U.S. DEPARTMENT OF ENERGY

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

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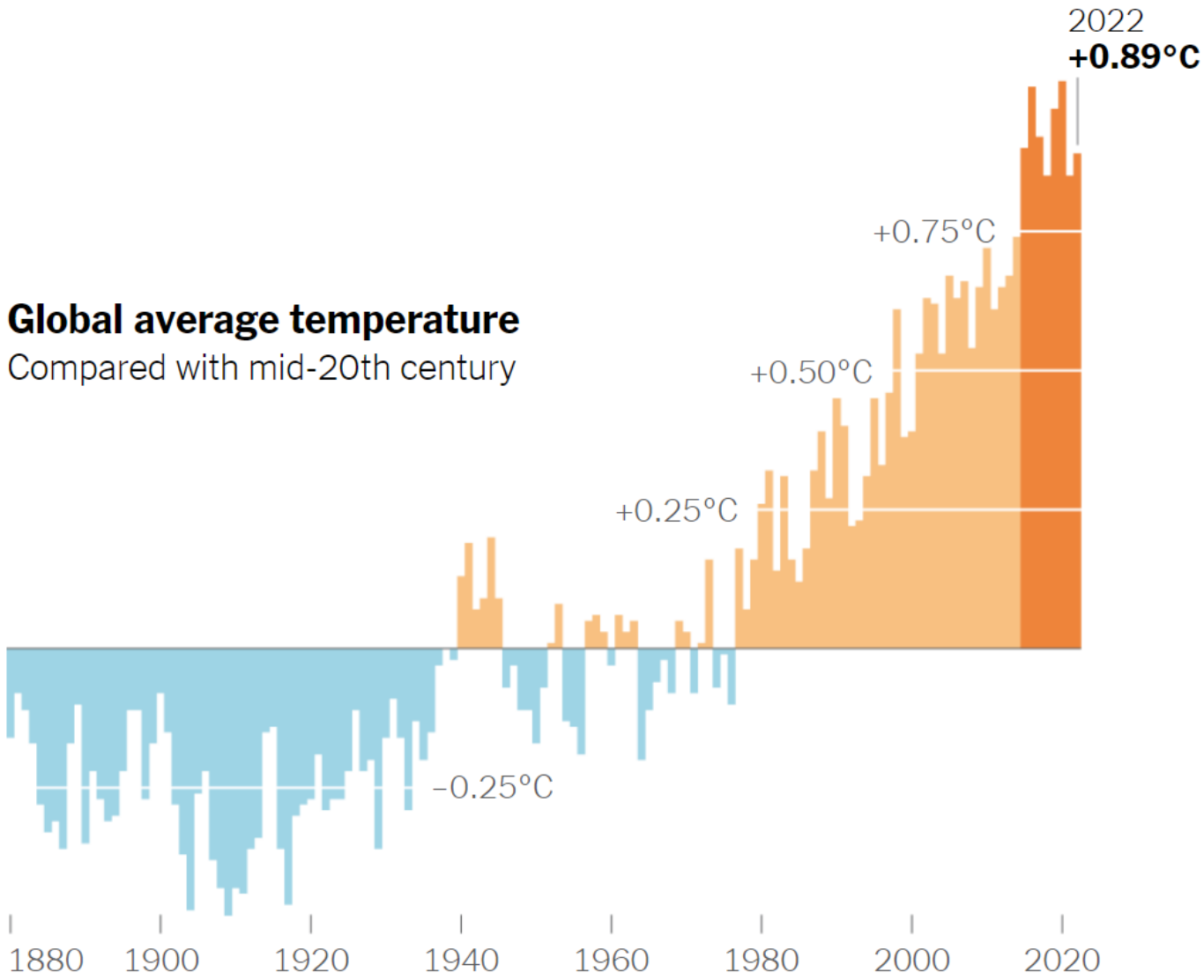
U.S. Department of Energy

June 5, 2023

Introduction – Energy, Market, and Policy Context

The Global Challenge….

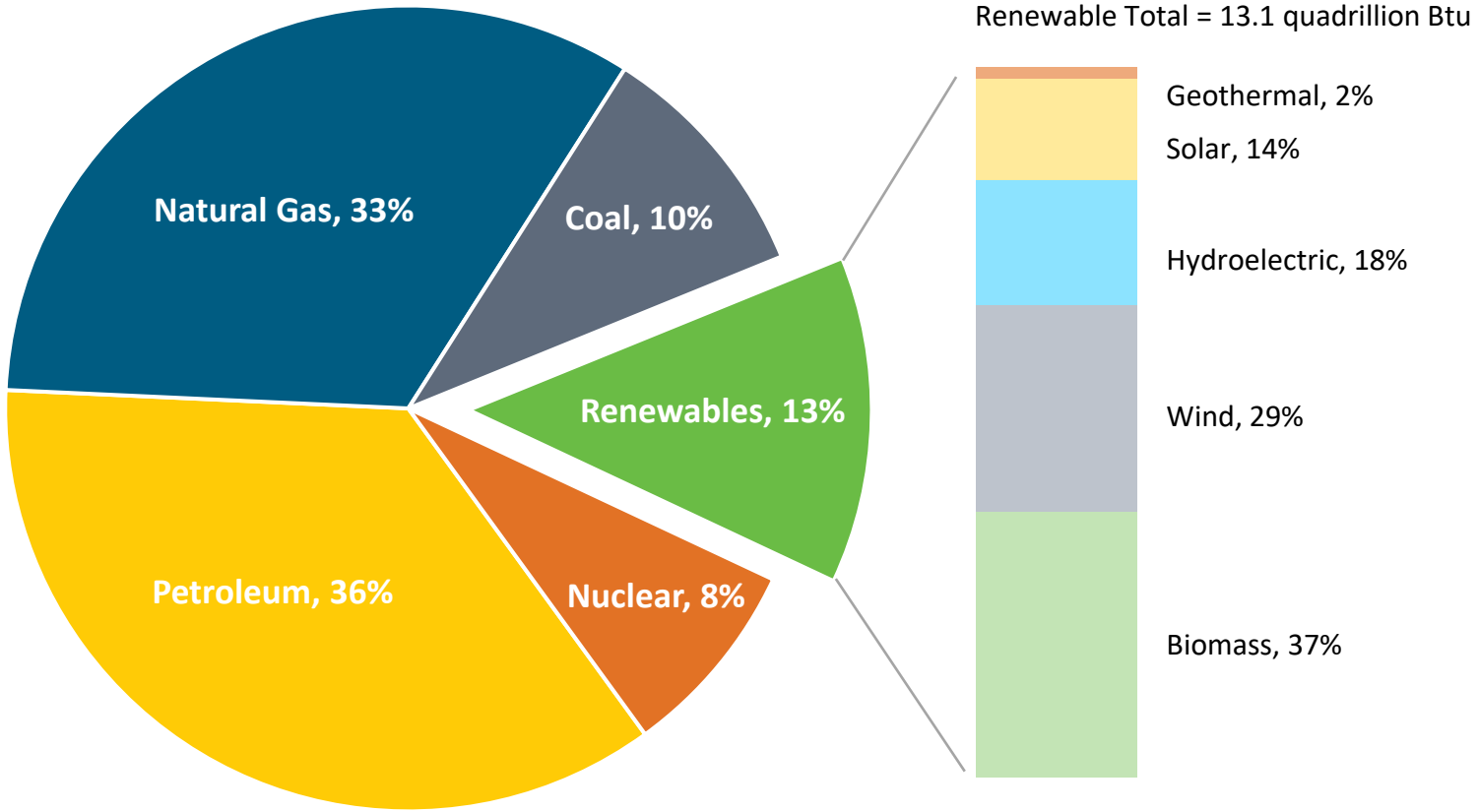


Source: NASA Goddard Institute for Space Studies

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

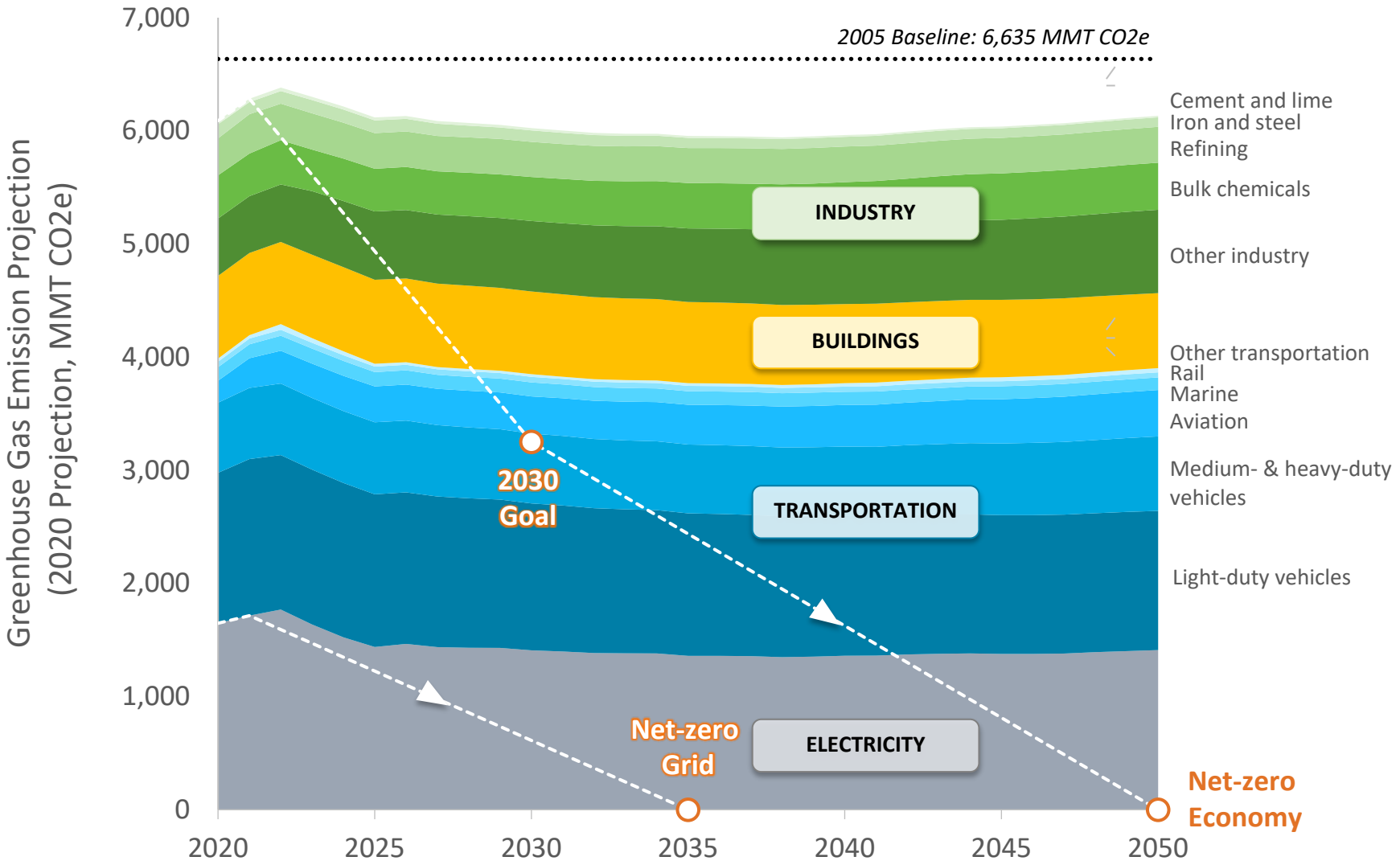
Administration Goals include:

- 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

EJ: Environmental Justice

Carbon Dioxide Emissions by Sector



U.S. DOE Hydrogen Program

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

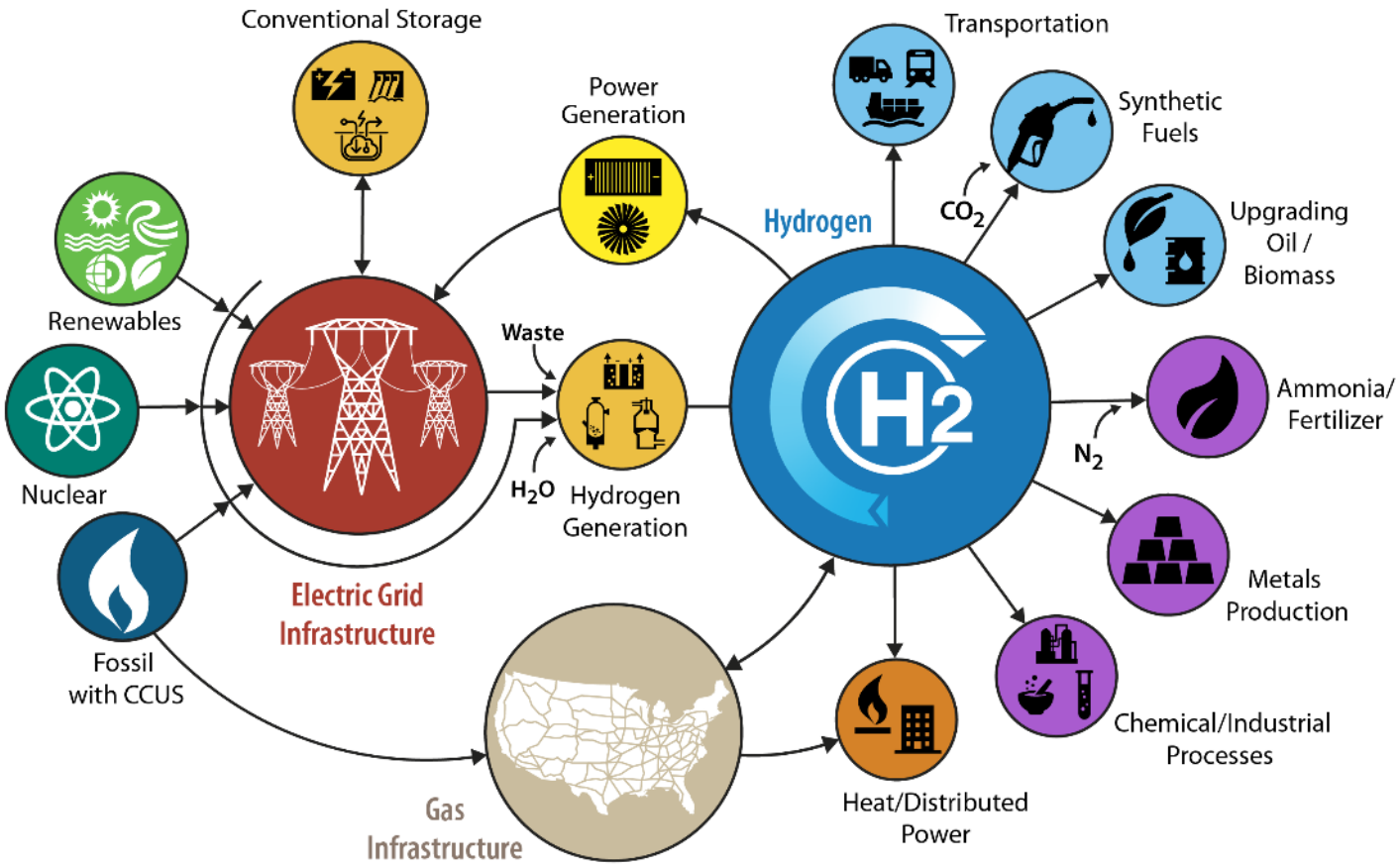
Hydrogen Program

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

- **The entire H_2 value chain** from production through end use
- **H_2 production from <u>all</u> resources** (renewables, nuclear, and fossil + CCS)

