



U.S. DEPARTMENT OF  
**ENERGY**

# U.S. DOE Hydrogen Program Annual Merit Review (AMR) Plenary Remarks

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U.S. Department of Energy

June 5, 2023

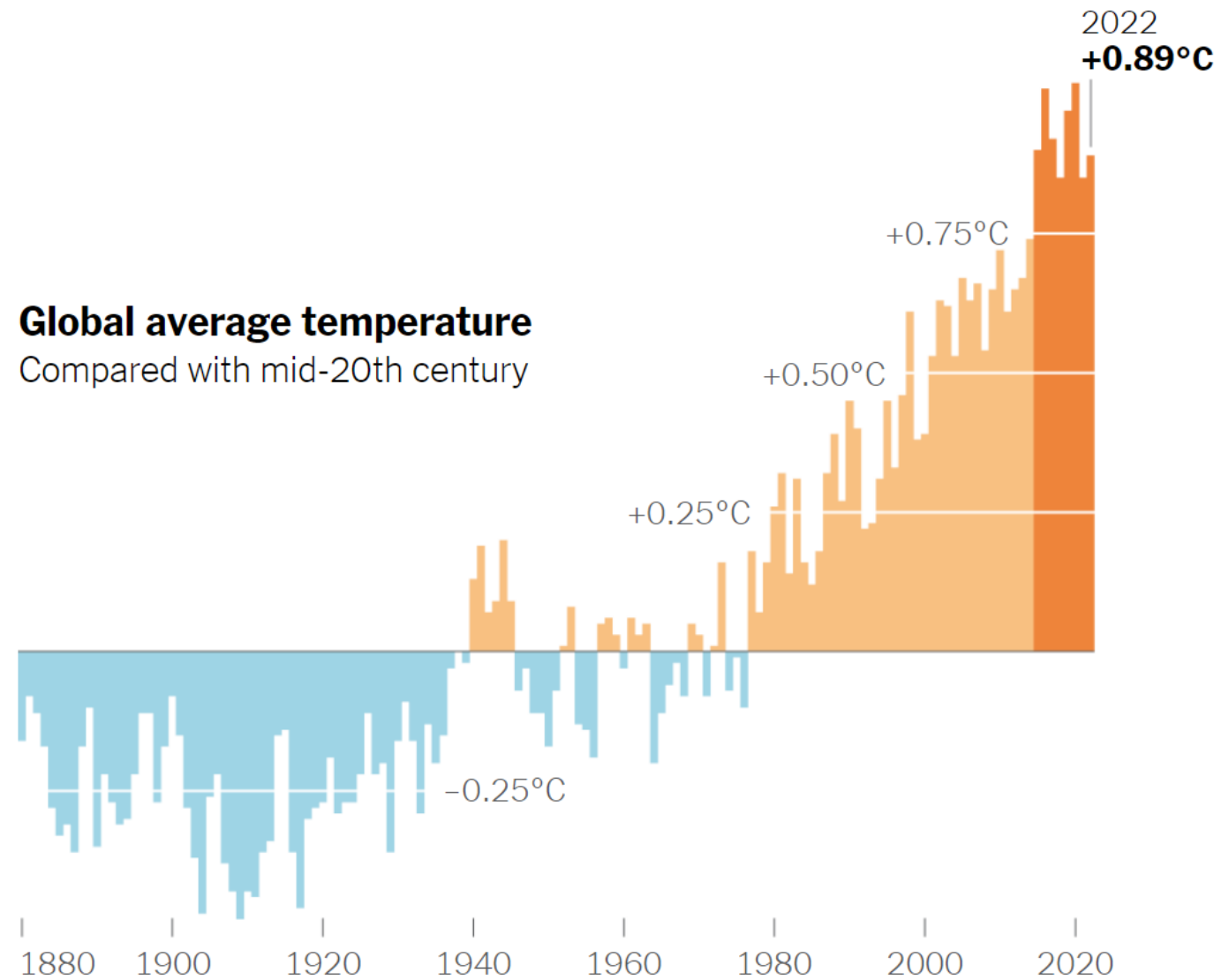




# *Introduction – Energy, Market, and Policy Context*



# The Global Challenge....

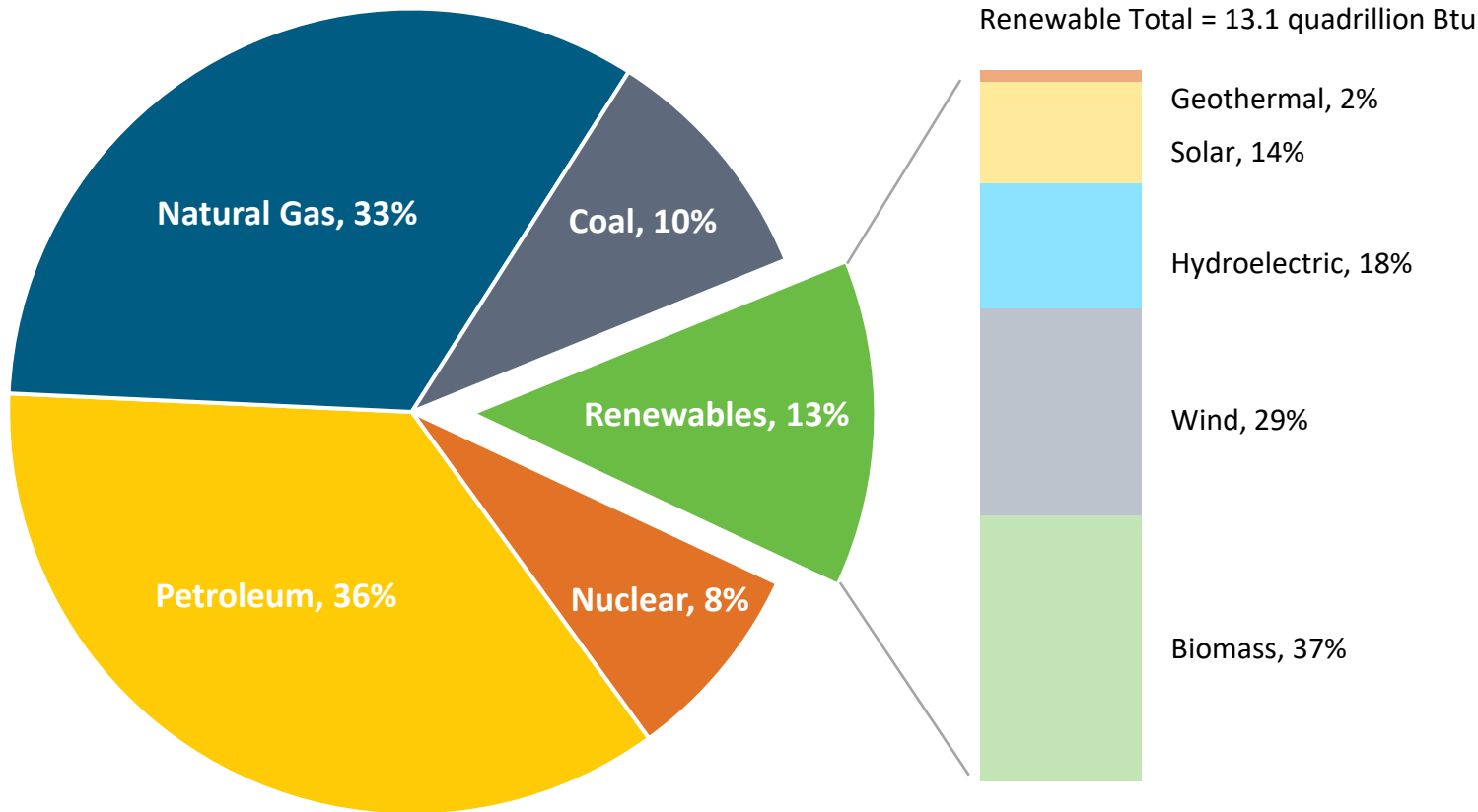


Source: NASA Goddard Institute for Space Studies

# U.S. Energy Landscape and Key Goals

## U.S. primary energy consumption by energy source, 2022

Total = 100.4 quadrillion  
British thermal units (Btu)



**Note:** Sum of components may not equal 100% because of independent rounding  
**Source:** Data collected from U.S. Energy Information Administration, May 2023, *Monthly Energy Review*, preliminary data

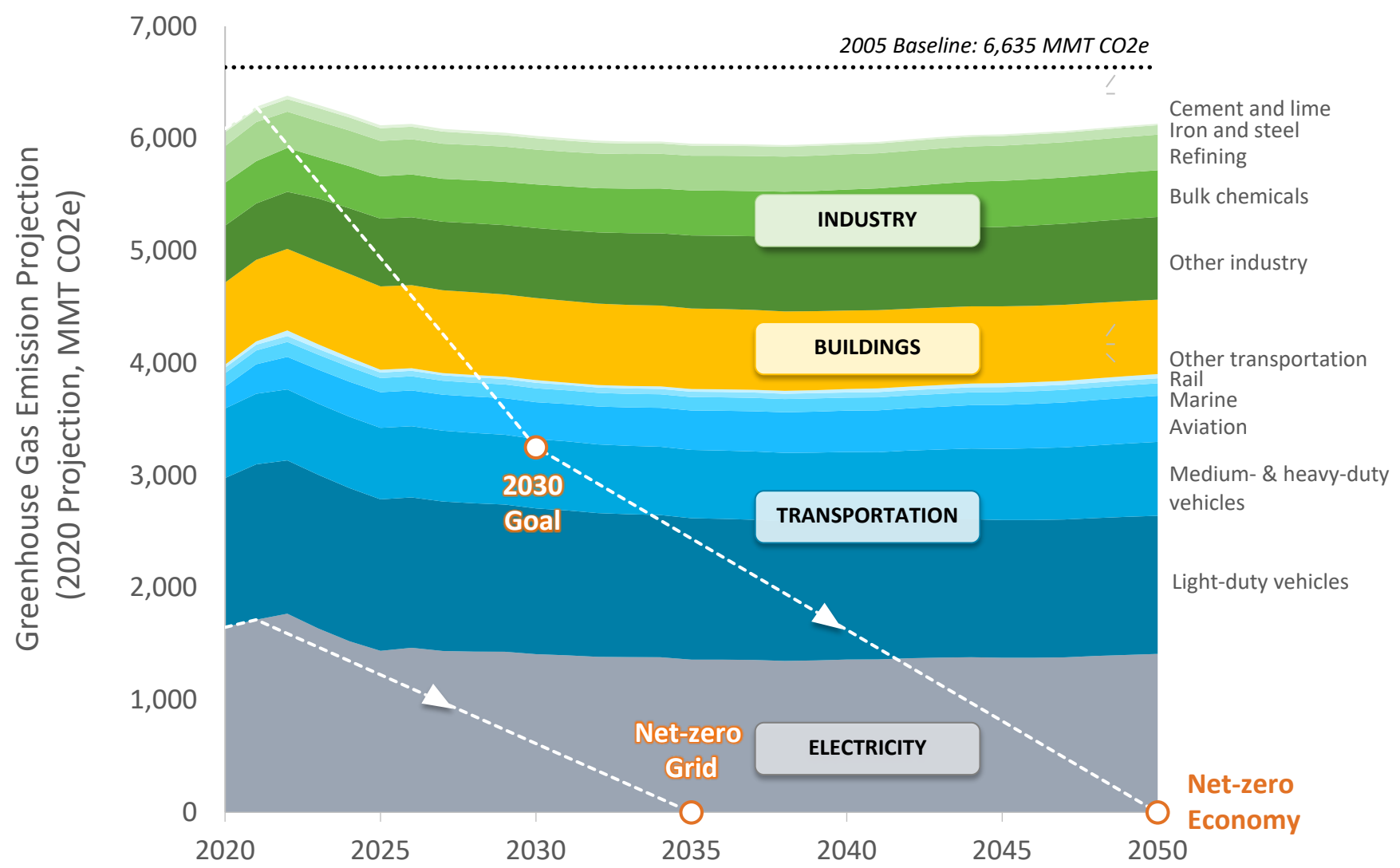
## Administration Goals include:

- Net-zero emissions economy by 2050 and 50–52% reduction by 2030
- 100% carbon-pollution-free electric sector by 2035

**Priorities:** Ensure benefits to all Americans, focus on jobs, Justice40: 40% of benefits in disadvantaged communities



# Carbon Dioxide Emissions by Sector



Hydrogen is a key element of a portfolio of solutions to decarbonize the economy.

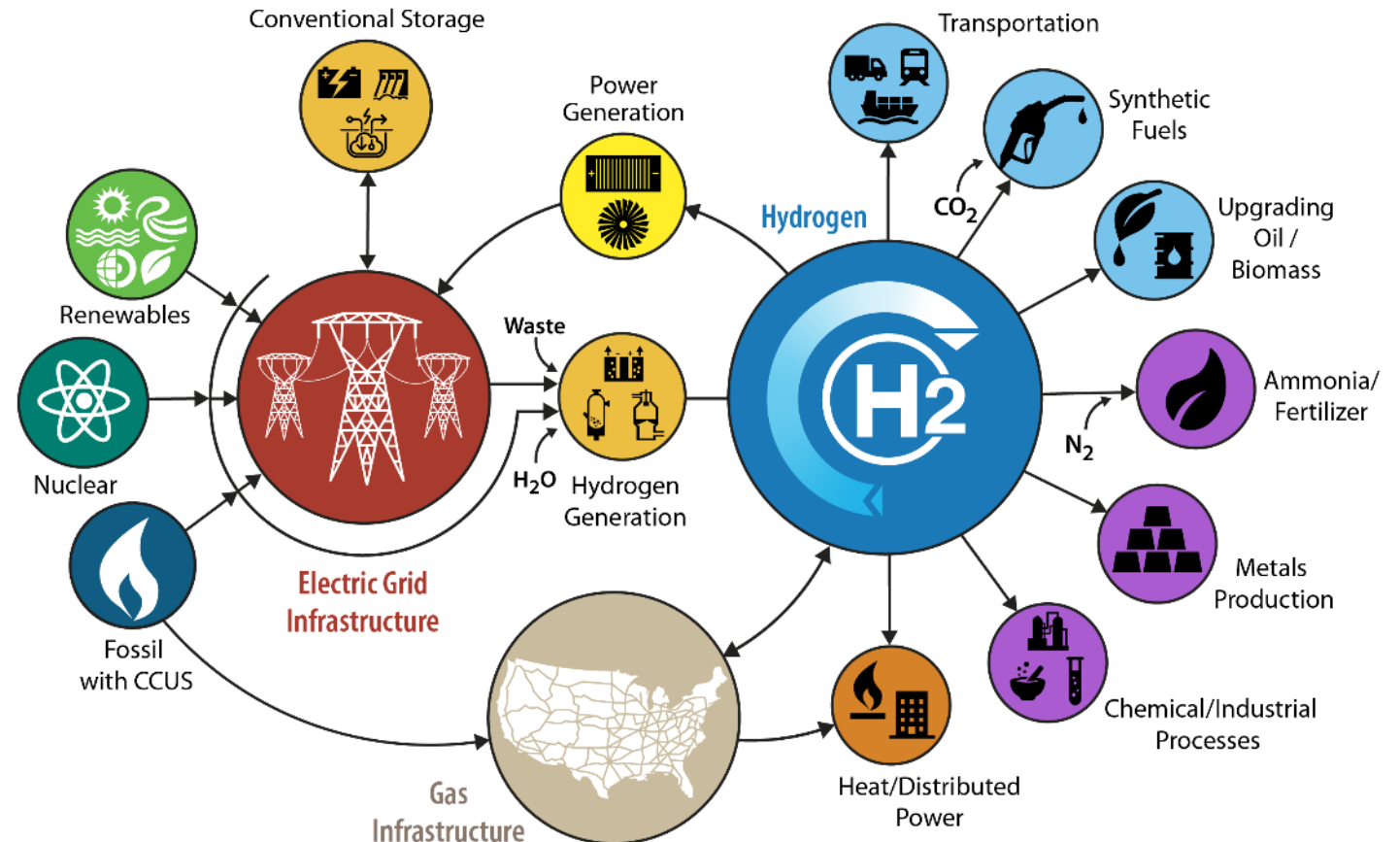
## Hydrogen Program

Coordinated across DOE on research, development, demonstration, and deployment (RDD&D) to address:

- The entire H<sub>2</sub> value chain from production through end use
- H<sub>2</sub> production from all resources (renewables, nuclear, and fossil + CCS)

[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

## H2@Scale vision: Enables clean-energy pathways across sectors



# Legislation Highlights: 2021 – 2022

## Bipartisan Infrastructure Law

- Includes \$9.5B for clean hydrogen:
  - \$1B for electrolysis
  - \$0.5B for manufacturing and recycling
  - \$8B for at least four regional clean hydrogen hubs
- Requires developing a **National Clean Hydrogen Strategy and Roadmap**



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

## Inflation Reduction Act

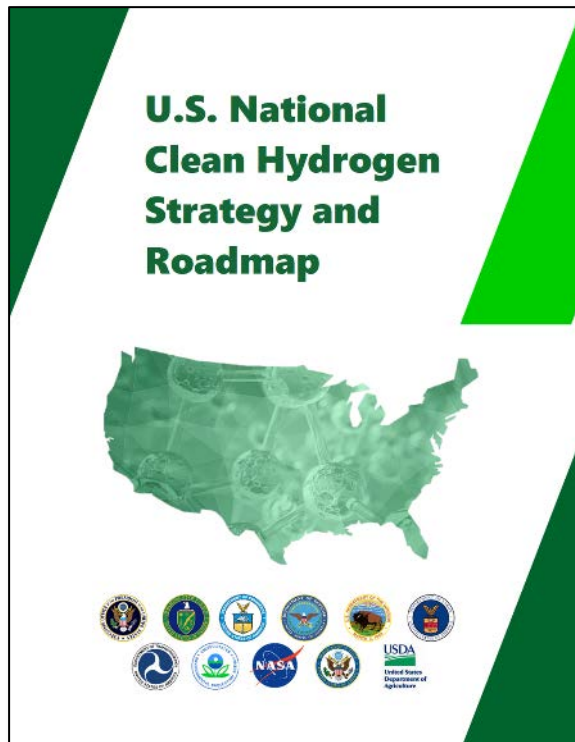
- Includes significant **tax credits** (e.g., up to \$3/kg for production of clean hydrogen)



# Recent DOE Announcements and BIL Deliverables

## U.S. National Clean Hydrogen Strategy and Roadmap

Final Document Released



## Clean Hydrogen Electrolysis, Manufacturing, & Recycling FOA

Funding Opportunity Announcement (FOA) for **\$750 million** to **dramatically reduce the cost of clean-hydrogen technologies**

Concept papers due 4/19/2023

Full applications due 7/19/2023

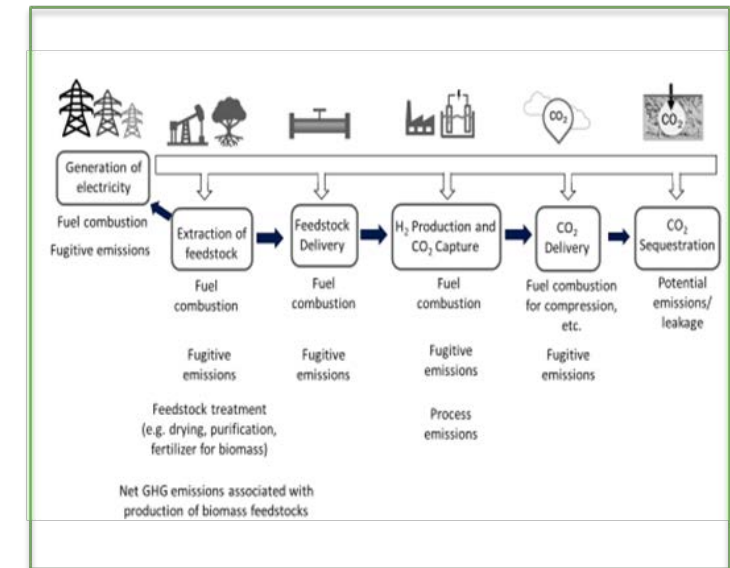
## Regional Clean Hydrogen Hubs (H2 Hubs) FOA

**6 to 10 H2 Hubs for a combined total of \$7B**

*Applications Closed—Stay Tuned!*

## Clean Hydrogen Production Standard (CHPS)

Guidance Document Released for Initial Standard



<https://www.hydrogen.energy.gov/clean-hydrogen-production-standard.html>

# Inflation Reduction Act (IRA) – Examples of H<sub>2</sub> and Fuel Cell Incentives

## Clean Hydrogen Production Tax Credit (45V) up to \$3/kg

Carbon Intensity (kg CO <sub>2</sub> per kg H <sub>2</sub> )*	Max Tax Credit (\$/kg H <sub>2</sub> )
4–2.5	\$0.60
2.5–1.5	\$0.75
1.5–0.45	\$1.00
0.45–0	\$3.00

## Qualified Commercial Clean Vehicles Credit (45W)

- Creates a **new 30% credit** for commercial fuel cell electric vehicles through 2032, capped at **\$40,000**:
- Class 1–3 vehicles: **\$7,500 tax credit** for purchase of qualified clean vehicles
  - Class 4 and above: **\$40,000 tax credit**

## Alternative Fuel Refueling Property Credit (30C)

**Tax credit up to 30%** of the cost of alternative fuel refueling property up to **\$100,000**

\* Well-to-gate, using GREET

View more at: [www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects](https://www.energy.gov/eere/fuelcells/financial-incentives-hydrogen-and-fuel-cell-projects)

# Manufacturing of Hydrogen Production Equipment and Fuel Cells Eligible for \$4 Billion in Tax Credits, among other technologies

## What is 48C?

- Competitively awarded Investment Tax Credit (ITC) established in 2009 with \$2.3B
- Expanded by IRA with \$10B available; [guidance](#) issued March 2023
- Projects receive up to 30% ITC
- Treasury, IRS, and DOE have opened applications for Round 1, which allocates up to \$4B
- Approximately 40% of credits (\$1.6B) will be allocated to projects in coal communities

- Clean Energy Manufacturing and Recycling
- Critical Materials Processing, Refining, and Recycling
- Industrial GHG Emissions Reductions



## Timeline & Review

**Notice Released:**  
May 31

**Informational Webinar:** June 27

**Concept Papers Due:** July 31

**Full Applications Due:** Fall 2023



# New EPA and DOT PHMSA Notice of Proposed Rules

## EPA issued proposed carbon emissions standards for fossil fuel-fired power plants

New Turbines	Phase II (beginning 2032)	Phase III (beginning 2038)
Intermediate generators (20-50% capacity factor)	<b>Blending up to 30% low-GHG H<sub>2</sub></b> by volume can be used to meet the 1000-lb CO <sub>2</sub> /MWh standard	
Base load generators (over ~50% capacity factor)	<b>Blending up to 30% low-GHG H<sub>2</sub></b> can be used to meet the 680-lb CO <sub>2</sub> /MWh standard	<b>Blending up to 96% low-GHH H<sub>2</sub></b> can be used to meet the 90-lb CO <sub>2</sub> /MWh standard

For existing turbines >300 MW capacity, > 50% capacity factor: highly efficient generation coupled with 30% co-firing by volume low-GHG H<sub>2</sub>, by 2038 co-firing with 96% low-GHG H<sub>2</sub>

[Clean Air Act Section 111 Regulation of Greenhouse Gas Emissions from Electric Generating Units \(epa.gov\)](#)

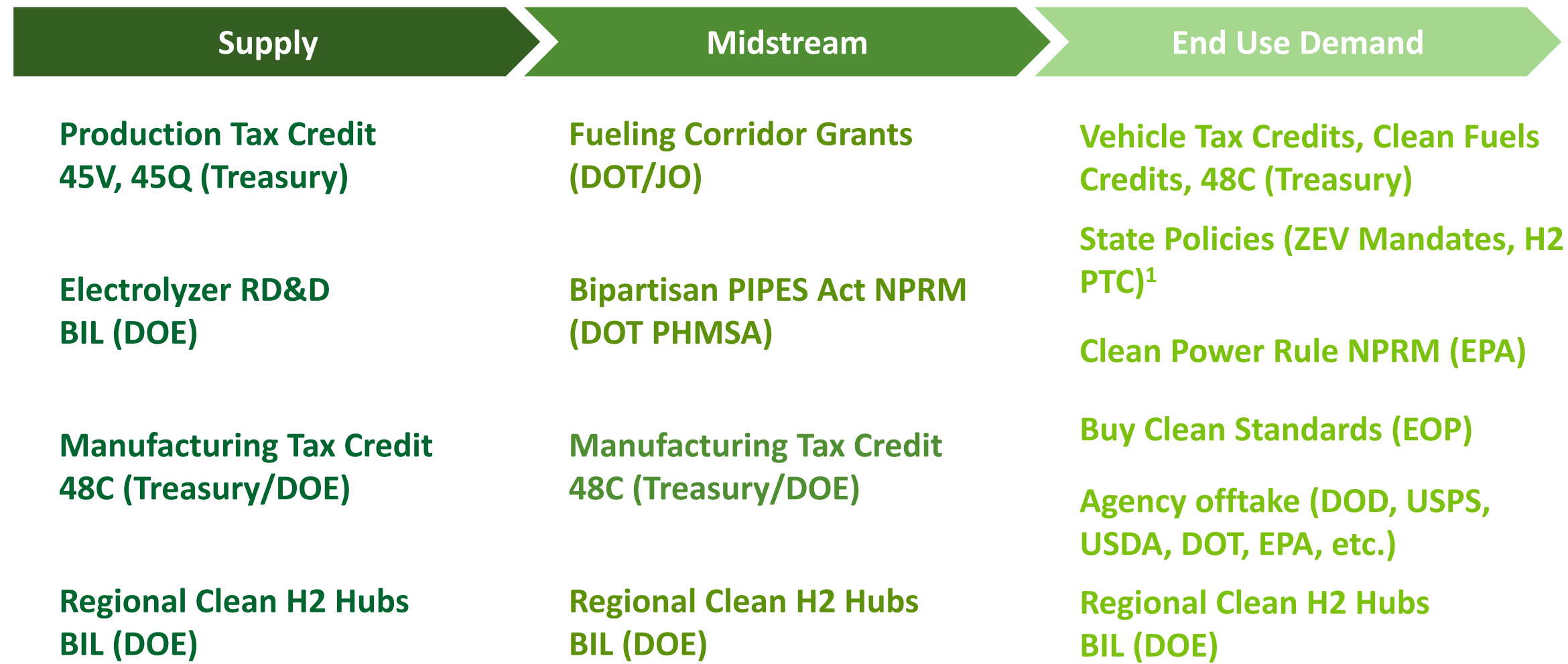
## PHMSA issued proposed H<sub>2</sub> pipeline leak detection and repair as part of Leak Detection and Repair Rule

“Unless otherwise specified in the proposed amendments, the proposals in this NPRM apply the same requirements to hydrogen gas pipelines (and other gas pipelines) as to natural gas pipelines.”

NPRM: Notice of Proposed Rulemaking

<https://www.phmsa.dot.gov/news/usdot-announces-bipartisan-pipes-act-proposal-modernize-decades-old-pipeline-leak-detection>

# Drivers to Enable Clean Hydrogen at Scale and Cross-Agency roles - Examples



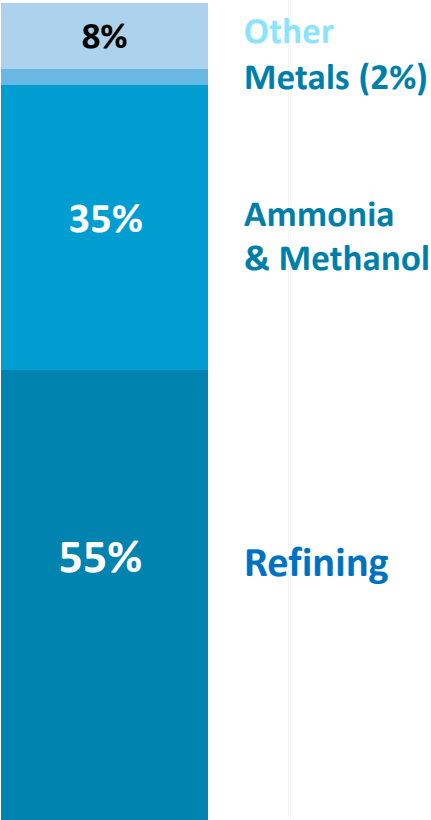
JO: Joint Office of Energy and Transportation; EOP: Executive Office of the President  
NPRM: Notice of proposed rulemaking

1: ZEV Mandates see: <https://www.c2es.org/document/us-state-clean-vehicle-policies-and-incentives/>. Colorado’s H2 PTC see: <https://leg.colorado.gov/bills/hb23-1281>.

