U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# U.S. Department of Energy’s Hydrogen and Fuel Cell Perspectives


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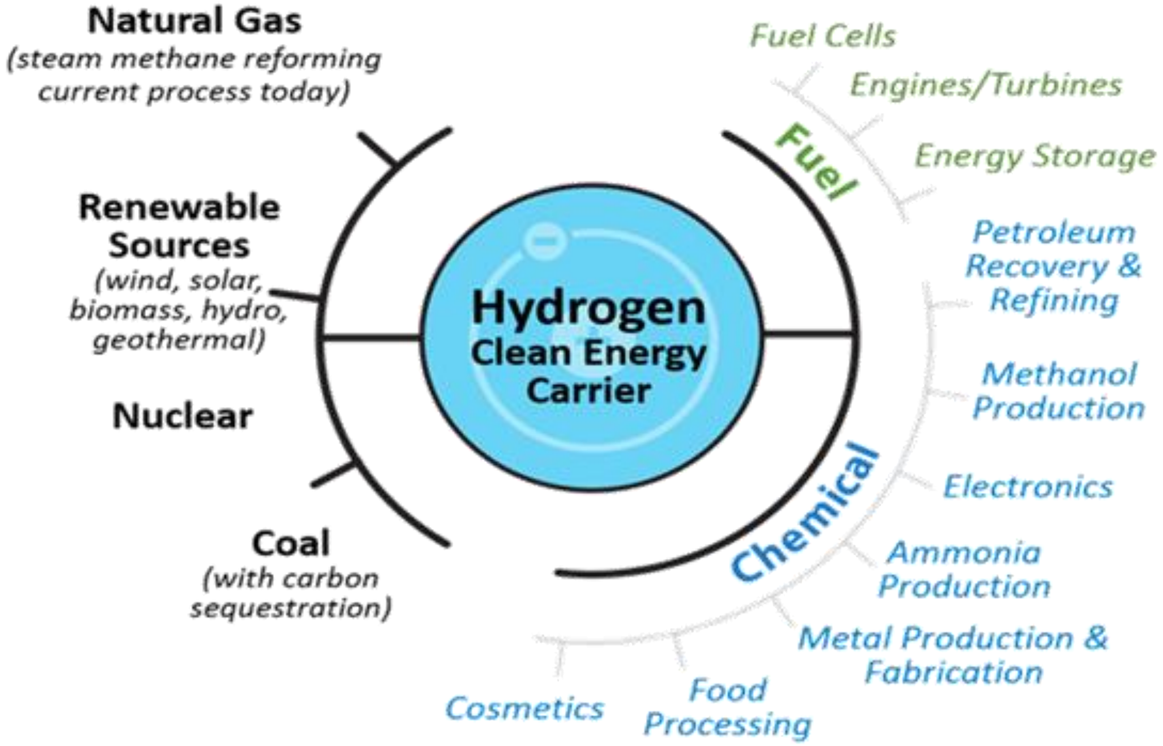
August 24, 2021

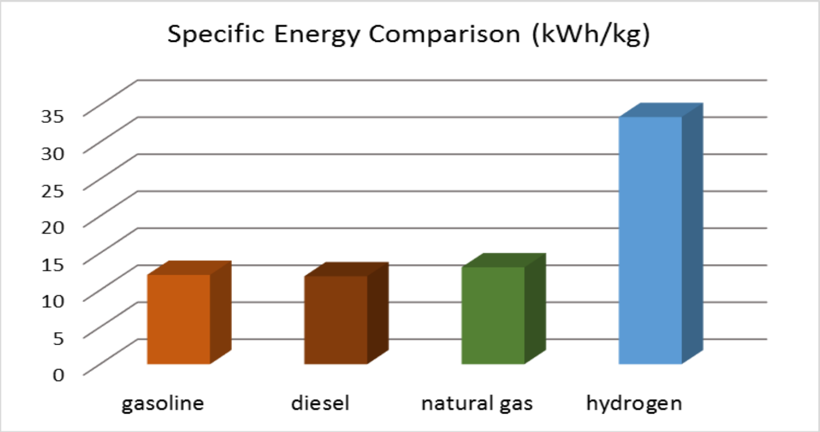

# Hydrogen Introduction

## An energy carrier that can be produced from diverse domestic resources and address multiple applications with zero emissions