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

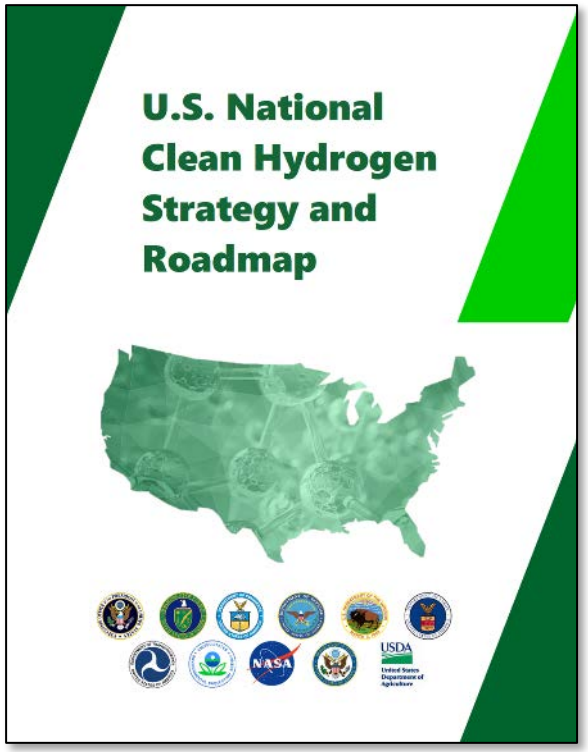
Inflation Reduction Act

- **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

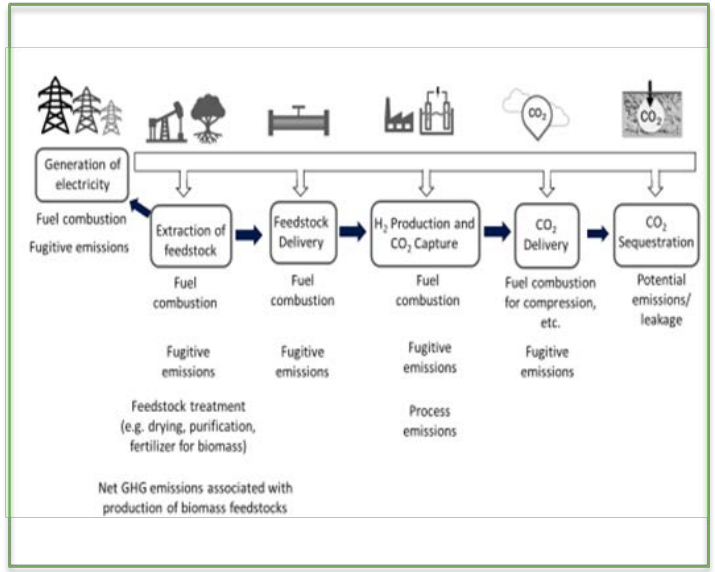
Regional Clean Hydrogen Hubs (H2 Hubs) FOA

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_2 and Fuel Cell Incentives

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

Carbon Intensity (kg CO_2 per kg H_2)*	Max Tax Credit ($/kg H_2)
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

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)	**Blending up to 30% low-GHG H_2** by volume can be used to meet the 1000-lb CO_2/MWh standard	
Base load generators (over ~50% capacity factor)	**Blending up to 30% low-GHG H_2** can be used to meet the 680-lb CO_2/MWh standard	**Blending up to 96% low-GHH H_2** can be used to meet the 90-lb CO_2/MWh standard

For existing turbines >300 MW capacity, > 50% capacity factor: highly efficient generation coupled with 30% co-firing by volume low-GHG H_2, by 2038 co-firing with 96% low-GHG H_2

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

PHMSA issued proposed H_2 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

Supply	Midstream	End Use Demand
Production Tax Credit 45V, 45Q (Treasury)	Fueling Corridor Grants (DOT/JO)	Vehicle Tax Credits, Clean Fuels Credits, 48C (Treasury)
Electrolyzer RD&D BIL (DOE)	Bipartisan PIPES Act NPRM (DOT PHMSA)	State Policies (ZEV Mandates, H2 PTC)[1]
Manufacturing Tax Credit 48C (Treasury/DOE)	Manufacturing Tax Credit 48C (Treasury/DOE)	Clean Power Rule NPRM (EPA)
Regional Clean H2 Hubs BIL (DOE)	Regional Clean H2 Hubs BIL (DOE)	Buy Clean Standards (EOP)
		Agency offtake (DOD, USPS, USDA, DOT, EPA, etc.)
		Regional Clean H2 Hubs BIL (DOE)

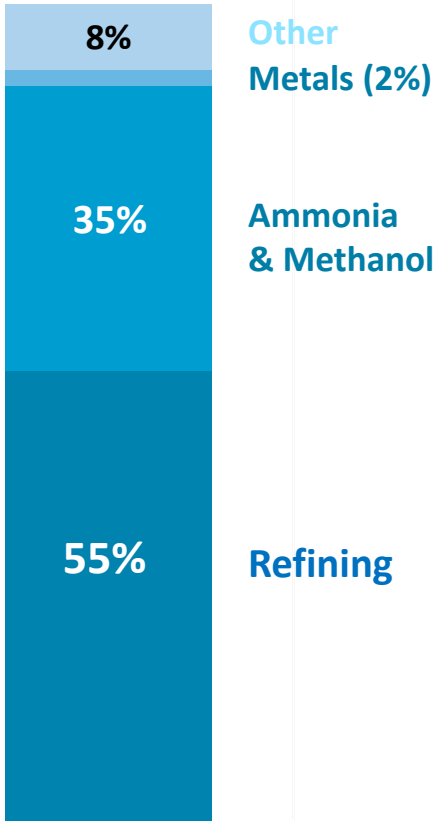
JO: Joint Office of Energy and Transportation; EOP: Executive Office of the President
NPRM: Notice of proposed rulemaking

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.

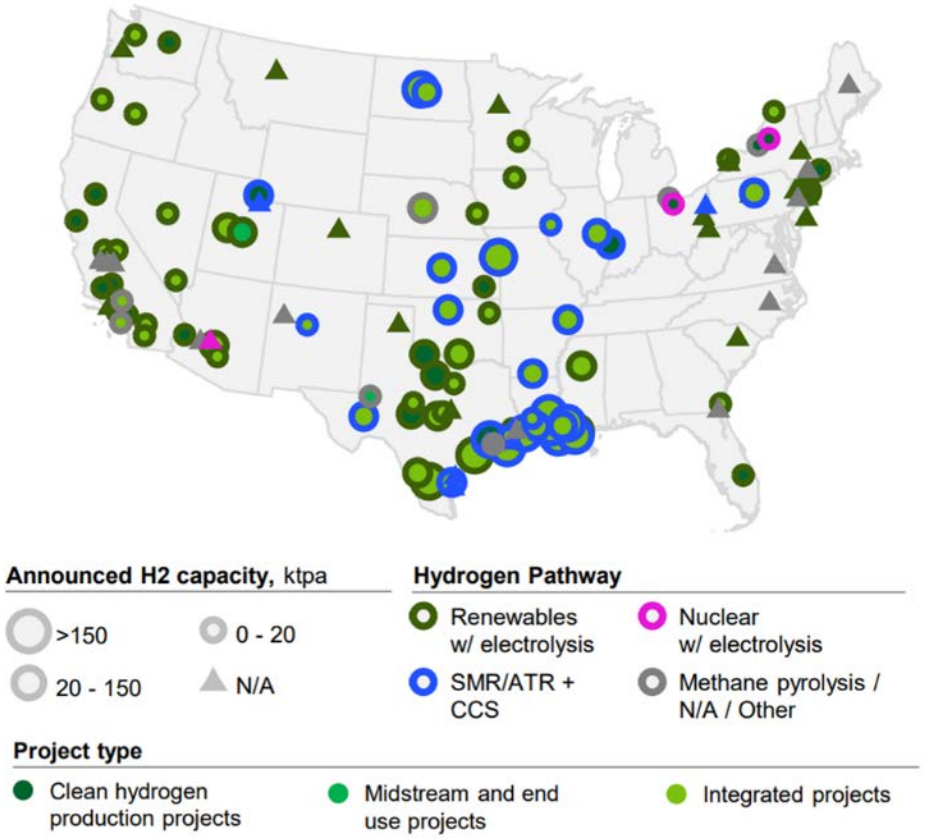
Snapshot of Hydrogen and Fuel Cells in the U.S.

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

Use of Hydrogen in the U.S. Today

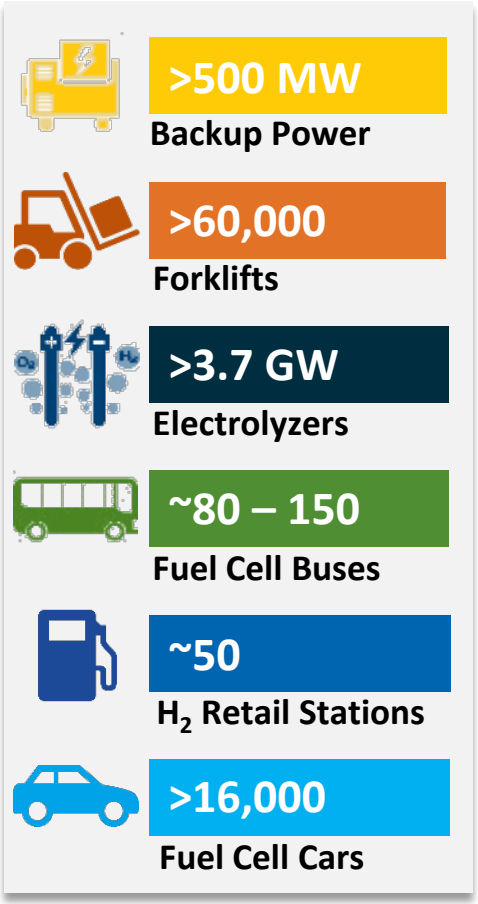


Current publicly announced clean hydrogen production projects*



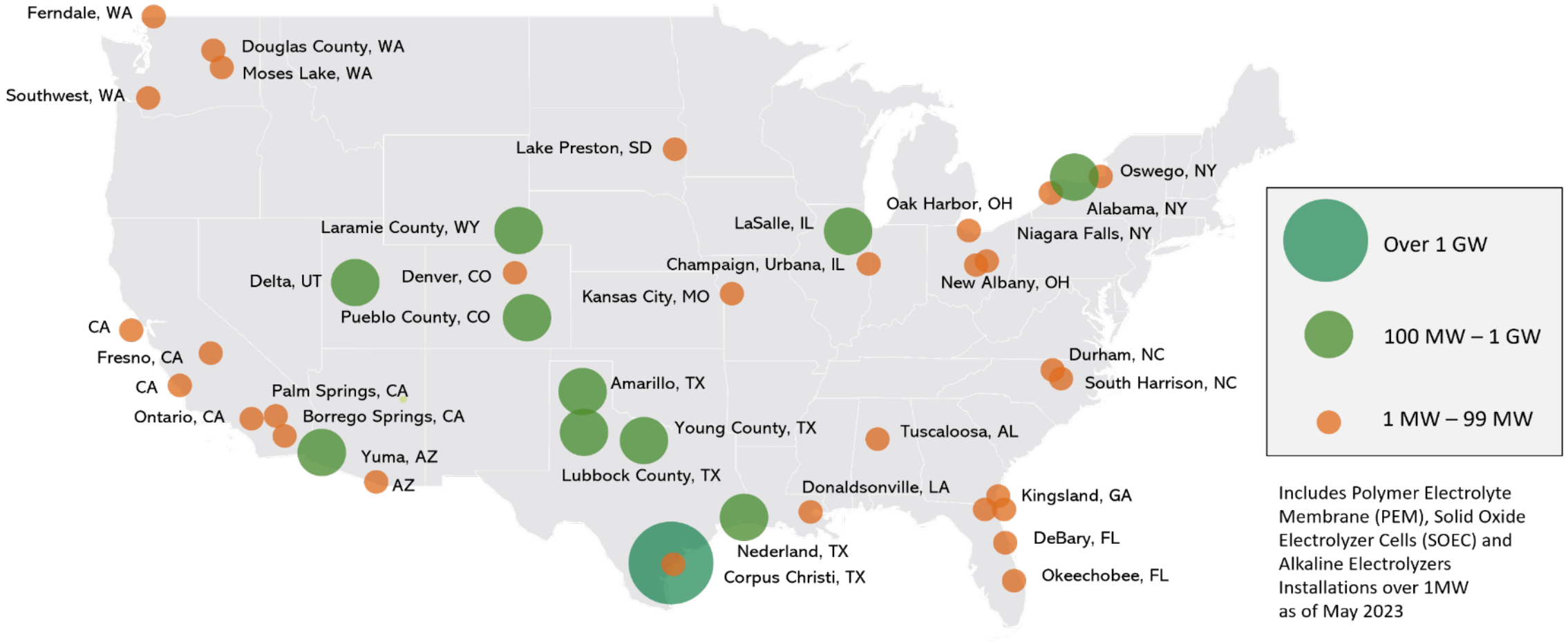
*as of EOY 2022, DOE Commercial Liftoff Report