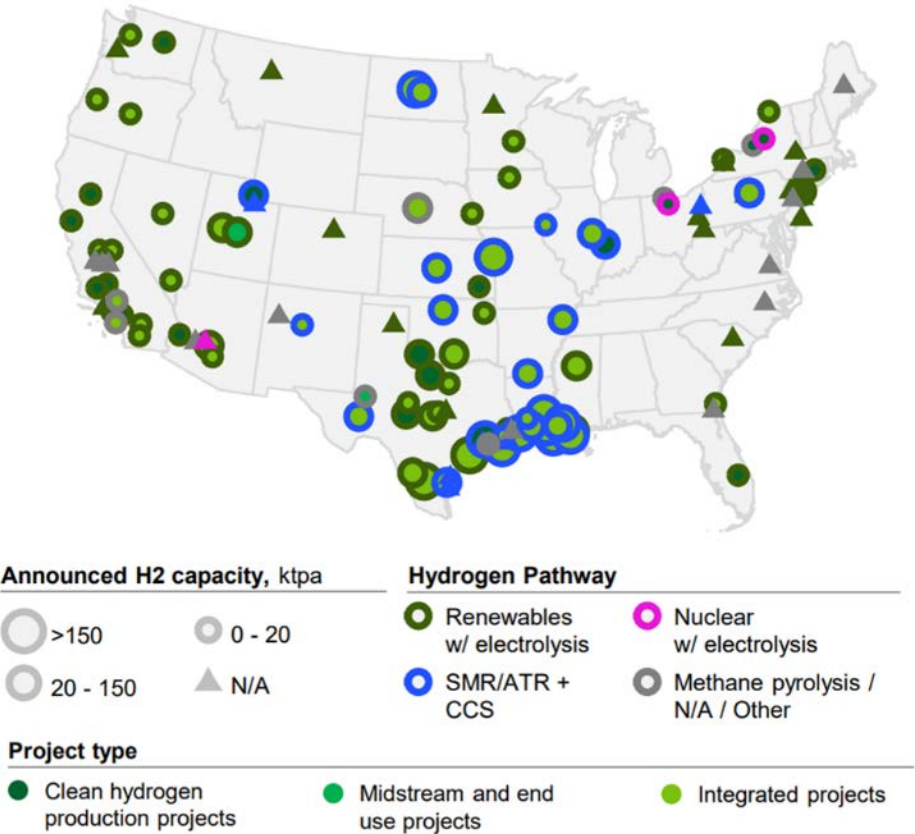
# Snapshot of Hydrogen and Fuel Cells in the U.S.

- 10 million metric tons produced annually
- More than 1,600 miles of H<sub>2</sub> pipeline
- World's largest H<sub>2</sub> storage cavern

## Use of Hydrogen in the U.S. Today

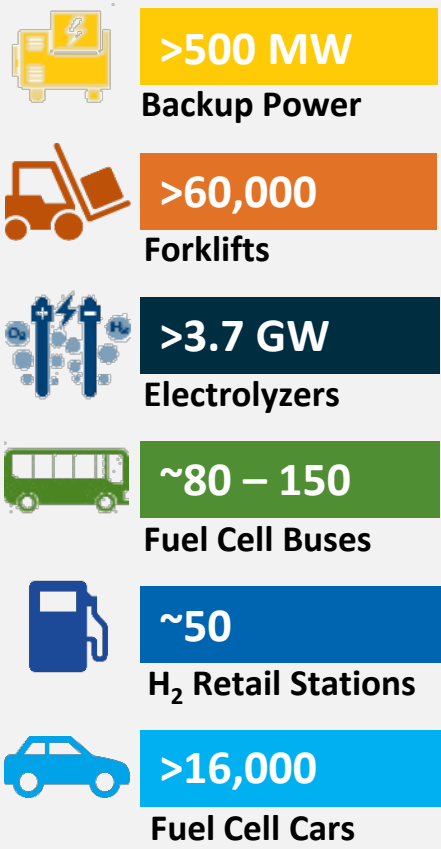


## Current publicly announced clean hydrogen production projects\*



\*as of EOY 2022, DOE Commercial Liftoff Report

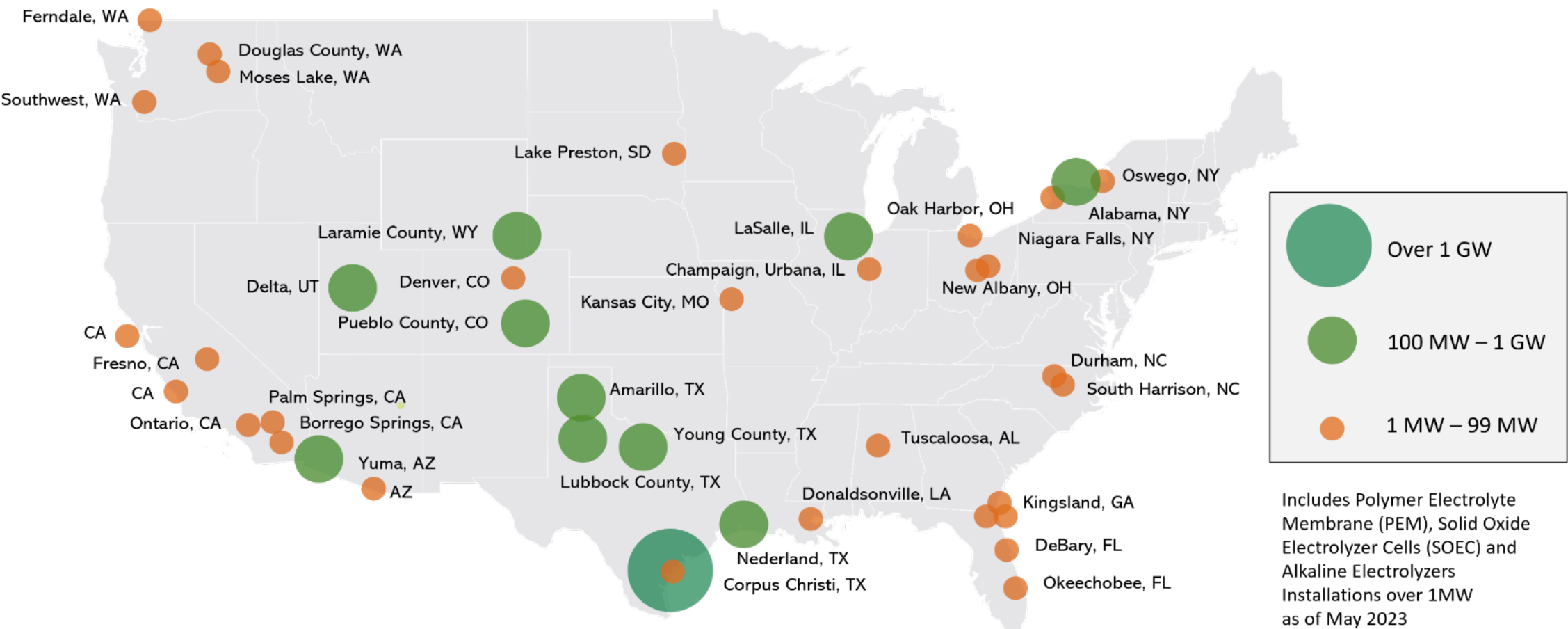
## Examples of Deployments





# New Announcement: Planned and Installed Electrolyzer Capacity in the U.S.

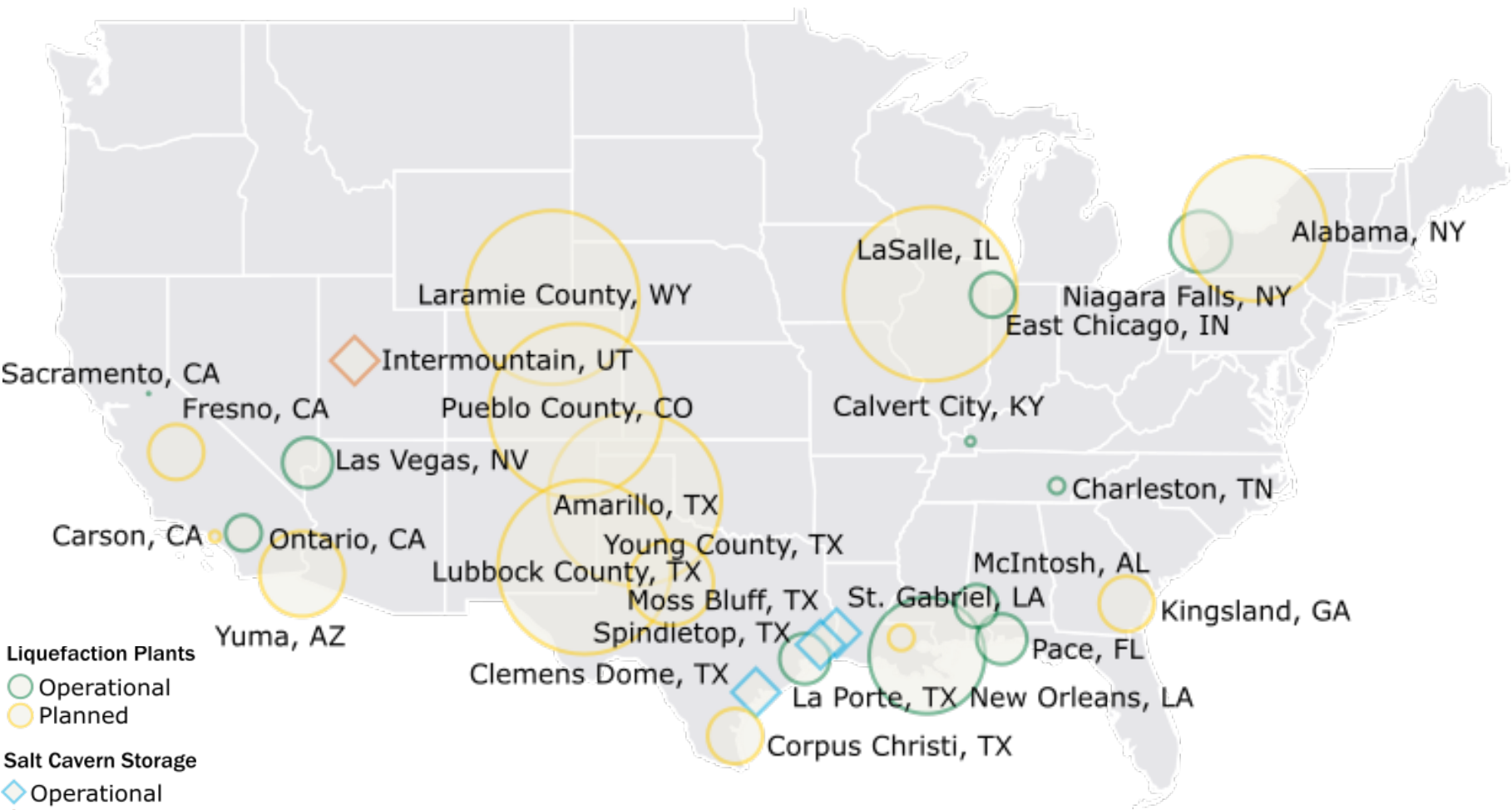
Total 3.7 GW in Electrolyzer Capacity  
5-fold increase since 2022



Source: Arjona, V., DOE Program Record #23003, June 2023

# Existing and Planned Liquefaction and Salt Cavern Storage

~1,020 Tons per Day (tpd) Liquefaction Capacity Expected  
>330 GWh Salt Cavern Storage Currently; 150-300 GWh More Planned



**Operating U.S. Hydrogen Liquefaction Plants**  
11 Operating at 5-60 tpd  
289 tpd total capacity

**Planned U.S. Hydrogen Liquefaction Plants**  
13 Planned at 10-90 tpd  
730 tpd total capacity

**U.S. Hydrogen Storage Caverns**  
3 Operating  
1 Planned  
4 Total  
100-150 GWh capacity

Source: Wieliczko, M. DOE, HFTO based on publicly available media from industry and NREL

Additional liquefaction plants in Canada: 5 operating + 1 planned

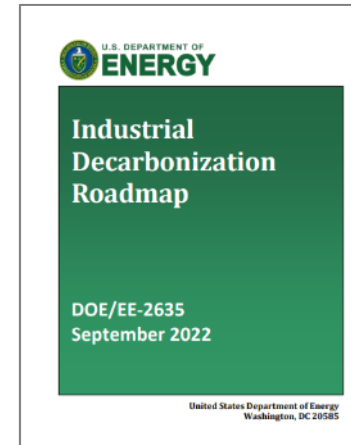
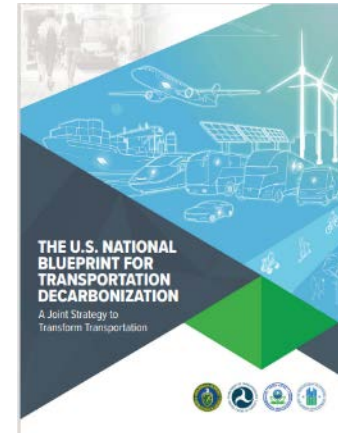
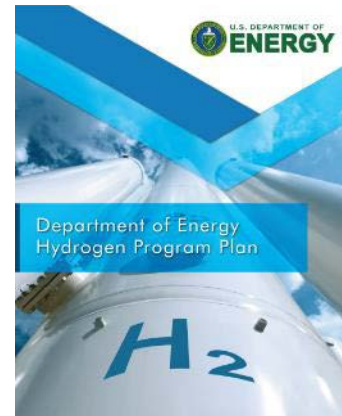
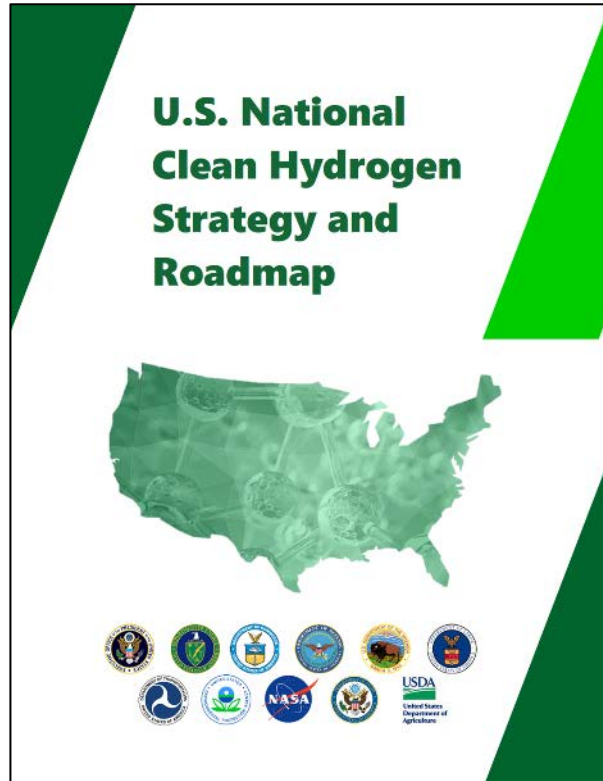
# *Strategy & Goals*





# Key Publications

Analysis and guiding documents provide framework for key activities from basic science through deployment



[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

# U.S. National Clean Hydrogen Strategy and Roadmap

## Strategy



## Enablers

Work with other agencies to accelerate market lift off



Good Jobs and Workforce Development



Safety, codes and standards



Policies and incentives

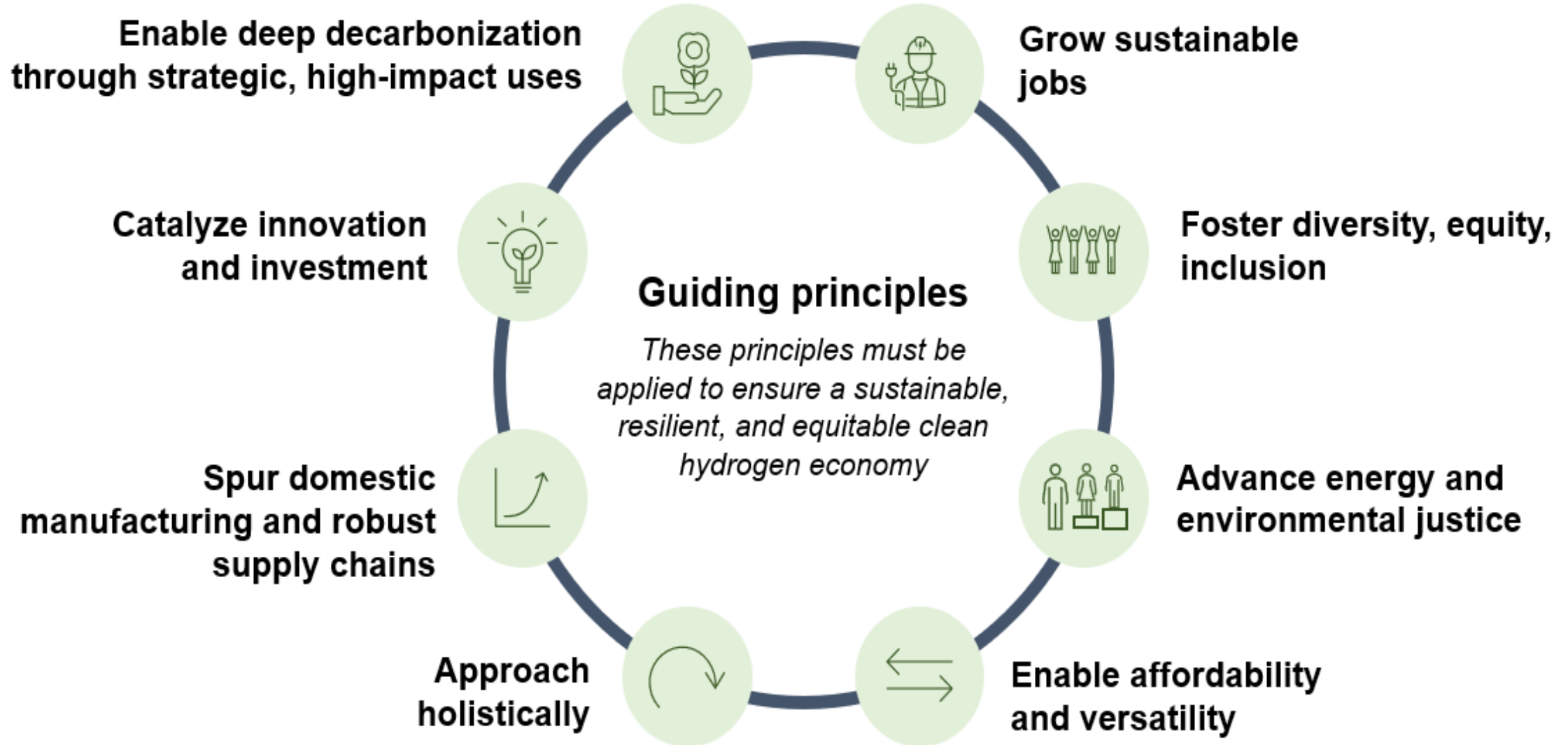


Stimulating private sector investment



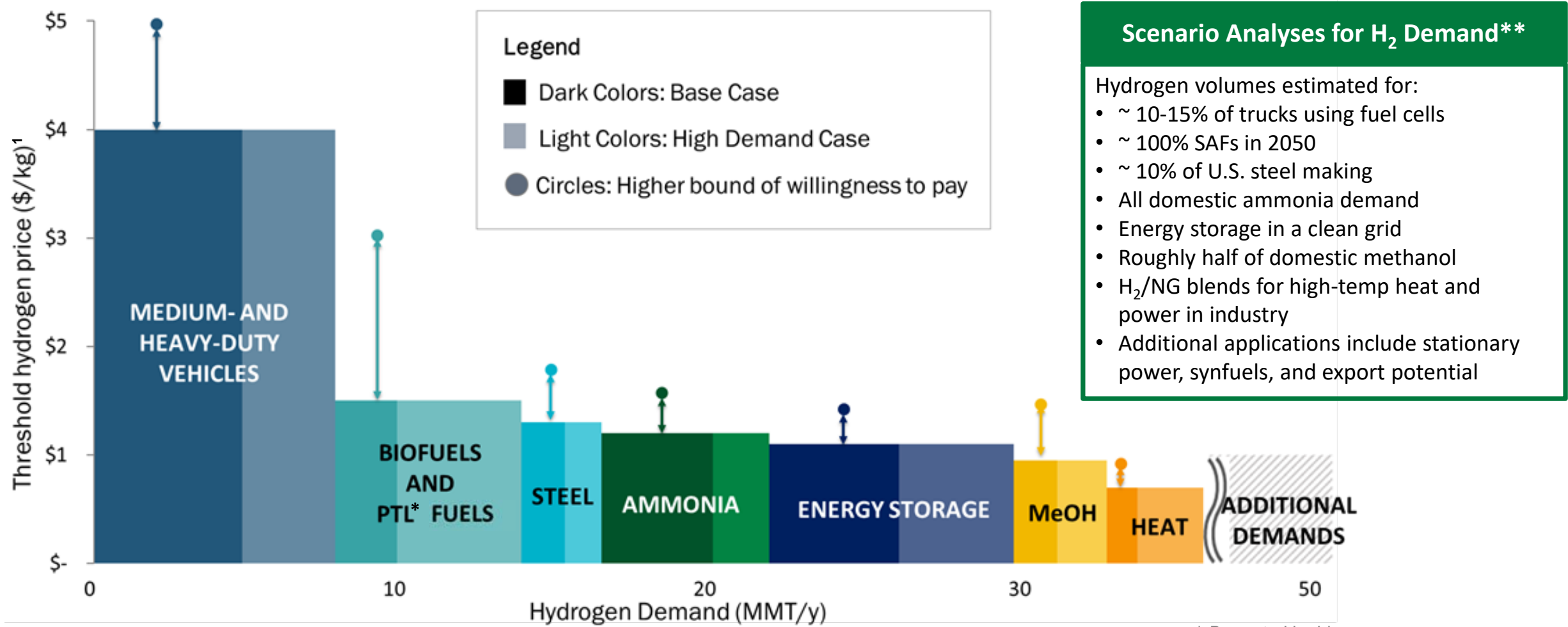
Energy and environmental justice

# Guiding Principles



# Strategy 1: Target High-Impact Uses of Hydrogen

## Clean Hydrogen Demand and Costs for Market Penetration



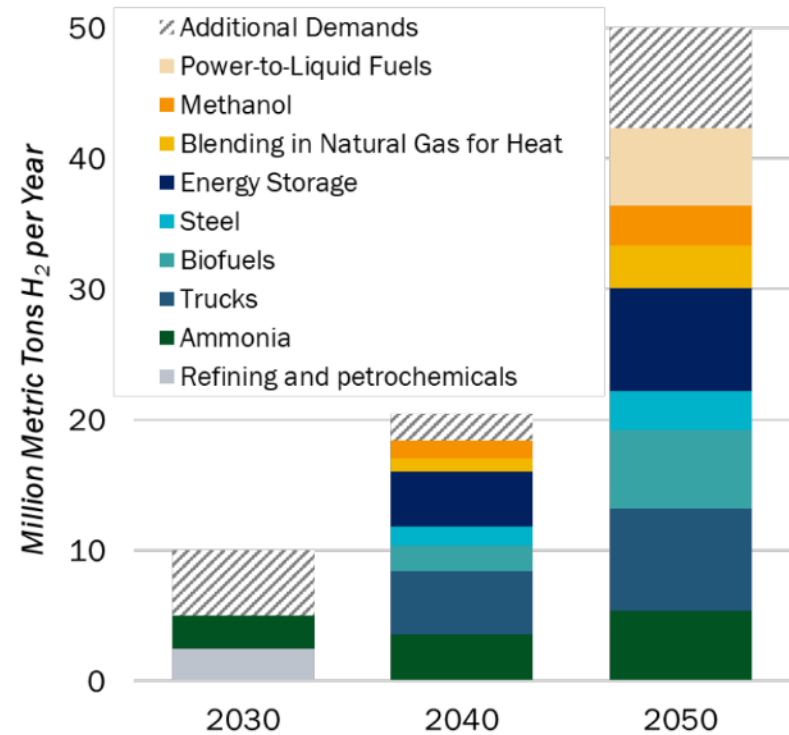
<sup>1</sup>Costs include production, delivery, dispensing to the point of use (e.g., high-pressure fueling for vehicle applications)

\* Power to Liquid  
\*\* Volumes dependent on multiple variables



# Strategy 1: Target High-Impact Uses of Hydrogen

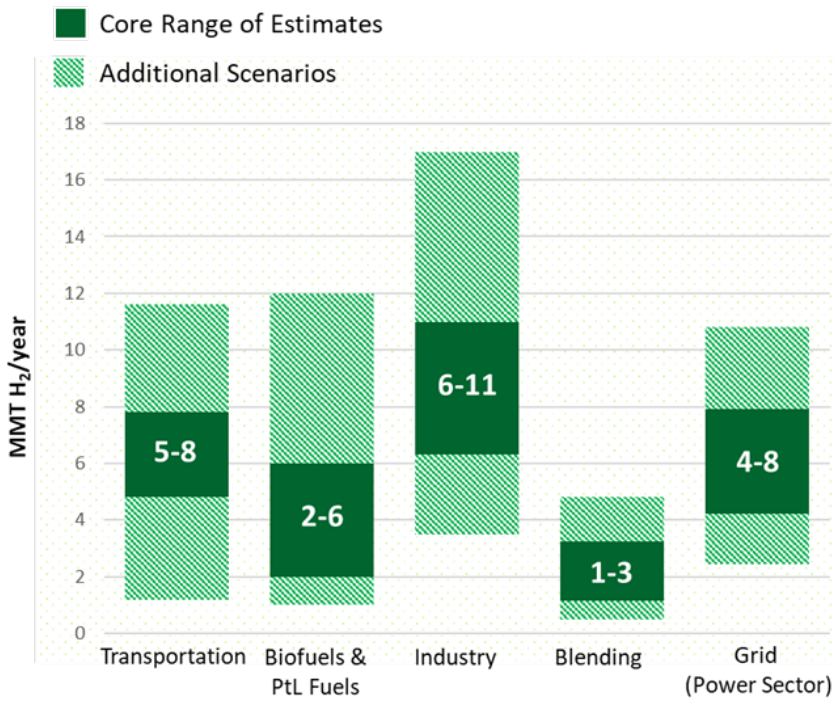
## Opportunities for Clean Hydrogen Across Applications



## Clean Hydrogen Use Scenarios

- Catalyze clean H<sub>2</sub> use in existing industries (ammonia, refineries), initiate new use (e.g., sustainable aviation fuels [SAFs], steel, potential exports)
- Scale up for heavy-duty transport, industry, and energy storage
- Market expansion across sectors for strategic, high-impact uses

