U.S. DEPARTMENT OF ENERGY

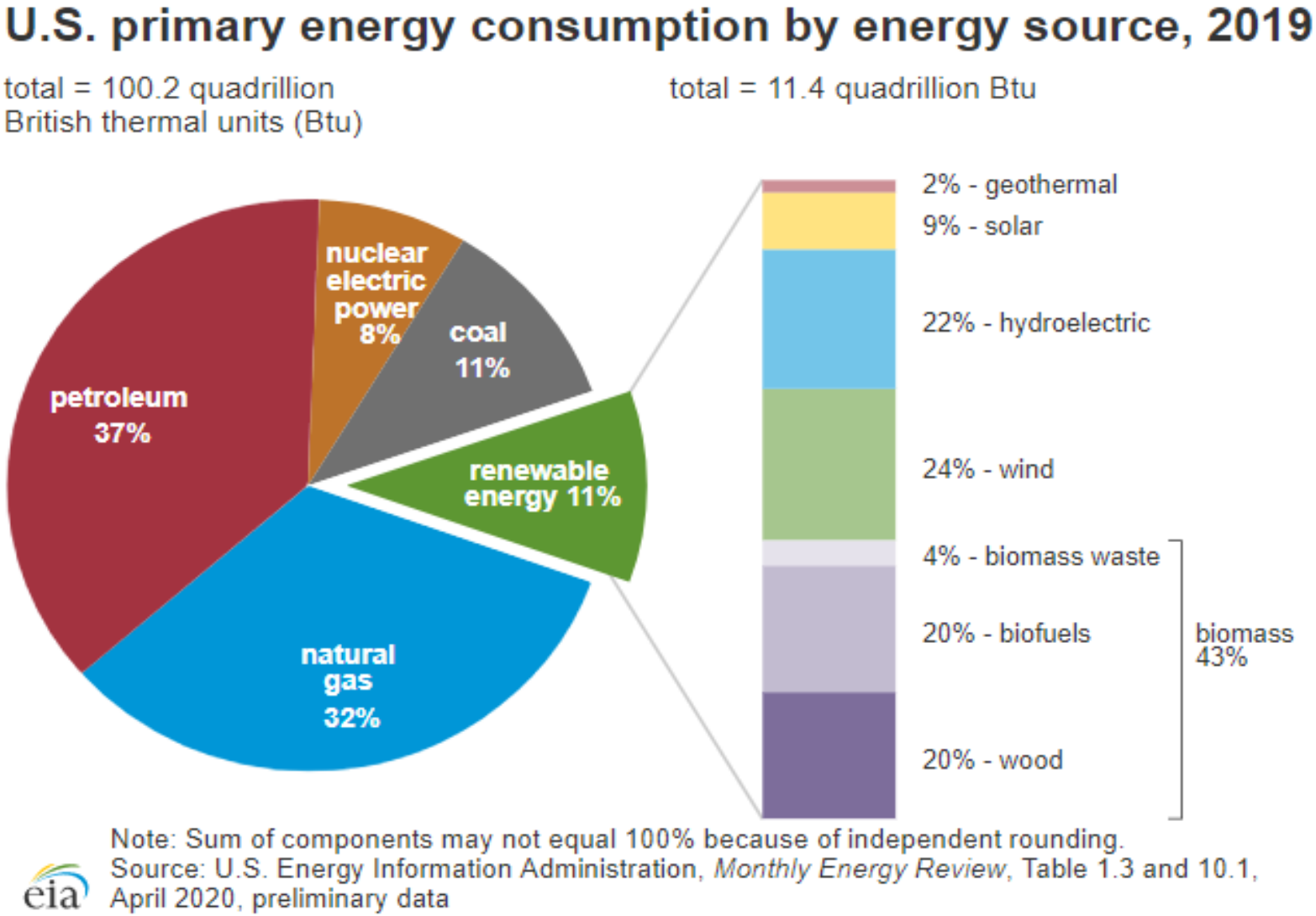
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. DOE Hydrogen and Fuel Cell Perspectives

Dr. Sunita Satyapal, Hydrogen and Fuel Cell Technologies Office Director and Hydrogen Program Coordinator, U.S. Department of Energy

December 1, 2021

U.S. Energy Landscape and Key Goals



Administration Goals include:

- Net zero emissions economy by 2050
- 100% carbon-pollution-free electric sector by 2035

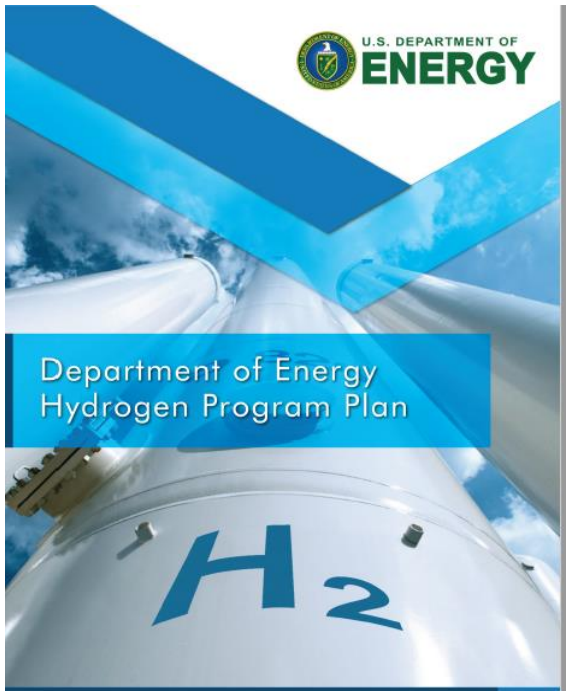
Priorities: Ensure benefits to all Americans, focus on jobs, EJ40: 40% of benefits in disadvantaged communities