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

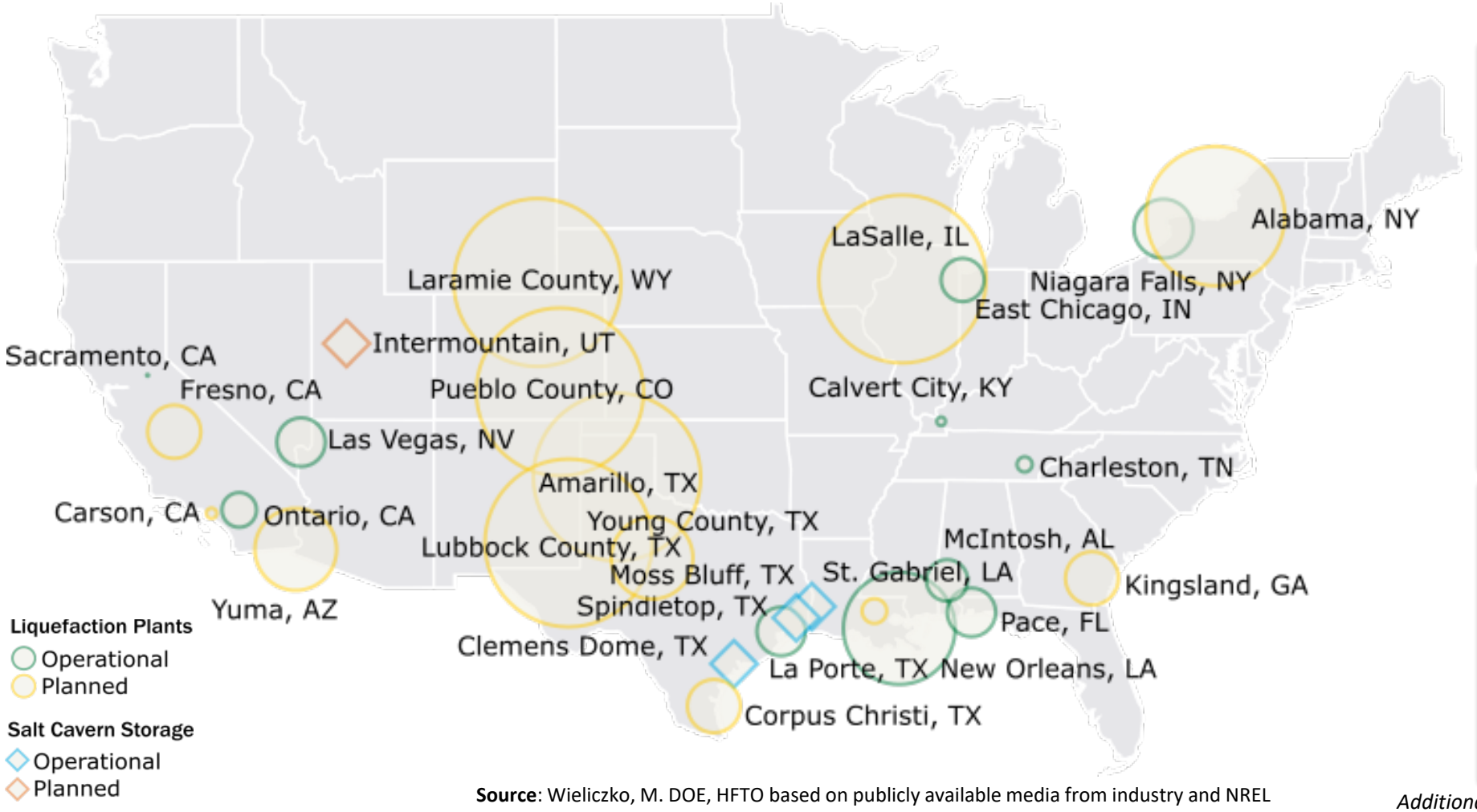


Includes Polymer Electrolyte Membrane (PEM), Solid Oxide Electrolyzer Cells (SOEC) and Alkaline Electrolyzers Installations over 1MW as of May 2023

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

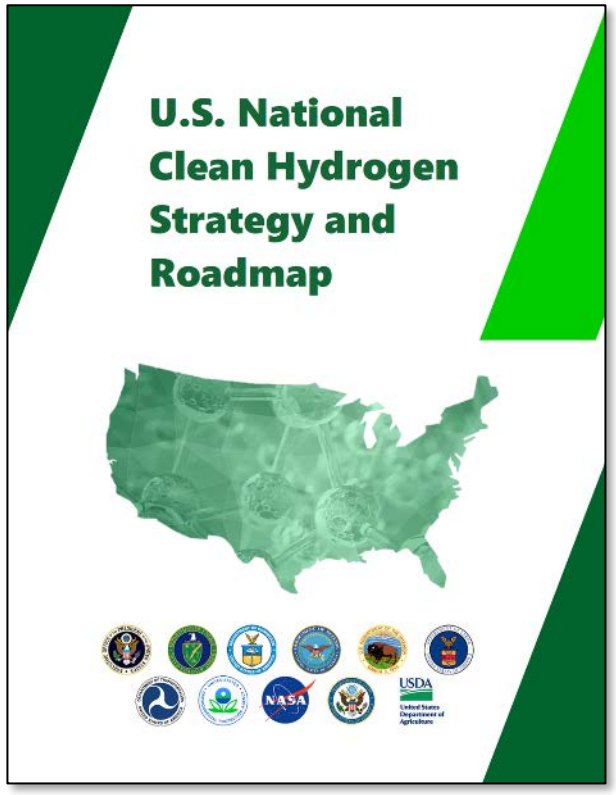
Source: Wieliczko, M. DOE, HFTO based on publicly available media from industry and NREL

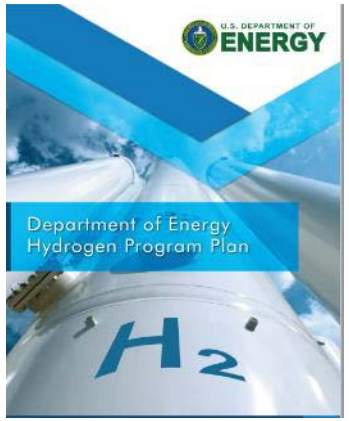
Additional liquefaction plants in Canada: 5 operating + 1 planned

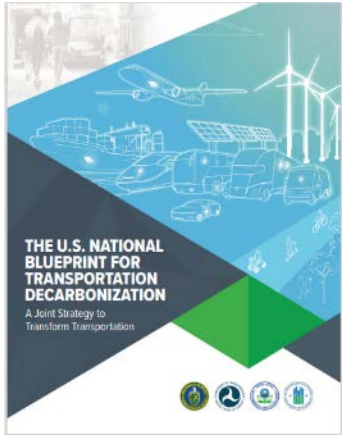
Strategy & Goals

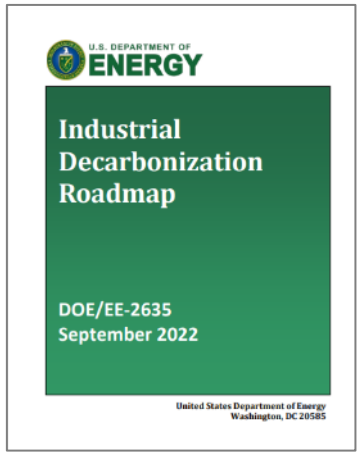
Key Publications

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









www.hydrogen.energy.gov

U.S. National Clean Hydrogen Strategy and Roadmap

Strategy

1. **Target strategic, high-impact end uses**
   Achieve 10 MMT/year of clean hydrogen by 2030
2. **Reduce the cost of clean hydrogen**
   Enable $2/kg by electrolysis by 2026 and $1/kg H_2 by 2031
3. **Focus on regional networks**
   Deploy regional clean hydrogen hubs and ramp up scale

Vision:
Affordable clean hydrogen for a net-zero carbon future and a sustainable, resilient, and equitable economy

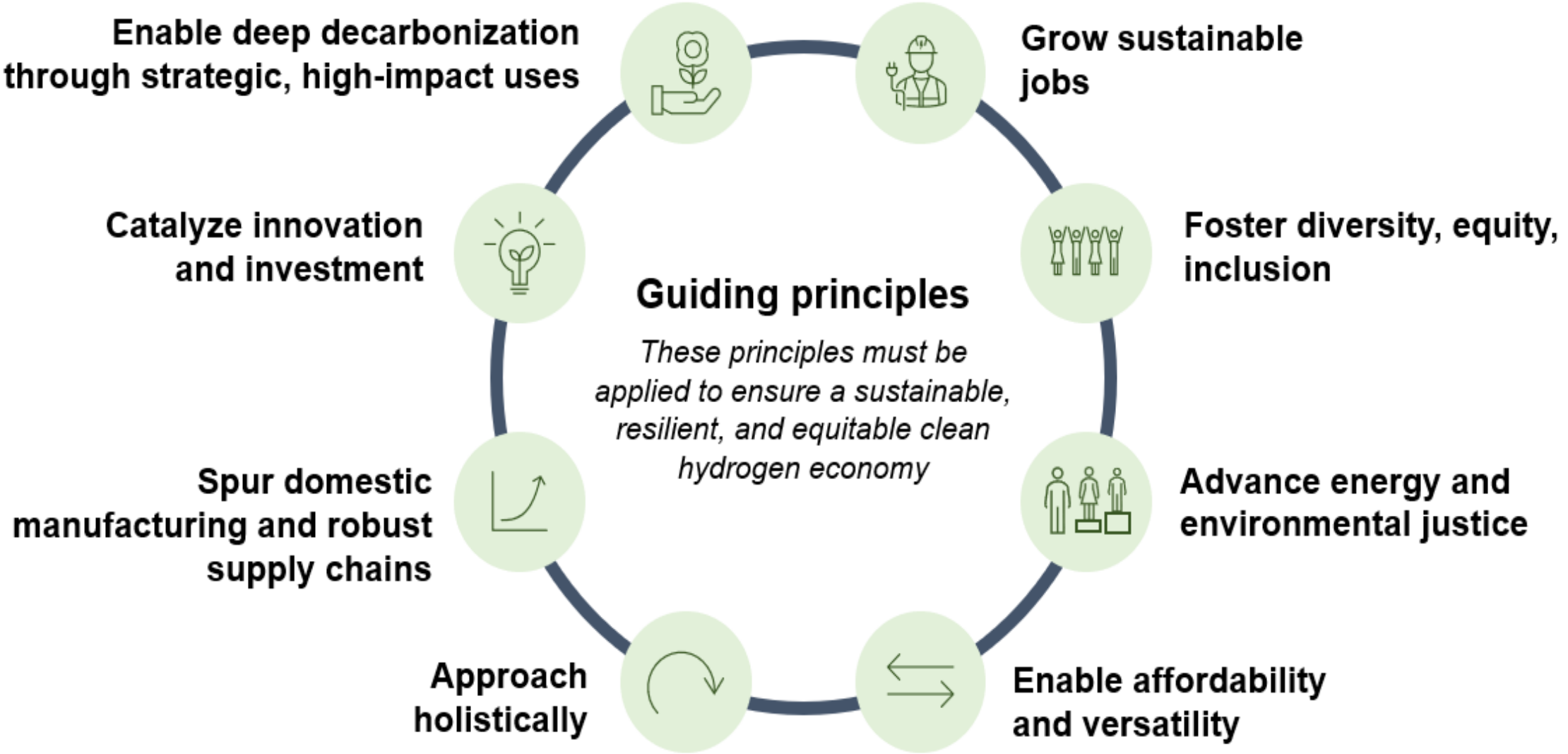
Benefits:
Emissions reduction; job growth; energy security and resilience