## Range of Potential Demand for Clean Hydrogen by 2050



• Core range: ~ 18–36 MMT H<sub>2</sub>

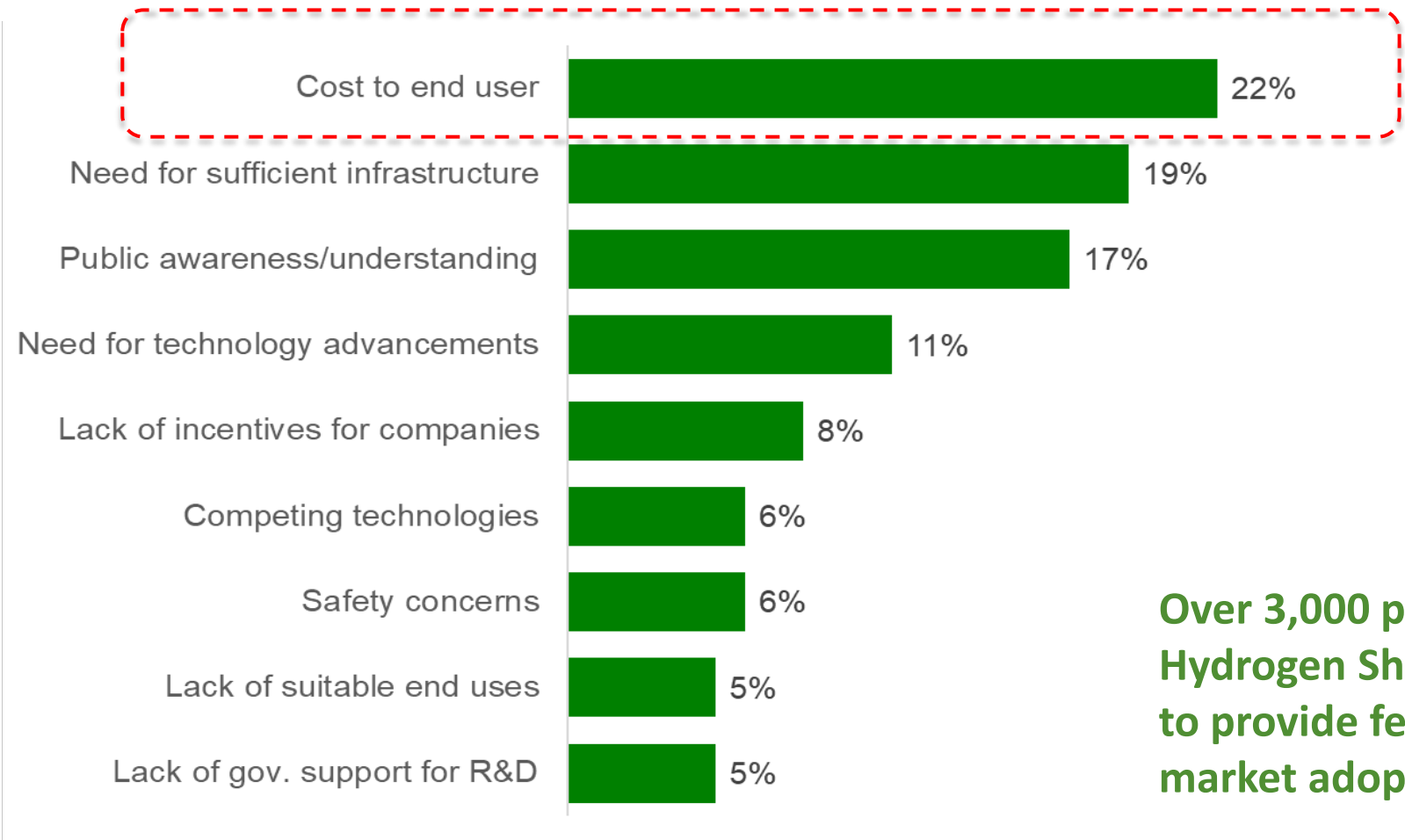
• Higher range: ~ 36–56 MMT H<sub>2</sub>

Refs: 1. NREL MDHD analysis using TEMPO model; 2. Analysis of biofuel pathways from NREL; 3. Synfuels analysis based off H2@Scale ; 4. Steel and ammonia demand estimates based off DOE Industrial Decarbonization Roadmap and H2@Scale. Methanol demands based off IRENA and IEA estimates; 5. Preliminary Analysis, NREL 100% Clean Grid Study; 6. DOE Solar Futures Study; 7. Princeton Net Zero America Study

**U.S. Opportunity: 10MMT/yr by 2030, 20 MMT/yr by 2040, 50 MMT/yr by 2050; ~10% Emissions Reduction; ~100K Jobs by 2030**

# Strategy 2: Focus on Cost-Reduction

## Stakeholder Reported Barriers to Hydrogen Market Adoption



Over 3,000 participants at DOE Hydrogen Shot Summit were requested to provide feedback on key barriers to market adoption of hydrogen

Source: Hydrogen Shot Summit, Sept 2021

<https://www.energy.gov/eere/fuelcells/hydrogen-shot-summit>



Hydrogen

## Hydrogen Energy Earthshot

**“Hydrogen Shot”**

**“1 1 1”**

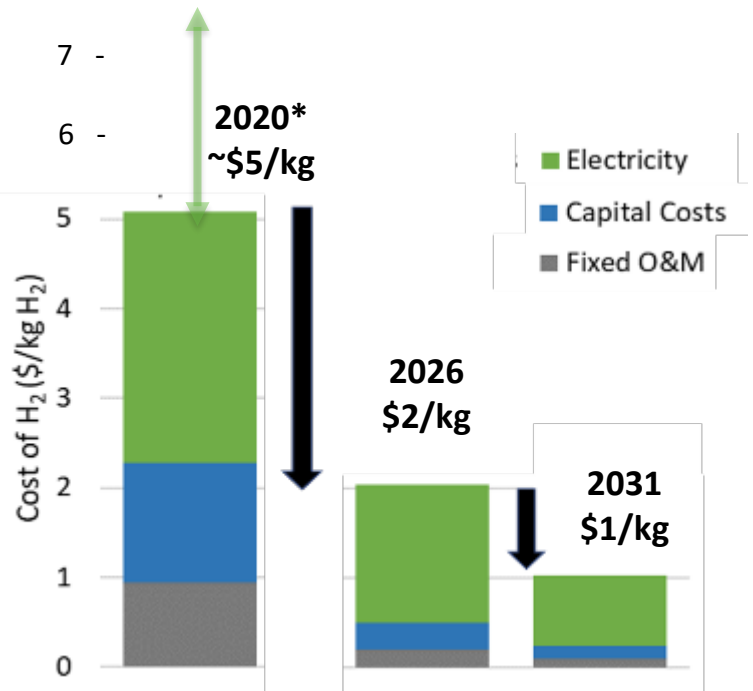
**\$1 for 1 kg clean hydrogen in 1  
decade**

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

# How to reduce cost? Examples across multiple pathways

## Strategies and scenarios being developed to reduce cost and emissions across pathways

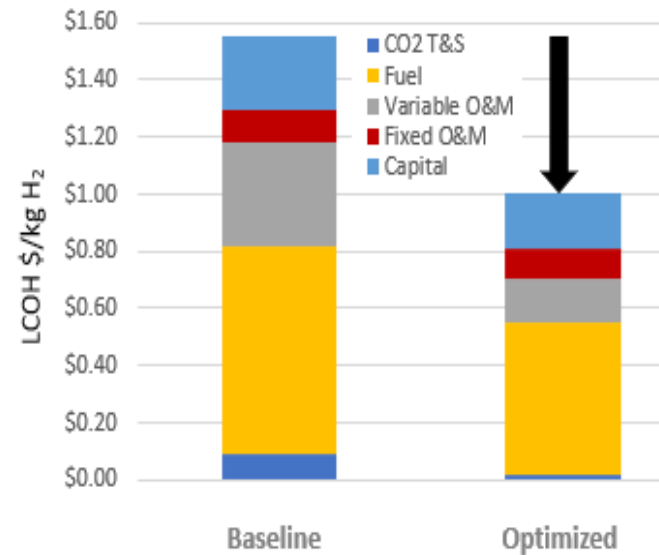
### H<sub>2</sub> from Electrolysis



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

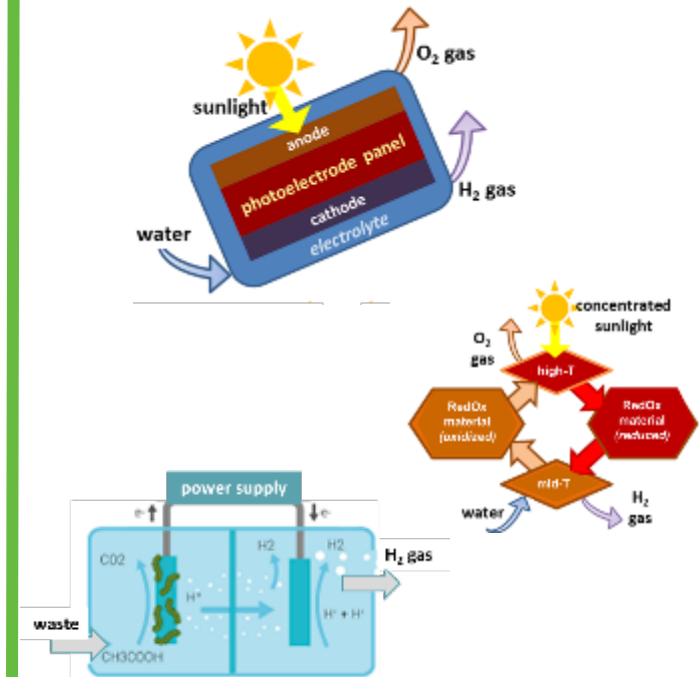
### Thermal Conversion

Example: Autothermal Reforming + CCS



- Reforming; pyrolysis; air separation; catalysts; carbon capture and storage (CCS); upstream emissions

### Advanced Pathways



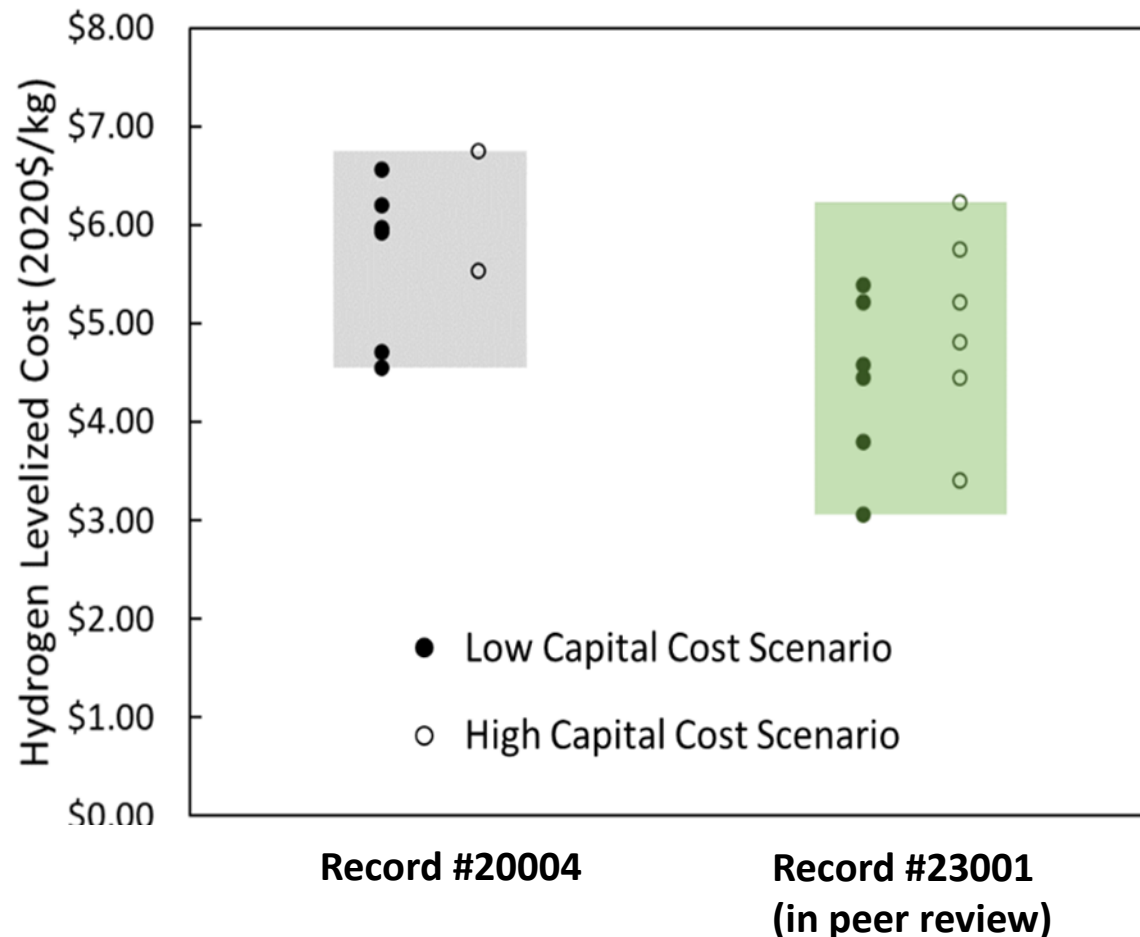
- Photoelectrochemical (PEC), thermochemical, biological, etc.

\*2020 Baseline: PEM (Proton Exchange 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



# Tracking Electrolytic Hydrogen Production Cost

## Levelized Cost of Hydrogen from PEM Electrolysis Analysis



- Ongoing tracking of key parameters (capital cost, lifetime, efficiency, installation, O&M, etc.) vetted by industry
- Specific use cases:
  - Cost from PEM electrolyzers can be ~\$4 – 6/kg with renewable energy, and as low as \$3/kg in a specific nuclear energy scenarios
- Ongoing efforts to document cost of H<sub>2</sub> from other electrolyzer types

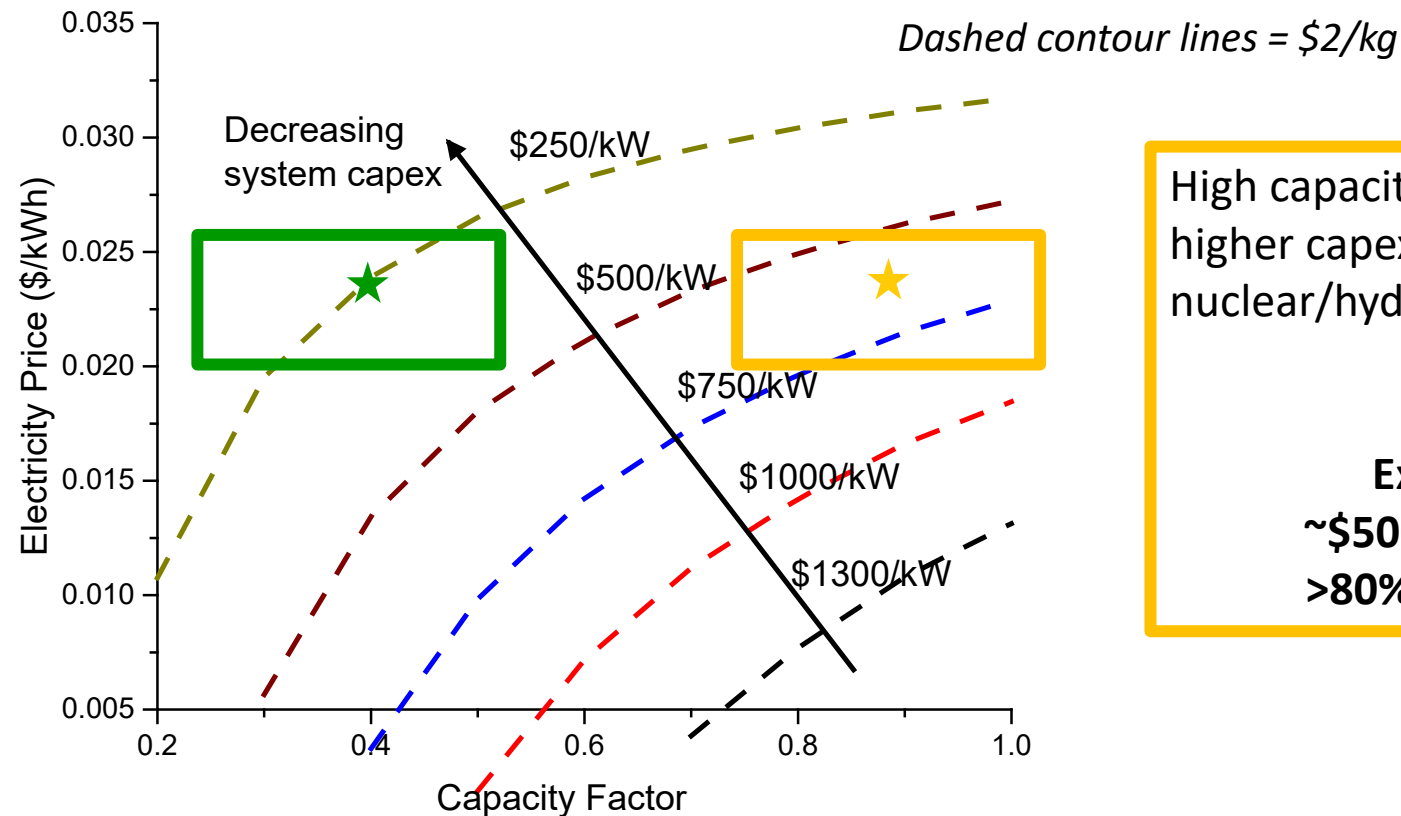
DOE Hydrogen Program Record #23001, "Hydrogen Production Cost with Current PEM Electrolyzer Technology – 2022",  
Under peer review; to be published at [https://www.hydrogen.energy.gov/program\\_records.html](https://www.hydrogen.energy.gov/program_records.html)

# Use Case Strategies: How to get to \$2/kg?

## Case Study: Two 'book end' approaches to achieving \$2/kg H<sub>2</sub> via electrolysis

Low-capacity factor and lowest possible capex  
Focus on otherwise curtailed/excess PV/wind

**Example:**  
**\$250/kW**  
**~40% cap factor**



High capacity-factor allows higher capex. Focus on nuclear/hydro/hybridization.

**Example:**  
**~\$500-\$750/kW**  
**>80% cap factor**

Contour lines represent electricity price and capacity factor combinations that achieve \$2/kg H<sub>2</sub> for different system capital costs ranging from \$1,300/kW to \$250/kW (2026 target, assuming economies of scale); assumes 2026 improved performance, 51 kWh/kg, 80khr. PEM case study preliminary analysis; M. Hubert, et al, (DOE HFTO)

# Execution Strategy to achieve \$2/kg at scale, supply chain, and enable \$1/kg

## Goals

- Enable GW/yr domestic electrolyzer manufacturing at \$100/kW stack cost, <50 kWh/kg, 10 yr life
- Develop low-cost advanced components and robust domestic supply base
- Ensure zero/limited dependence on critical materials and foreign supplies

Address enabling ecosystem: workforce, justice, inclusion, safety, codes, standards, infrastructure

## Execution Strategy

Leverage and Expand Existing National Lab Consortia & Capabilities



FOAs enable manufacturing, supply chain, first of a kind demos

Support industry and universities to build U.S. manufacturing, components, and expertise

SBIRs, TCF, Prizes, and more to incentivize new/small players and collaborations

Support emerging domestic start-ups and enable a diverse domestic supply chain

## New FOA Topics FY23 (BIL)

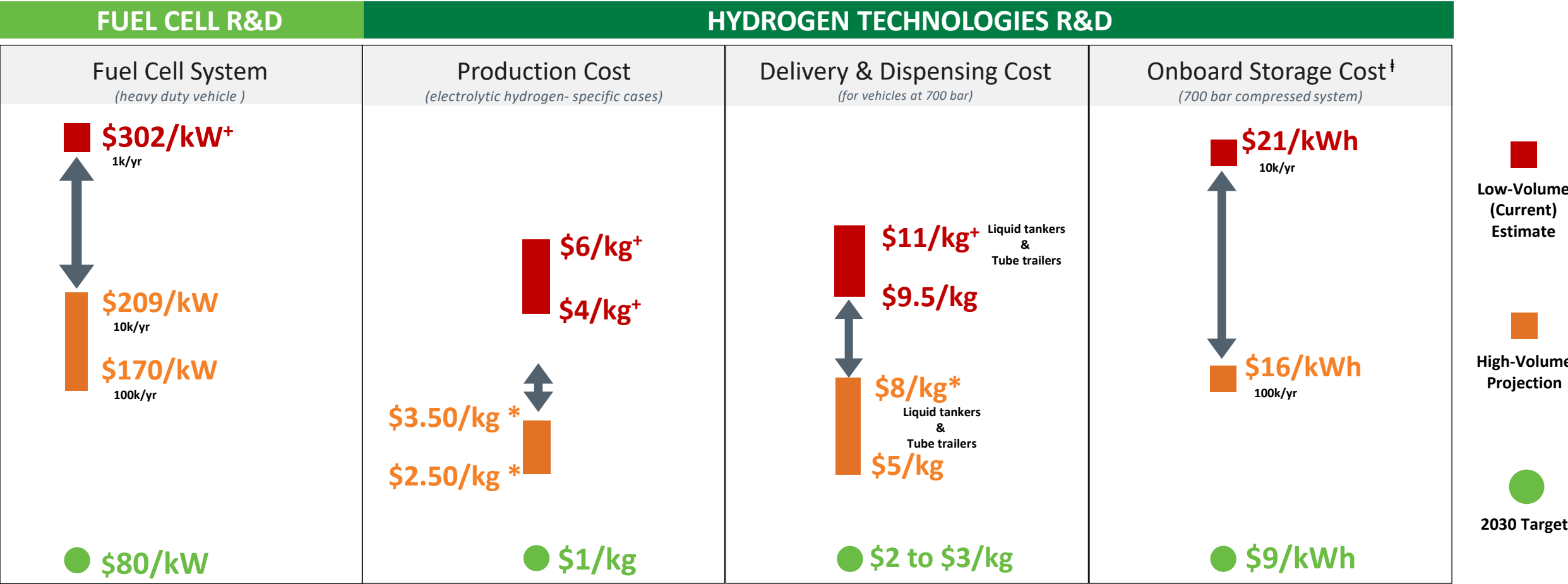
Large manufacturing RD&D projects for electrolyzers and fuel cells

Component RD&D including innovative concepts (e.g., to address PFAS issues)

Recovery & Recycling Consortium (with nonprofits, industry, labs)

# Still Need Technology Cost Reductions – Targets Guide RD&D

Key Goals: Reduce the cost of fuel cells and hydrogen production, delivery, storage; and meet performance and durability requirements—guided by application-specific targets



<sup>\*</sup>Based on 275 kW Heavy Duty Fuel Cell System Cost Analysis (2022), adjusted to reflect cost of system that meets 25,000 hours durability

<sup>\*</sup> 2.5 to 4 cents/kWh, 50% capacity factor, \$1000/kW-\$1300/kW; See H2 Technologies presentation for details on pending Record.  
<sup>\*</sup>2.5 to 4 cents/kWh, 50% capacity factor, \$600/kW.

<sup>†</sup> Delivery and dispensing at today's (2020) stations at ~450 kg/day  
<sup>\*</sup>Delivery and dispensing at today's (2020) stations with capacity 450-1,000 kg/day at high volume manufacturing. Note high volatility and market/supply chain factors; current at station H<sub>2</sub> prices as high as ~ \$25/kg in some regions

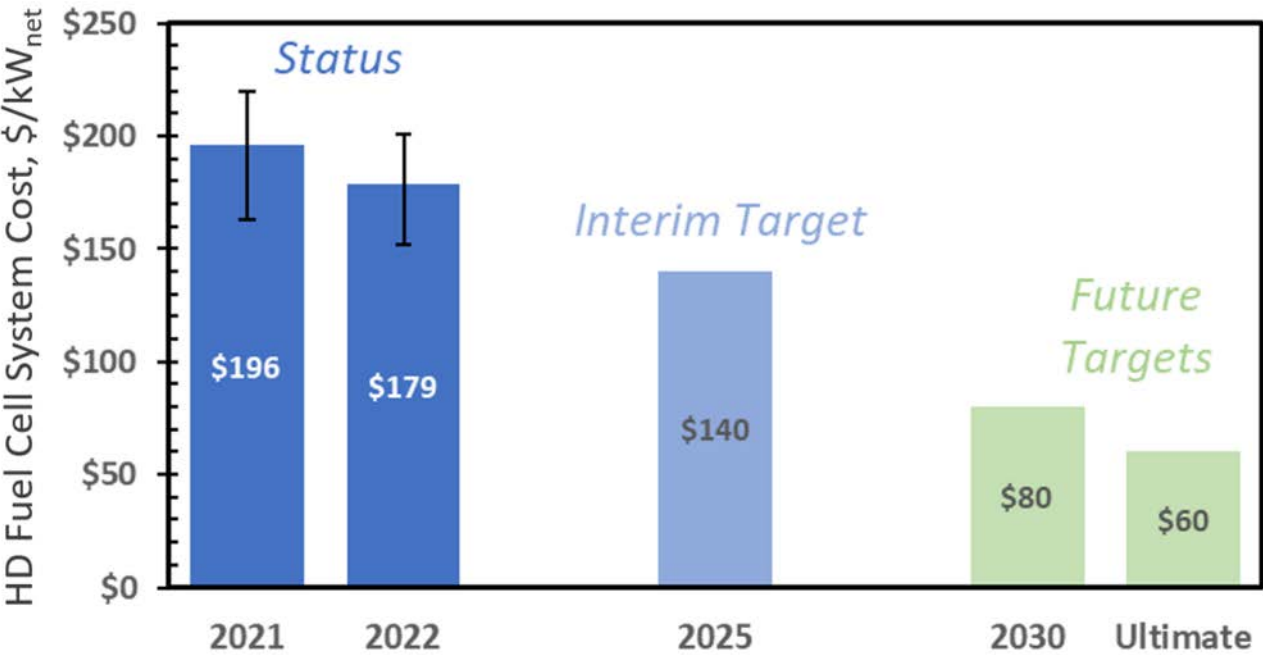
<sup>†</sup>Storage costs based on 2019 storage cost record

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



# Heavy Duty Truck Fuel Cell Durability-Adjusted Costs (for 25,000-hour lifetimes)

## Modeled cost of a 275-kW<sub>net</sub> HD Truck PEMFC system

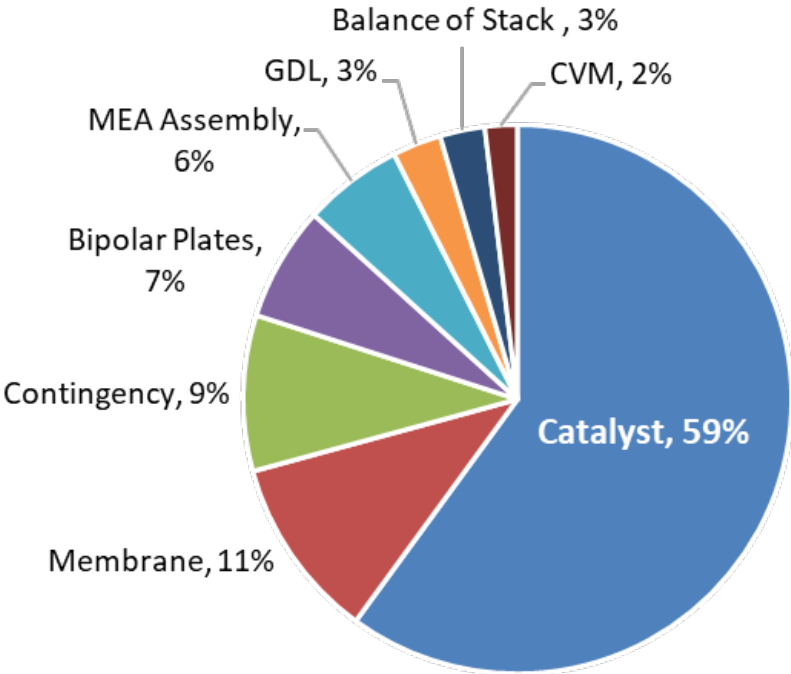


Cost status (2021, 2022) and interim target (2025) for a manufacturing volume of 50,000 systems/yr. Future (2030, ultimate) targets at 100,000 systems/yr; (\$302/kW<sub>net</sub> at 1,000 systems/yr; \$179/kW<sub>net</sub> at 50,000 systems/yr; \$170/kW<sub>net</sub> at 100,000 systems/year



DOE Million Mile Fuel Cell Truck Consortium with labs, industry, universities to achieve cost, durability, efficiency targets

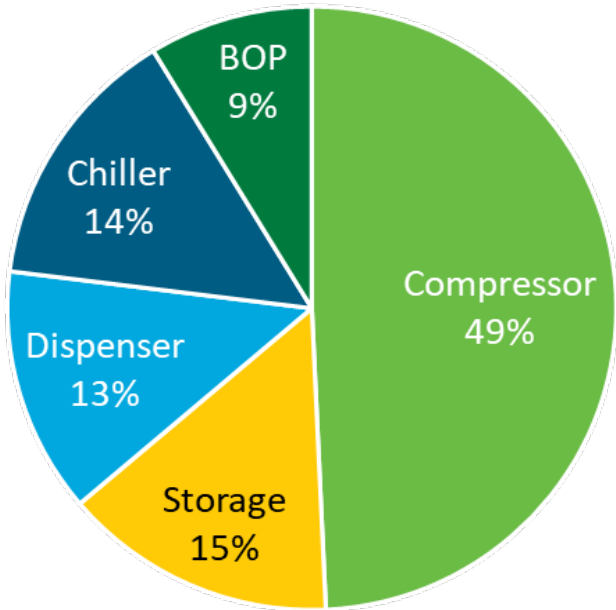
## Stack cost breakdown (\$112/kW<sub>net</sub> at 50,000 systems/year)



**Stack cost dominates system cost**  
**Catalyst cost projected to be largest single component of stack cost to meet durability requirements**