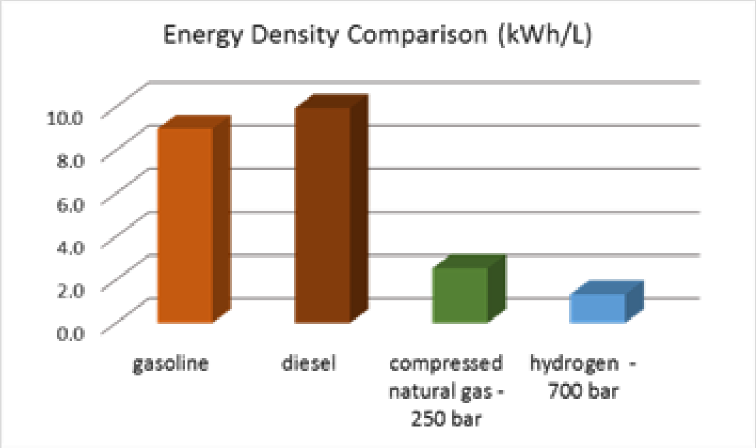



**~ $150 Billion Global Industry**

## Has high energy content by mass, nearly 3x more than conventional fuels

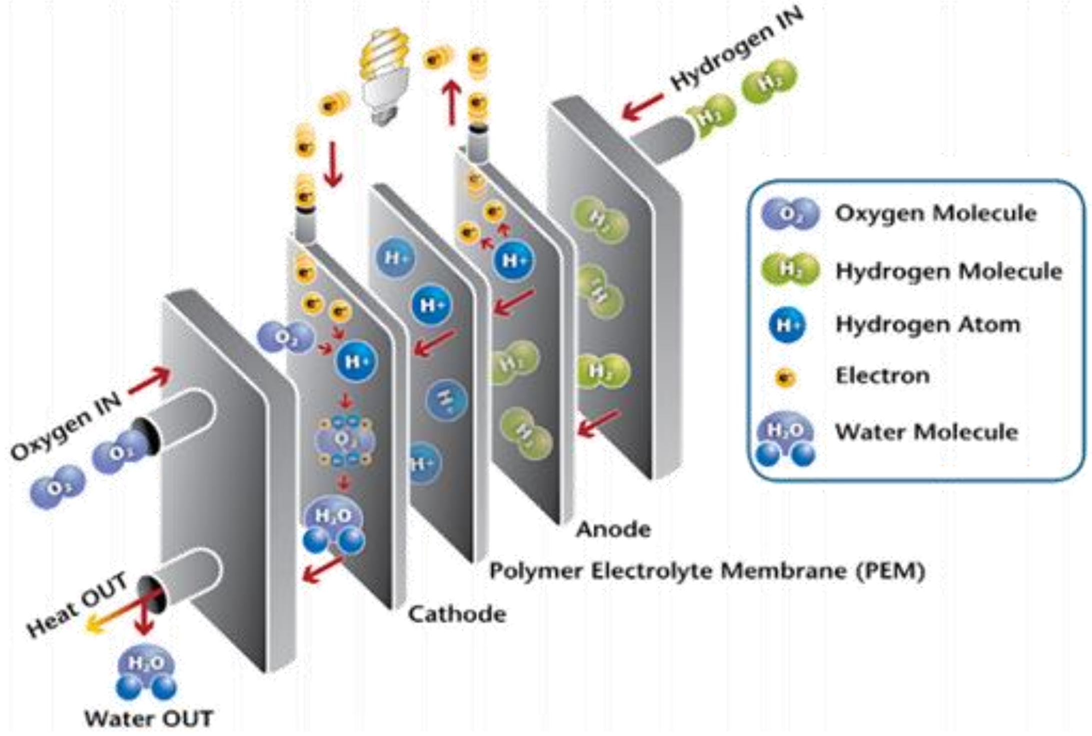



## Has low energy by volume



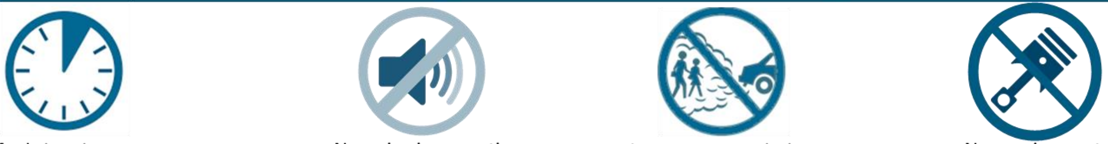
# Fuel Cells and Electrolyzers Intro

**Fuel cells can operate on hydrogen or other fuels and do not involve combustion, so have high electrical efficiencies. Electrolyzers are like fuel cells 'in reverse' and split water to $H_2$ and $O_2$**




## Fuel Cells are:

**Convenient** **Quiet** **Clean**



Refuels in minutes | No noise in operation | Low to zero emissions | No moving parts