EJ: Environmental Justice

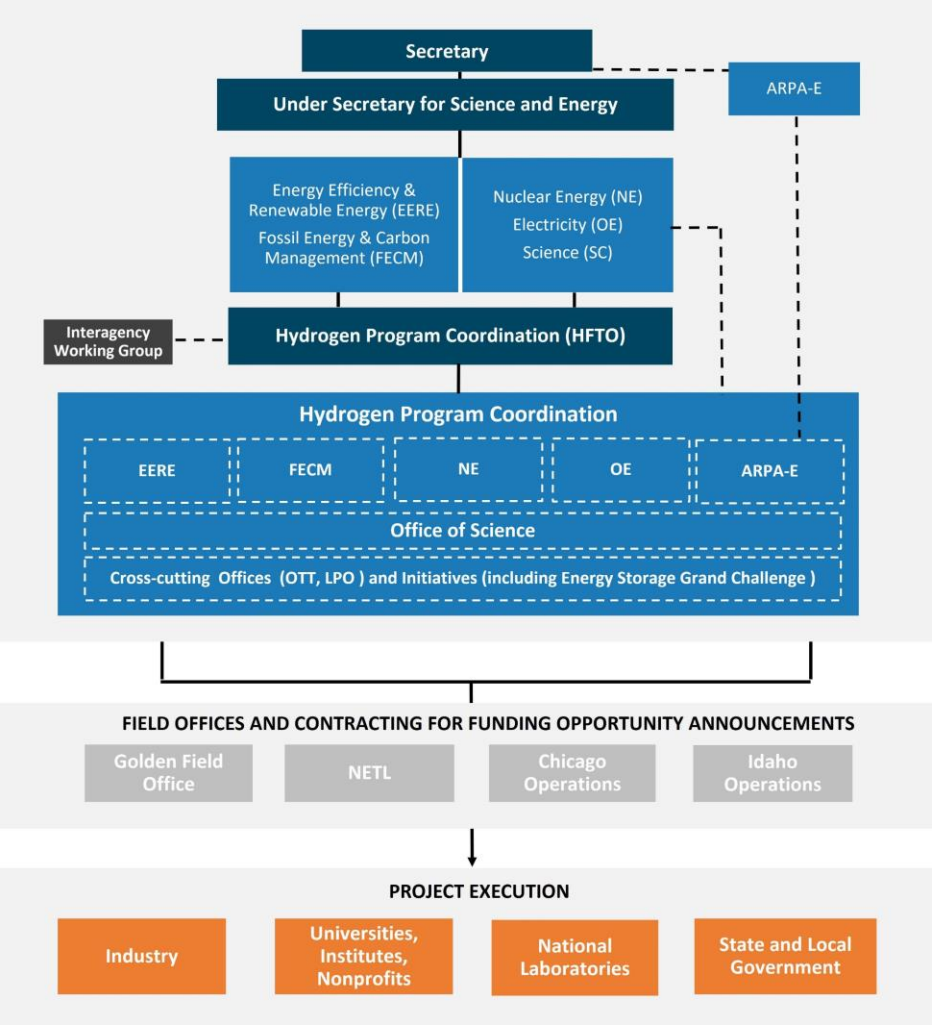
The U.S. DOE Hydrogen Program

The Energy Policy Act (2005) Title VIII and Energy Policy Act of 2020 provide key authorization, coordinated across DOE Offices