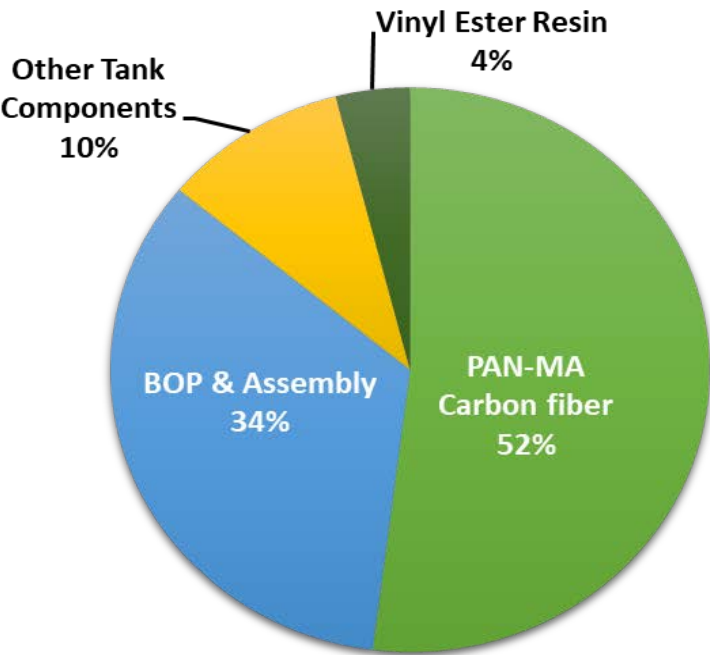
# Examples of Cost Drivers and Focus Areas for Hydrogen Technologies

## H<sub>2</sub> Infrastructure Cost Drivers: Compressors, Chiller, Dispenser and Storage



**Hydrogen Fueling Station Levelized Cost Example**  
(700 Bar, 800 kg/day Station)

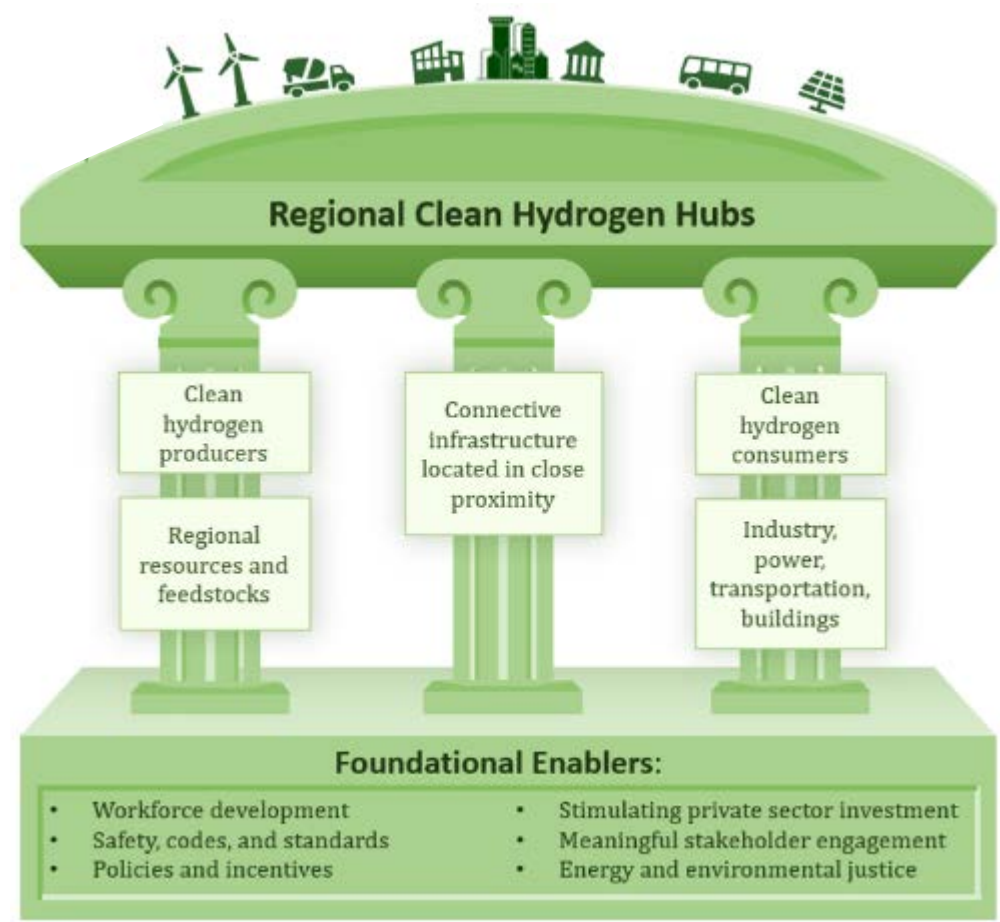
## H<sub>2</sub> Onboard Storage Cost Drivers: Carbon Fiber Precursors and Processing



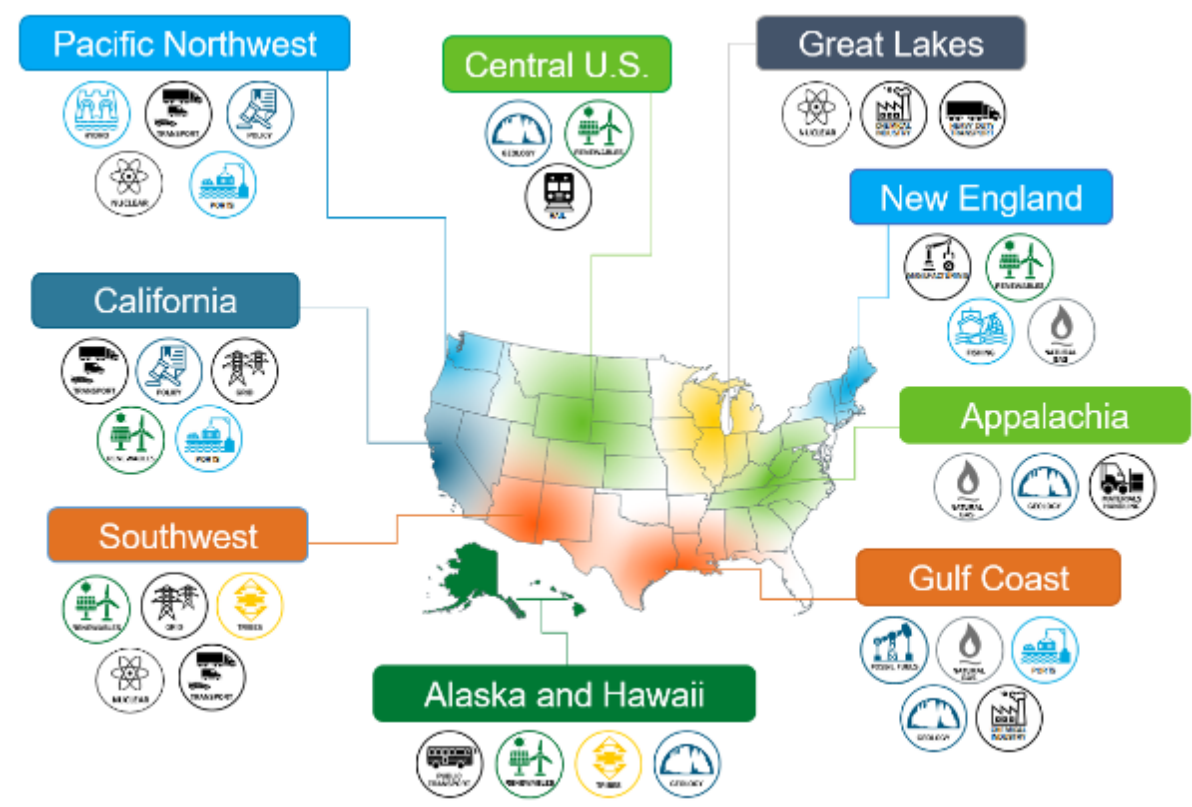
**On-board Vehicle Hydrogen Storage Cost Example**  
(700 bar Type IV, 5.6 kg Hydrogen Storage System)

# Strategy 3: Focus on Regional Networks and Ramp-up Scale

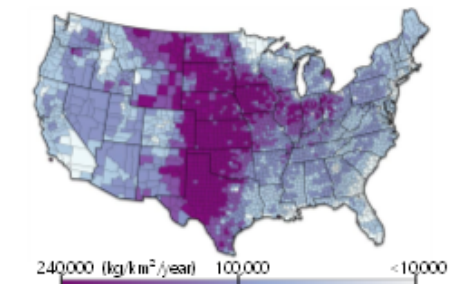
## Build Regional Networks through “Clean Hydrogen Hubs”



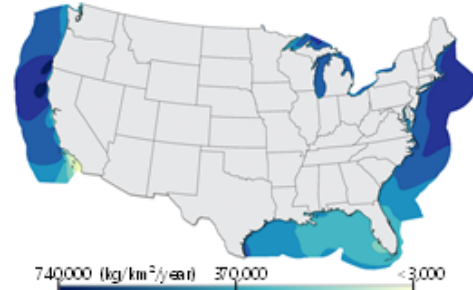
Examples of Stakeholder and RFI Input



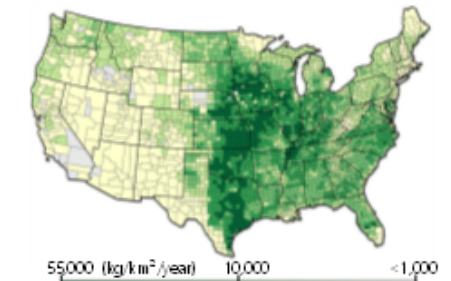
# Analysis of Potential Supply Resources and Underground Storage



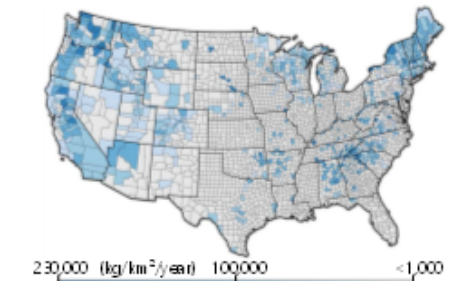
a) Hydrogen production potential from onshore wind resources, by county land area



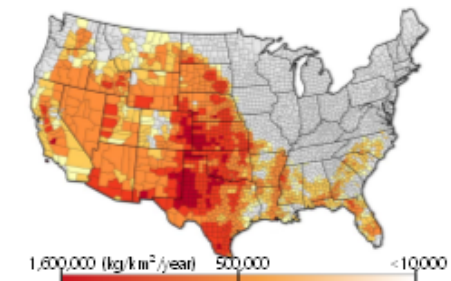
b) Hydrogen production potential from offshore wind resources, by area



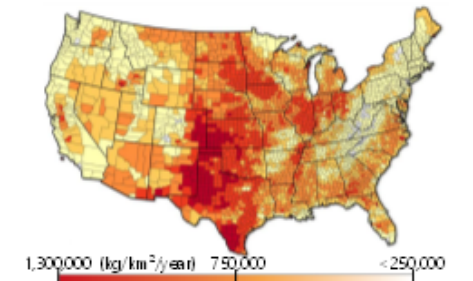
c) Hydrogen production potential from solid biomass resources, by county land area



d) Hydrogen production potential from existing hydropower assets, by county land area

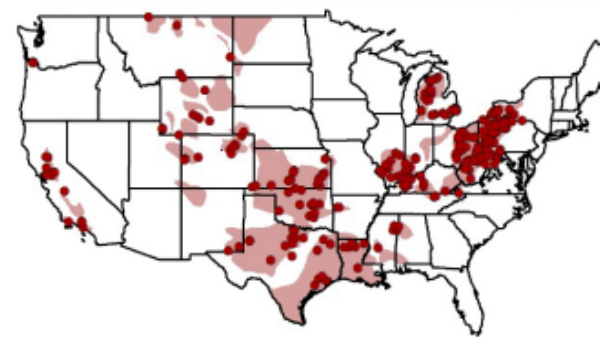


e) Hydrogen production potential from concentrated solar power, by county land area

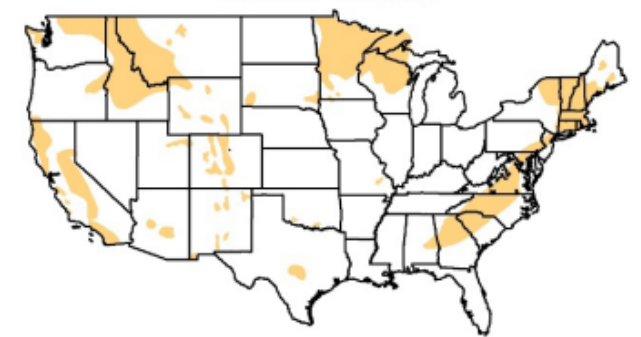


f) Hydrogen production potential from utility-scale PV, by county land area

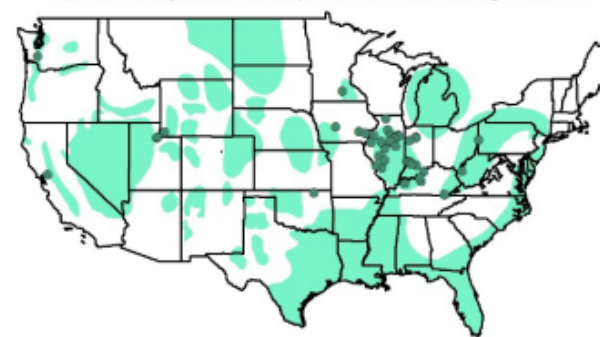
a) Oil & Gas Fields and Depleted Field Natural Gas Storage Facilities



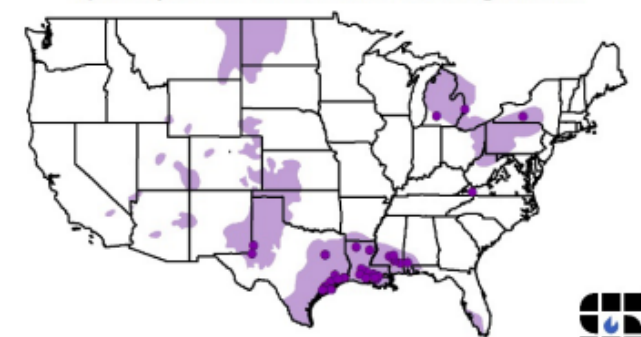
b) Hardrock Outcroppings



c) Sedimentary Basins and Aquifer Natural Gas Storage Facilities



d) Salt Deposits and Salt Dome Natural Gas Storage Facilities



Source: NREL, Lab analysis, National Strategy

Source: SHASTA, NETL, funded by FECM



# H2 Matchmaker Final Results

## H<sub>2</sub> Matchmaker launched to facilitate partnering for Hydrogen Hubs

>50X more supply than demand\*

**Production: ~268,800 MT/day**

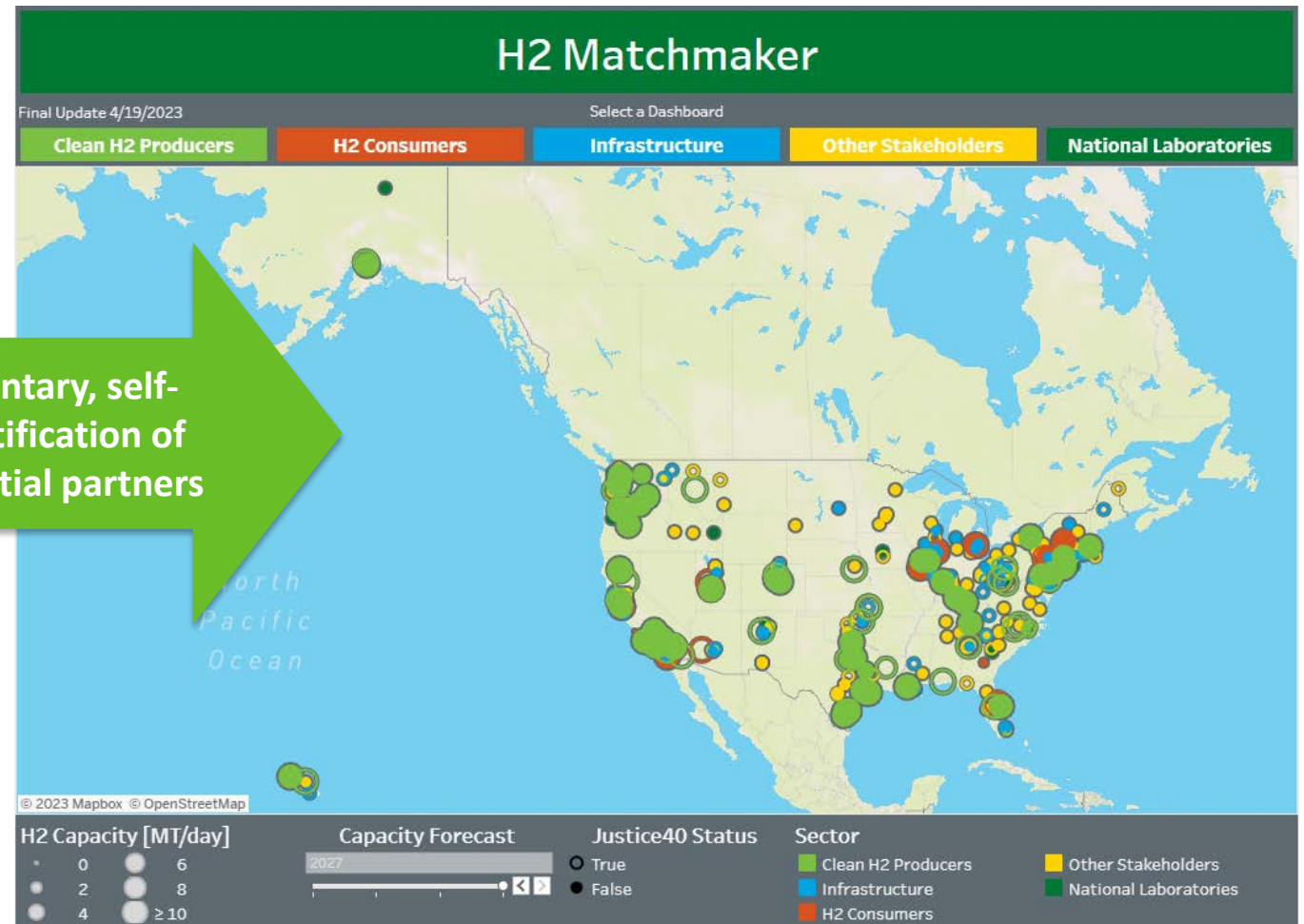
**Demand: ~5,870 MT/day**

- 55% Transportation
- 25% Green ammonia
- 20% Industrial & heating

\*self-identified values

Stakeholder responses from: 105 producers, 43 consumers, 136 infrastructure providers/operators, 21 national lab campuses, 295 other

Voluntary, self-identification of potential partners

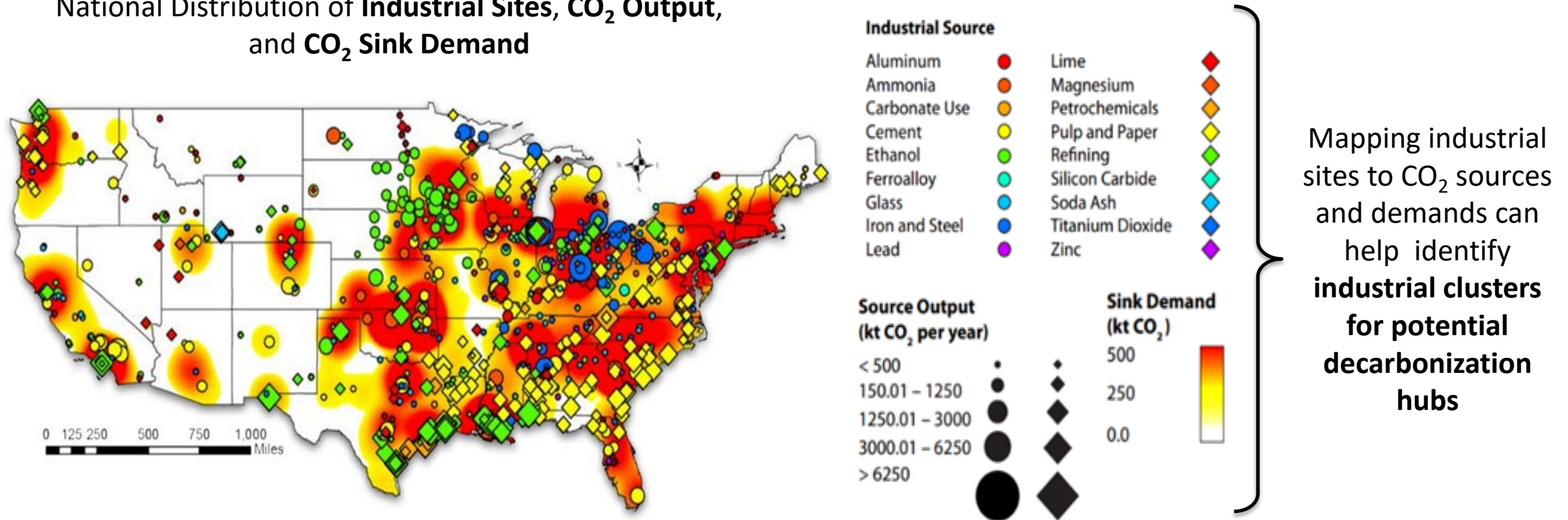


Final update: 4/19/2023. Application process for the Regional Clean Hydrogen Hubs is closed, and H2 Matchmaker is no longer collecting submissions through the self-identification form.

# Example: Industrial Clusters to Enable Large-Scale Offtakers

Priority deployments for hydrogen in industry include sectors where other decarbonization pathways are challenging, such as high-temperature heat generation, steelmaking, and ammonia production.

National Distribution of Industrial Sites, CO<sub>2</sub> Output, and CO<sub>2</sub> Sink Demand



Adapted from [Carbon Capture and Utilization in the Industrial Sector | Environmental Science & Technology \(acs.org\)](https://doi.org/10.1021/acs.est.1c01111)

# New Award Selected: Gas Technologies Institute (GTI)

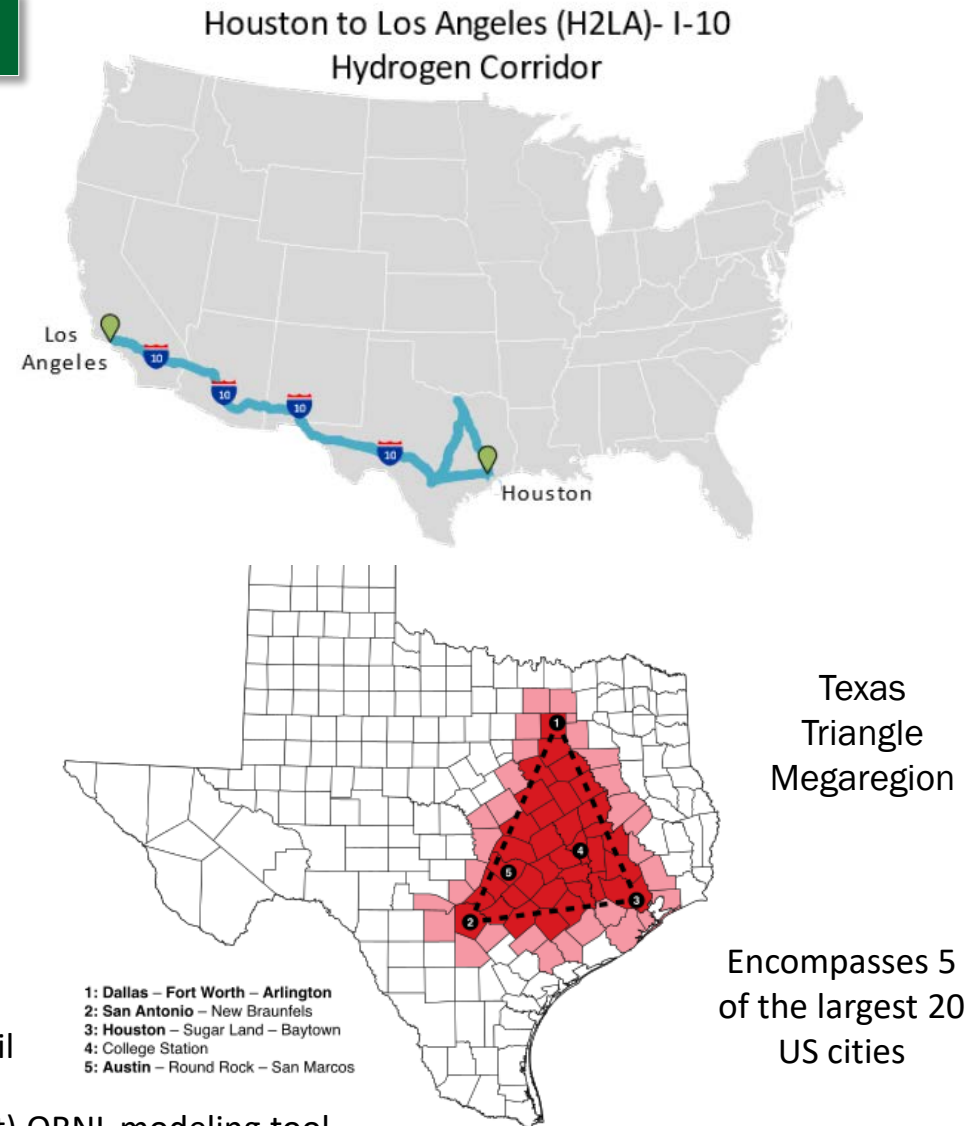
## Houston to Los Angeles (H2LA) – I-10 Hydrogen Corridor Project

- Aims to assess fueling infrastructure, capacity, locations
- Create pathway to National Blueprint for an equitable, actionable, investment-ready H<sub>2</sub> corridor plan

**Mega-region sees 306M ton-miles of daily truck freight movement, 5.3% of total U.S. truck freight.**  
**I-10 freight corridor adds 118M ton-mile of daily freight movement, 2.1% of the total U.S. truck freight.**

Partners proposed: GTI, ORNL, ExxonMobil, University of Texas at Austin, Walmart, Toyota, Hyundai, Nikola, DOE Clean Cities Coalitions, Metropolitan Planning Organizations, Hydrogen Fuel Cell Partnership, Air Liquide, Trillium, Center for Houston's Future, Alternative Fuels Council

Will use OR-AGENT (Optimal Regional Architecture Generation for Electrified National Transport) ORNL modeling tool





# Coordination with new Joint Office



## Funding Opportunities

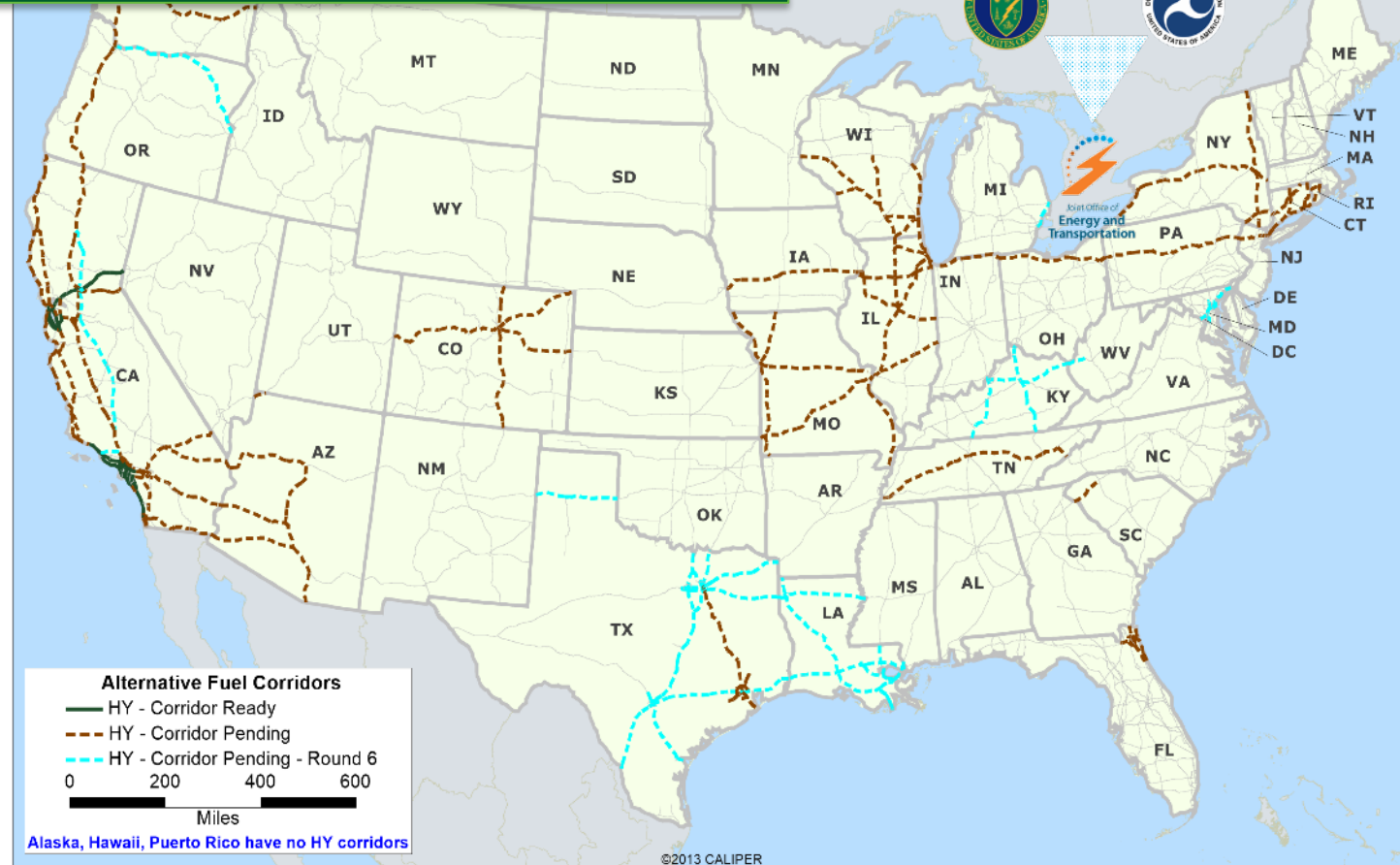
**National Electric Vehicle Infrastructure (NEVI) Formula Program (DOT):** \$5B for states to build a national EV charging network along corridors