**Versatile and easily scalable**

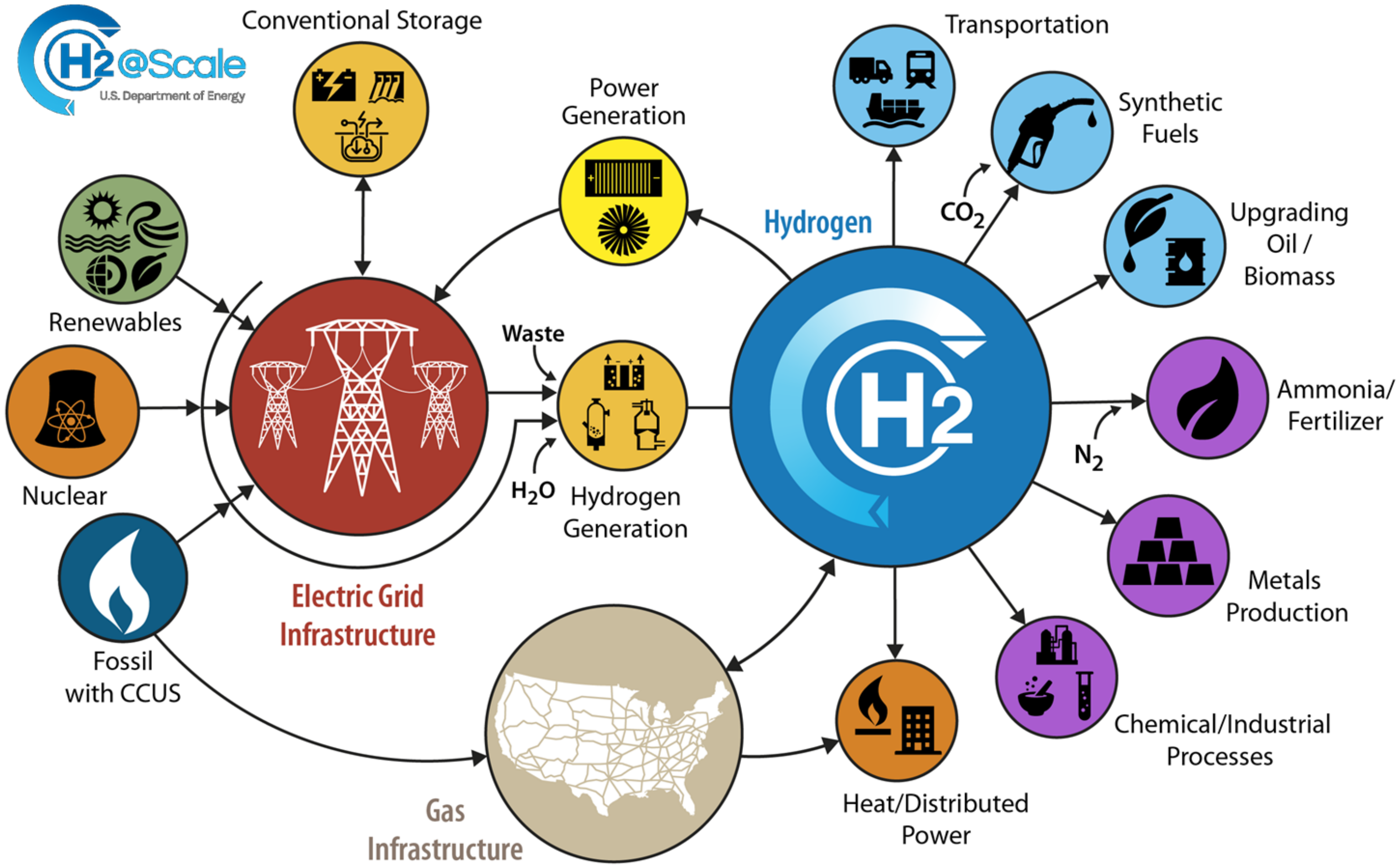
Transportation | Stationary

## Fuel Cells can:

**Have higher efficiencies compared to conventional technologies**

**Reduce life cycle emissions >90%**

# H2@Scale: Deep Decarbonization, Economic Growth, Jobs




**$H_2$ is part of a broad portfolio that contributes to Administration goals including:**

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

**Environmental Justice (EJ) 40 Initiative: 40% of benefits in disadvantaged communities**

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

Industry study shows potential for $140B in revenue, 700K jobs by 2030. 16% GHG reduction. Analysis underway (export, etc.)