Enablers

Work with other agencies to accelerate market lift off

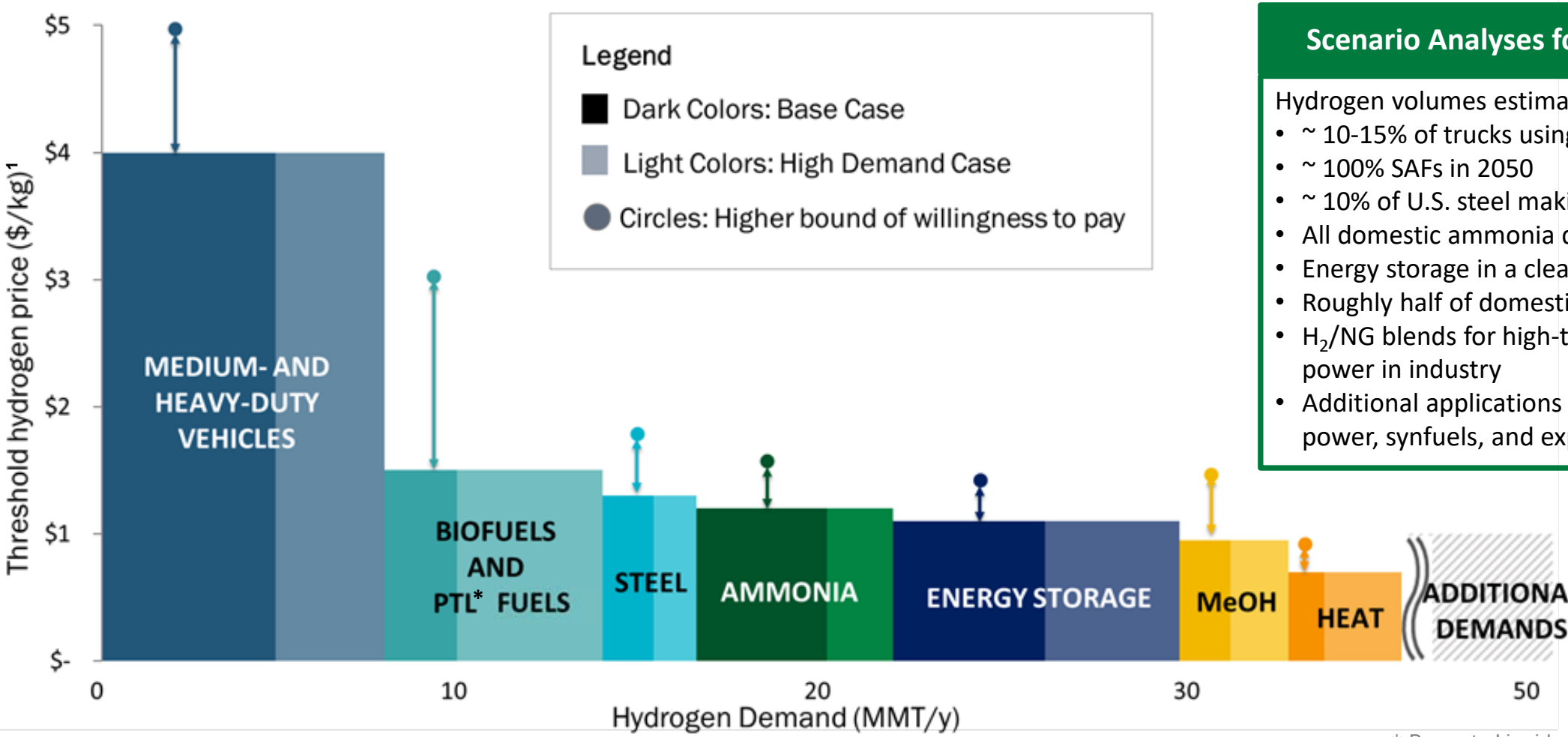
- Good Jobs and Workforce Development
- Safety, codes and standards
- Policies and incentives
- Stimulating private sector investment
- Energy and environmental justice

Guiding Principles



Strategy 1: Target High-Impact Uses of Hydrogen

Clean Hydrogen Demand and Costs for Market Penetration



Scenario Analyses for H_2 Demand**

Hydrogen volumes estimated for:

- ~ 10-15% of trucks using fuel cells
- ~ 100% SAFs in 2050
- ~ 10% of U.S. steel making
- All domestic ammonia demand
- Energy storage in a clean grid
- Roughly half of domestic methanol
- H_2/NG blends for high-temp heat and power in industry
- Additional applications include stationary power, synfuels, and export potential

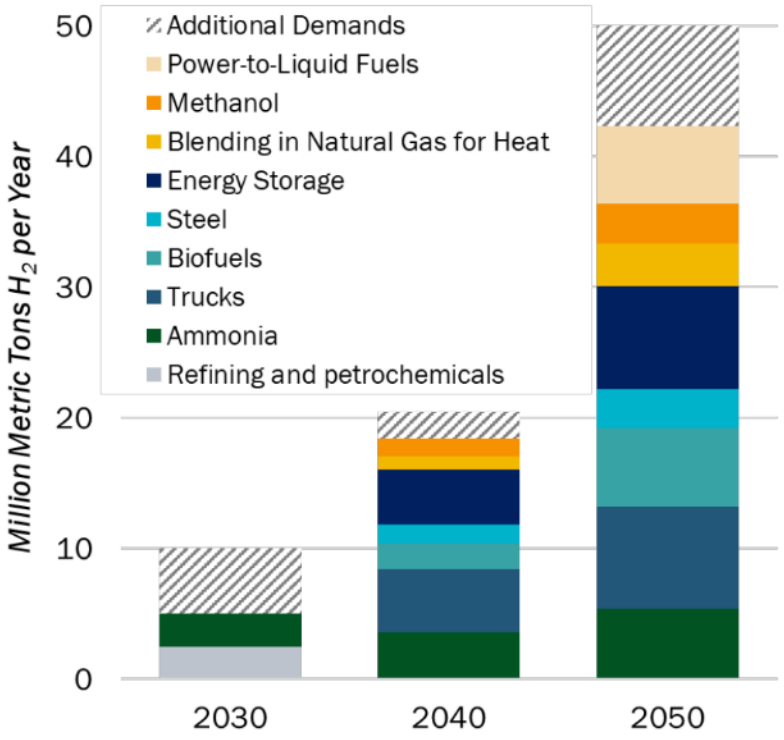
[1]Costs include production, delivery, dispensing to the point of use (e.g., high-pressure fueling for vehicle applications)

* Power to Liquid

** Volumes dependent on multiple variables

Strategy 1: Target High-Impact Uses of Hydrogen

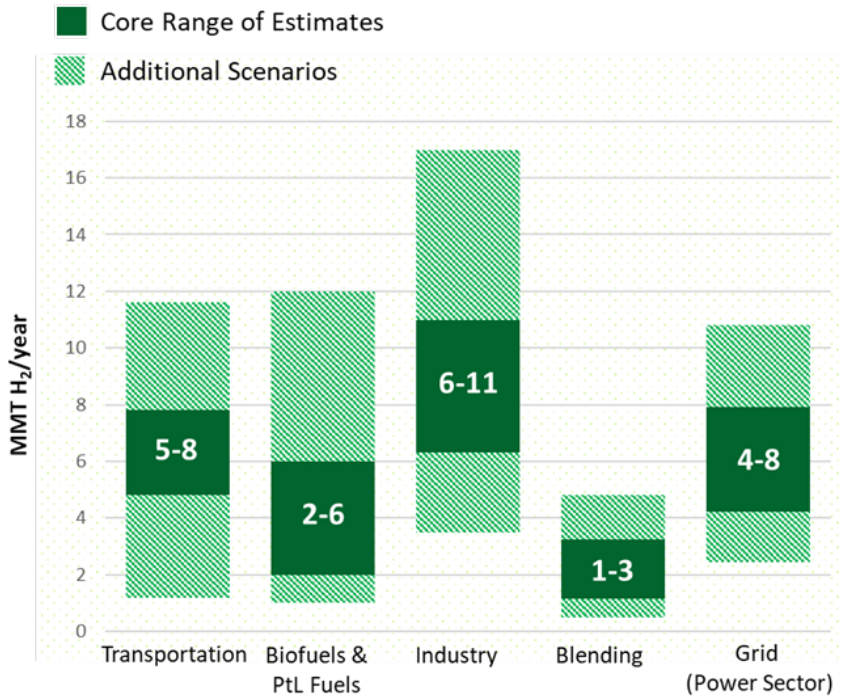
Opportunities for Clean Hydrogen Across Applications



Clean Hydrogen Use Scenarios

- Catalyze clean H_2 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



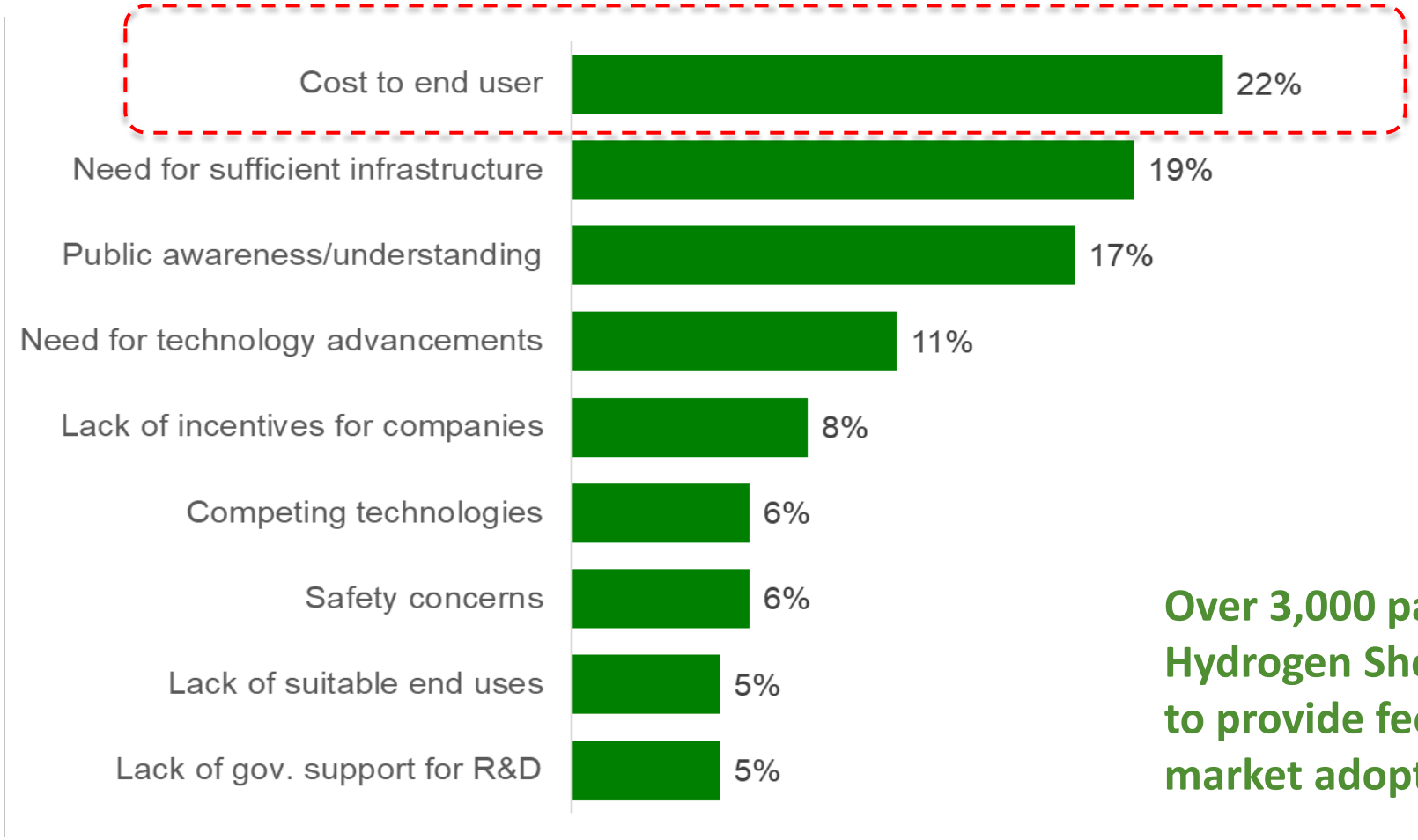
- **Core range: ~ 18–36 MMT H_2**
- **Higher range: ~ 36–56 MMT H_2**

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

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

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 Energy Earthshot

“Hydrogen Shot”

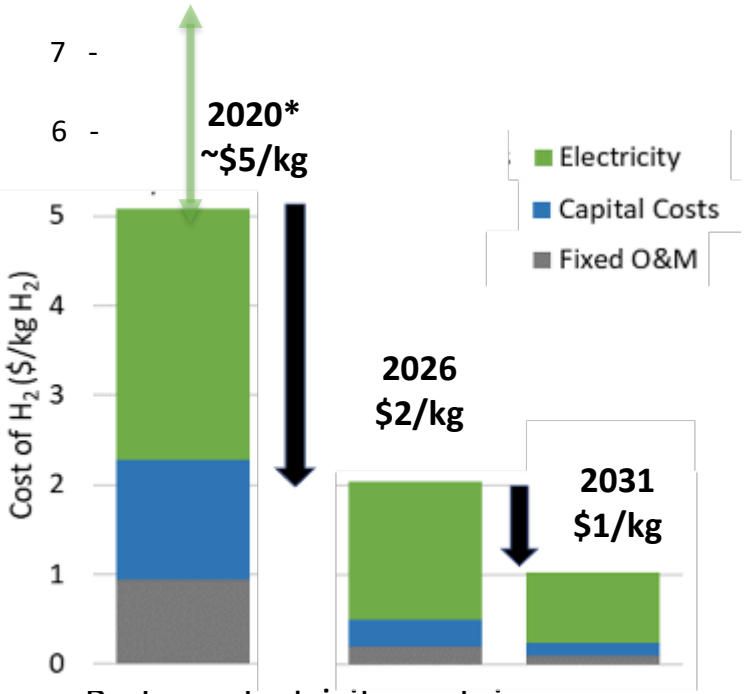
“1 1 1”
$1 for 1 kg clean hydrogen in 1 decade