Hydrogen is one part of a broad portfolio of activities



www.hydrogen.energy.gov

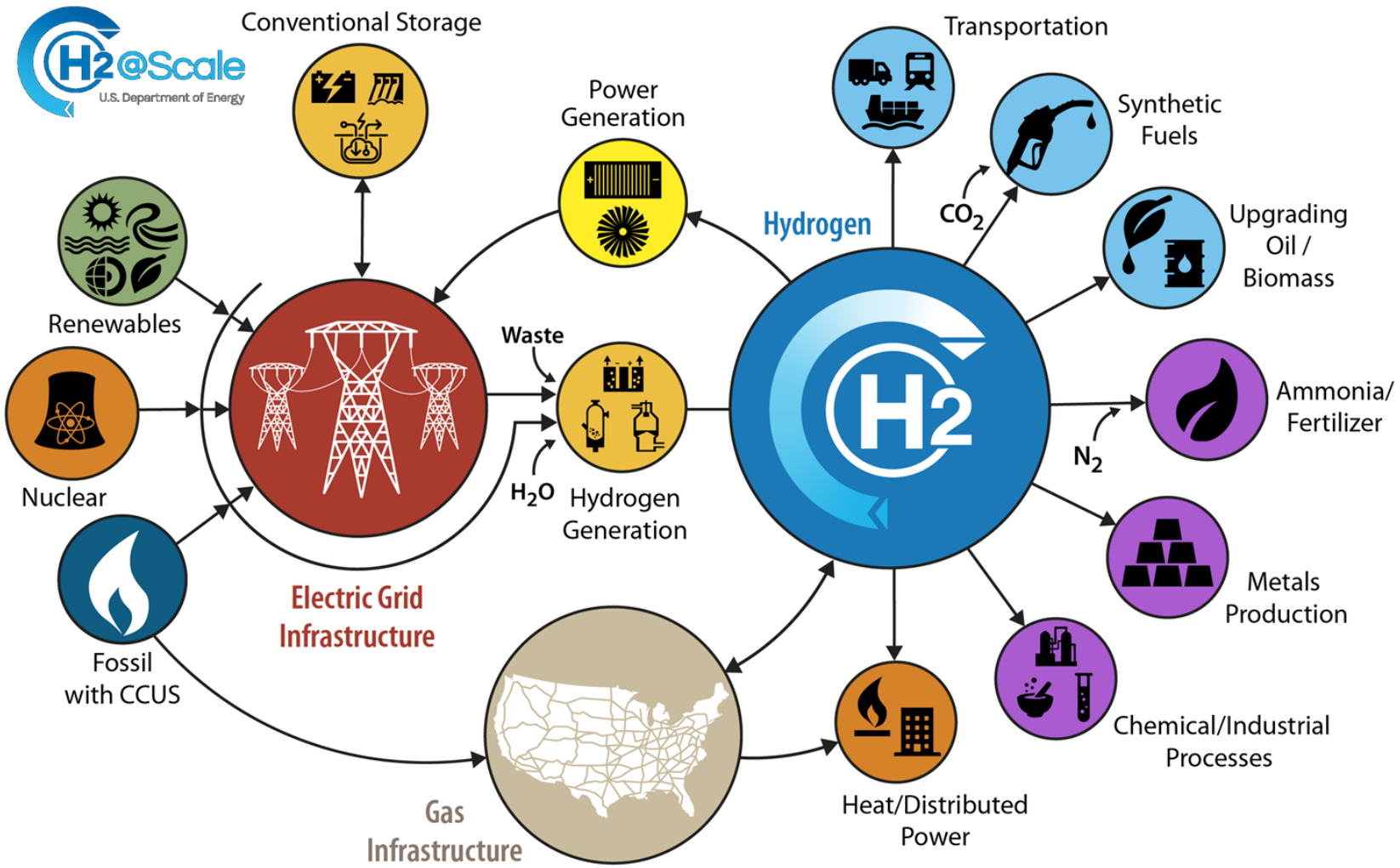


Priorities

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

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

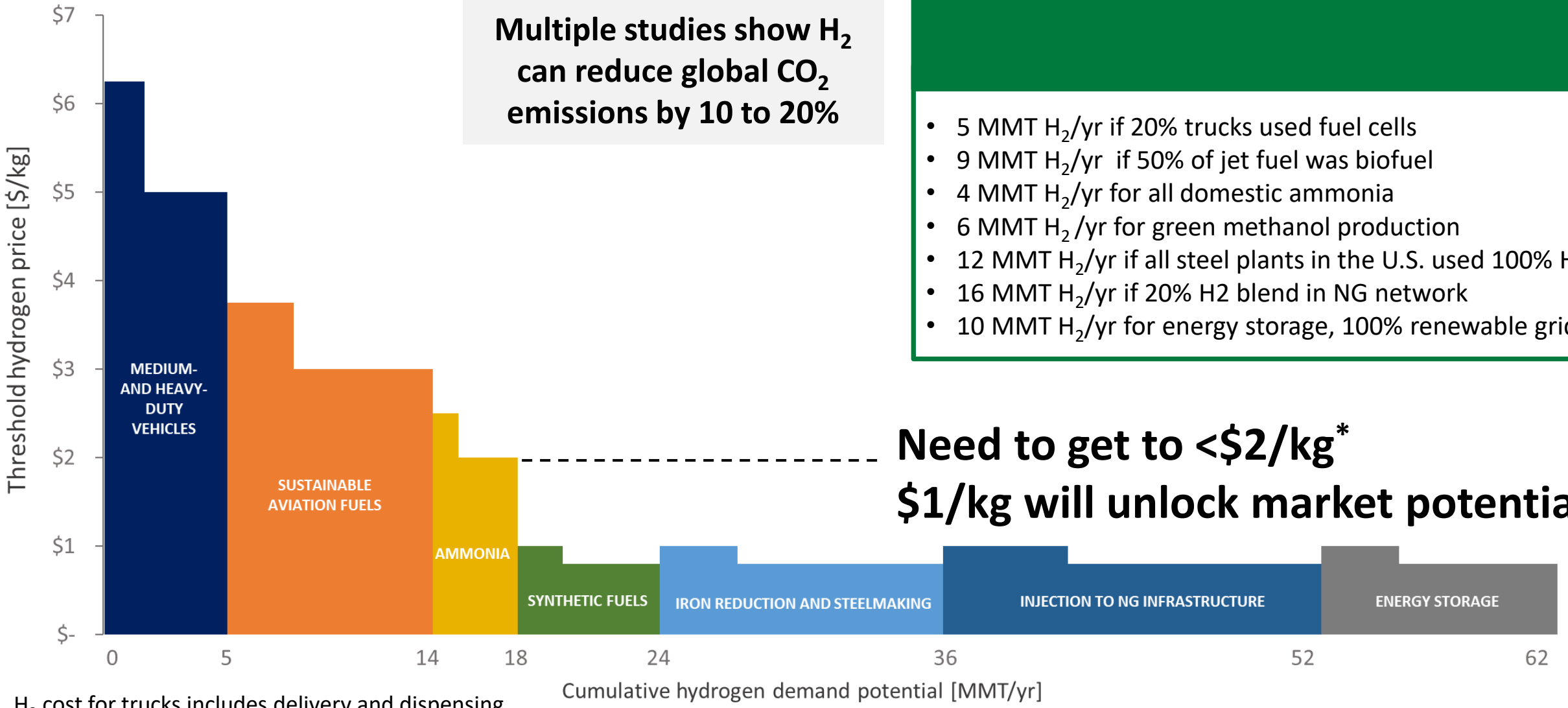
U.S. Snapshot

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

Analysis Determines Market Potential Scenarios

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

- 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

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

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Hydrogen Energy Earthshot

"Hydrogen Shot"

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

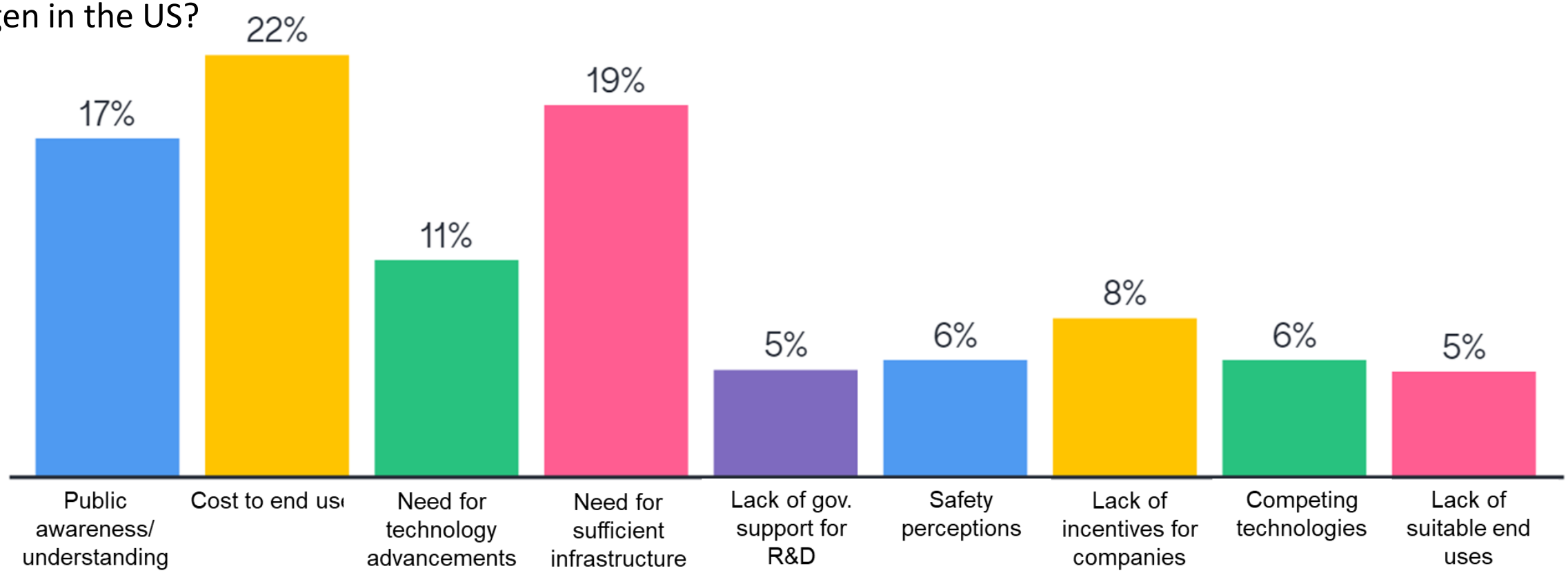
Launched June 7, 2021
Summit Aug 31-Sept 1, 2021