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

## Examples of Applications Deployed

**>500MW**
Backup Power

**>40,000**
Forklifts

**>172 MW**
PEM* Electrolyzers

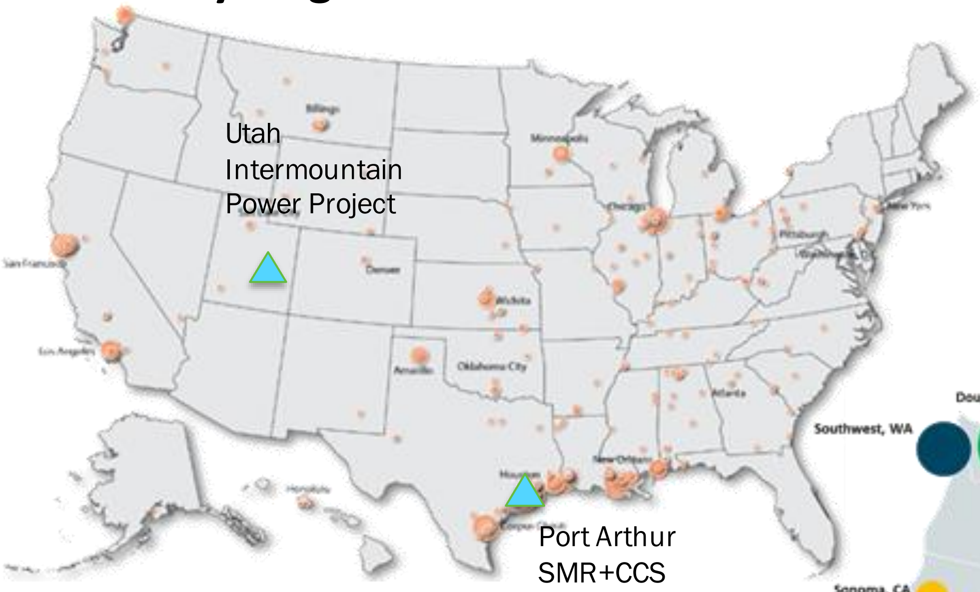
**>60**
Fuel Cell Buses

**>45**
$H_2$ Retail Stations

**~10,000**
Fuel Cell Cars

* Polymer electrolyte membrane

## Hydrogen Production Facilities




## Hydrogen Stations Plans Across States

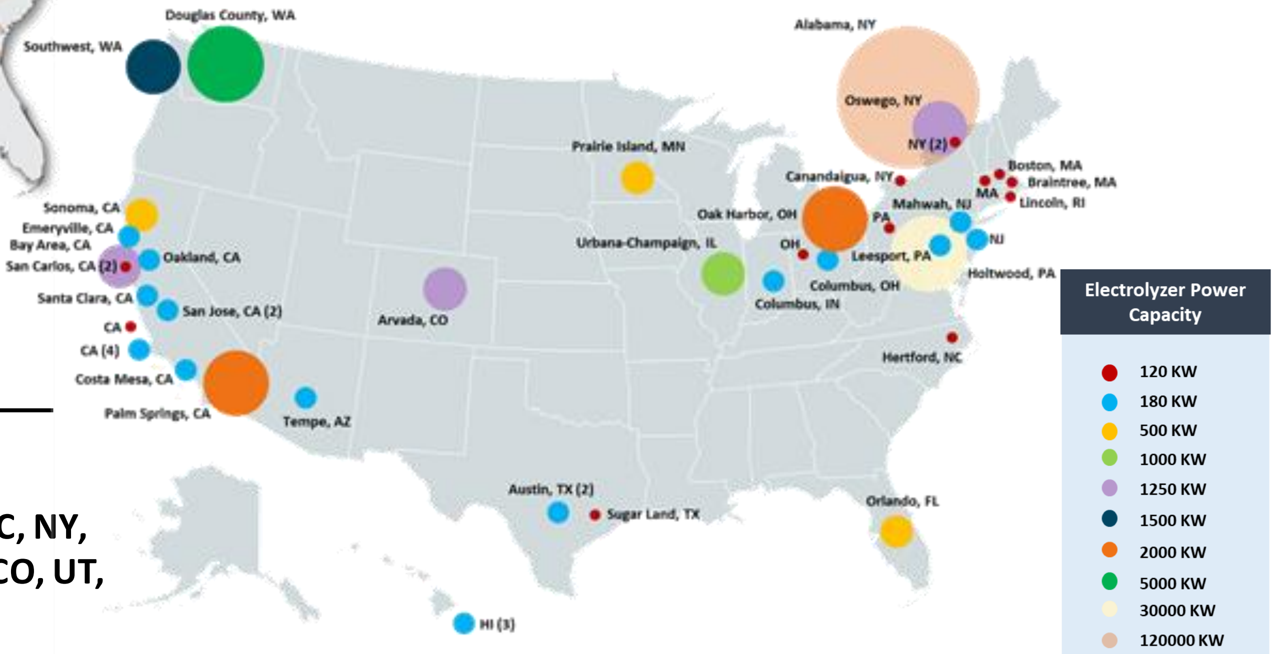
**California**
200 Stations Planned
California Fuel Cell Partnership Goal