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

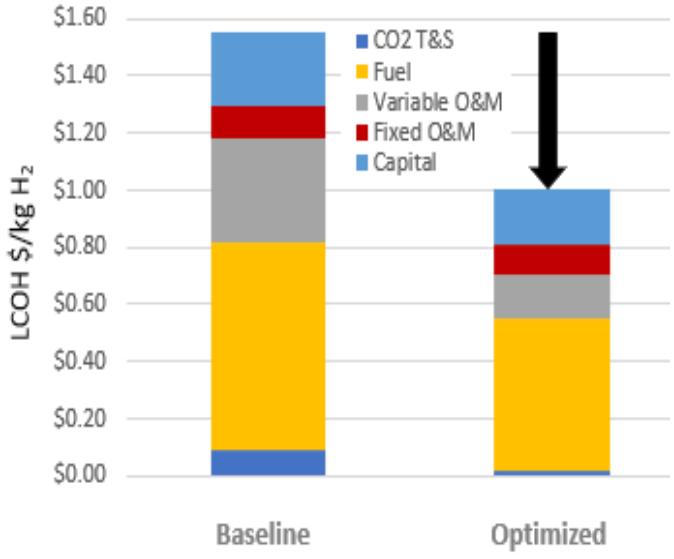
H_2 from Electrolysis



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

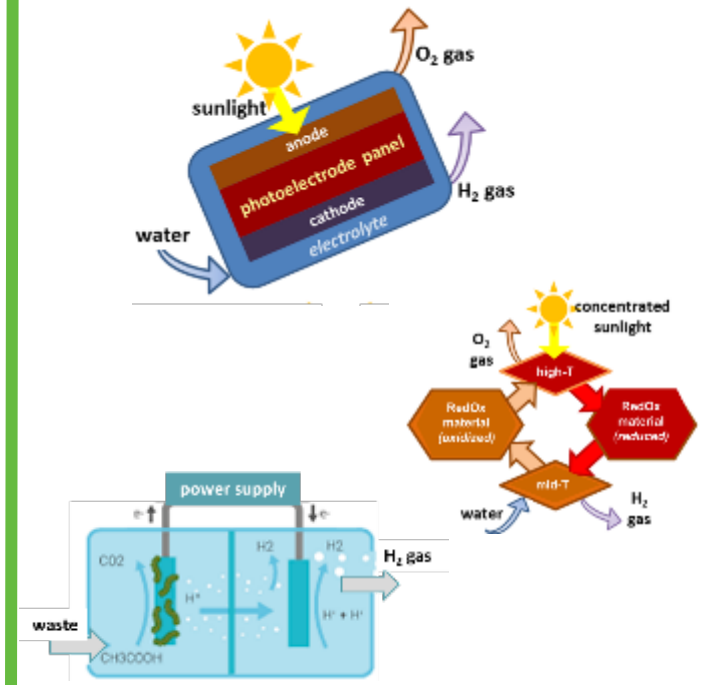
Thermal Conversion

Example: Autothermal Reforming + CCS



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

Advanced Pathways

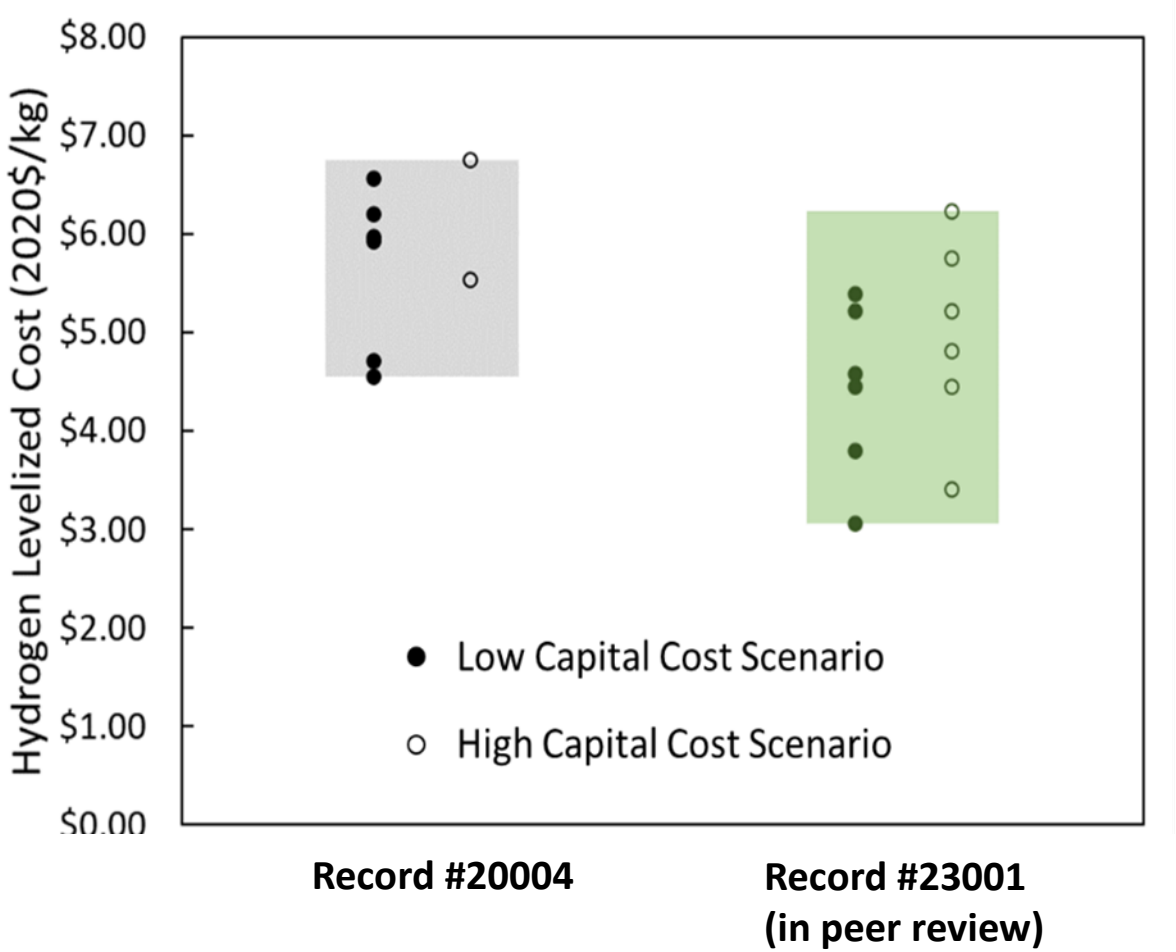


- Photelectrochemical (PEC), thermochemical, biological, etc.

*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_2 from other electrolyzer types

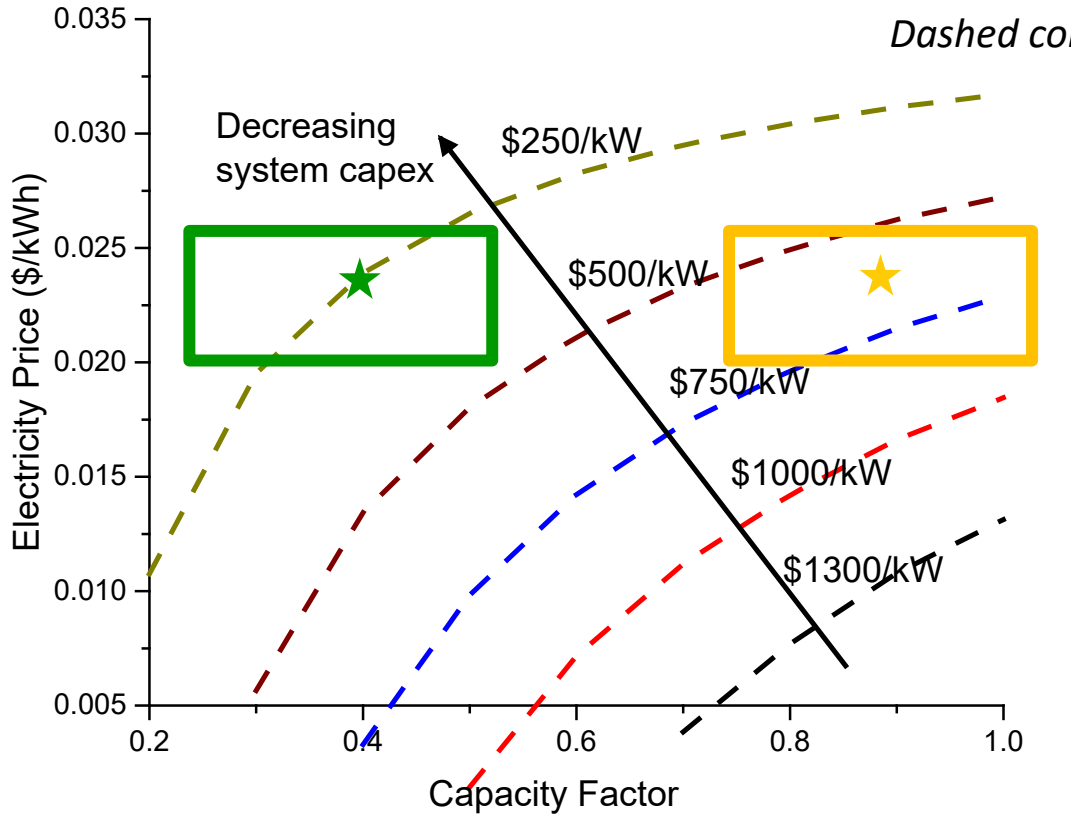
DOE Hydrogen Program Record #23001, "Hydrogen Production Cost with Current PEM Electrolyzer Technology – 2022", Under peer review; to be published at https://www.hydrogen.energy.gov/program_records.html

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

Case Study: Two 'book end' approaches to achieving $2/kg H2 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 $_{H2}$ 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

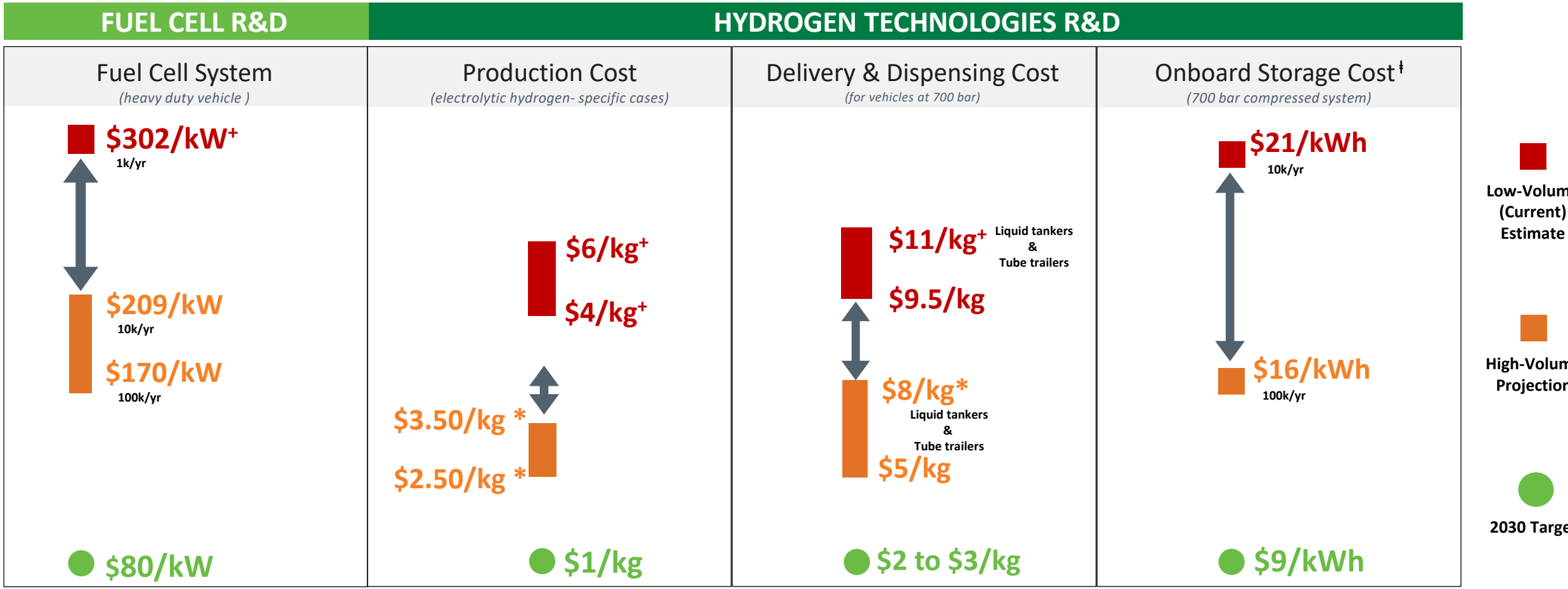
Leverage and Expand Existing National Lab Consortia & Capabilities	FOAs enable manufacturing, supply chain, first of a kind demos	SBIRs, TCF, Prizes, and more to incentivize new/small players and collaborations
H2NEW Hydrogen from Next-generation Electrolyzers of Water; U.S. DEPARTMENT OF ENERGY; HydroGEN Advanced Water Splitting Materials; ElectroCat Electrocatalysis Consortium	Support industry and universities to build U.S. manufacturing, components, and expertise	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



†Based on 275 kW Heavy Duty Fuel Cell System Cost Analysis (2022), adjusted to reflect cost of system that meets 25,000 hours durability

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

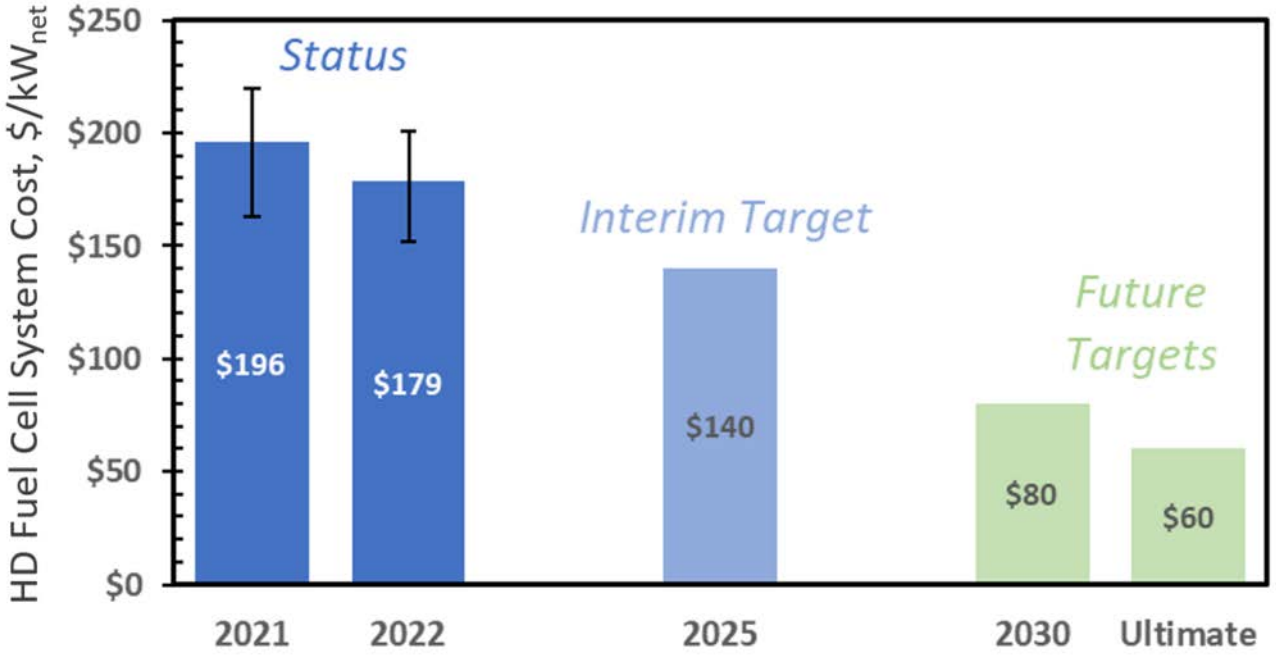
† Delivery and dispensing at today's (2020) stations at ~450 kg/day *Delivery and dispensing at today's (2020) stations with capacity 450-1,000 kg/day at high volume manufacturing. Note high volatility and market/supply chain factors; current at station H_2 prices as high as ~ $25/kg in some regions