**Charging & Fueling Infrastructure (CFI) Discretionary Grant Program (DOT):** \$2.5B in community and corridor grants for EV charging, **as well as hydrogen**, natural gas, and propane fueling infrastructure – **applications now open!**

**Low- or No-Emission Vehicle Program (DOT):** \$5.6B for low- and no-emission transit bus deployments – **includes hydrogen**

[www.driveelectric.gov/contact](http://www.driveelectric.gov/contact)

Fueling corridors of interest for H<sub>2</sub>  
Deadline for the CFI program  
extended to June 13\*



\*<https://www.fhwa.dot.gov/environment/cfi/>

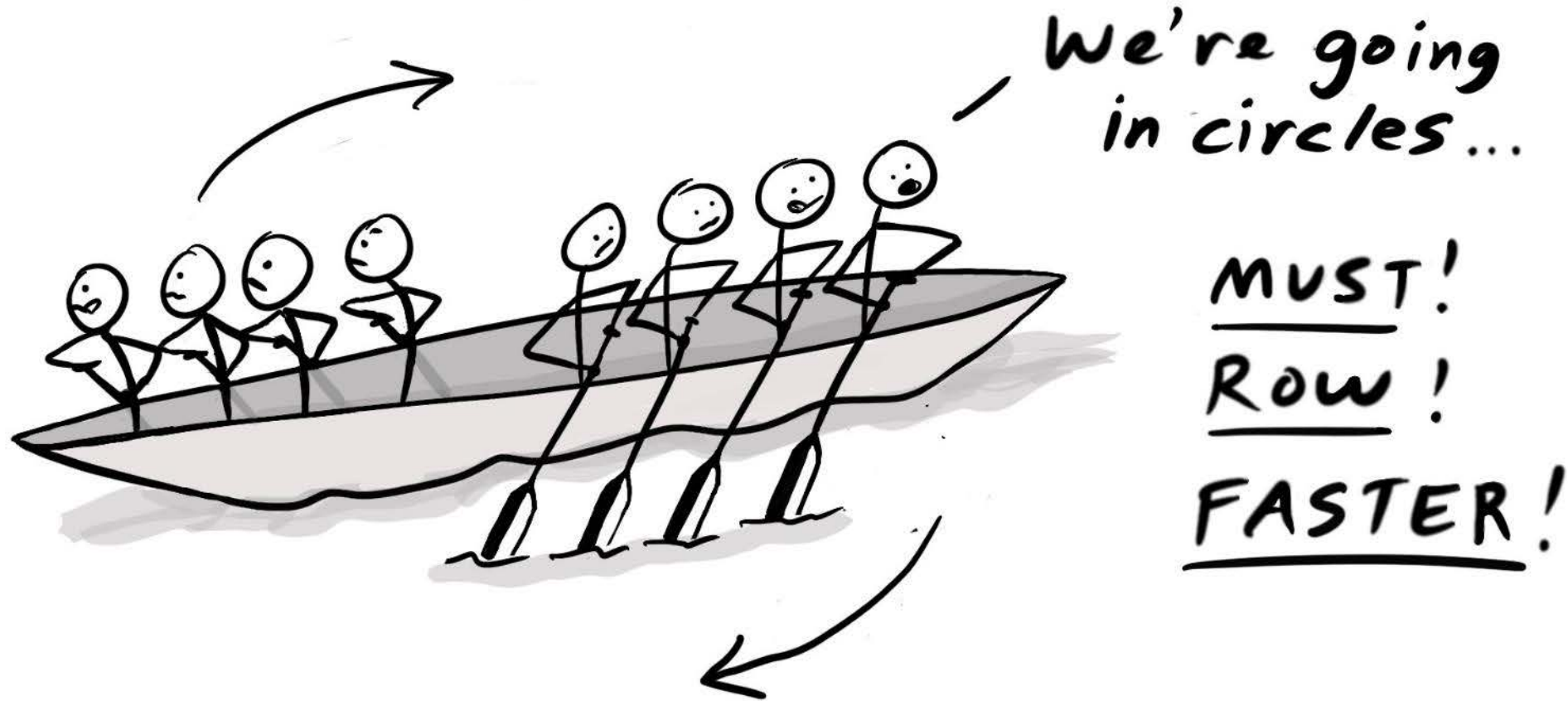


# *Whole-of-Government Coordination*

*And with the private sector, communities,  
and more*

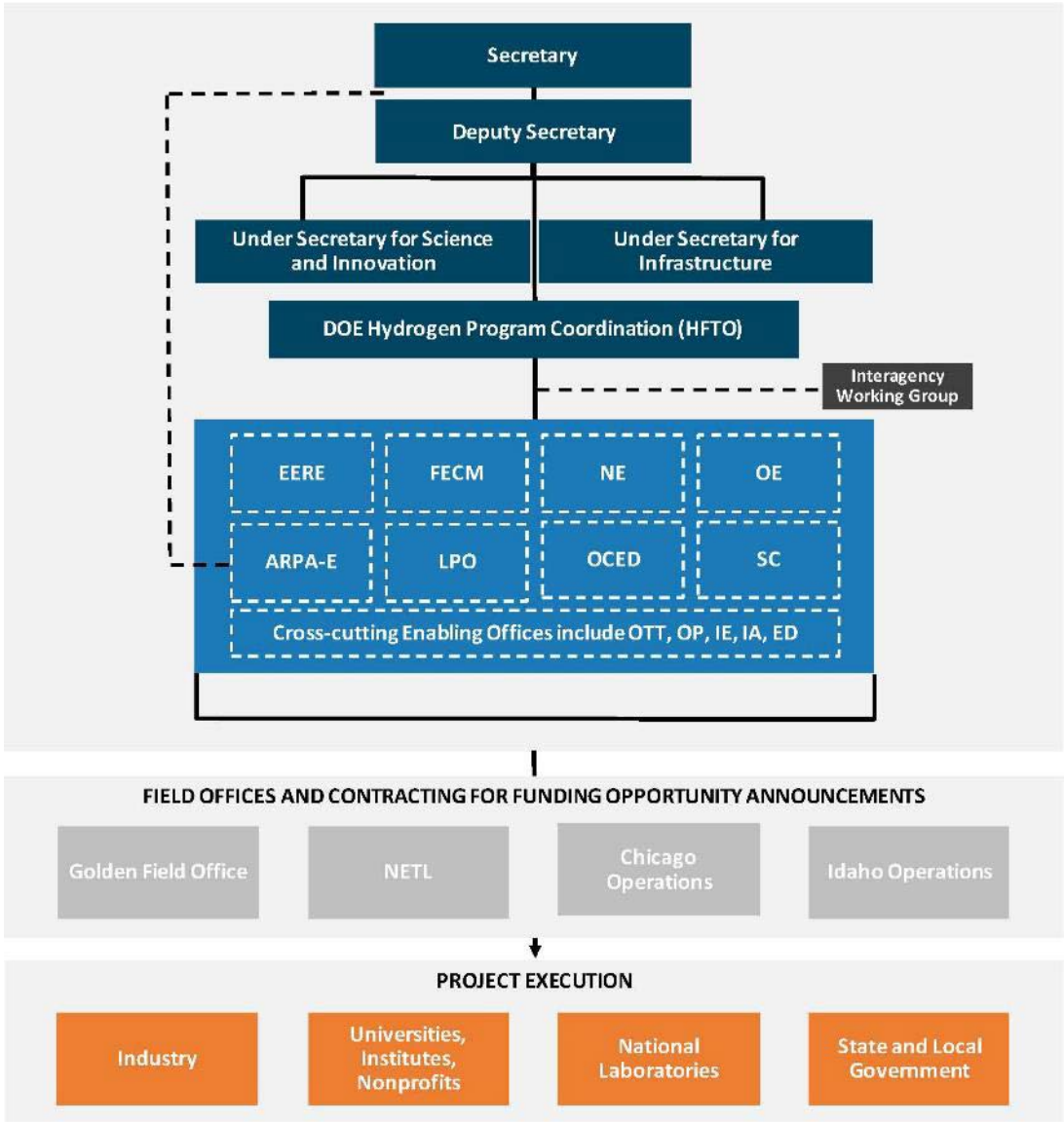


We need to make sure we're rowing together...

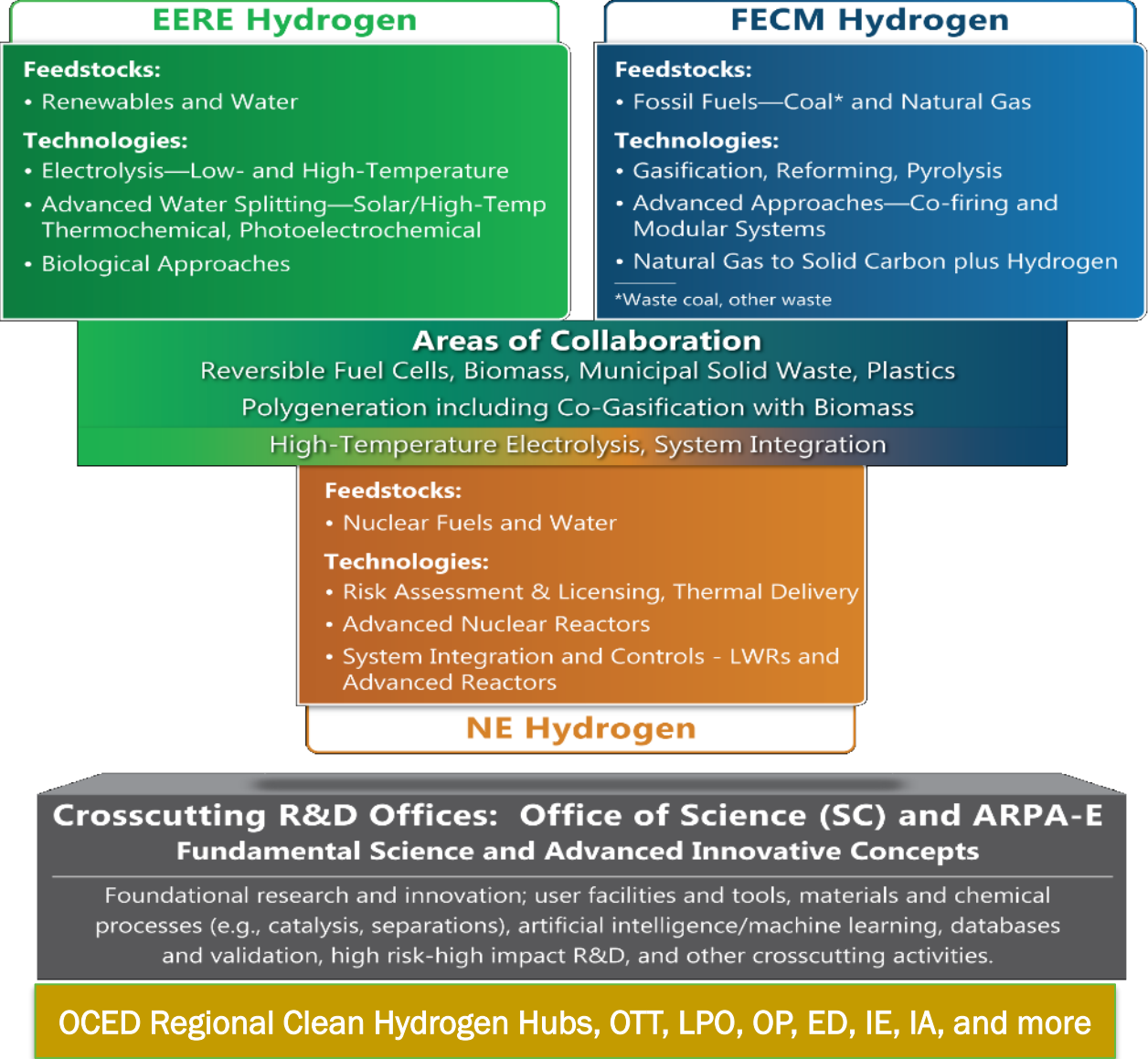


And in the same direction!

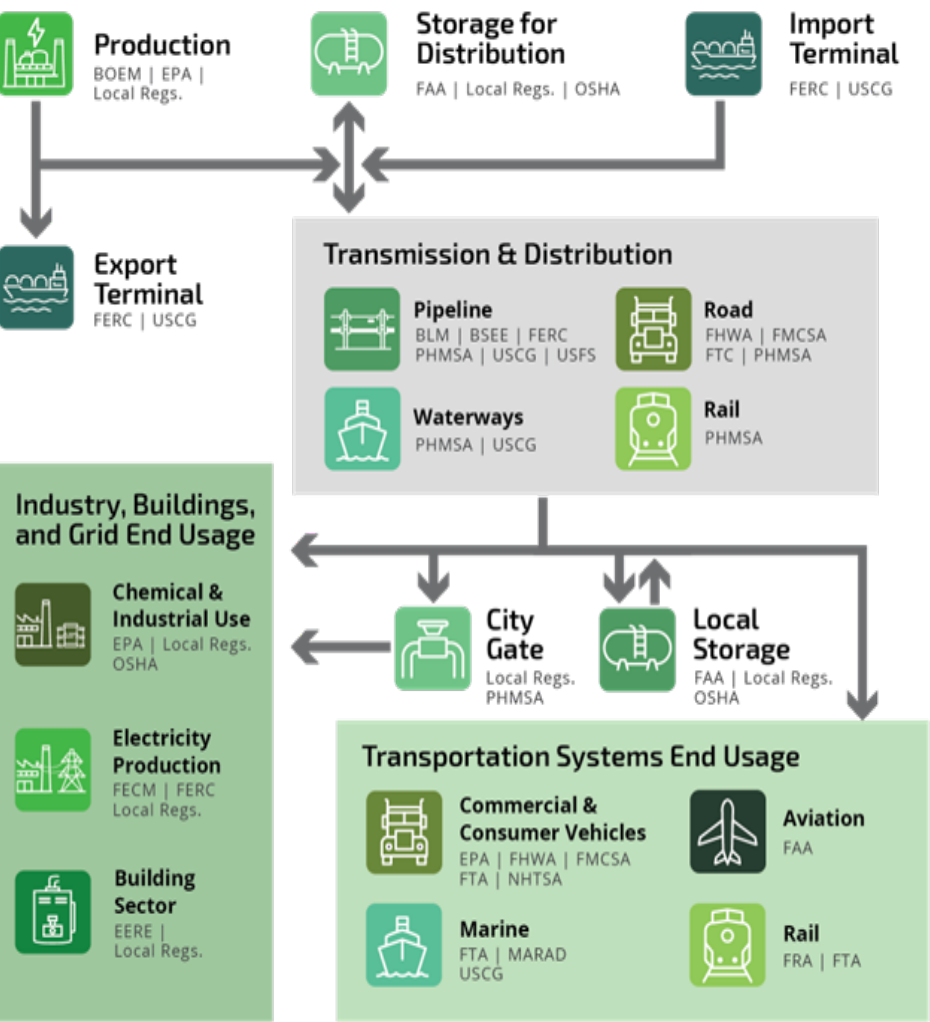
# The U.S. DOE Hydrogen Program – Coordinated across Offices



[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)



# Key USG Focus Areas for Cross-Agency Collaboration and Coordination



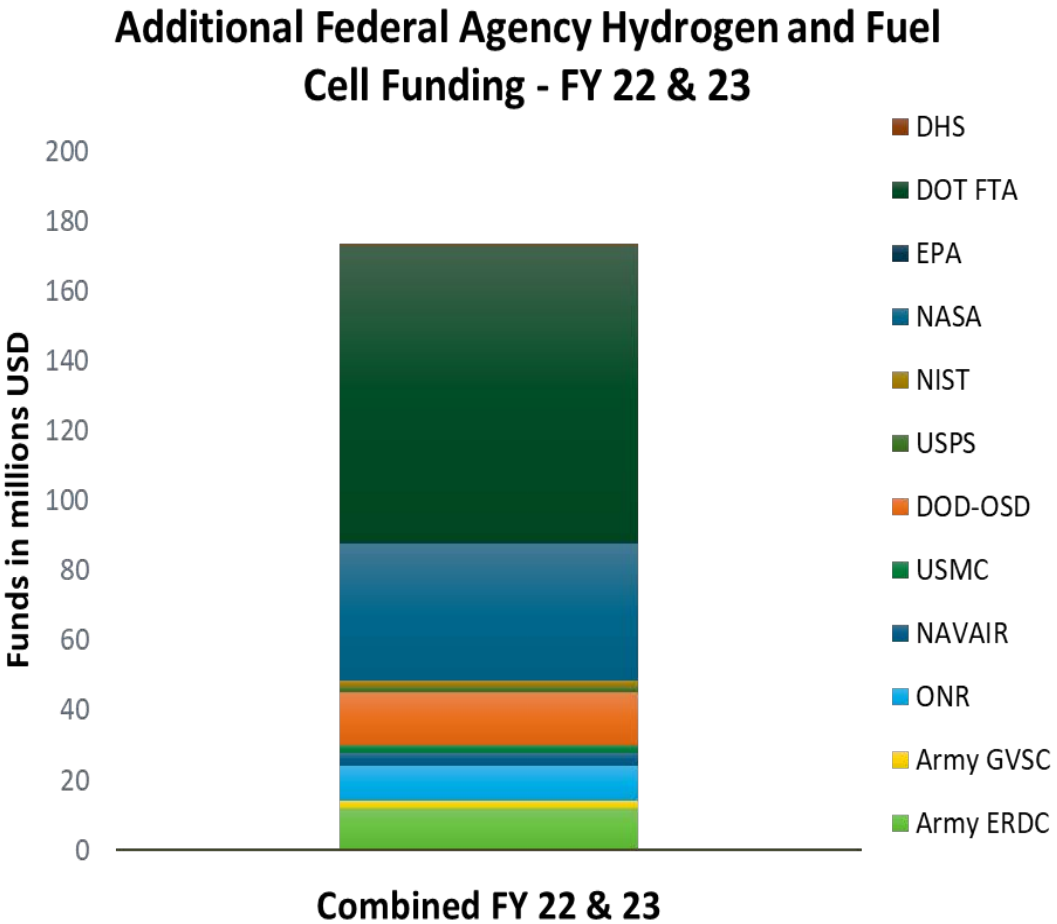
National Clean Hydrogen Strategy and Roadmap

Enable National Goals: 10 MMT/yr supply and use by 2030, 20 MMT/yr by 2040, 50 MMT/yr by 2050		
Supply and Demand at Scale	Infrastructure, Siting, Permitting	Analysis and Global Competitiveness
<ul style="list-style-type: none"><li>Enabling large scale production and demand creation</li><li>Financing, incentives, and compliance tools for commercial scale up</li><li>Metrics for deployment and USG as offtaker</li><li>Supply chains and resiliency (critical materials, strategic reserve)</li><li>R&amp;D to accelerate cost reductions and end use commercialization (JST interface)</li></ul>	<ul style="list-style-type: none"><li>Siting, permitting, pipelines, storage, and infrastructure</li><li>Harmonized codes and standards</li><li>Interoperability and global standardization</li><li>Safety, emissions (including secondary), sensors, risk mitigation, environmental impact</li><li>Environmental review and best practices (NEPA, etc.)</li><li>Pipeline and blending test facilities</li></ul>	<ul style="list-style-type: none"><li>National strategy and commercial liftoff analysis</li><li>Impacts and gap assessments (technoeconomic analysis, incentives, resource/water availability, emissions, jobs, manufacturing, etc.)</li><li>Intellectual property and global landscape assessment</li><li>Export market analysis</li><li>Systems integration and optimization</li></ul>
Clean Hydrogen Production, Delivery, Storage, Conversion, Applications, H2 Hubs		
Workforce, Equity, and Justice		



# Hydrogen and Fuel Cell Interagency Working Group – Project Examples

Partners	Examples of Collaborations & Focus Areas
DOT, DOE	Pipelines, buses, marine, fueling corridors
DOD, DOE, DHS across services	H2Rescue Truck, vehicles, infrastructure, UAVs, UUVs, soldier power, microgrids, and more
DOE, USPS	FC lift trucks and hydrogen infrastructure
NASA, DOE, NSF	Cryogenics/LH2, fuel cells, electrolyzers, storage, DOE consortia (NSF)
DOC (NIST), DOE	Metering, diagnostics, supply chain, blends, standards
EPA, DOE, etc.	Clean H2 standard, emissions analysis, ports, proposed rulings
USDA	REAP and rural community programs



# *Ongoing Work and Accomplishments to Address Key Priorities*

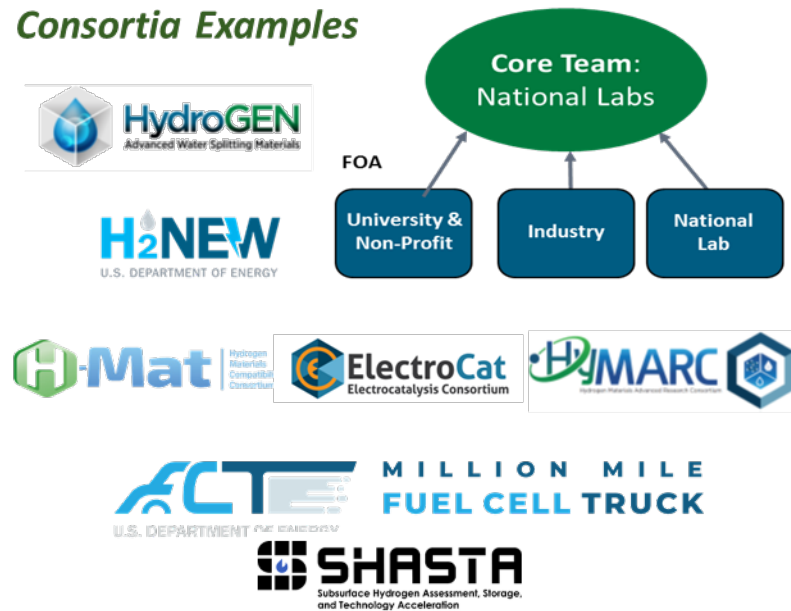


# DOE Hydrogen Activities across RDD&D – Examples

## Research and Development

Basic and applied research through individual projects and consortia

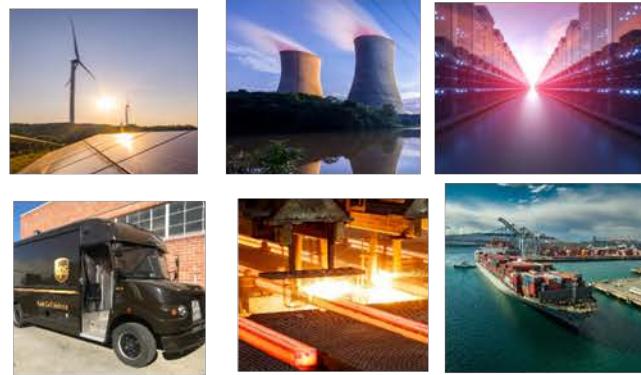
### Consortia Examples



## Technology Integration, Validation, Demos

1<sup>st</sup> of a kind demonstrations and systems integration to de-risk deployments

### Examples:



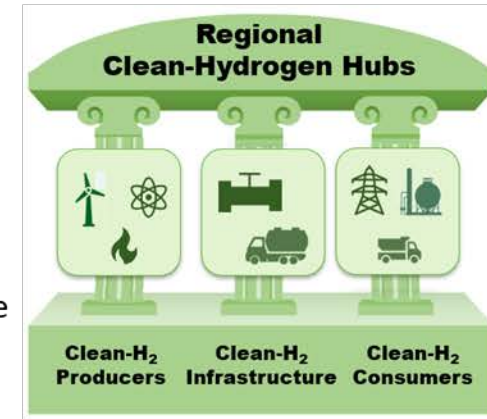
*Renewables and nuclear to H<sub>2</sub>, 15 delivery trucks in disadvantaged area, 3 Super Truck projects, data center, fueling for passenger ferry, energy storage, H<sub>2</sub> for steel*

## Deployment and Financing

H2 Hubs, loan guarantee program, workforce development

### Example:

**\$8 billion for at least 4 hubs:**  
Renewables, fossil w/CCS, nuclear; multiple end-uses



*2 new loan guarantee projects (\$1.5B total) on pyrolysis and large-scale electrolysis, H<sub>2</sub> energy storage and power generation*

## Enabling Activities

- Analysis and tools
- Safety, codes & standards
- Manufacturing
- Workforce development