**Northeast**
12 – 20 Stations Planned

**HI, OH, SC, NY, CT, MA, CO, UT, TX, MI**
And Others

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

## PEM Electrolyzer Installations

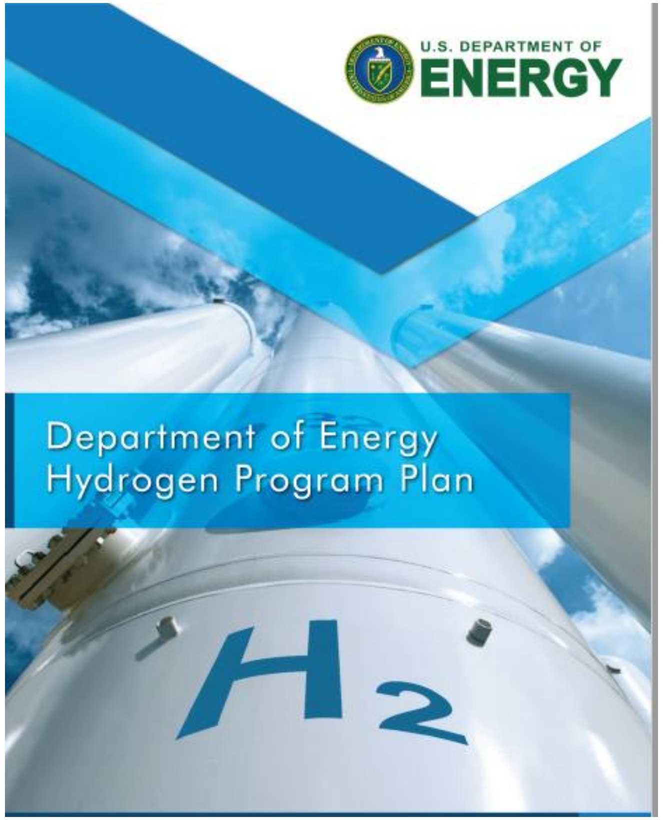



Current and under construction installations over 120 kW as of Jun. 2021

** Source: Arjona, et al, DOE HFTO Program Record, June 2021*

# The U.S. DOE Hydrogen Program

## Hydrogen is one part of a broad portfolio of activities



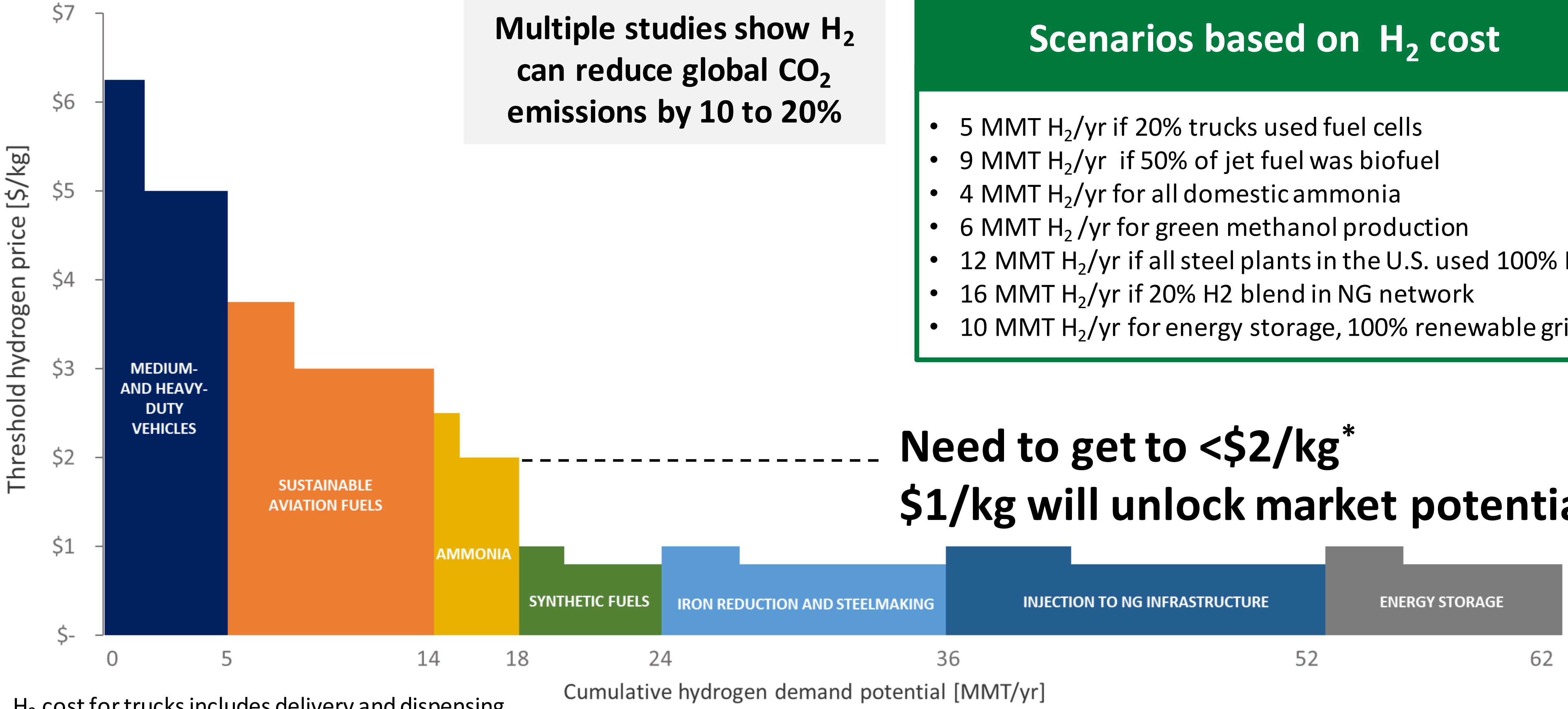

www.hydrogen.energy.gov

### 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

# Analysis Determines Market Potential 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

# 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”

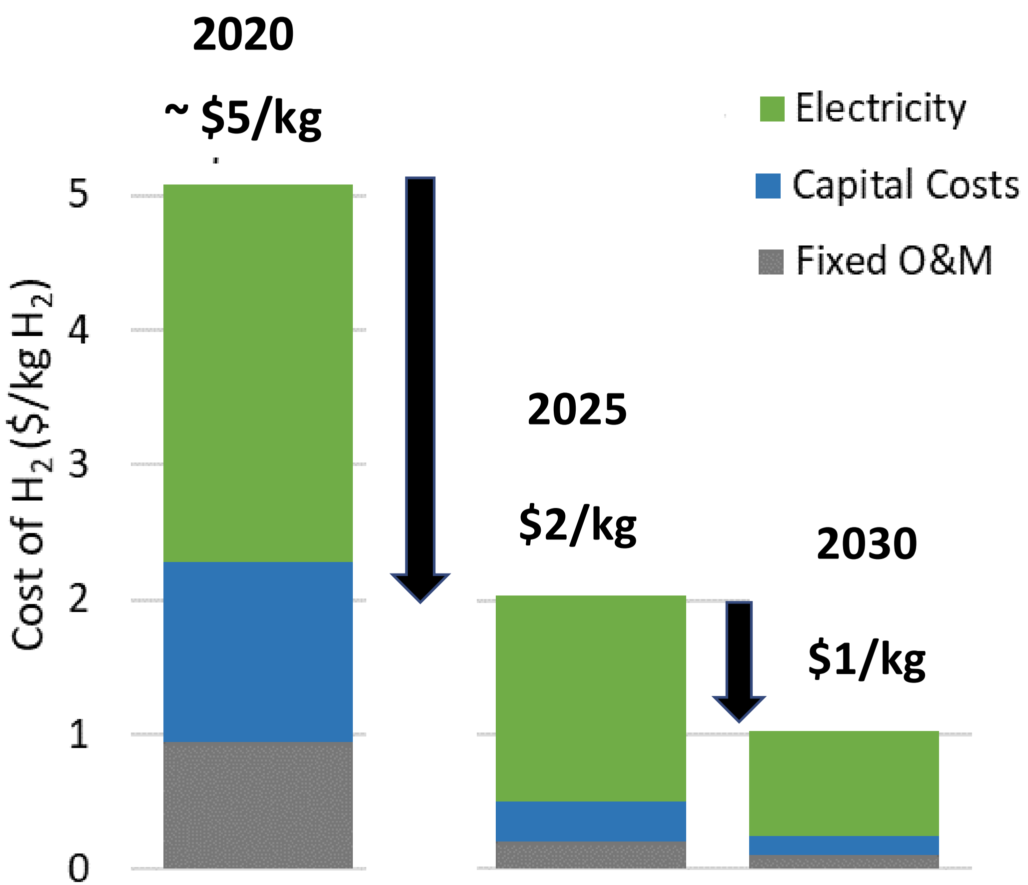
## “1 1 1”
## $1 for 1 kg clean hydrogen in 1 decade

