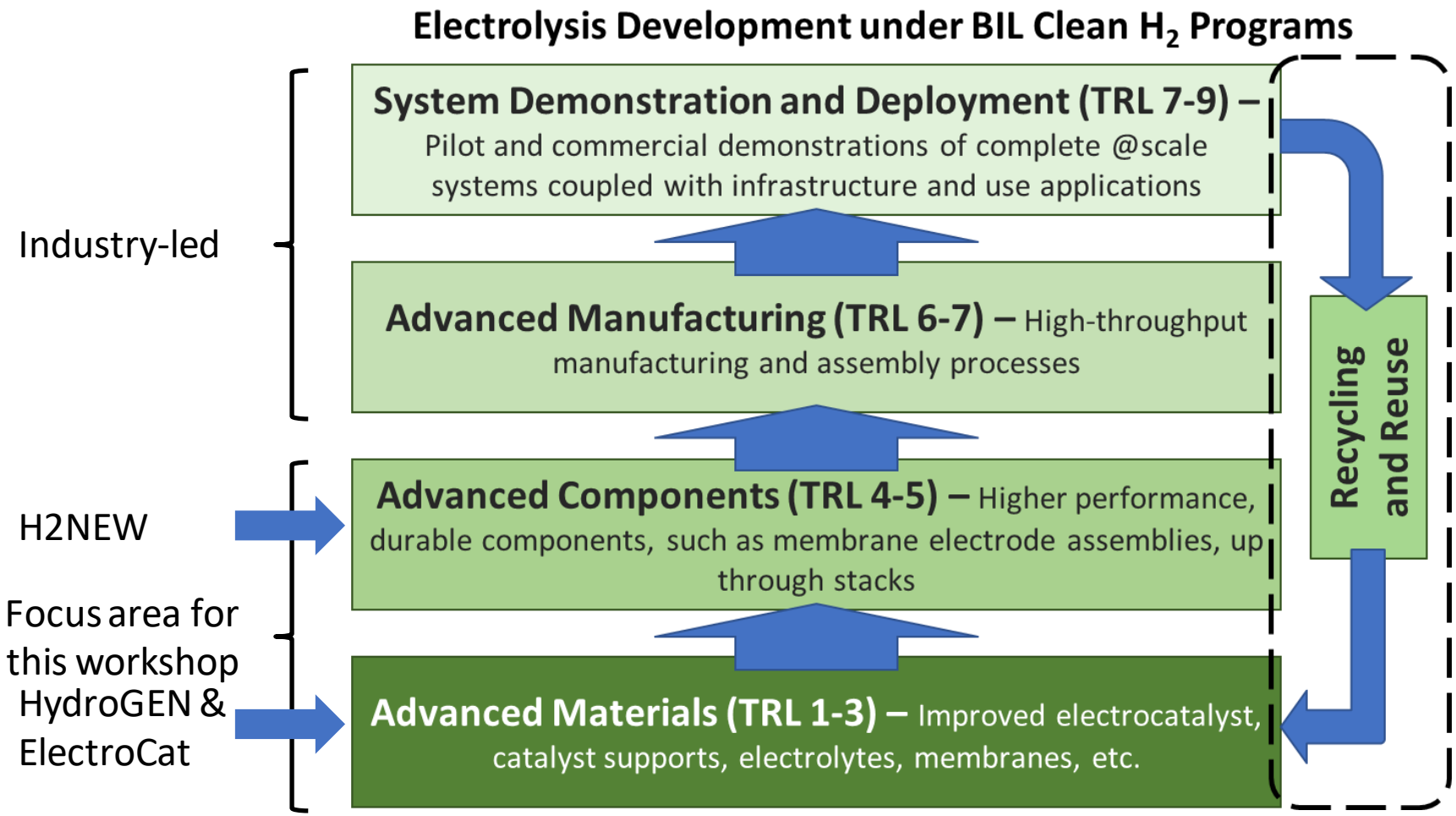


Key enablers for lower cost electrolytic H_2:

- Low-cost electricity, variable operation
- High electrical efficiency
- Low-cost capital expense
- Increased durability/lifetime
- Low-cost manufacturing processes
- Manufacturing at MW-scale
- Increased power density

Electrolyzer goals for 2026	Unit	PEM	SOEC
Higher electrical efficiency	kWh/kg	≤ 48	≤ 34
Lower stack costs	$/kW	≤ 100	≤ 100
Increased durability	hours	80,000	60,000
Lower system CAPEX	$/kW	≤ 250	≤ 300

Comprehensive electrolysis RDD&D Program



BIL Clean Hydrogen Programs allows for the complete development, demonstration, deployment and end-of-life recovery lifecycle for electrolysis technologies

Workshop focus and objectives

- **To achieve the DOE H_2 Shot's and BIL Electrolysis Program's goals, low-cost commercial electrolyzer technologies will be essential**
  - What advanced materials need to be developed for PEM electrolyzers?
  - What is needed to advance novel PEM electrolyzer materials to the point of incorporation into commercial products?
- **What is the role for the DOE in developing and supporting advanced materials for PEM electrolysis**
  - What are the priority areas DOE should focus on?
  - What are the R&D needs for individual components?
- **Provide input on stakeholder needs that can form a basis for DOE-supported R&D efforts to advance electrolyzer technology for clean H_2 production**

Meeting Objectives

Day 1 – Expert Presentations

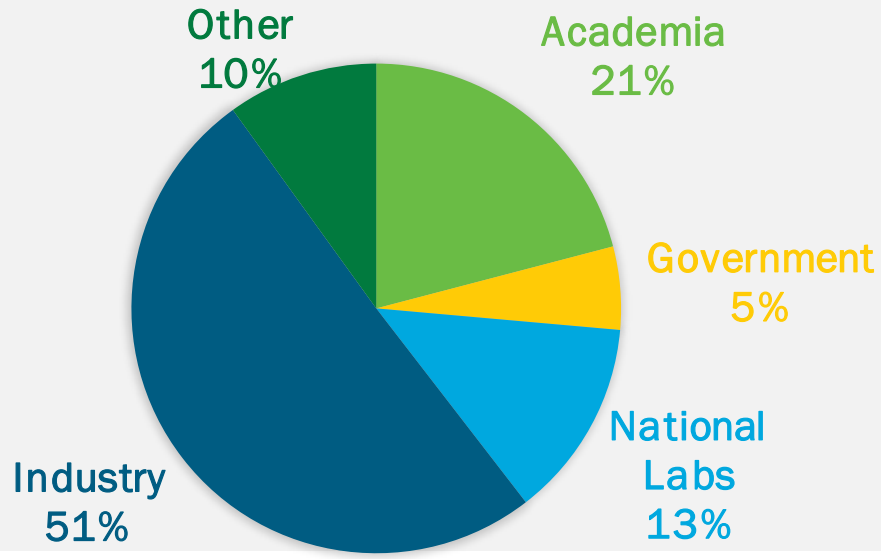
Hear from experts on the challenges and opportunities for advanced PEM electrolyzer materials

Day 2 – Breakout Discussions

Discuss and prioritize the most promising and impactful opportunities for PEM Advanced Materials

Identify pathways to achieve $1/kg H_2

Diverse stakeholders from industry, government, academia & the labs



Please use the Zoom *Q&A* feature to submit your comments & questions during the meeting

Thank you for your participation

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www.energy.gov/fuelcells
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