‡ 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-kWnet HD Truck PEMFC system

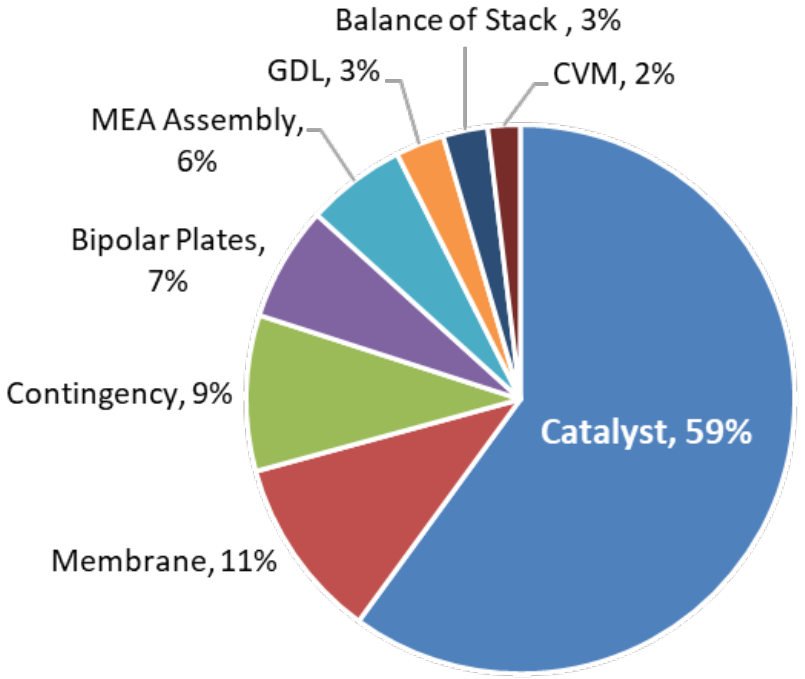


Cost status (2021, 2022) and interim target (2025) for a manufacturing volume of 50,000 systems/yr. Future (2030, ultimate) targets at 100,000 systems/yr; ($302/kW$_{net}$ at 1,000 systems/yr; $179/kW$_{net}$ at 50,000 systems/yr; $170/kW$_{net}$ at 100,000 systems/year

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

Stack cost breakdown

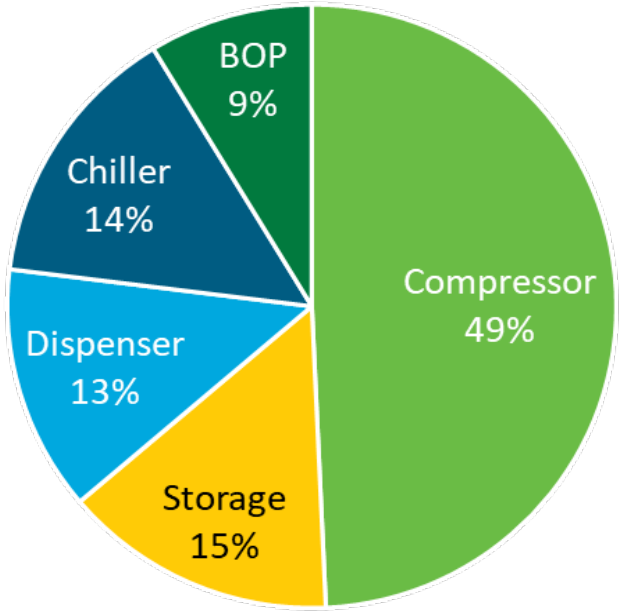
($112/kW$_{net}$ at 50,000 systems/year)



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

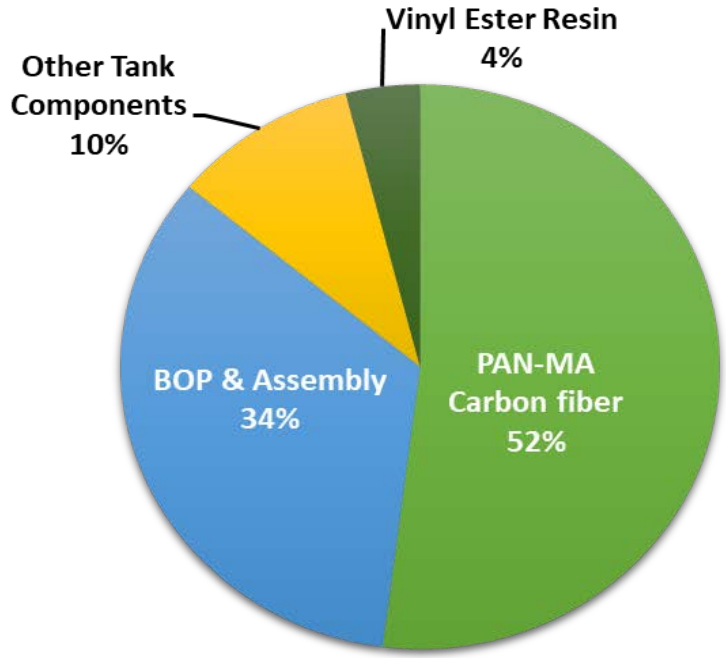
Examples of Cost Drivers and Focus Areas for Hydrogen Technologies

H_2 Infrastructure Cost Drivers: Compressors, Chiller, Dispenser and Storage



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

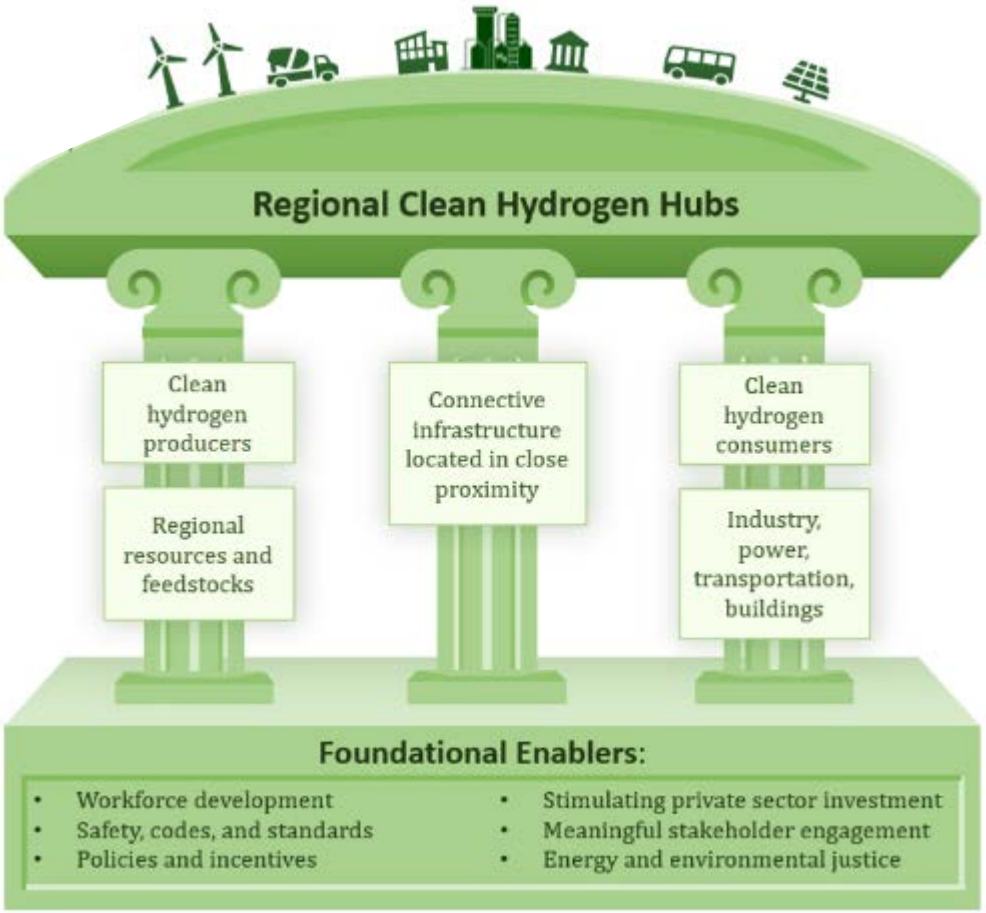
H_2 Onboard Storage Cost Drivers: Carbon Fiber Precursors and Processing



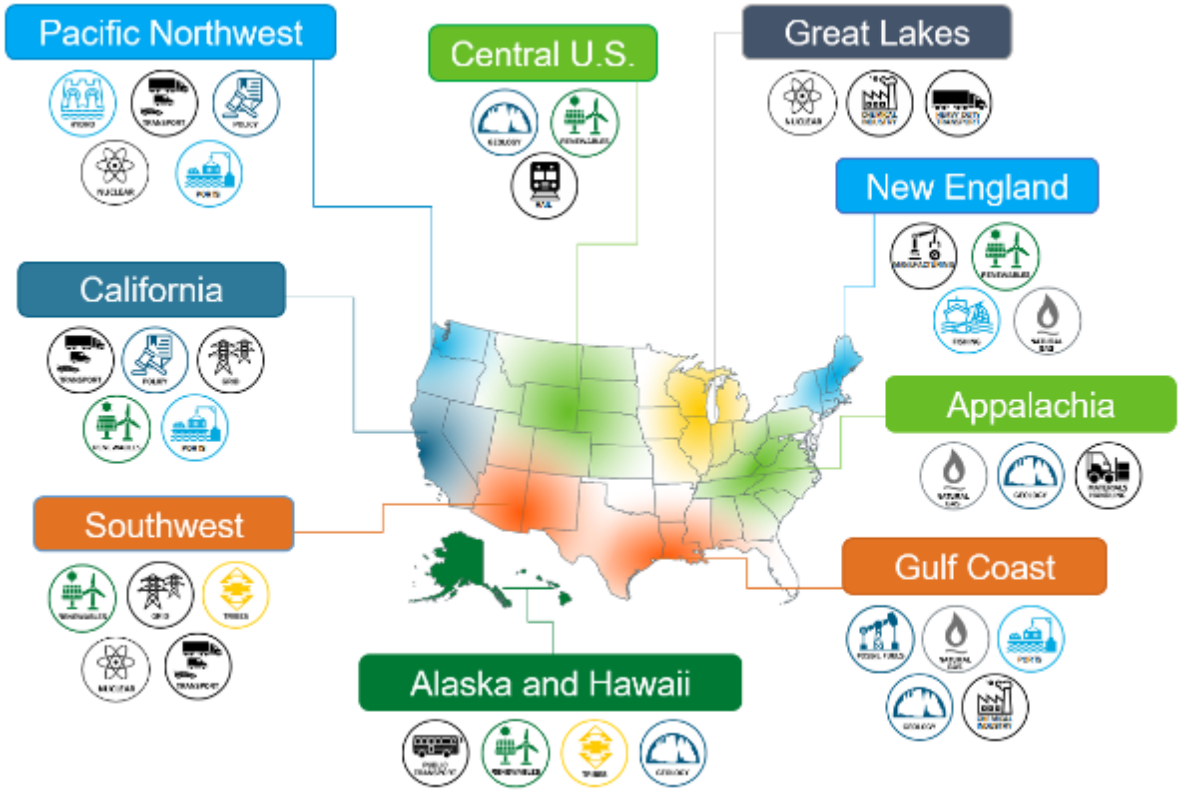
On-board Vehicle Hydrogen Storage Cost Example
(700 bar Type IV, 5.6 kg Hydrogen Storage System)

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

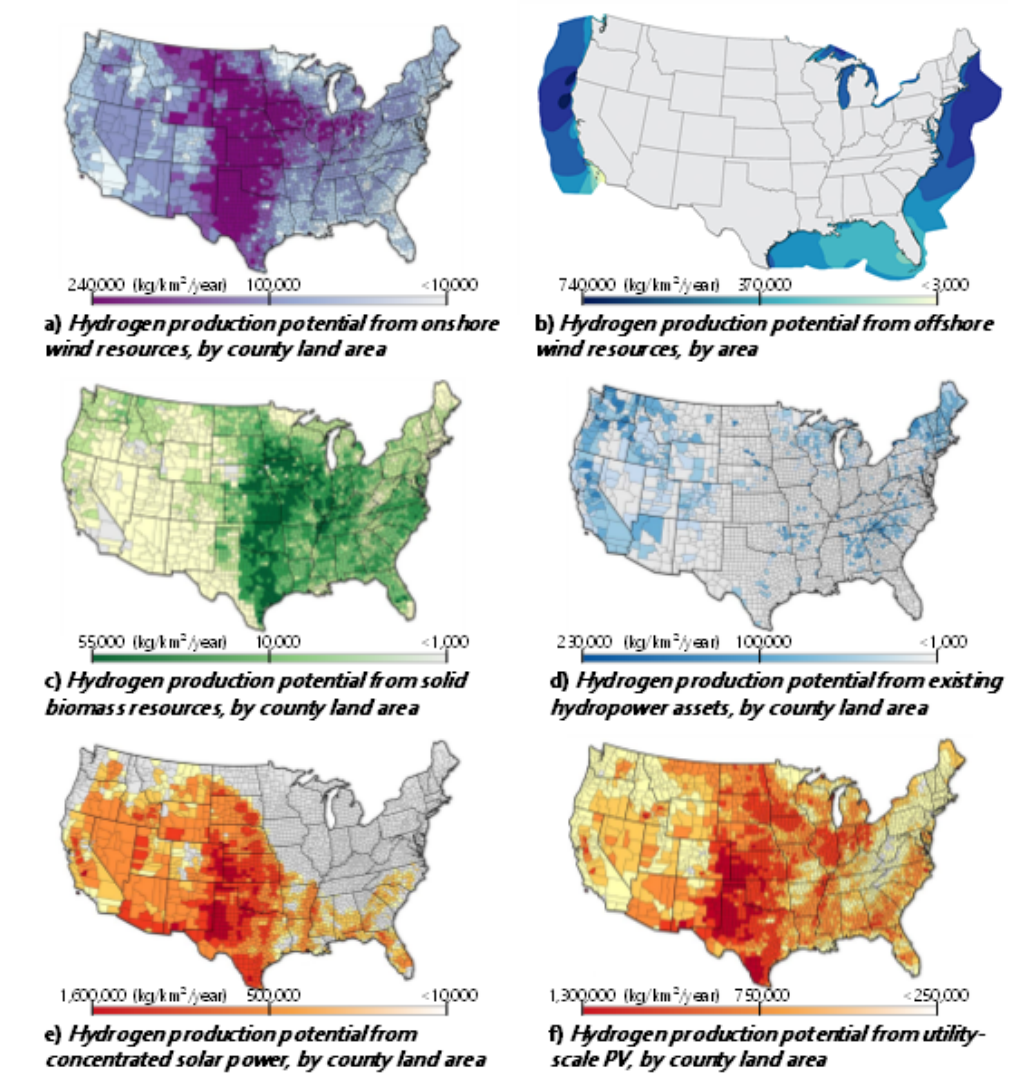
Build Regional Networks through "Clean Hydrogen Hubs"