Launched June 7, 2021

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

# Pathways to Reduce Cost

### Example: Cost of Clean $H_2$ from Electrolysis




### One of several pathways

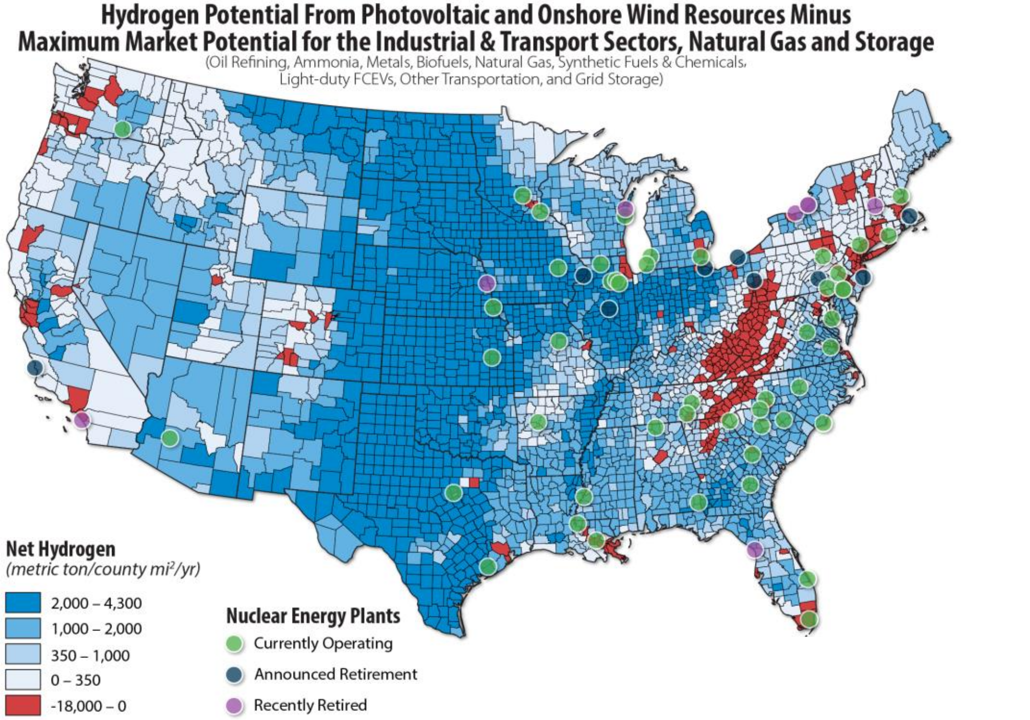
- Reduce electricity cost from >$50/MWh to
  - $30/MWh (2025)
  - $20/MWh (2030)
- Reduce capital cost >80%
- Reduce operating & maintenance cost >90%

All pathways for clean hydrogen included: Thermal conversion with CCS, advanced water splitting, biological approaches, etc.

2020 Baseline: PEM low volume capital cost ~$1,500/kW, electricity at $50/MWh. Need less than $300/kW by 2025, less than $150/kW by 2030 (at scale)

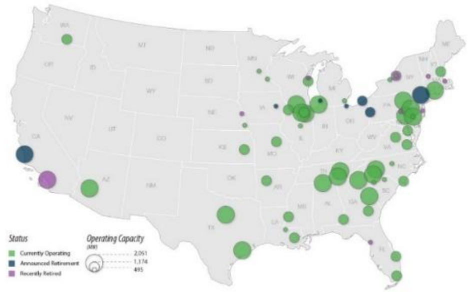
# Stakeholder Engagement, Production and End-Use Collocation and Environmental Justice to Drive Activities

## Renewables



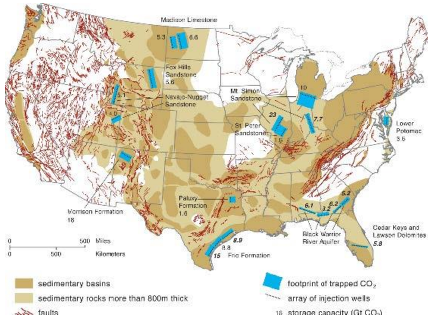

Red: Regions where projected industrial & transportation demand exceeds local supply.

- Hydrogen Shot Summit and Stakeholder Engagement Planned Aug 31-Sept 1
- Request for Information on Key Topics Issued



## Natural Gas (SMR)

## CCS



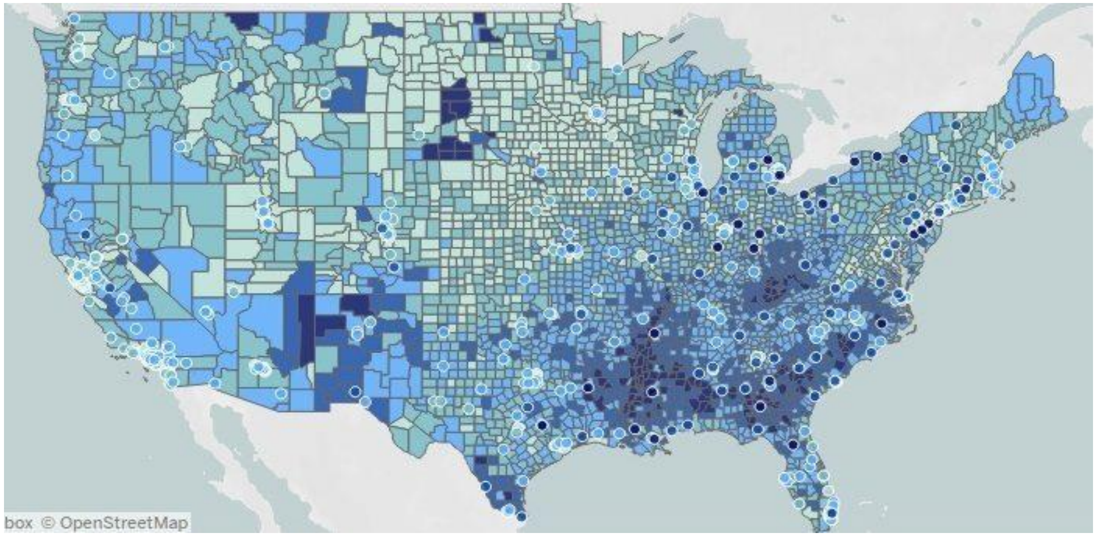
## DOE Request of Information covered key themes:

- Production, Resources, Infrastructure
- End Users, Cost, Value Proposition
- Co-location potential
- Emissions Reduction Potential
- DEI, Jobs, EJ
- Science & Innovation Needs and Challenges