DOE Hydrogen Shot Summit Stakeholder Feedback

4,900+ total registrants, 3,200+ participants in Plenary, 48 states + DC

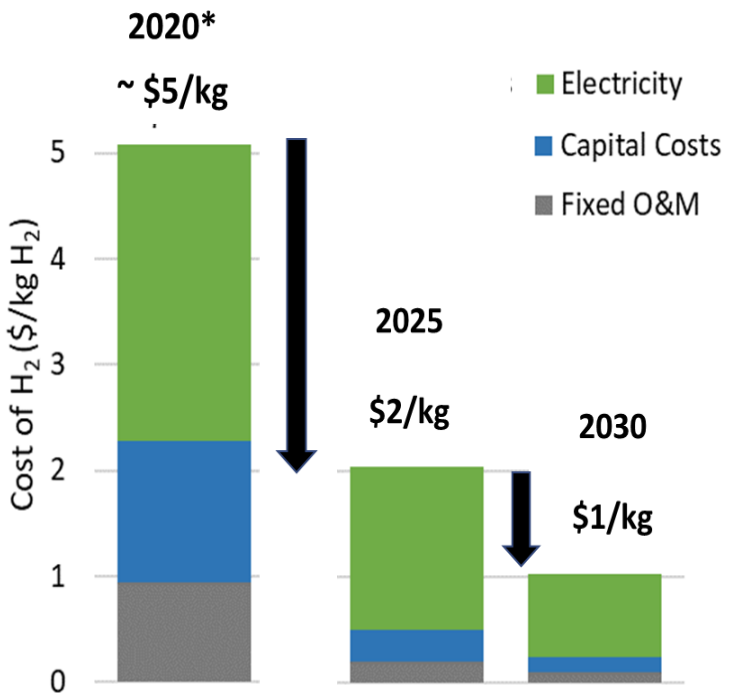
33 countries + USA

Responses to: Which are the greatest barriers currently preventing public acceptance of wide-spread hydrogen in the US?



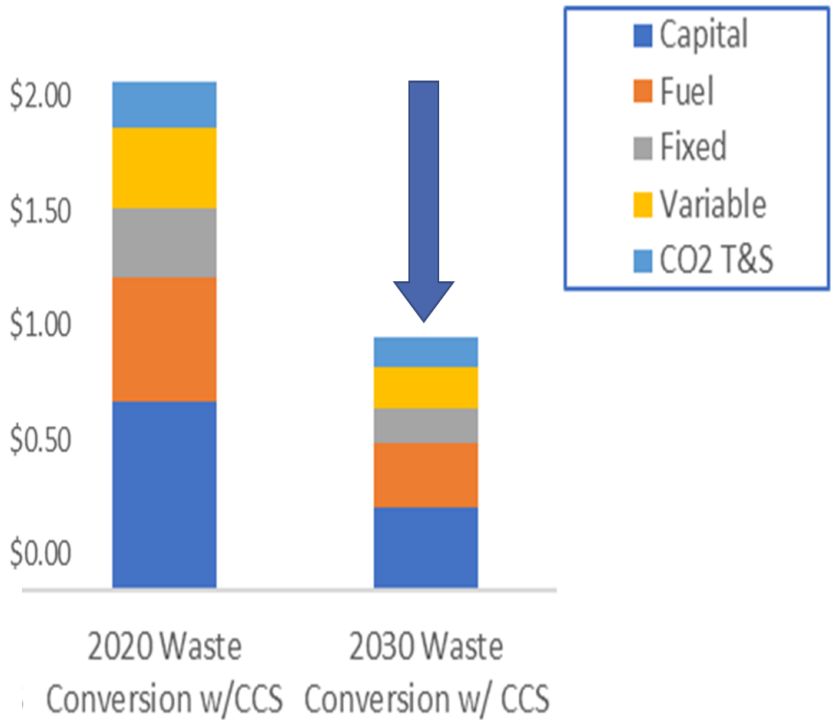
All pathways with potential for “1 1 1” being assessed

H_2 from Electrolysis



- Reduce electricity cost, improve efficiency and utilization
- Reduce capital cost >80%; operating & maintenance cost >90%