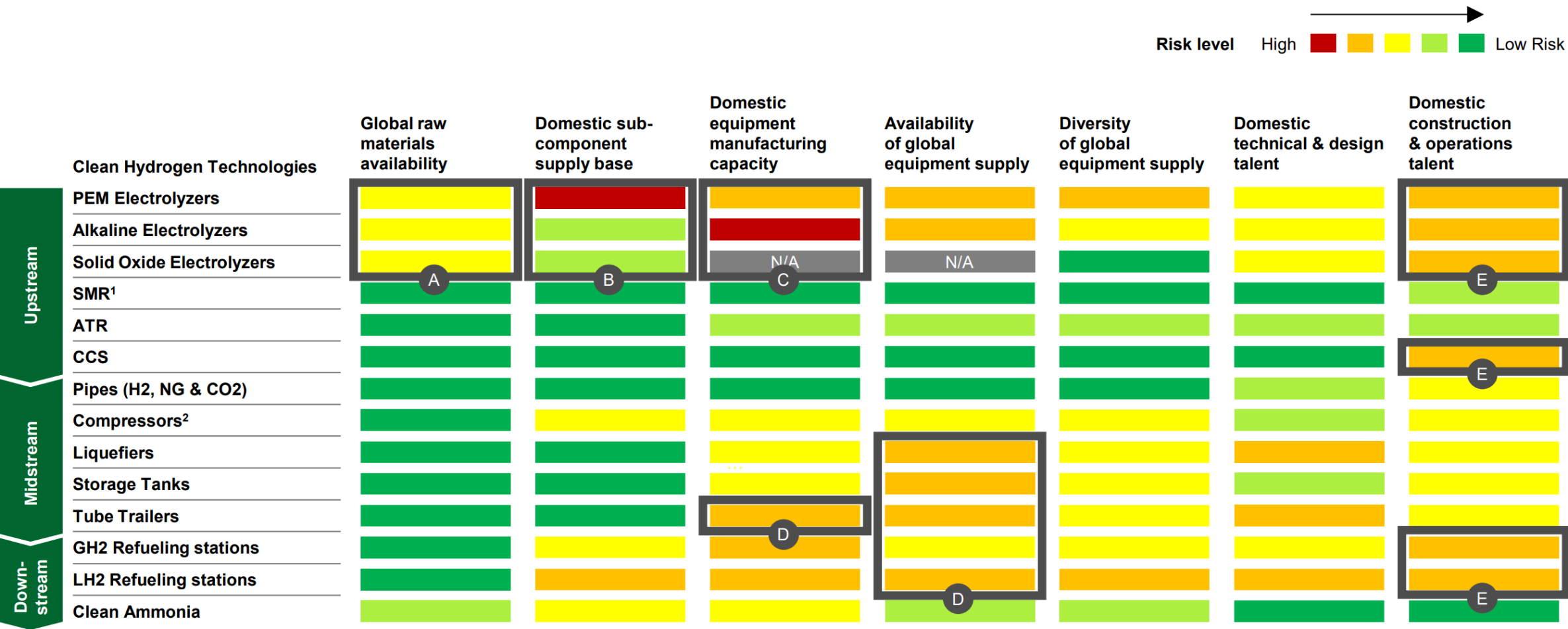


**H<sub>2</sub> Matchmaker**



# Assessments to Guide Priorities—Vulnerabilities across Value Chain

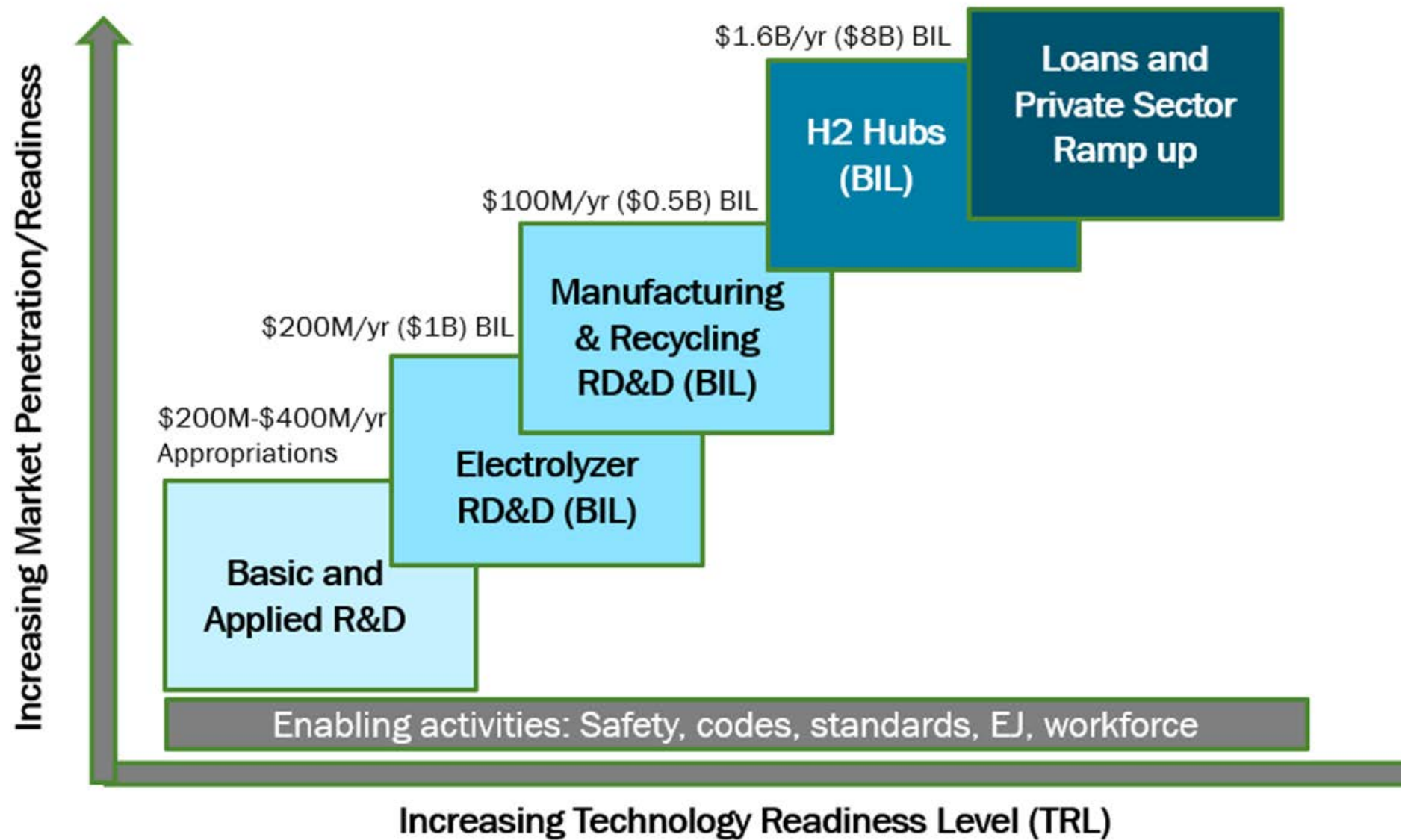
## Potential supply chain vulnerabilities, 2025



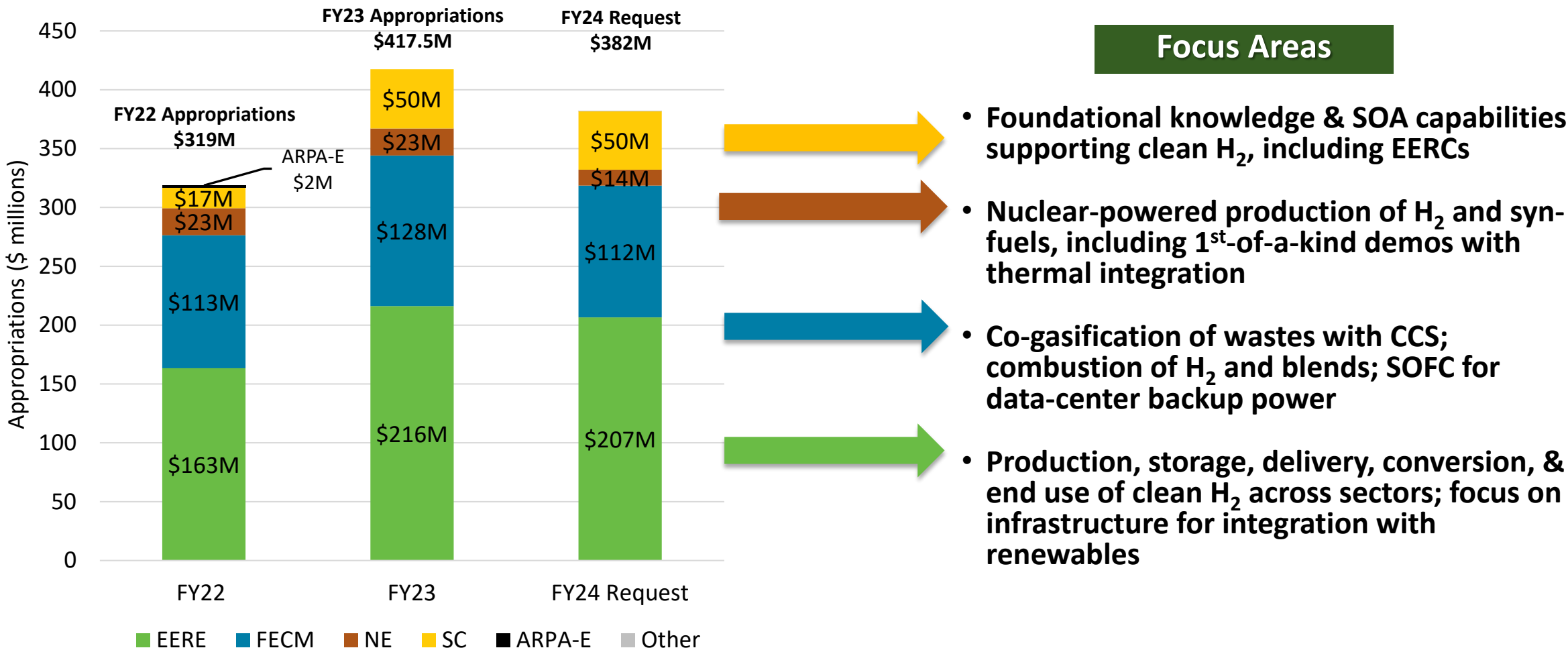
1: Includes large scale compressors at industrial and productions sites and compressors at refueling facilities | 2: No significant additional build out of Steam Methane Reformers anticipated  
Source: Department of Energy Fuel Cells & Electrolyzers Supply Chain Report, ENS Interviews, NREL experts



# Hydrogen Program RDD&D Portfolio across TRLs



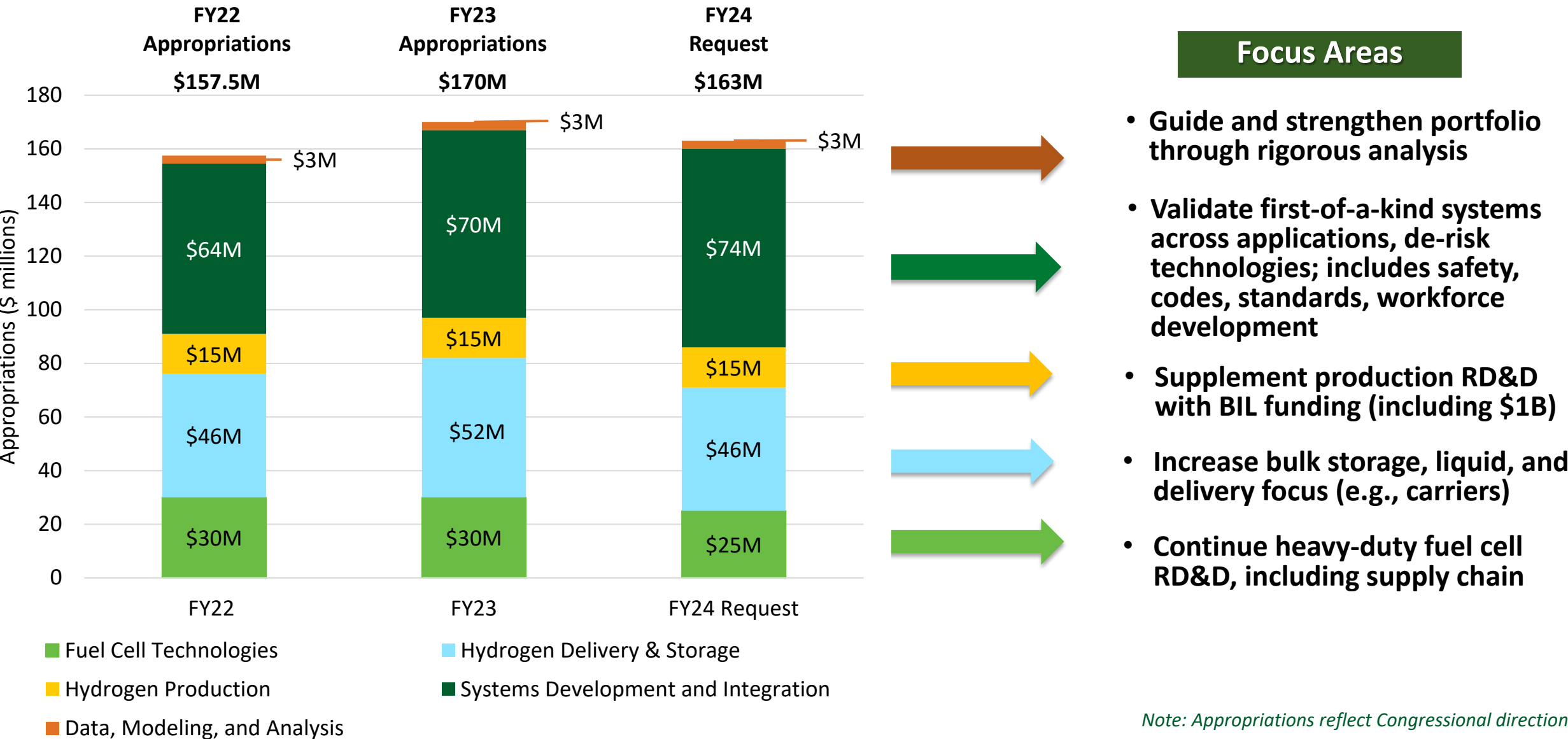
# DOE Hydrogen Program Fiscal Year (FY) Funding across Offices



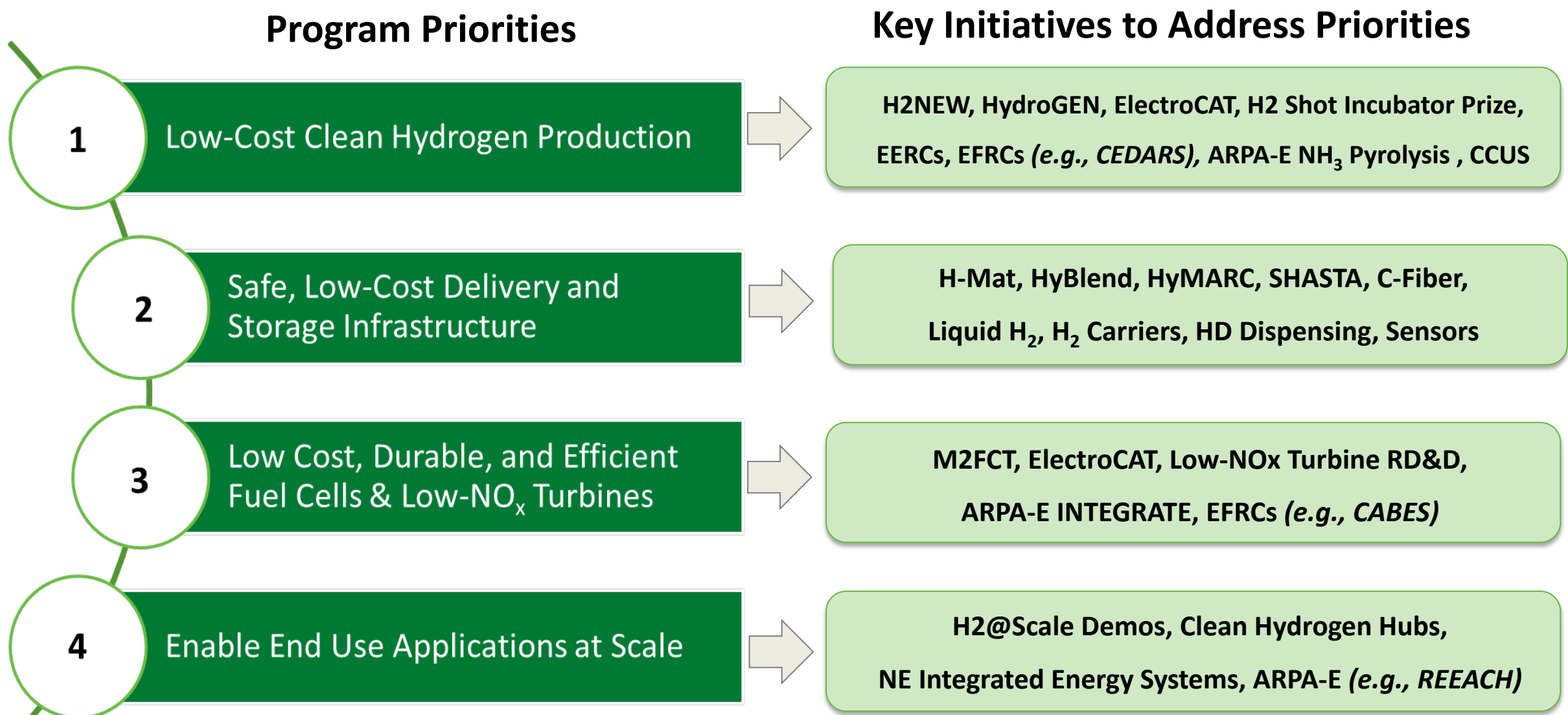
DOE Hydrogen Program coordinated through HFTO

\*Final to be updated EOY; pending SC, ARPA-E, and other final allocations by end of year. ARPA-E funding is determined annually based on programs. Annual funding only, excludes BIL funding and new offices (e.g., OCED) developed through office and stakeholder priorities. FY funding 2024 is TBD. Appropriations reflect Congressional direction.

# Hydrogen and Fuel Cell Technologies Office Budget



# Key Activities Across DOE Addressing Program Priorities



Examples from multiple offices across DOE



# Program Enabled Accomplishments

## Innovation



**1,306 Patents**

in hydrogen and fuel cell technologies through HFTO funding from Labs, Industry and Academia

**36% from National Labs**

## Technology-to-Market

**30 Technologies Commercialized**

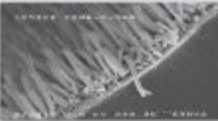
By private industry

**65 With Potential to Enter Market**

in the next 3-5 years

### Examples of Technologies Enabled

Fuel Cell Catalysts



Catalyst and Supports for PEM Fuel Cells 3M

Hydrogen Tube Trailers



Hydrogen Tube Trailers Hexagon Lincoln

Forklifts



Class-1, -2, and -3 Forklifts Plug Power (GenDrive FCs)

Electrolyzers

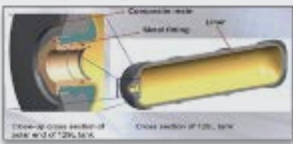


Electrolyzer System Proton Series



PEM Electrolyzer System Giner

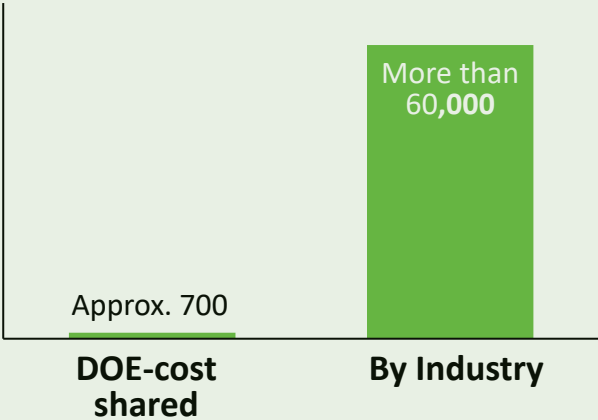
Hydrogen Tanks



Optimized 129L Tank Quantum Technologies

## Market Uptake

**Hydrogen fuel cell forklifts in the U.S.**



**American-made small-scale hydrogen refueler**



- Exported to Japan
- Uses electrolysis

# Snapshot of Patents due to HFTO Funding

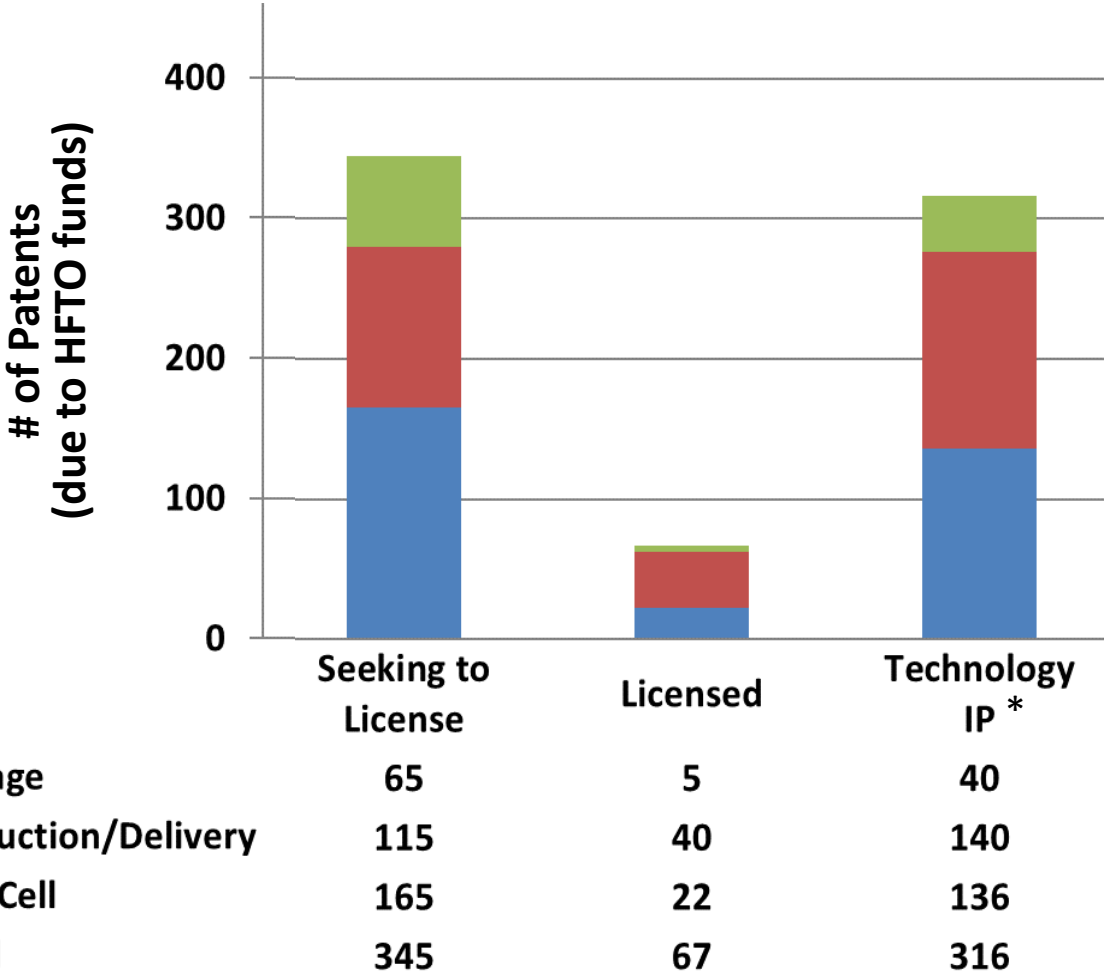
211 organizations received patents as a result of HFTO funding

~46% of patents across 129 companies  
~36% of patents across 14 national labs

## Next Steps

Accelerate tech transfer and connecting innovations with investors and manufacturers

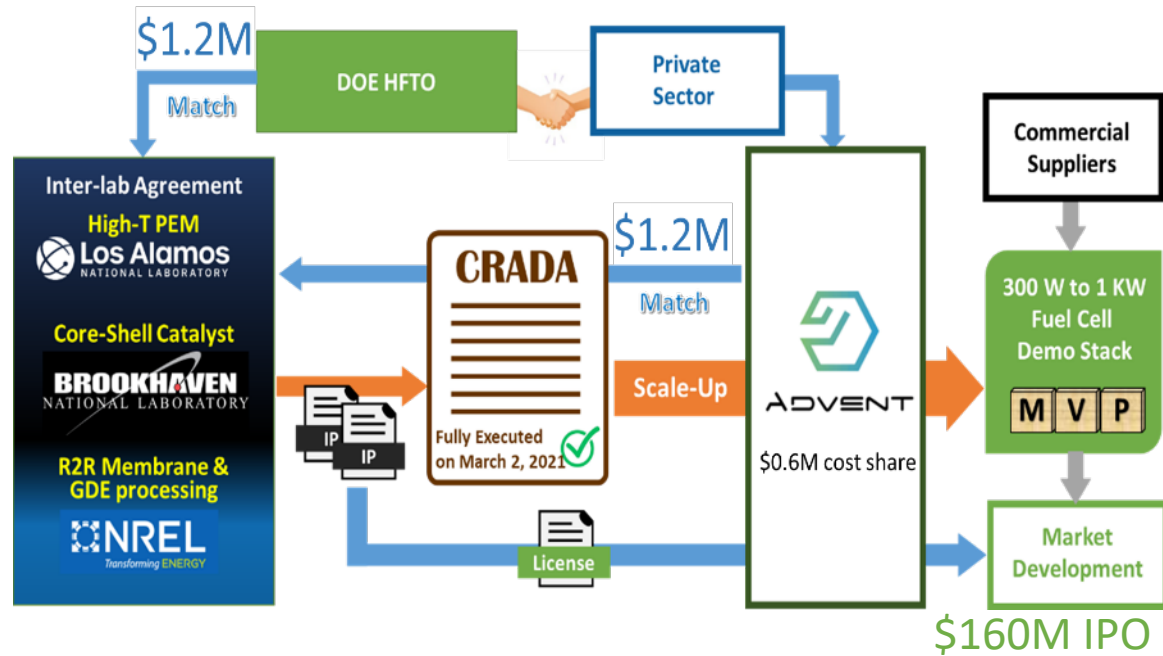
Stay tuned at [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)



\* Technology IP relates to commercial technologies and emerging technologies with commercial potential in the next ~3 years  
Source: Annual HFTO-funded patent tracking study at PNNL

# L'Innovator™ Transitions National Lab Technologies to the Private Sector

## Facilitating innovative partnerships and commercial success



L'Innovator™ accelerates new national lab innovations to market, by bundling lab IP and partnering labs with industry to create a minimal viable product.

L'Innovator™ enabled Advent to secure ~**\$160M of investment** and led to a new manufacturing and R&D facility in Boston, MA



Massachusetts Governor Maura Healy tours Advent's new facility



# Examples of Recent Highlights – Just a Few!



**Nation's first integrated (behind the meter) 1.25MW PEM electrolyzer at a nuclear plant (Constellation)**



NREL's Heavy-Duty Hydrogen Fast-Flow Research Station

**Achieved fast fueling  
for heavy duty fuel  
cell trucks**

**82.3 kg in 6.6 min  
12.6 kg/min average  
23 kg/min peak**

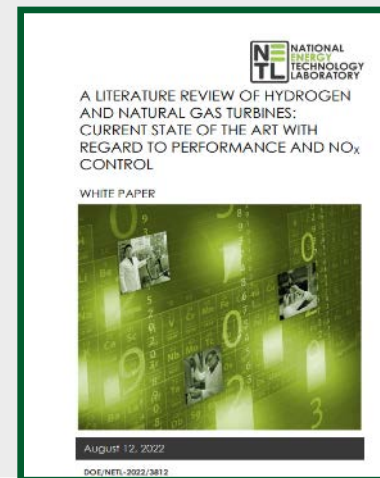
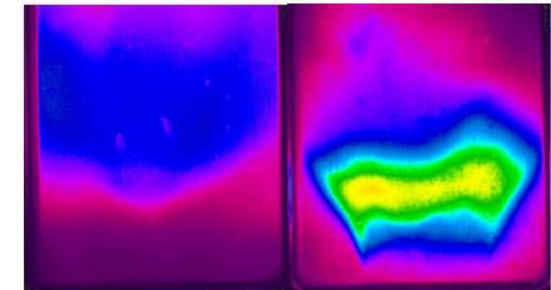


Exhibit 2-1. Chemiluminescence images of flames for natural gas (left) and 80% hydrogen (right)



**NETL Review of H<sub>2</sub> and NG turbines**

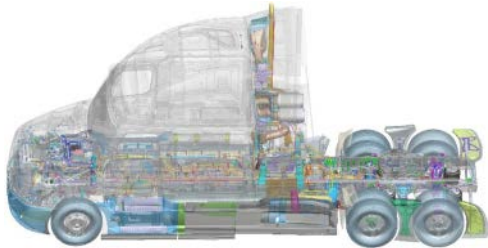
<https://netl.doe.gov/sites/default/files/publication/A-Literature-Review-of-Hydrogen-and-Natural-Gas-Turbines-081222.pdf>



# Hydrogen Fuel Cell Heavy Duty Truck Projects

## SuperTruck 3 Demonstrations include H<sub>2</sub> Fuel Cells (>75% GHG Reduction)

### DAIMLER



#### Goals:

- Demonstrate 2 total (Class 8) HD long-haul fuel cell electric trucks (B-sample & final truck demo)
- 6.0 mi/kg H<sub>2</sub> fuel economy
- 600-mile range (onboard LH<sub>2</sub> storage)
- 65,000 pounds GVW

Fleet Operators: Schneider National, Walmart



#### Goals:

- Demonstrate 8 total (Class 4-6) MD trucks
  - 4 fuel cell & 4 battery electric trucks
- Fuel Cell System Goals:
  - 65% peak efficiency
  - <\$80/kW system cost (100K units/yr)
  - 20K-30K hour lifetime
- Demonstrate microgrid w/ electrolyzer & fuel cell (H<sub>2</sub> fueling & fast charging)

Fleet Operators: Southern Co, Metro Delivery

*The above image is not final product/visual and is subject to change*



### Ford Motor Company



#### Goals

- Demonstrate 5 total (Class 4-6) MD vocational trucks
- 300+kW net vehicle power, H<sub>2</sub> PEM FC + Li-Ion battery
- 300-mile range (700 bar H<sub>2</sub> storage)
- 10K/20K pounds payload/tow capacity

Fleet Operators: Consumers Energy, Ferguson, SoCalGas

# Example of Interagency Collaboration - H2Rescue

**Objective:** Demonstrate a prototype fuel-cell/battery hybrid emergency relief truck that can deploy to a disaster site and power 20+ American homes for 3 days during a grid outage.