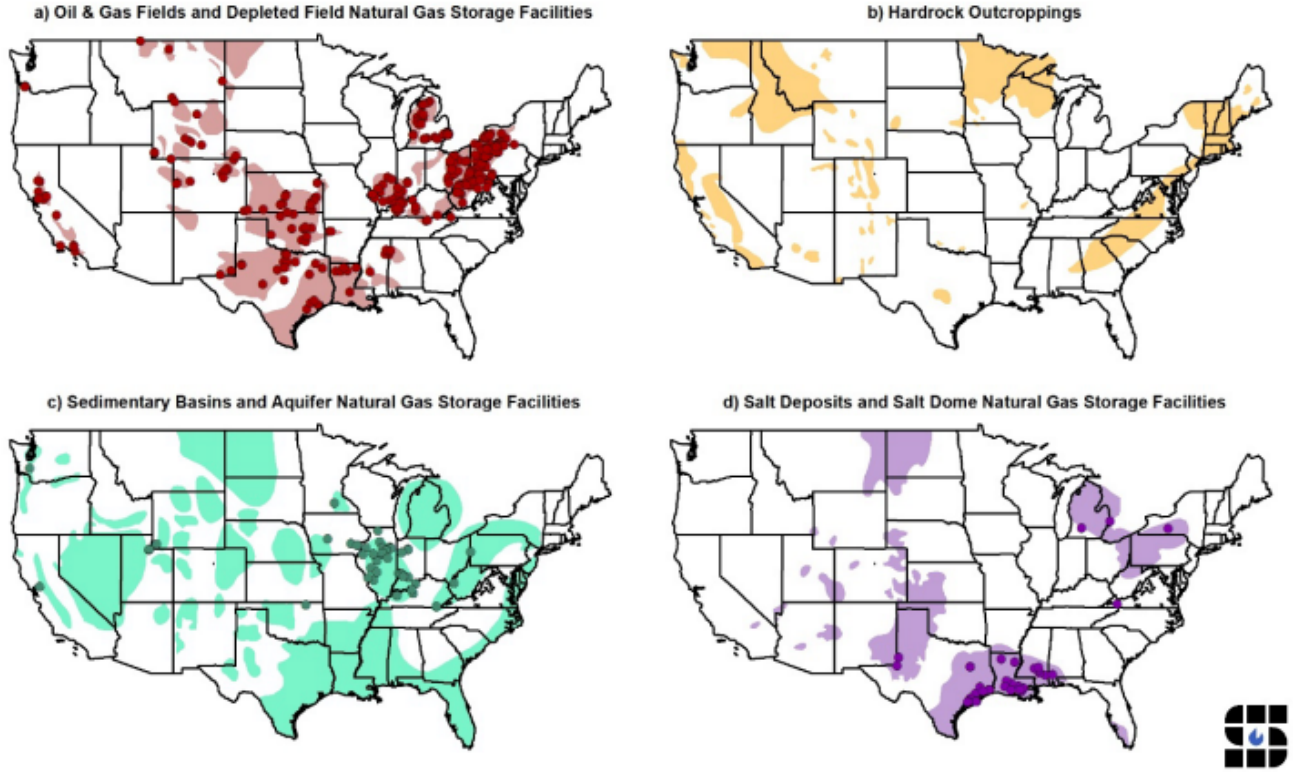
Examples of Stakeholder and RFI Input



Analysis of Potential Supply Resources and Underground Storage



Source: NREL, Lab analysis, National Strategy



Source: SHASTA, NETL, funded by FECM

H2 Matchmaker Final Results

H_2 Matchmaker launched to facilitate partnering for Hydrogen Hubs

>50X more supply than demand*

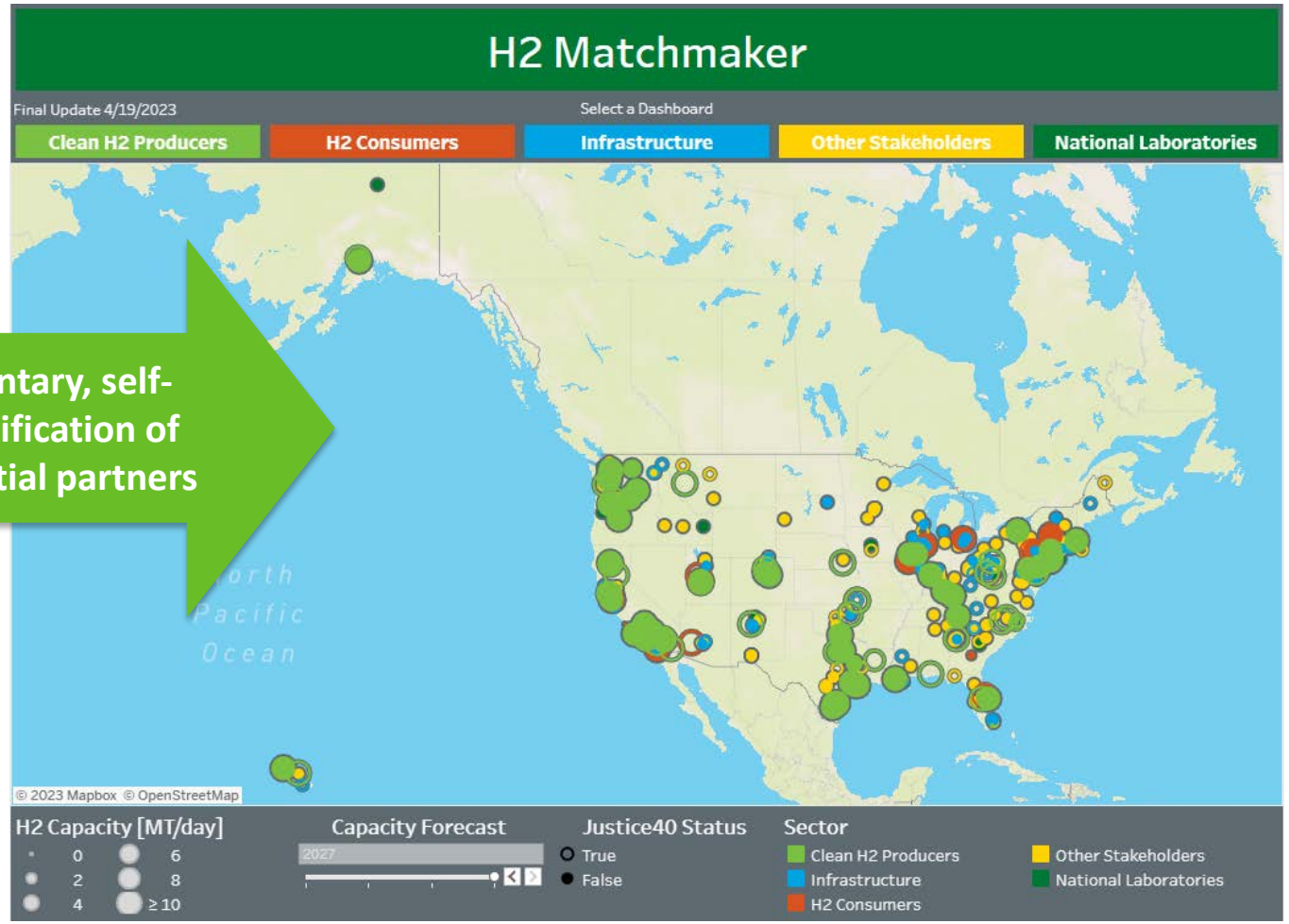
Production: ~268,800 MT/day

Demand: ~5,870 MT/day

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

*self-identified values

Voluntary, self-identification of potential partners



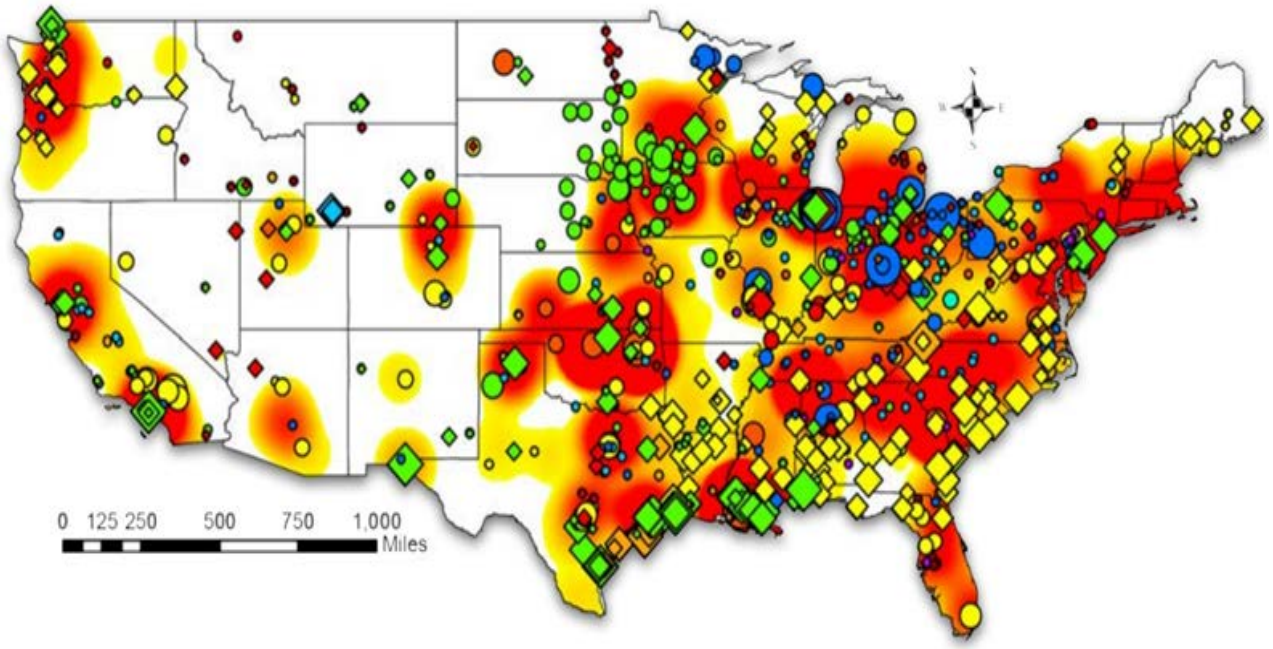
Stakeholder responses from: 105 producers, 43 consumers, 136 infrastructure providers/operators, 21 national lab campuses, 295 other

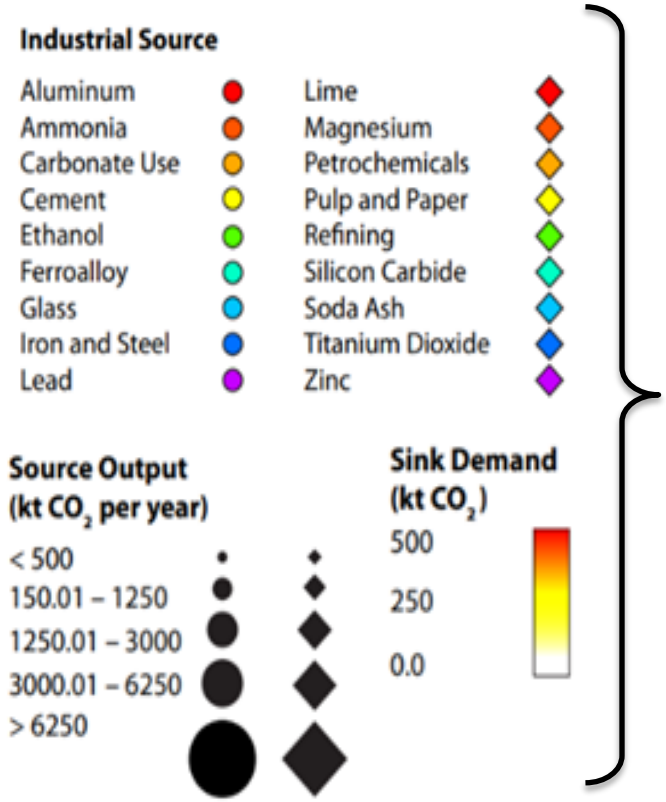
Final update: 4/19/2023. Application process for the Regional Clean Hydrogen Hubs is closed, and H2 Matchmaker is no longer collecting submissions through the self-identification form.