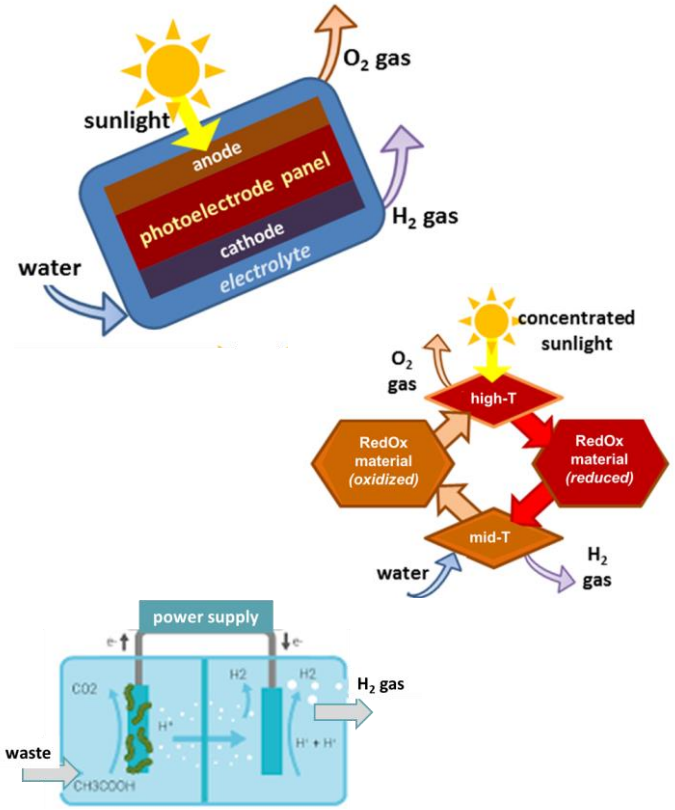
H_2 from Waste Conversion + CCS



* Waste coal, plastics, biomass residuals, municipal solid waste (MSW), and biogas

- Reforming, pyrolysis, air separation, catalysts, CCS, upstream emissions

Advanced Pathways

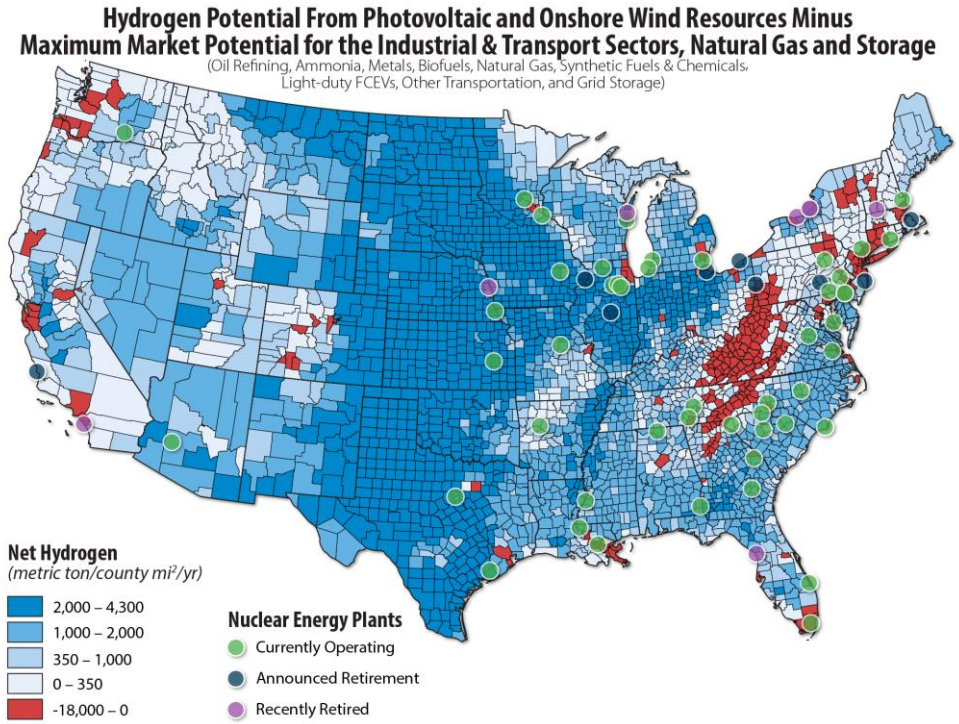


- Photelectrochemical (PEC), thermochemical, biological, etc.

*2020 Baseline: PEM (Polymer Electrolyte Membrane) low volume capital cost ~$1,500/kW, electricity at $50/MWh. Pathways to targets include capital cost < $300/kW by 2025, < $150/kW by 2030 (at scale). Assumes $50/MWh in 2020, $30/MWh in 2025, $20/MWh in 2030

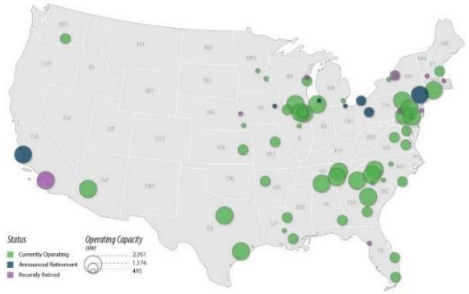
Stakeholder Engagement, Strategy, and Next Steps

Renewables



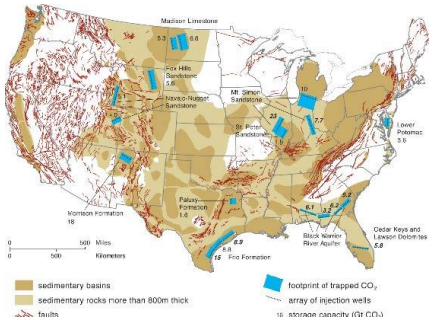
Red: Regions where projected industrial & transportation demand exceeds local supply.

Regional and national analyses planned stay tuned to Hydrogen Shot and www.hydrogen.energy.gov



Natural Gas (SMR)

CCS



Strategy and Next Steps

- Accelerate R&D to reduce cost
- De-risk demonstrations and enable deployments
- Strategic scale up through clusters – co-locate production, end use
- Enablers: Workforce development, safety, codes, standards, DEI, EJ activities