## Government Team



## Key Stats

- Kenworth Class 7 Truck
- 176 kg H<sub>2</sub> Onboard (700 Bar)
- 90 kW Fuel Cell System / 155 kWh battery
- 245 kW Tractor Motor
- Range: 180 miles + 72h of export power up to 25 kW
- Road testing & demos completed at FEMA, Army, and DOE



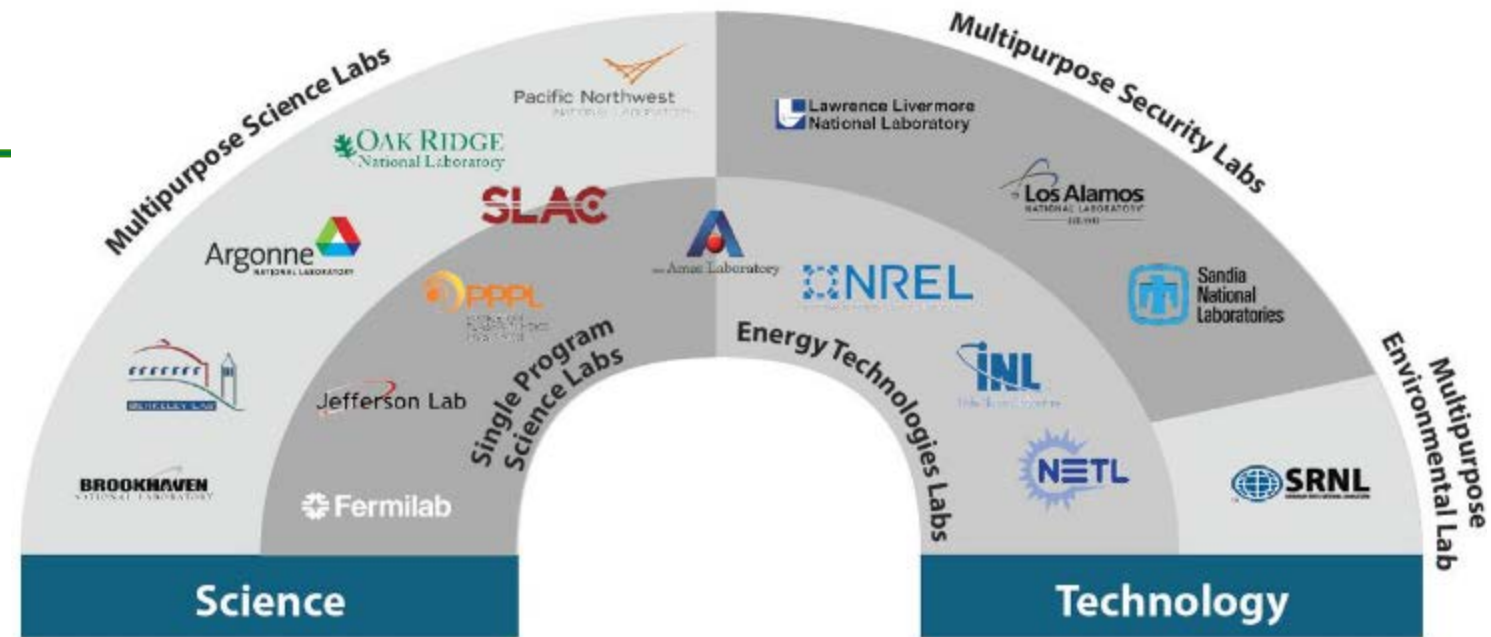


# DOE National Laboratories

Strategy leverages DOE National Laboratories, partnering with industry and academia

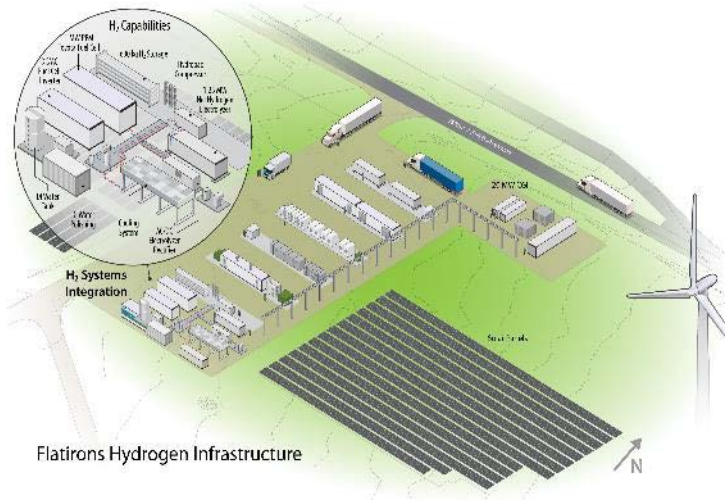
DOE National Laboratories across energy, science, and security:

- Support RD&D
- Offer User Facilities and science resources
- Help to de-risk technology adoption, accelerating progress



## Expansion to Multi-MW Electrolyzer Stack and System Test Capabilities

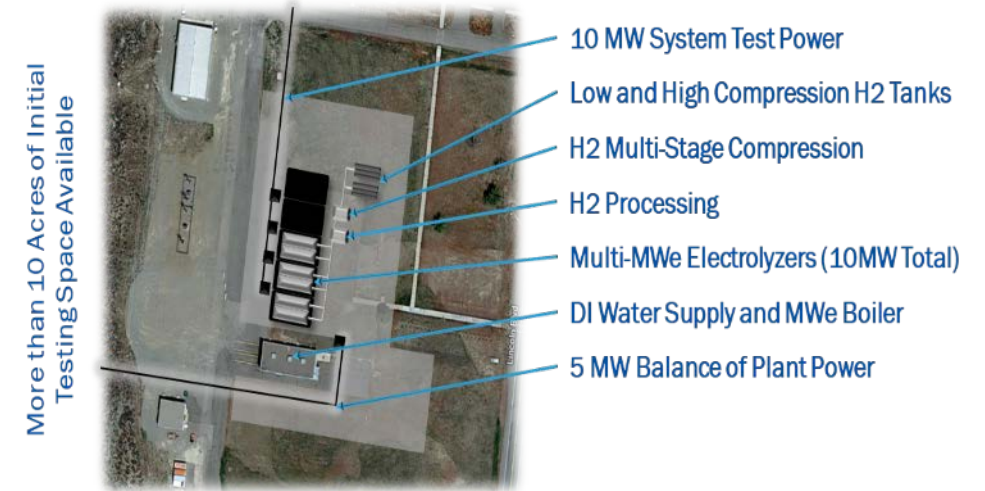
## Low-Temperature Electrolyzers – NREL (P207)



Please visit  
posters for more  
details

## Coming online in 2026!

## High-Temperature Electrolyzers – INL (SDI006)



## Coming online in 2024!

## Unique Sensor Testing and Deployment Capability

## Safety Sensor Test Apparatus (SSTA)

## Enclosed/outdoor sensor deployment capability

## Process Gas Characterization Apparatus (PGCA)

## NEC-compliant apparatus for up to 100 vol% H<sub>2</sub> (or H<sub>2</sub>-NG Blends)

For more information, contact NREL Hydrogen Safety R&D: [HSRD@groups.nrel.gov](mailto:HSRD@groups.nrel.gov)



# Our National Labs are Open for Partnering! NREL - Example



Hydrogen Infrastructure Testing and Research Facility in Golden, CO at NREL

# Safety Codes and Standards: Activities Supporting Deployment

## Lab Technical Assistance for Small U.S. Projects where Timely Support is Essential

Projects that integrate information sharing and inform near-term deployment activities encouraged

### NREL

- Evaluate hydrogen sensors
  - Metrological performance (in air/nitrogen)
  - Use in pure hydrogen and natural gas blends
- Support performance testing of hydrogen contaminant detectors

Please contact: [HSRD@groups.nrel.gov](mailto:HSRD@groups.nrel.gov)

### SNL

- Conduct risk assessments
- Develop models and diagnostics for measuring behavior of hydrogen releases and flames
- Answer questions regarding hydrogen-metal material interactions

Please contact:  
[H2\\_SCS\\_Technical\\_Assistance@sandia.gov](mailto:H2_SCS_Technical_Assistance@sandia.gov)

### PNNL

- Assist incident investigations
- Support questions from AHJs
- Inform and review outreach materials on hydrogen safety
- Present topical webinars
- Provide virtual training

Please contact: [hsp@h2tools.org](mailto:hsp@h2tools.org)  
For ongoing support in safety topics, please explore Center for Hydrogen Safety

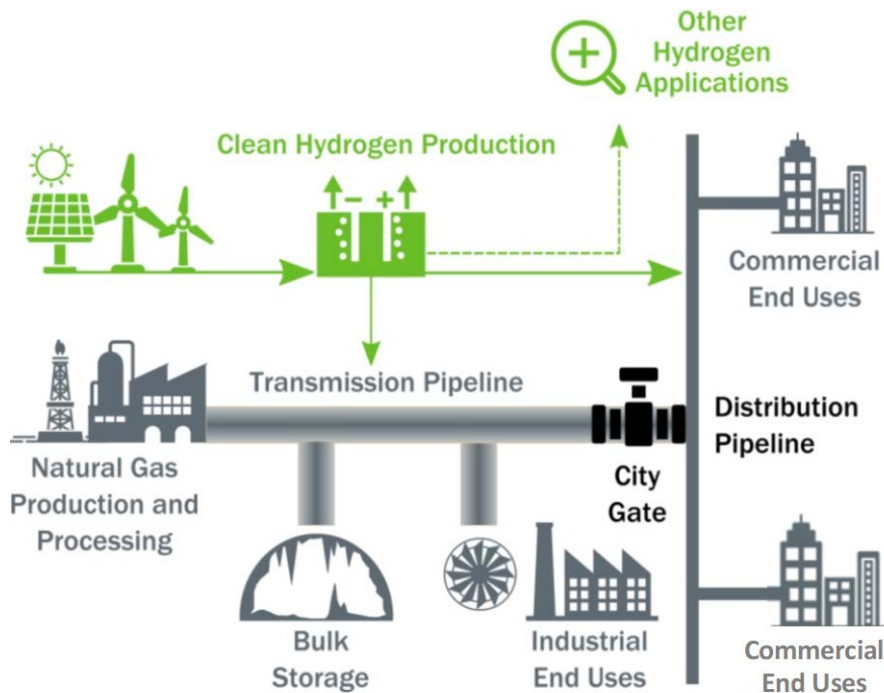
**Stay tuned: Listening session webinar planned later this summer with FCHEA on permitting and siting to identify challenges and next steps**



## Reducing the Carbon Intensity of the Natural Gas Grid via Hydrogen Blends

### Two-year, \$15M Project

- 4 National Laboratories, 31 partners from industry and academia (CRADA)
- Objectives
  - Pipeline materials compatibility R&D
  - Techno-economic & life-cycle analysis



### Key Findings and Outputs

- **Metals R&D (SNL)**
  - Science-based probabilistic tools for structural integrity assessment of H<sub>2</sub> pipelines (**HELPR software release: Sept. 2023**)
- **Polymer R&D (PNNL)**
  - Blended gases affect morphology of high-density polyethylene, impacts toughness, pipe stability, and outcome depending on polymer chemistry
- **Life-cycle Analysis (ANL)**
  - Maintaining energy delivery limits the H<sub>2</sub> blending ratio to ~30%, resulting in ~6% life cycle GHG emissions reduction
- **Techno-economic Analysis (NREL)**
  - Open-source software providing case-by-case economic analysis of preparing transmission pipelines to blend H<sub>2</sub> (**PPCT software release: Sept. 2023**)

#### Future work:

- Expand testing capabilities (in-situ, larger scale)
- Advance models with new data and feedback from industry

Visit HyBlend™ initiative webpage for more details and links to tools and publications:

<https://www.energy.gov/eere/fuelcells/hyblend-opportunities-hydrogen-blending-natural-gas-pipelines>

# 20 Years of the Hydrogen Safety Panel

## By The Numbers...

32

panel members since 2003

609

safety reviews

300+

global safety presentations

>600

combined years of experience

>10,000

first responders trained

1

hydrogen tools portal

## 3 Panelists Have Been with HSP Since the Start!

Special thanks to:  
**Bob Zalosh, Don Frikken, and Dave Farese** for their commitment to hydrogen safety





# GREET: New Website Version and Train the Trainer Announcement!

## Get Involved

## Learn how to use GREET Model



GREET "Train the Trainer" Fellowships

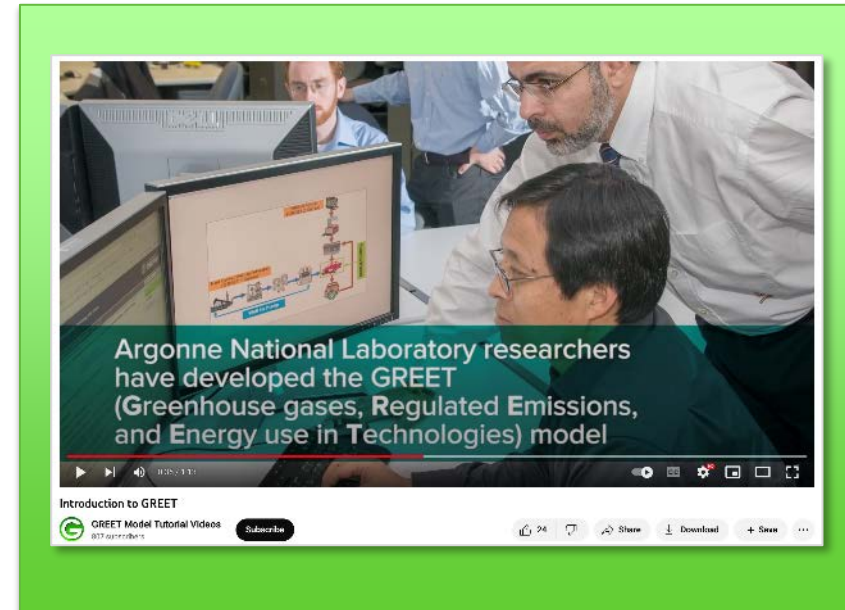
[www.zintellect.com](http://www.zintellect.com)

Apply Now! Key word: GREET Trainer

Become a GEM Fellow

[www.gemfellowship.org](http://www.gemfellowship.org)

Focus on minority students



GREET Model Tutorial Videos

@greetmodeltutorialvideos5576 812 subscribers 27 videos

More about this channel >



[www.youtube.com/@greetmodeltutorialvideos5576](http://www.youtube.com/@greetmodeltutorialvideos5576)

Partners include U. MN, GPI

GREET: Greenhouse gases, Regulated Emissions, and Energy use in Technologies

A top-down view of several hands of different skin tones (dark brown, light brown, and fair) stacked together in a circular formation. The hands are wearing light-colored, long-sleeved shirts. The background is blurred, showing what appears to be a wooden floor.

# ***Energy and Environmental Justice Diversity, Equity, Inclusion, and Accessibility***



**Communities are considered disadvantaged:**

- If they are in a census tract or geographically dispersed groups that share a common characteristic and meet the thresholds for at least one of the tool’s categories of burden listed below, or
- If they are on land within the boundaries of Federally Recognized Tribes

**INDICATORS:**

CLIMATE CHANGE

ENERGY

WATER & WASTEWATER

HEALTH

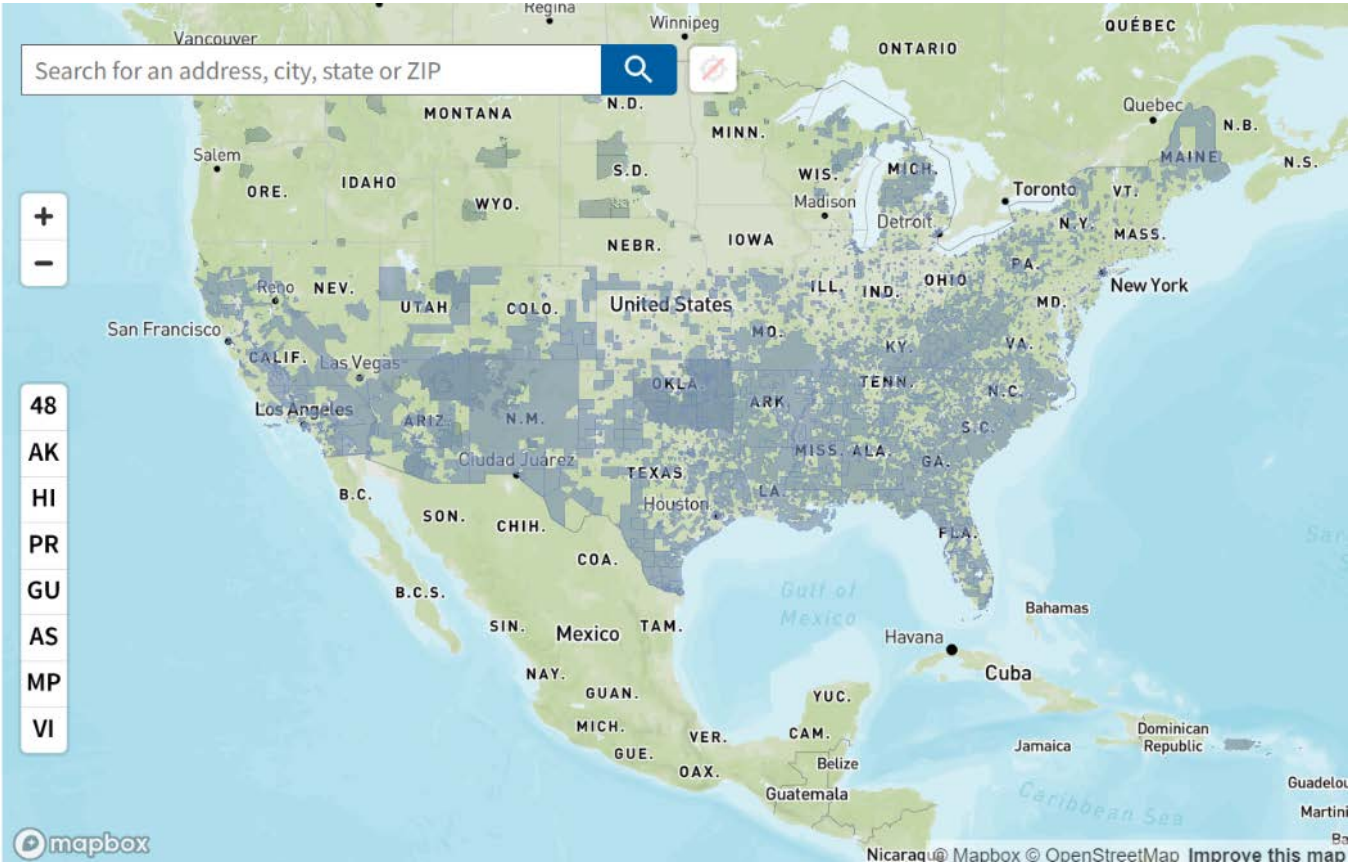
HOUSING

TRANSPORTATION

LEGACY POLLUTION

WORKFORCE DEVELOPMENT

**Distribution of census tracts identified as DACs**

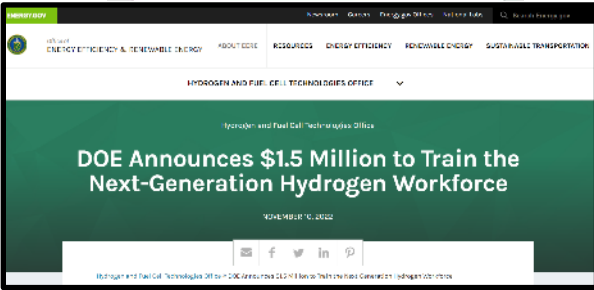
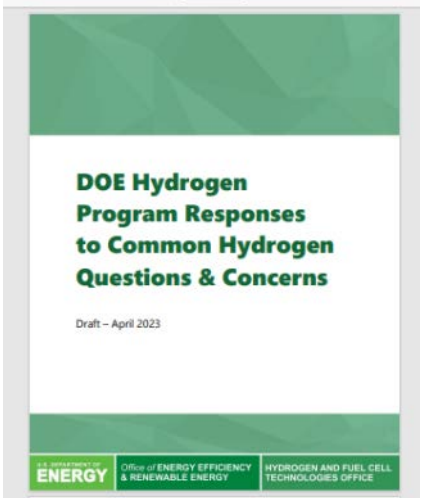
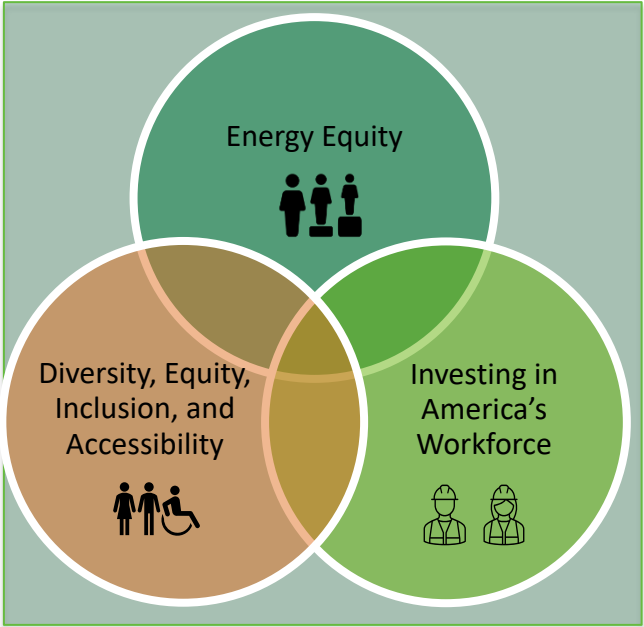


Census tracts that are overburdened and underserved are highlighted as being **disadvantaged** on the map. Federally Recognized Tribes, including Alaska Native Villages, are also considered disadvantaged communities.

[Explore the map - Climate & Economic Justice Screening Tool \(geoplatform.gov\)](https://geoplatform.gov)



# Environmental Justice Initiatives





# Examples of Tribal Engagement

## Recent Engagement with Tribes

- Participated in Tribal Clean Energy Summit & the Reservation Economic Summit (RES)
- Celebrated Native American Heritage Month with a Spotlight article on members of the Shoshone-Bannock and Navajo Tribes
- Collaboration with DOE Office of Indian Energy & Office of Congressional & Intergovernmental Affairs

## Planning Tribal Regional Roundtables for Autumn 2023



“The Power of Hydrogen” on display at the Reservation Economic Summit (April 2023)

See: [www.energy.gov/indianenergy/office-indian-energy-policy-and-programs](https://www.energy.gov/indianenergy/office-indian-energy-policy-and-programs)

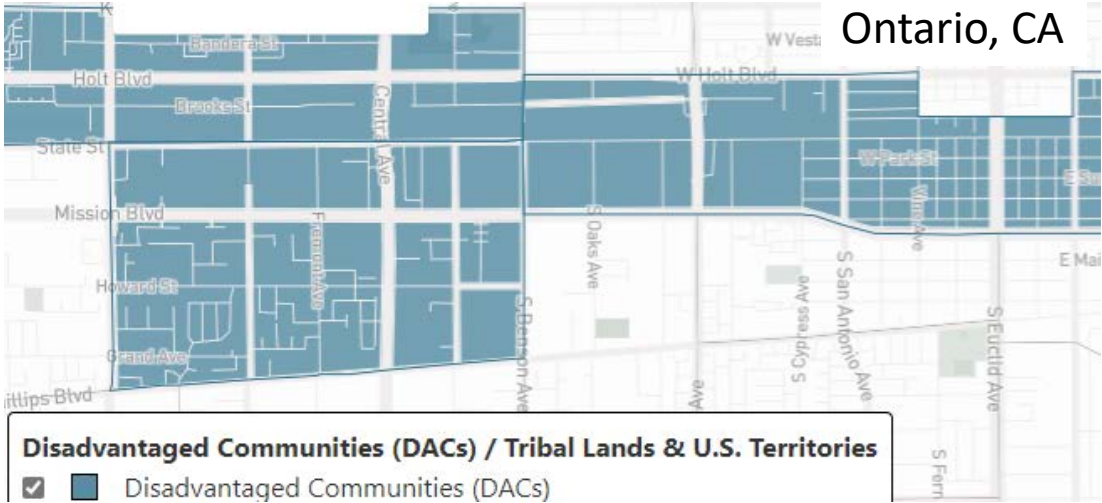
# Example of DOE-funded Project in a Disadvantaged Community

## EERE HFTO project with CTE for UPS Fuel Cell Delivery Vans in Ontario, CA



**Key Accomplishments and Status:**

- 15 trucks built; validation testing complete on 10
- UPS safety certification complete
- UPS driver and mechanic training complete
- First package delivered!