DEI: Diversity, Equity and Inclusion
EJ: Environmental Justice


Collaboration
Diversity, Equity, Inclusion

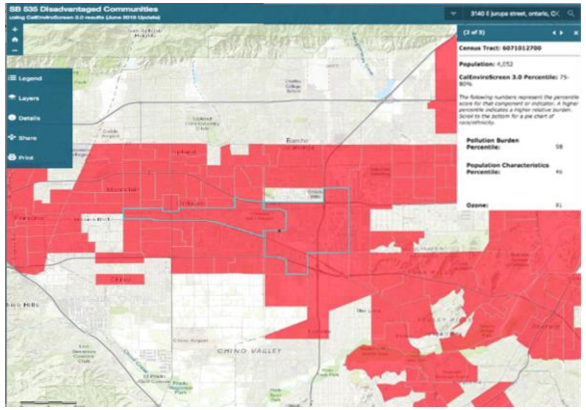
# Focus on Benefits in Underserved & Disadvantaged Communities




[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

**Goal: Demonstrate 15 fuel cell trucks (up to 125-mile range)**

**Project impact per year: Savings of**

- **285 metric tons of $CO_{2e}$**
- **280,000 grams of criteria pollutants**
- **56,000 gallons of diesel**

**in honor of Bob Rose, founder of US Fuel Cell Council*

# Global Center for Hydrogen Safety

**Global Center for Hydrogen Safety established to share best practices, training resources and information**

**High Priority: Lessons learned and best practices on safety**

**Encourage membership (industry, govt, universities, labs) to join CHS**

CENTER FOR Hydrogen SAFETY 水素安全センター

Connecting a Global Community

**www.aiche.org/CHS**

IPHE

Hydrogen Council

AIChE

Pacific Northwest NATIONAL LABORATORY

hySafe

Over 60 partners: government, industry, universities and more

Access to >110 countries, 60,000 members

CENTER FOR Hydrogen SAFETY

Connecting a Global Community

HYDROGEN Safety Panel

HYDROGEN Emergency Response Training Resources

# Upcoming Opportunities for Engagement

## Hydrogen Shot Summit
## Aug 31 – Sept. 1

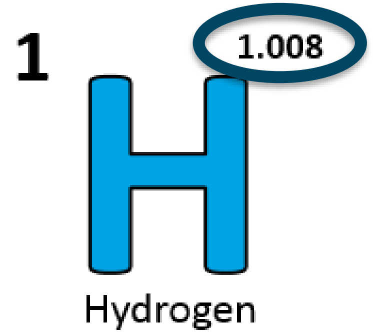
**Registration is now open!**
**https://www.energy.gov/eere/fuelcells/articles/registration-open-hydrogen-shot-summit**

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

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

## Hydrogen and Fuel Cells Day
## October 8

- Held on hydrogen's very own atomic weight-day
- DOE EERE comms campaign all week




INCREASE YOUR $H_2IQ$

**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

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

# Additional Information

**www.energy.gov/fuelcells**

**www.hydrogen.energy.gov**

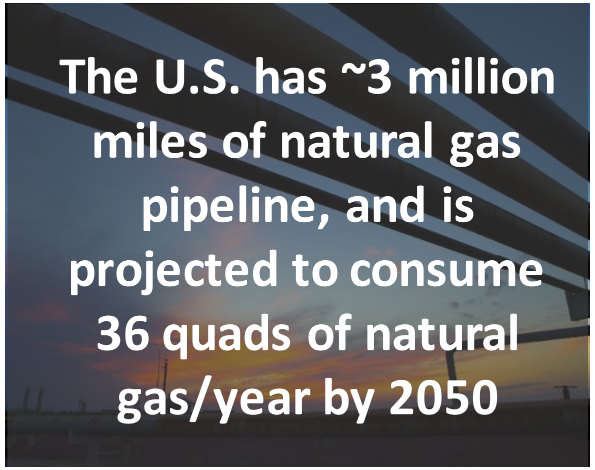
# HyBlend and H-Mat

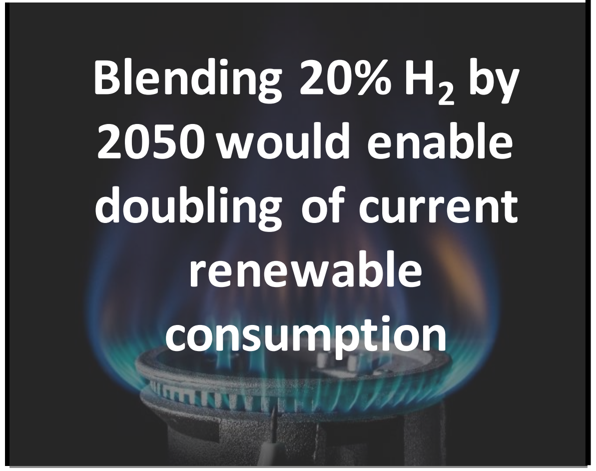
**Purpose: To assess and enhance compatibility of key materials with hydrogen, and to accelerate the use of hydrogen in multiple applications (including in natural gas blending)**

HyBlend
U.S. DEPARTMENT OF ENERGY

**>20 Stakeholders and 6 National Labs**

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.