DEI: Diversity, Equity and Inclusion
EJ: Environmental Justice

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

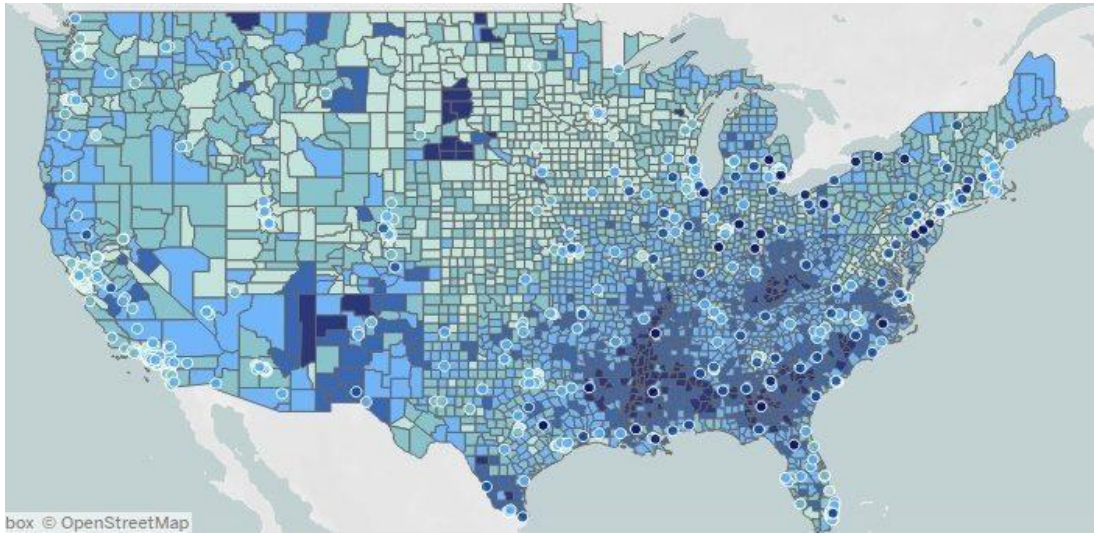
Main Hydrogen Sections of the Bipartisan Infrastructure Law

- SEC. 40313. CLEAN HYDROGEN RESEARCH AND DEVELOPMENT PROGRAM
- SEC. 813. REGIONAL CLEAN HYDROGEN HUBS
  - $8,000,000,000 for the period of fiscal years 2022 through 2026
- SEC. 814. NATIONAL CLEAN HYDROGEN STRATEGY AND ROADMAP
- SEC. 815. CLEAN HYDROGEN MANUFACTURING AND RECYCLING
  - $500,000,000 for the period of fiscal years 2022 through 2026
- SEC. 816. CLEAN HYDROGEN ELECTROLYSIS PROGRAM
  - $1,000,000,000 for the period of fiscal years 2022 through 2026
- SEC. 822. CLEAN HYDROGEN PRODUCTION QUALIFICATIONS

Tune in to DOE Webinar Dec 8, 2021


Collaboration
Diversity, Equity, Inclusion

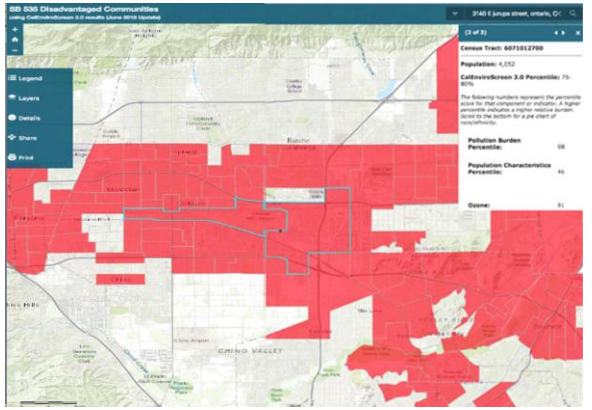
Focus on Benefits in Underserved & Disadvantaged Communities



[New index ranks America's 100 most disadvantaged communities | University of Michigan News (umich.edu)]

Funding Opportunities will encourage broader engagement, demonstrating benefits, including DEI (minorities, gender equity, etc.)

Example: DOE project with CTE for UPS Fuel Cell Delivery Vans



Trucks will be demonstrated in Ontario, CA- disadvantaged community

HyBlend and H-Mat Consortia – Opportunities Available

To assess and enhance compatibility of key materials with hydrogen, and to accelerate the use of hydrogen in multiple applications (including in natural gas blending)

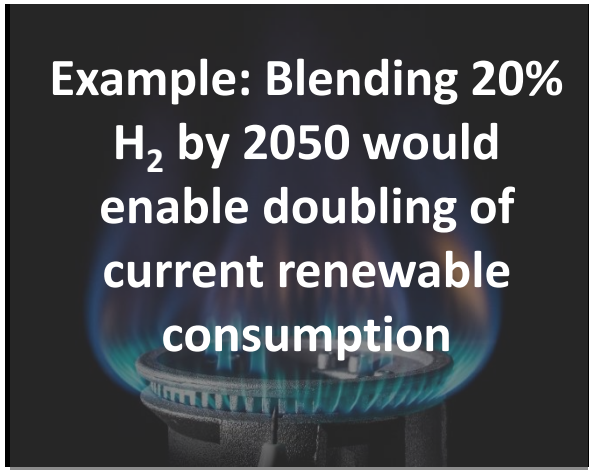
H-Mat Hydrogen Materials Compatibility Consortium℠

National lab consortium to assess and improve performance and reliability of materials in hydrogen, reduce costs, and inform codes & standards.

HyBlend U.S. DEPARTMENT OF ENERGY

Pipeline materials compatibility R&D, technoeconomic analysis, and life cycle analysis to assess the feasibility of hydrogen blending in the US natural gas pipeline infrastructure.

Over 40 partners



Labs | Sandia National Laboratories | PNNL | SRNL | Oak Ridge National Laboratory | Argonne National Laboratory

Labs | NREL National Renewable Energy Laboratory | Sandia National Laboratories | PNNL | Oak Ridge National Laboratory | Argonne National Laboratory | NETL