# New Selection: The University Research Consortium for Grid Resilience

Partners
Stanford University (Prime Recipient)
Iowa State U. of Science & Technology
Massachusetts Institute of Technology
North Carolina A&T State University
Northwest Indian College*
Princeton University
Tec de Monterrey (Mexico)
University of Alaska Fairbanks*
University of Calgary (Canada)
University of California San Diego*
University of Hawaii at Manoa*
University of Michigan Ann Arbor
University of Tennessee Knoxville
University of Texas at Austin*
University of Waterloo (Canada)
Washington State University
EPRI
NRECA
Argonne National Lab
Lawrence Livermore National Lab
National Renewable Energy Lab
Pacific Northwest National Lab

\*Minority Serving Institution

### EARNEST CONSORTIUM (\$20M DOE investment)

**Eight pilot projects leveraging multiple regional partnerships focus on resilience and environmental justice**

The map displays the United States with eight numbered callouts indicating pilot project locations:

- 1. Sector Coupling Offshore Wind, Solar and Hydrogen to enhance Resource Adequacy (transmission interconnection vs hydrogen transport)
- 2. Distribution grid redesign for Spokane Indian reservation
- 3. Next Generation Clean Energy Storage and Management for Indian Tribes (Solar, Hydrogen, Microgrid Management)
- 4. Dynamic Monitoring and De Systems (DyMonDS) framework Puerto Rico and Beyond
- 5. Climate Change Mitigation and adaptation Internal building electrification
- 6. Resilience strategies for a low-income net-zero neighborhood
- 7. Resilience study with landfill sites repurposed to integrated energy microgrid systems (solar, hydrogen and battery storage)
- 8. Resilience against high-wind events in the Midwest

**Pilot projects include clean hydrogen integration**

Impacts
The first-ever baseline of the current state of resilience, equity, and energy-related emissions and damages
A standard set of grid resilience and equity metrics
Open-source data products, tools, & models that support grid investment decisions in the North America
Supporting 100 National Grid Resilience Fellows
Training an interdisciplinary highly skilled workforce

# Understanding and Addressing Indirect Impacts of Hydrogen Releases

Co-organized international workshop with industry, environmental stakeholders, and national labs on current knowledge and key R&D gaps<sup>1</sup>

## Recent Activities to Measure H<sub>2</sub> Releases

- Ongoing national lab R&D on sensors, leak rates, hydrogen and blends release behavior, advanced leak detection
- **\$8.6M announced for R&D on ppb-level sensors!**
  - Indrio Technologies Inc.
  - Palo Alto Research Center Incorporated
  - University of Georgia
  - Iowa State University
  - Oakland University
  - General Electric Company
- FY23 SBIR topic on leak quantification (closed)

## Interagency Agreement with NOAA (IA013)

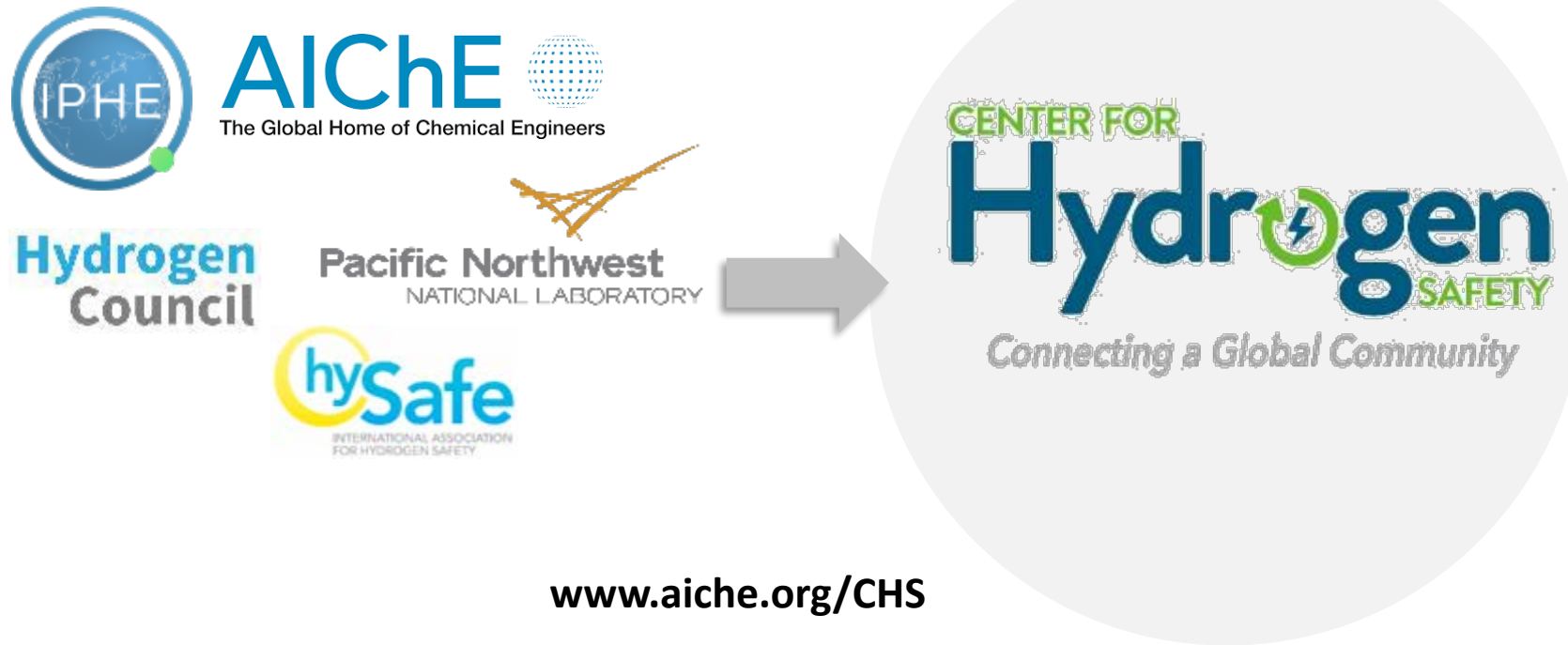
- **\$2.2M over 3 years to NOAA Climate Program Office**
  - Analysis and data collection to improve H<sub>2</sub> cycle modeling, better understand rates of H<sub>2</sub> uptake in soil, and develop more precise estimates of indirect warming impacts
- NOAA Global Monitoring Laboratory
- NOAA Geophysical Fluid Dynamics Laboratory
- Princeton University
- University of California - Irvine



<sup>1</sup>Workshop technical report: <https://publications.jrc.ec.europa.eu/repository/handle/JRC130362>



# Call to Action: Join the Center for Hydrogen Safety!



**Over 100 members from industry, government, and academia—and growing!**



## **New Hydrogen Safety Credential!**

Composed of 7 fundamental hydrogen safety e-courses, including:

- Properties & Hazards
- Safety Planning
- System Operation
- Inspection & Maintenance

# ***Global Collaboration***



# H2 Twin Cities 2022 Winners Announced!



## H2 Twin Cities 2022 Winners Announced

*Connecting Communities Around the World to Deploy Clean Hydrogen Solutions*



### H2 – TRANS – PACIFIC Team

*Mentor-Mentee Cities*

Lancaster, CA (US), County of Hawaii, HI (US),  
and Namie Town (Japan)



### Hydrogen is Here! Team

*Sibling Cities*

Aberdeen (UK) and Kobe (Japan)



- **Announced at COP27 on Nov 16** by US DOE Sec. Granholm in collaboration **with UK, Japan and CEM H2I**

- H2 Twin Cities 2023:  
To be announced soon  
and to focus on  
**Mentor-Mentee partnerships**

Learn more about the winners: [www.energy.gov/eere/h2twincities/h2-twin-cities-2022-winners](https://www.energy.gov/eere/h2twincities/h2-twin-cities-2022-winners)

## Examples of International Collaboration

**Collaborating through multiple global and bilateral partnerships—key priority is creating coordinated framework to leverage activities, identify gaps, and avoid duplication to accelerate progress**



**CEM Global Ports Coalition with EC**  
**Numerous Bilaterals on Hydrogen**  
**Hydrogen Council, IRENA, and more**



## H<sub>2</sub> Production Analysis (H2PA)

To facilitate international trade  
Common analytical framework for  
GHG emissions footprint

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

[www.iphe.net](http://www.iphe.net)



**Breakthrough Agenda in collaboration with other partnerships is mapping activities across global H<sub>2</sub> initiatives to identify gaps, focus areas, and prioritized workstreams**

[illegible]



# Mapping of International Hydrogen Initiatives and Collaborations Underway

## Hydrogen Breakthrough – Overview of the Priority Actions for 2023



Priority International Action	Coordinating initiative(s) To date
<b>H.1: Standards &amp; Certification</b> Accelerate the development of standards for clean hydrogen	IPHE, IEA’s Hydrogen TCP, IRENA’s Collaborative Framework on Green Hydrogen
<b>H.2: Demand Creation &amp; Management</b> Coordinate internationally to drive demand for clean hydrogen	First Movers Coalition, Clean Energy Ministerial Hydrogen Initiative, Mission Innovation Clean Hydrogen Mission
<b>H.3: Research &amp; Innovation</b> Expand the number and scope of innovative clean hydrogen projects	Mission Innovation Clean Hydrogen Mission
<b>H.4: Finance &amp; Investment</b> Scale and facilitate access to financial & technical assistance, particularly for developing countries	World Bank & UNIDO
<b>H.5: Landscape Coordination</b> Enhance the coordination and transparency of international collaboration on clean hydrogen	Breakthrough Agenda project team in close partnership with initiatives

Under discussion among partnerships

# IPHE Early Career Network

- 350+ members
- 40 countries
- **Students, post-docs, and early career professionals** worldwide
- Networking
- Career Development
- Webinars
- Leadership Opportunities



International Partnership  
for Hydrogen and Fuel Cells  
in the Economy

**Early Career Network**



Join IPHE Early  
Career LinkedIn  
Group



[www.iphe.net/early-career-chapter](http://www.iphe.net/early-career-chapter)





# HYDROGEN AMERICAS

## 2023

SUMMIT & EXHIBITION

**2 – 3 OCTOBER 2023**

RONALD REAGAN INT. TRADE CENTER,  
WASHINGTON D.C.

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**CONNECTING  
THE WORLD'S SENIOR  
HYDROGEN LEADERS  
WITH THE AMERICAS**

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CO-HOSTED BY:



U.S. DEPARTMENT OF  
**ENERGY**

# SAVE THE DATE!

YOUR FREE ACCESS TO HYDROGEN AMERICAS  
EXHIBITION AND H2 TECH SERIES

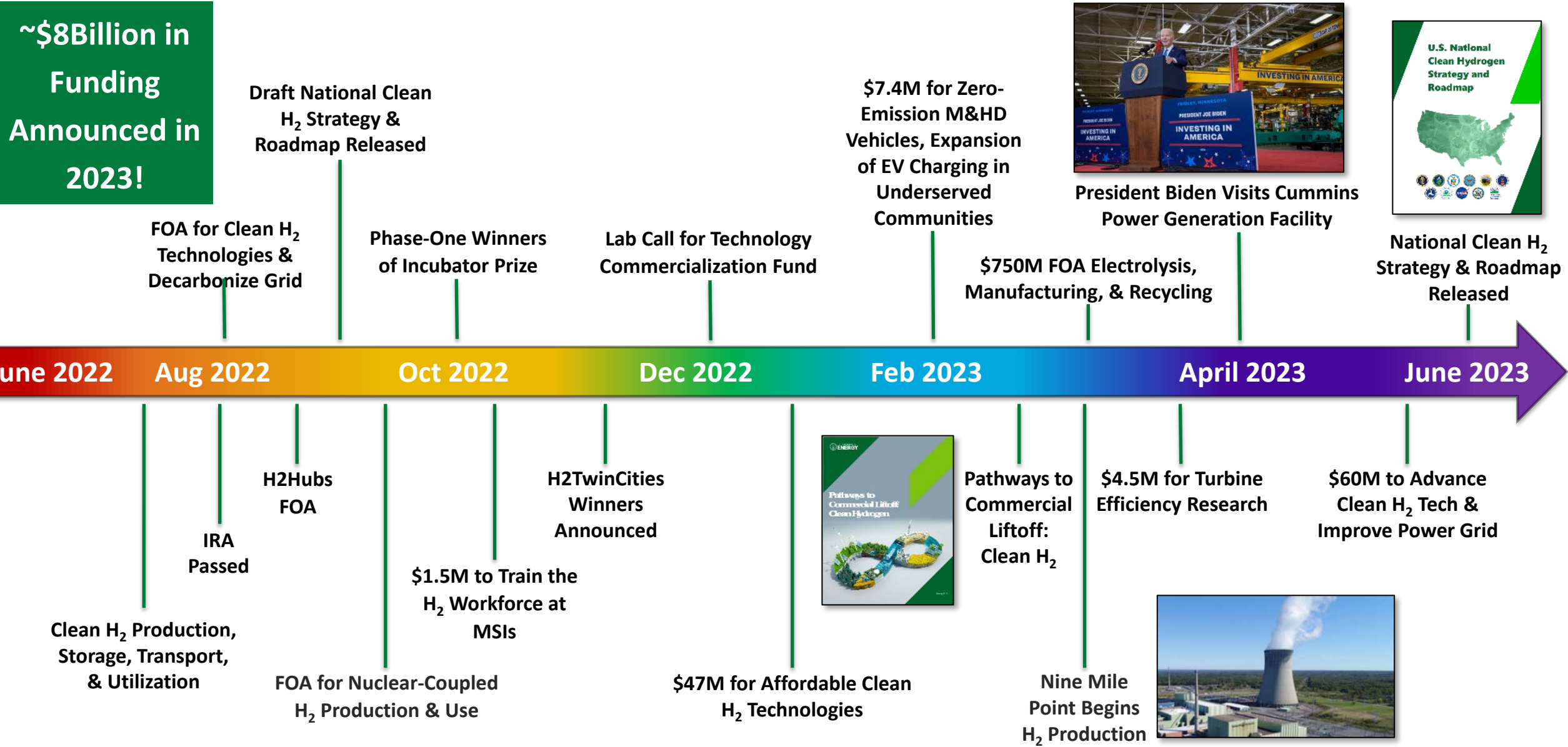
Meet with over **3000** industry leaders from across the **value chain**, including **government representatives, hydrogen and energy stakeholders, service providers and end-users.**

**Free-to-attend** H2 tech series designed specifically to provide you with a steppingstone into further research and collaboration.

Access to a wide range of **hydrogen research, demonstrations and analysis** to embark on your journey into the hydrogen value chain.

[www.hydrogen-americas-summit.com](http://www.hydrogen-americas-summit.com)

# Year in Review Highlights





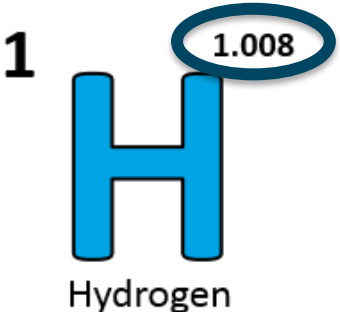
# Resources and Opportunities for Engagement

Save the date!

2024 DOE Annual Merit Review  
and Peer Evaluation Meeting  
May 6-9, 2024

Hydrogen and Fuel Cells Day  
October 8

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



INCREASE YOUR  
**H<sub>2</sub>IQ**  
hydrogen.energy.gov

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](http://www.aiche.org/CHS)

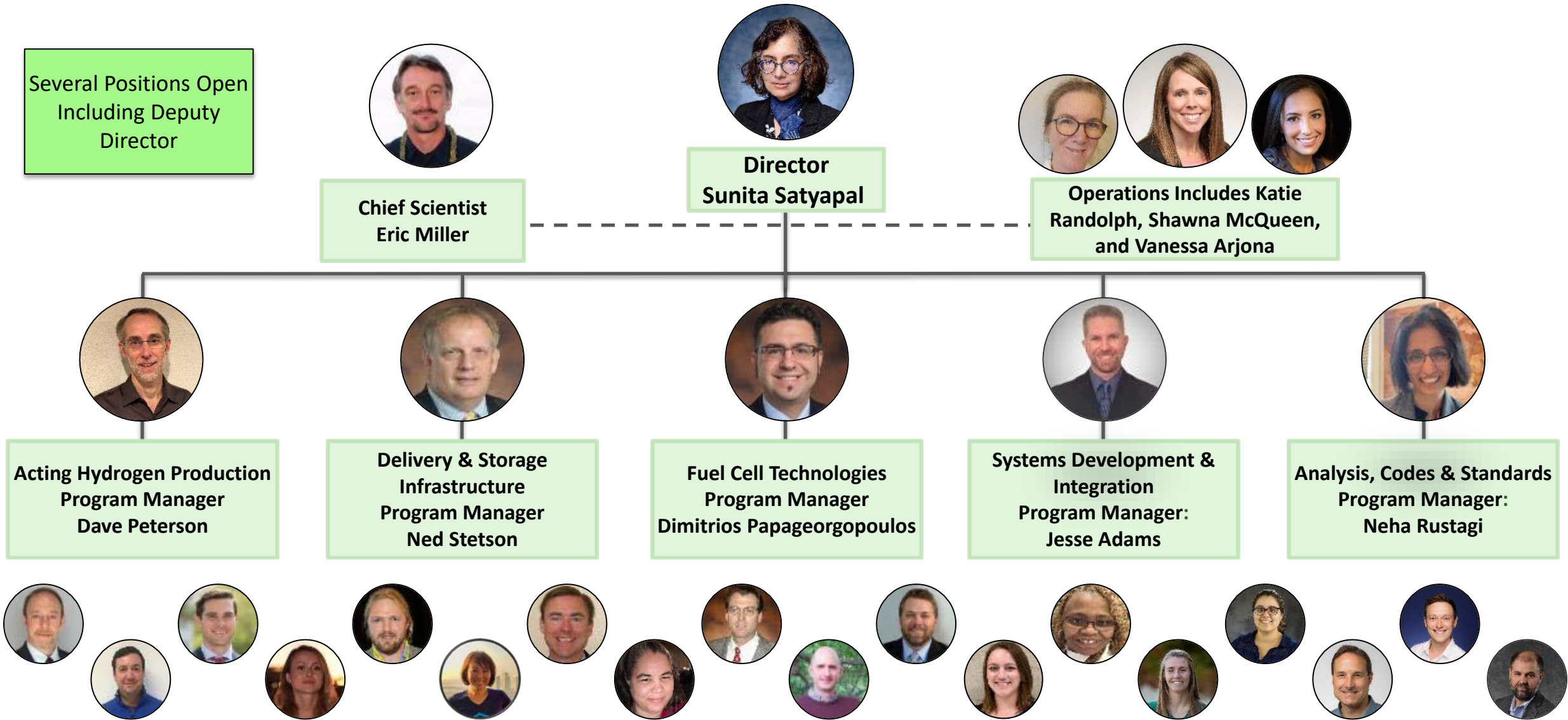


Sign up to receive hydrogen and fuel cell updates

[www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter](http://www.energy.gov/eere/fuelcells/fuel-cell-technologies-office-newsletter)

Learn more at: [energy.gov/eere/fuelcells](http://energy.gov/eere/fuelcells) AND [www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)

# Acknowledgements: Hydrogen and Fuel Cell Technologies Office



DOE Clean Energy Corps Applicant Portal: [www.energy.gov/applicant-portal](http://www.energy.gov/applicant-portal)



# Champions #1 for Element #1



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# Thank you

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

[www.energy.gov/fuelcells](http://www.energy.gov/fuelcells)  
[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)



# Acknowledging our Collaboration Network

## Collaboration and coordination to accelerate progress and advance environmental justice

**Project Partners**

*14 National Labs*

*~190 Companies*

*>100 Universities*

**Cross-Office work with Multiple DOE Offices**

*EERE (Solar, Wind, Vehicles., Advanced Manufacturing, Industry; Bioenergy, Buildings, Waterpower); OCED; FECM; NE; OE; ARPA-E; SC; OTT; LPO; ED; IE; IA; and more Joint Strategy Team*

**DOE Crosscutting Initiatives**

*Adv. Manufacturing, Adv. Transportation, AI/ML, Alt. Fuel, Cybersecurity, Critical Minerals, Decarbonization*

**Interagency Collaboration & Coordination**

*Including **DOC, DOD, DOT, DHS, EPA, NASA, NSF, State, Treasury**, and more (Interagency Working Group since early 2000s)*

**International Collaboration**

*IEA, IPHE, CEM, HEM, MI, IRENA, CH-JU, NALS, Bilaterals, and many more*

**Other External Partners**

*Regional and National Associations and States  
FCHEA, NASEO and many more*

*Labor groups, Tribes, and EJ Communities*

*Public-private partnerships  
21 CTP, USDRIVE, etc.*

# HFTO Project Partners: Labs, Universities, and Industry

<i>3M Company</i>	<i>General Electric Company, GE Research*</i>	<i>Nikola Motor Company</i>	<i>Treadstone Technologies, Inc.</i>
<i>Air Products and Chemicals</i>	<i>Georgia Institute of Technology</i>	<i>North Carolina State University</i>	<i>University of Alabama</i>
<i>Ames Laboratory</i>	<i>Giner ELX, Inc.</i>	<i>Northbound</i>	<i>University of California, Irvine</i>
<i>Argonne National Laboratory</i>	<i>GKN Hydrogen*</i>	<i>Northwestern University</i>	<i>University of California, San Diego</i>
<i>Arizona State University*</i>	<i>Hexagon R&amp;D LLC</i>	<i>Oak Ridge Institute</i>	<i>University of Colorado</i>
<i>Army Corps Engineers</i>	<i>Hornblower Energy</i>	<i>Oak Ridge Institute for Science &amp; Education</i>	<i>University of Delaware</i>
<i>Brookhaven National Laboratory</i>	<i>Hy-Performance Materials Testing, LLC</i>	<i>Oak Ridge National Laboratory</i>	<i>University of Florida</i>
<i>California Institute of Technology*</i>	<i>Idaho National Laboratory</i>	<i>Oak Ridge Associated Universities</i>	<i>University of Georgia Research Foundation*</i>
<i>Carnegie Mellon University</i>	<i>Indrio Technologies Inc.*</i>	<i>Oakland University*</i>	<i>University of Hawaii</i>
<i>Caterpillar Inc.</i>	<i>Iowa State University*</i>	<i>OCO Inc.*</i>	<i>University of Illinois at Urbana-Champaign</i>
<i>Center for Transportation and the Environment</i>	<i>Leland Stanford Junior University*</i>	<i>Oregon State University</i>	<i>University of Kansas Center for Research, Inc.</i>
<i>Chemours Company FC, LLC</i>	<i>Lawrence Berkeley National Laboratory</i>	<i>Orlando Utilities Commission</i>	<i>University of Kentucky</i>
<i>Clemson University</i>	<i>Lawrence Livermore National Laboratory</i>	<i>Pacific Northwest National Laboratory</i>	<i>University of Michigan</i>
<i>Collaborative Composite Solutions Corporation</i>	<i>Liox Power, Inc.</i>	<i>Palo Alto Research Center, Inc.*</i>	<i>University of North Texas</i>
<i>Colorado School of Mines</i>	<i>Los Alamos National Laboratory</i>	<i>Pennsylvania State University</i>	<i>University of Oregon</i>
<i>Cummins Inc.</i>	<i>Lubrizol</i>	<i>Plug Power Inc.</i>	<i>University of South Carolina</i>
<i>Daimler, Ford, GM</i>	<i>Mahle Powertrain</i>	<i>Raytheon Technologies Research Center</i>	<i>University of Southern California</i>
<i>DOT National Highway Traffic Safety Administration</i>	<i>Massachusetts Institute of Technology</i>	<i>Rensselaer Polytechnic Institute</i>	<i>University of Tennessee-Knoxville</i>
<i>Drexel University</i>	<i>Missouri University of Science &amp; Technology</i>	<i>Rice University*</i>	<i>University of Tennessee, Space Institute</i>
<i>Eaton Corporation</i>	<i>Montana State University</i>	<i>Saint-Gobain Ceramics and Plastics, Inc.</i>	<i>University of Texas, El Paso</i>
<i>Electric Power Research Institute Inc</i>	<i>NASA WSTF</i>	<i>Sandia National Laboratories</i>	<i>University of Toledo</i>
<i>Electricore Inc.</i>	<i>National Energy Technology Laboratory</i>	<i>Savannah River National Laboratory</i>	<i>University of Virginia</i>
<i>Exelon Corporation</i>	<i>National Institute of Standards and Technology</i>	<i>Shell</i>	<i>Vanderbilt University</i>
<i>Frontier Energy, Inc.</i>	<i>National Renewable Energy Laboratory</i>	<i>SLAC National Accelerator Laboratory</i>	<i>Washington State University</i>
<i>FuelCell Energy, Inc.</i>	<i>NEL Hydrogen, Inc.</i>	<i>Southern Company Services</i>	<i>Washington University in St. Louis*</i>
<i>Gas Technology Institute</i>	<i>Neograf Solutions LLC</i>	<i>Strategic Analysis, Inc.</i>	<i>West Virginia University</i>
<i>General Motors LLC</i>	<i>Nexceris, LLC</i>	<i>SUNY University at Buffalo*</i>	<i>Yale University*</i>

*\* Awards subject to negotiations*

# DOE Hydrogen Program FOAs/Lab Calls

	Office	FY	FOA / Lab Call	~Funds \$M	Relevant Focus Areas
ERRE	HFTO	22	Funding Opportunity in Support of the Hydrogen Shot and a University Research Consortium on Grid Resilience	\$61	Advanced pathways for H2 production & storage; H2 sensing; Grid resilience
	HFTO	23	Bipartisan Infrastructure Law: Clean Hydrogen Electrolysis, Manufacturing, and Recycling FOA	\$750	Clean H2 Electrolysis Program & Clean H2 Manufacturing & Recycling
	HFTO	23	HFTO FOA in Support of Hydrogen Shot	\$47	H2 storage & delivery R&D with LH & carriers; HD fuel cell RD&D
	HFTO	23	Clean Hydrogen Electrolysis Program HFTO Lab Call	\$30	Advanced Materials, Components, and Interfaces for Electrolyzers
	IEDO	22	Industrial Efficiency and Decarbonization FOA	\$104	Includes iron/steel decarbonization, including with clean H2
	IEDO	23	Industrial Efficiency and Decarbonization Office Multi-Topic FOA	\$156	Includes H2 as a low-carbon fuel, and for decarbonizing industrial processes
	AMMTO, BTO, OE	22	AMMTO-BTO and OE Multi-Topic FOA	\$52	Decarbonization under harsh environments, including with clean H2
	SETO	22	Concentrating Solar-Thermal Power RD&D FOA	\$25	CSP for industrial decarbonization, including with clean H2
	VTO	22	Vehicle Technologies Office Program Wide FOA	\$96	Includes H2 combustion for HD transportation
FECM NE	FECM	22	University Training and Research for Fossil Energy and Carbon Management - MSIs	\$7	Includes value-added NG conversion to H2
	FECM	23	Fossil Energy Based Production, Storage, Transport and Utilization of H2 Approaching Net-Zero or Net-Negative Carbon Emissions	\$32	H2 production, storage, transport, & utilization
	FECM, HFTO	22	University Training and Research for Fossil Energy and Carbon Management -MSIs	\$2	Materials R&D for H2 and fuel cell technologies
	NE	22	U.S. Industry Opportunities for Advanced Nuclear Technology Development FOA	\$22	Topic on nuclear-coupled H2 production and use

# DOE Hydrogen Program FOAs/Lab Calls

	Office	FY	FOA / Lab Call	~Funds \$M	Relevant Focus Areas
OCED, MESC OTT	OCED	22	Bipartisan Infrastructure Law: Regional Clean Hydrogen Hubs FOA	\$7,000	Establishment of Regional Clean Hydrogen Hubs
	OCED, OTT	23	Bipartisan Infrastructure Law TCF: Collaborative Alignment for Critical Technology Industries Lab Call	\$15	Topics on clean H2 and long duration energy storage
	OCED, MESC, IEDO	23	Industrial Decarbonization and Emissions Reduction Demonstration-to-Deployment FOA	\$6,000	Installations and retrofit demonstrations including H2-based industrial decarbonization
	MESC	23	Bipartisan Infrastructure Law: Advanced Energy Manufacturing and Recycling Grant Program FOA	\$350	New or expanded facilities, including for H2 & fuel cell components
SC ARPA-E	SC/BES	23	Science Foundations for Energy Earthshots FOA	\$150	Supporting Energy Earthshot goals including H2 Shot
	SC/BES	23	Energy Earthshot Research Centers Lab Call	\$200	Supporting Energy Earthshot goals including H2 Shot
	ARPA-E	22	Advanced Research Projects Agency- Energy: Exploratory Topics FOA	\$55	Broad RD&D, including potential relevance to H2 and fuel cells



## Loan Programs Office (LPO) Builds The Bridge to Bankability & Market Catalyzation

LPO announced loan guarantee conditional commitments for 2 clean hydrogen projects



**MONOLITH**

HALLAM, NEBRASKA

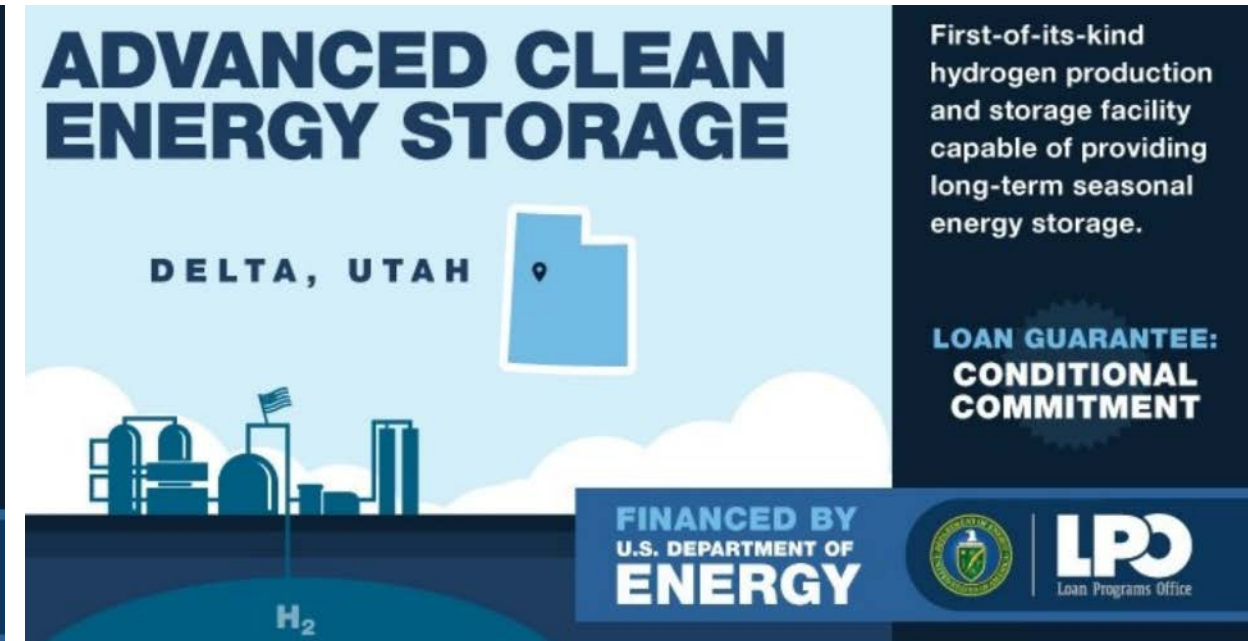
Employing innovative carbon black reactor technology, Monolith is a pioneering clean hydrogen and carbon utilization project.

**LOAN GUARANTEE: CONDITIONAL COMMITMENT**

FINANCED BY  
U.S. DEPARTMENT OF  
**ENERGY**

 **LPO**  
Loan Programs Office

**\$1.04B** for the first-ever commercial-scale project to deploy methane pyrolysis technology. Will enable 1,000 construction jobs and 75 operations jobs.  
(December 2021)




**ADVANCED CLEAN ENERGY STORAGE**

DELTA, UTAH

First-of-its-kind hydrogen production and storage facility capable of providing long-term seasonal energy storage.

**LOAN GUARANTEE: CONDITIONAL COMMITMENT**

FINANCED BY  
U.S. DEPARTMENT OF  
**ENERGY**

 **LPO**  
Loan Programs Office

**\$504.4M** for large-scale hydrogen energy storage, 220 MW electrolysis and turbine. Will enable up to 400 construction jobs and 25 operations jobs.  
(April 2022)

**Let's talk about your project. Call or email for a no-cost pre-application consultation: (202) 287-5900 or [LPO@hq.doe.gov](mailto:LPO@hq.doe.gov)**