**Labs** | NREL NATIONAL RENEWABLE ENERGY LABORATORY | Sandia National Laboratories | PNNL | Oak Ridge National Laboratory | Argonne NATIONAL LABORATORY | NETL

H-Mat Hydrogen Materials Compatibility Consortium SM

**Partners Across Industry and 5 National Labs**

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



**Labs** | Sandia National Laboratories | PNNL | SRNL | Oak Ridge National Laboratory | Argonne NATIONAL LABORATORY

# Comprehensive Strategy Across the Hydrogen Value Chain

**NEAR-TERM** → **LONGER-TERM**

**Production**
- Gasification of coal, biomass, and waste with carbon capture, utilization, and storage
- Advanced fossil and biomass reforming/conversion
- Advanced biological/microbial conversion
- Electrolysis (low-temperature, high-temperature)
- Advanced thermo/photoelectro-chemical $H_2O$ splitting

**Delivery**
- Distribution from on-site production
- Tube trailers (gaseous $H_2$)
- Widespread pipeline transmission and distribution
- Cryogenic trucks (liquid $H_2$)
- Chemical $H_2$ carriers

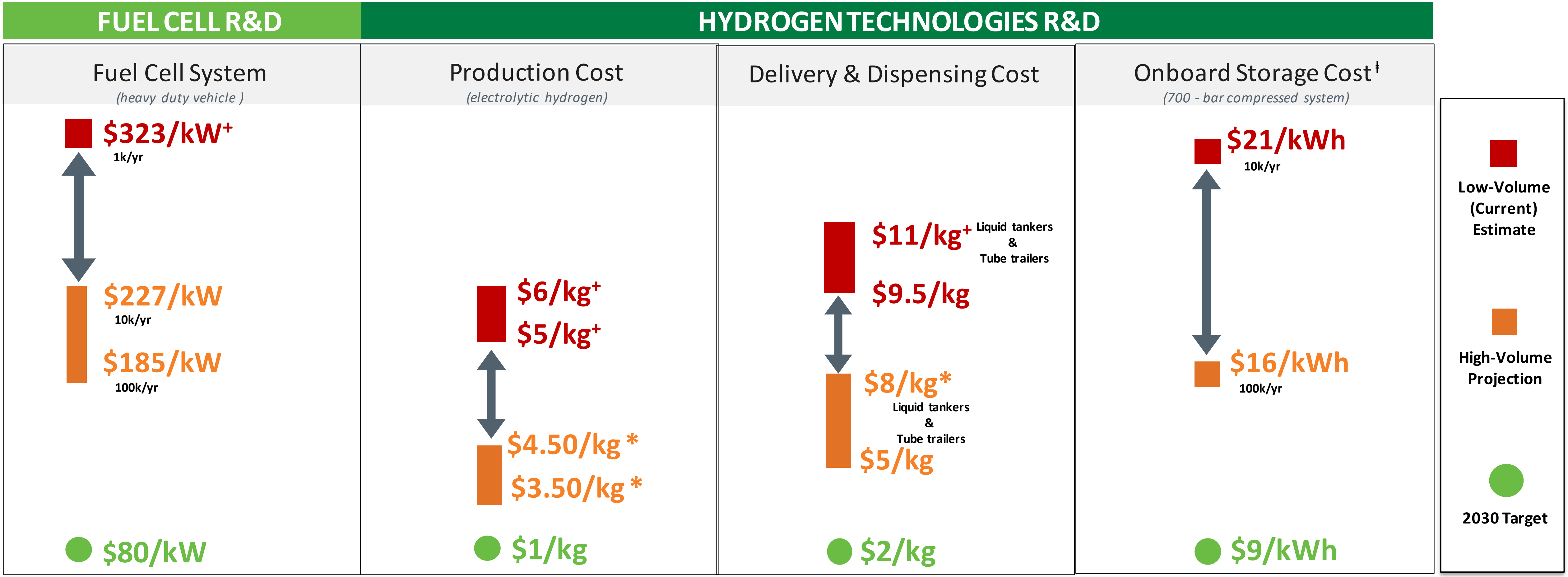
**Storage**
- Pressurized tanks (gaseous $H_2$)
- Geologic $H_2$ storage (e.g., caverns, depleted oil/gas reservoirs)
- Cryogenic vessels (liquid $H_2$)
- Cryo-compressed
- Chemical $H_2$ carriers
- Materials-based $H_2$ storage

**Conversion**
- Turbine combustion
- Advanced combustion
- Fuel cell/combustion hybrids
- Fuel cells
- Next generation fuel cells
- Reversible fuel cells

**Applications**
- Fuel refining
- Blending in natural gas pipelines
- Space applications
- Distributed stationary power
- Utility systems
- Portable power
- Transportation
- Distributed CHP
- Integrated energy systems
- Industrial and chemical processes
- Defense, security, and logistics applications

# Technology Targets Guide Research and Development Activities

**Key Goals: Reduce the cost of fuel cells and hydrogen production, delivery, storage, and meet performance and durability requirements – guided by applications specific targets**




⁺Based on 275 kW Heavy Duty Fuel Cell System Cost Analysis (2021), adjusted to reflect cost of system that meets 25,000 hours durability

ǂ 5 to 7 cents/kWh, 90% capacity factor at $1500/kW
*5 to 7 cents/kWh, 90% capacity factor at $460/kW

⁺For range: Delivery and dispensing at today's (2020) stations with capacity ~450 kg/day
*For range: Delivery and dispensing at today's (2020) stations with capacity 450-1,000 kg/day at high volume manufacturing

ǂ Storage costs based on 2019 storage cost record

All costs based on $2016

Note: Graph is not at scale. For illustrative purposes only

# International Early Career Network through IPHE

- **Established by IPHE's Education & Outreach (E&O) Working Group** to promote international $H_2$ and fuel cell awareness and launch a platform for the next generation of $H_2$ and fuel cell leaders
- **Open to students, post-docs and early career** professionals

Stephanie Azubike
Chair

**Learn more: iphe.net/early-career-chapter**

**Membership form:** https://forms.gle/gUnWyV7gU4QqoHLm7

Priya Buddhavarapu
Co-Chair

IPHE

#HydrogenNow

#FuelCellsNow

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