Examples of International Collaborations

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

IEA

HYDROGEN INITIATIVE
AN INITIATIVE OF THE CLEAN ENERGY MINISTERIAL

MISSION INNOVATION

CLEAN HYDROGEN MISSION

CENTER FOR 水素安全センター Hydrogen SAFETY
Connecting a Global Community

hySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

H2 PRHYDE
Protocol for heavy-duty Hydrogen refuelling

PRESLHY

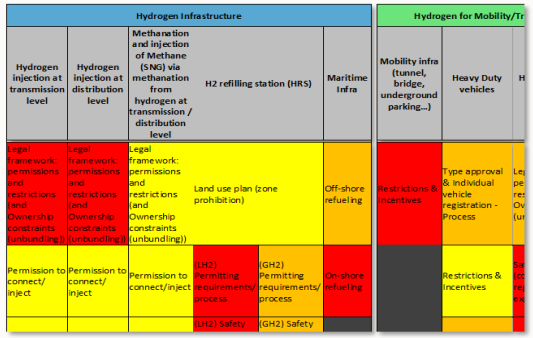
The International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling the global adoption of hydrogen and fuel cells in the economy

www.iphe.net

Regulations, Codes, Standards, Safety and Education & Outreach Working Groups

RCS&S Compendium

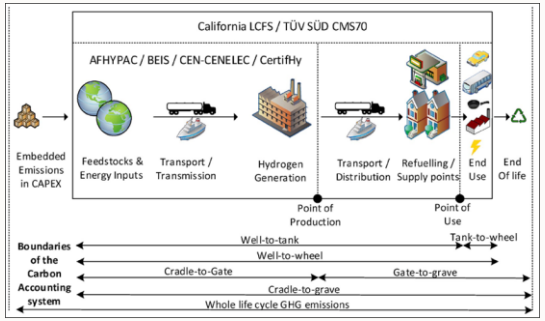


- Reports, workshops, safety sharing
- Assessing gaps
- Education, student engagement, compiling country info

Task Force to facilitate international trade of H_2

H_2 Production Analysis (H2PA)

- Developing a common analytical framework to determine emissions footprint for H_2
- Harmonizing approach across countries and pathways



(Source: Abad et al., Energy policy 138 (2020) 111300)

H2 Twin Cities Initiative Launched at COP26

Connecting Communities Around the World to Deploy Clean Hydrogen Solutions

H2 TWIN CITIES

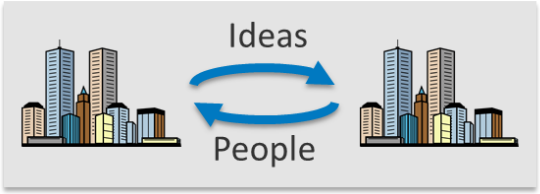
OFFICIAL APPLICATION GUIDELINES

H2 Twin Cities 2021

Phase 1: November 10 – December 29, 2021	Phase 2: January 3 – March 18, 2022	Selections WG will evaluate proposals
Applicants self-identify and self-pair on the H2 Twin Cities website	A single, joint application is prepared Open submission until March 18	Announce winners in early spring 2022

Pairing Types

Sibling Cities



Mentor - Mentee

Share and learn more: www.energy.gov/eere/twincities

Opportunities for Engagement

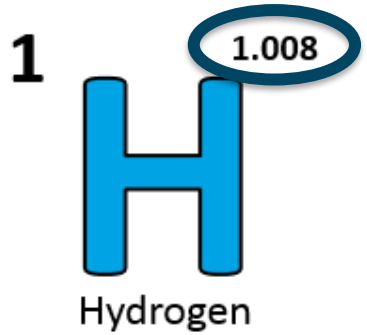
ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

DOE Annual Merit Review and Peer Evaluation Meeting
June 6 -9, 2022

Webinar Dec 8, 2021

Hydrogen and Fuel Cells Day
October 8

- Held on hydrogen's very own atomic weight-day



INCREASE YOUR H2IQ

Join Monthly
H2IQ Hour Webinars

Download
H2IQ For Free

Visit H2tools.Org For Hydrogen Safety And Lessons Learned

https://h2tools.org/

CENTER FOR Hydrogen SAFETY
Connecting a Global Community

www.aiche.org/CHS

Sign up to receive hydrogen and fuel cell updates

www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter

Learn more at: energy.gov/eere/fuelcells AND www.hydrogen.energy.gov

Thank you

Dr. Sunita Satyapal
Director, Hydrogen and Fuel Cell Technologies Office
Coordinator, DOE Hydrogen Program
Sunita.Satyapal@ee.doe.gov
U.S. Department of Energy

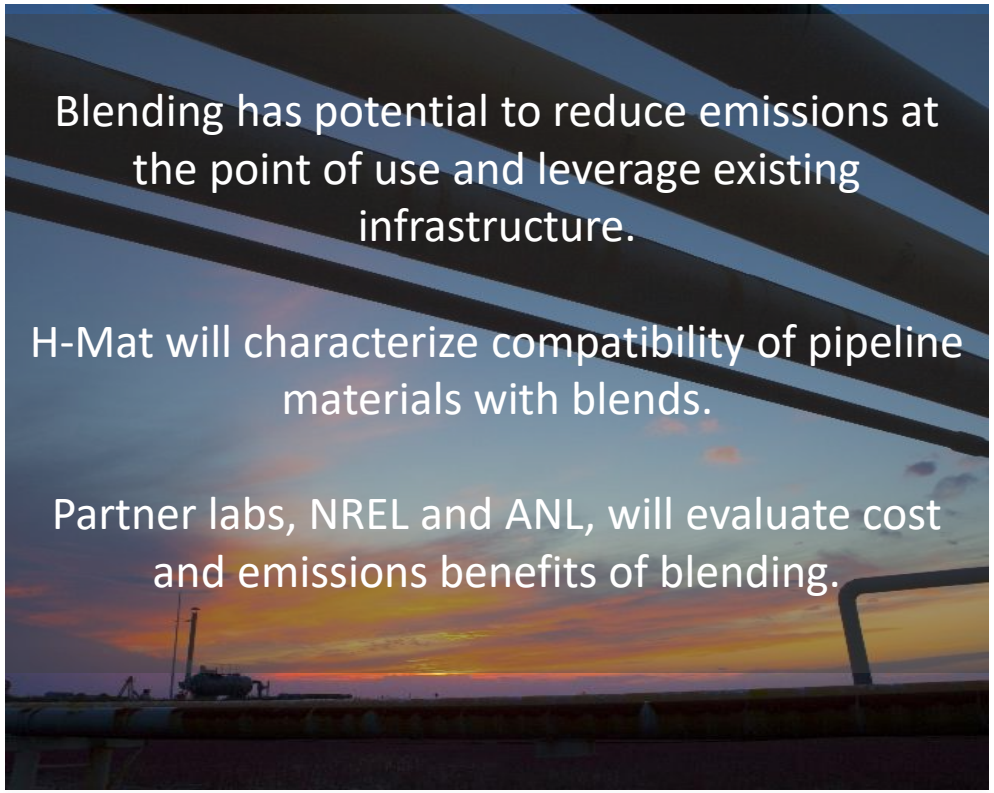
www.energy.gov/fuelcells
www.hydrogen.energy.gov

Additional Information

Ongoing R&D on Hydrogen Blending in Natural Gas

HyBlend
U.S. DEPARTMENT OF ENERGY

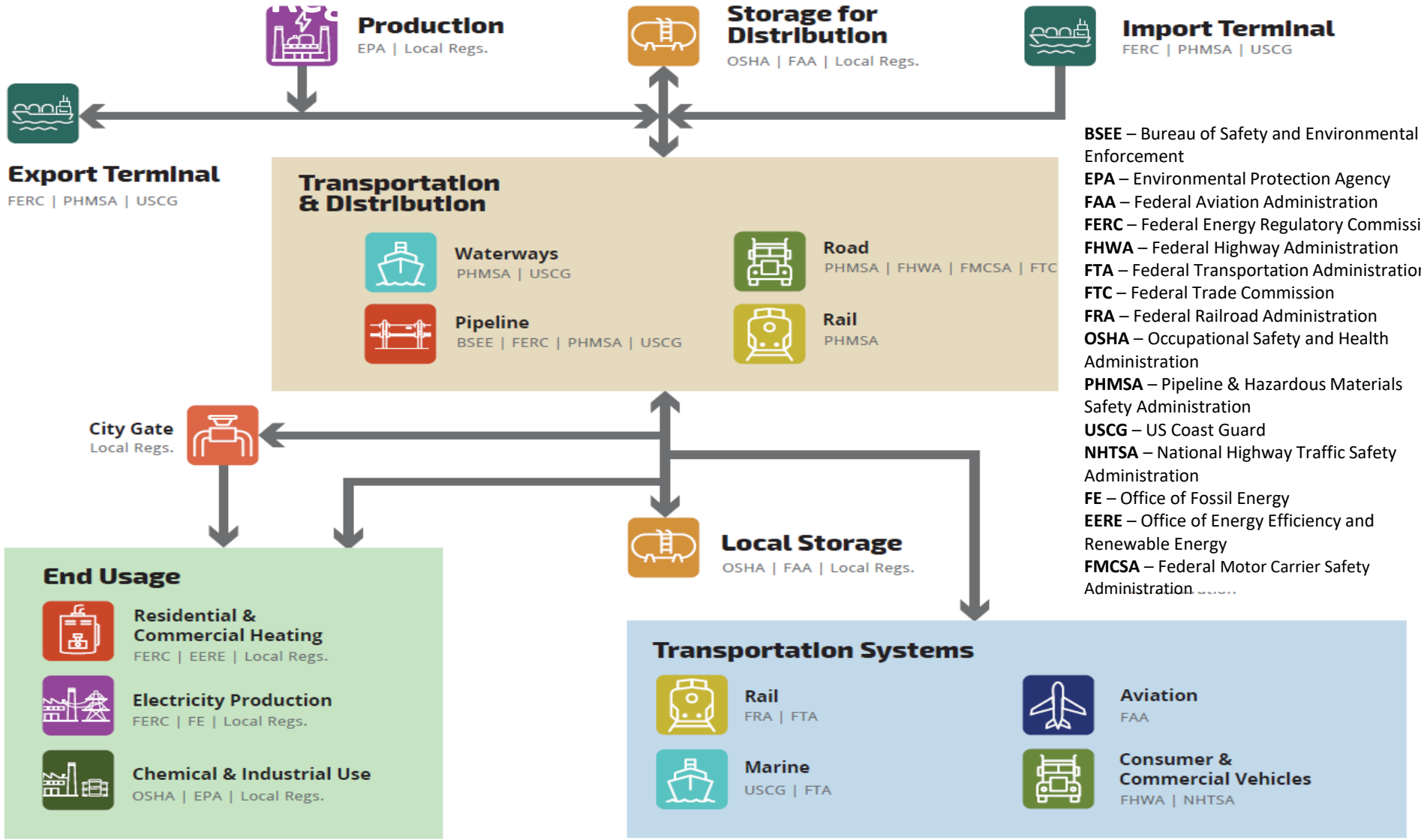
HyBlend collaboration between H-Mat, NREL, ANL, and ~30 stakeholders will assess the viability of hydrogen blending in natural gas pipelines.



- **Developing public model of pipeline integrity to identify opportunities and risks of blending given a system's age, operating conditions, and materials of construction.**
  - Evaluate microstructures of both legacy and anticipated pipeline installations.
  - Conduct experimentation to evaluate life of polymer and metallic materials used in pipeline segments and joints, under varying concentrations, temperatures, and pressures of blends.
  - Characterize relationships between pipeline microstructure, condition, and integrity under blend environments.

For more information, please see: https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines

US Cross Agency Collaboration: Federal Regulatory Map to Identify Gaps



BSEE – Bureau of Safety and Environmental Enforcement
EPA – Environmental Protection Agency
FAA – Federal Aviation Administration
FERC – Federal Energy Regulatory Commission
FHWA – Federal Highway Administration
FTA – Federal Transportation Administration
FTC – Federal Trade Commission
FRA – Federal Railroad Administration
OSHA – Occupational Safety and Health Administration
PHMSA – Pipeline & Hazardous Materials Safety Administration
USCG – US Coast Guard
NHTSA – National Highway Traffic Safety Administration
FE – Office of Fossil Energy
EERE – Office of Energy Efficiency and Renewable Energy
FMCSA – Federal Motor Carrier Safety Administration

Gaps Identified

- **FERC for pipeline transmission, electricity production, and heating**
- **FHWA for bridges and tunnels**
- **FRA, USCG, and FAA for rail, maritime, and aviation use**

Final Report Available:
energy.sandia.gov/wp-content/uploads/2021/03/H2-Regulatory-Map-Report_SAND2021-2955.pdf