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_2 Output**, and **CO_2 Sink Demand**





Mapping industrial sites to CO_2 sources and demands can help identify **industrial clusters for potential decarbonization hubs**

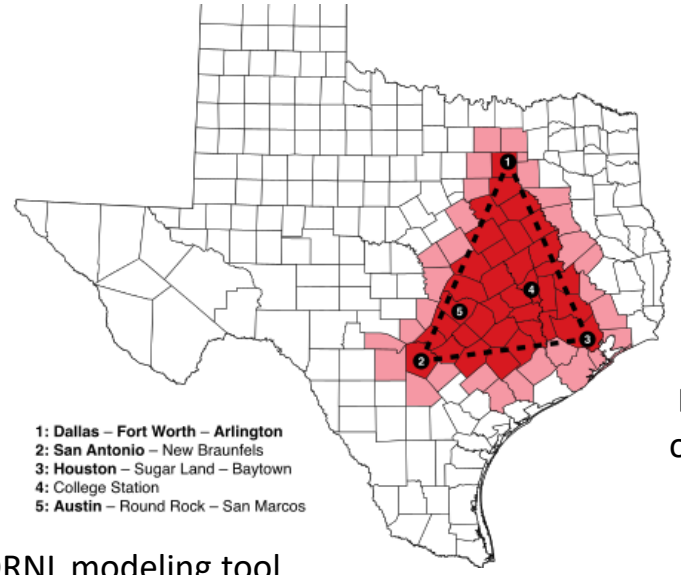
Adapted from Carbon Capture and Utilization in the Industrial Sector | Environmental Science & Technology (acs.org)

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_2 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.



Texas Triangle Megaregion

Encompasses 5 of the largest 20 US cities

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

Joint Office of Energy and Transportation

Funding Opportunities

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

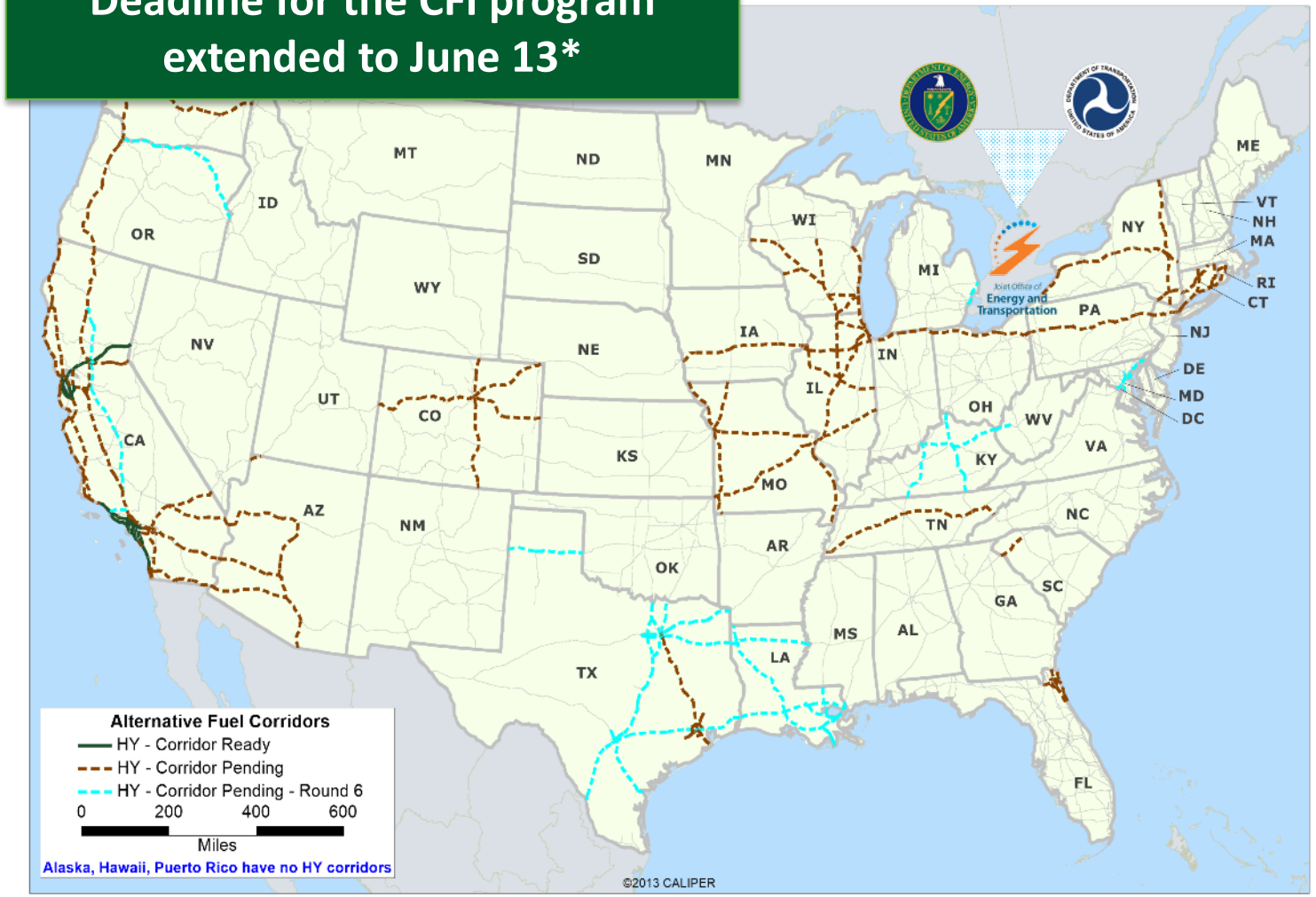
Charging & Fueling Infrastructure (CFI) Discretionary Grant Program (DOT): $2.5B in community and corridor grants for EV charging, **as well as hydrogen**, natural gas, and propane fueling infrastructure – **applications now open!**

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

www.driveelectric.gov/contact

Fueling corridors of interest for H_2

Deadline for the CFI program extended to June 13*

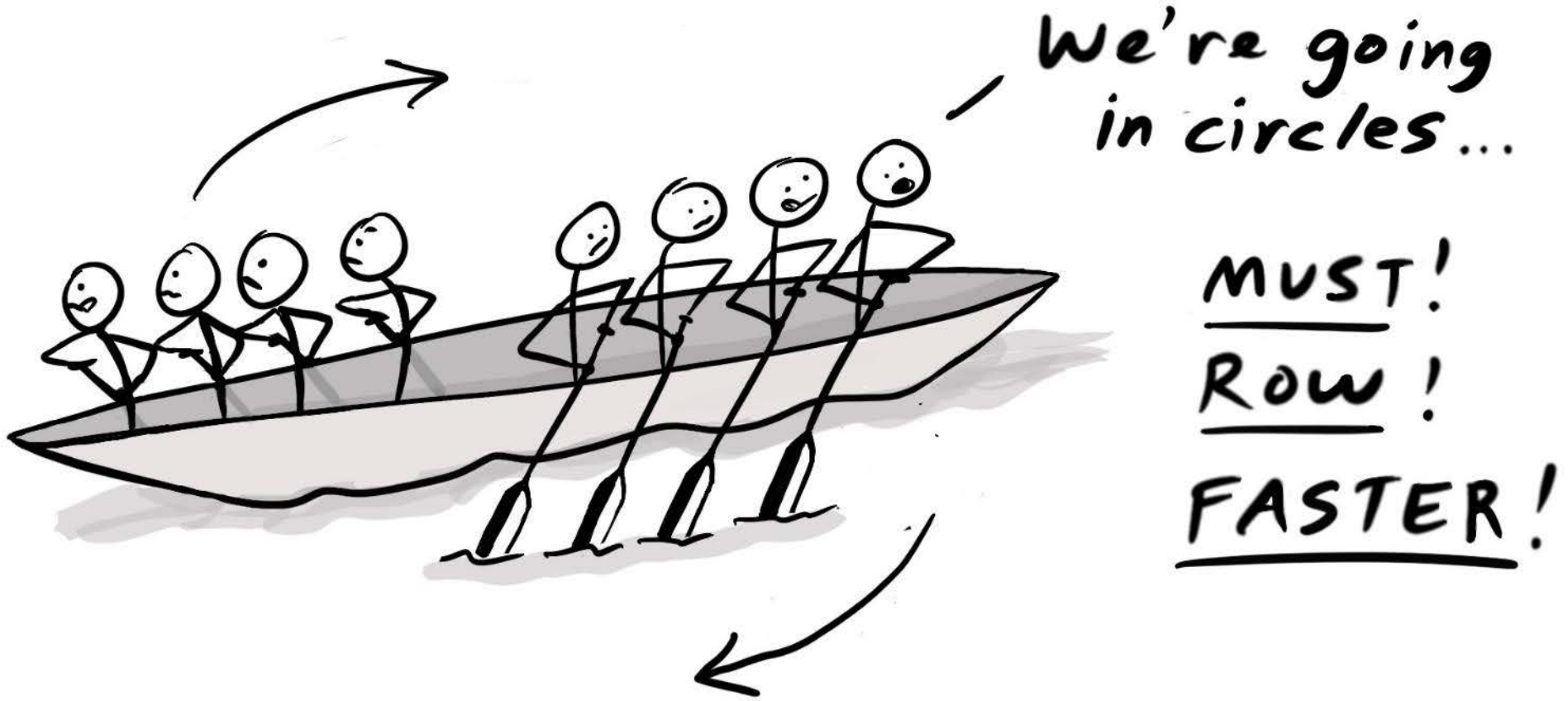


*https://www.fhwa.dot.gov/environment/cfi/

Whole-of-Government Coordination

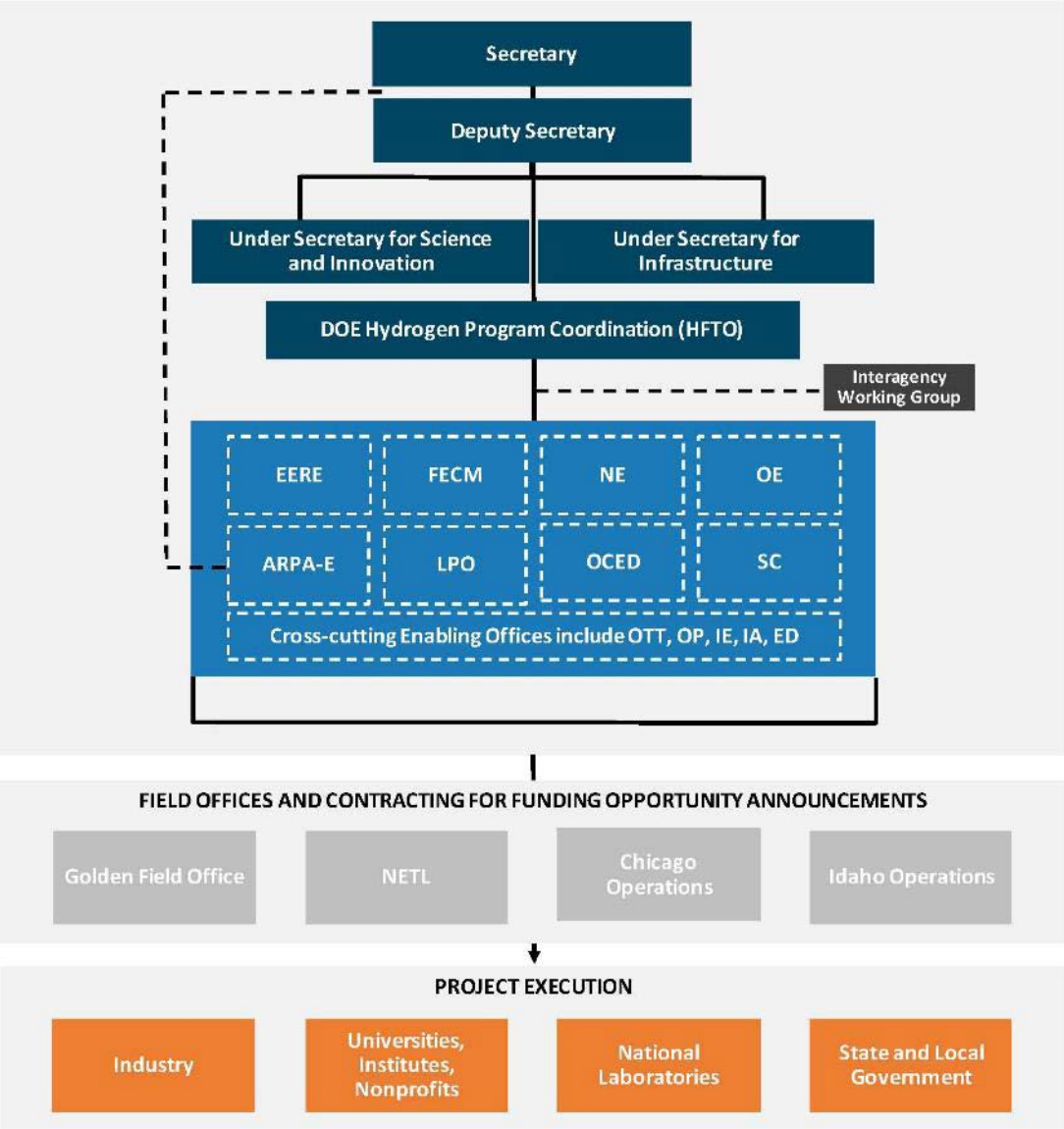
And with the private sector, communities, and more

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

EERE Hydrogen

Feedstocks:
- Renewables and Water

Technologies:
- Electrolysis—Low- and High-Temperature
- Advanced Water Splitting—Solar/High-Temp Thermochemical, Photoelectrochemical
- Biological Approaches

FECM Hydrogen

Feedstocks:
- Fossil Fuels—Coal* and Natural Gas

Technologies:
- Gasification, Reforming, Pyrolysis
- Advanced Approaches—Co-firing and Modular Systems
- Natural Gas to Solid Carbon plus Hydrogen

*Waste coal, other waste

Areas of Collaboration

Reversible Fuel Cells, Biomass, Municipal Solid Waste, Plastics

Polygeneration including Co-Gasification with Biomass

High-Temperature Electrolysis, System Integration

NE Hydrogen

Feedstocks:
- Nuclear Fuels and Water

Technologies:
- Risk Assessment & Licensing, Thermal Delivery
- Advanced Nuclear Reactors
- System Integration and Controls - LWRs and Advanced Reactors

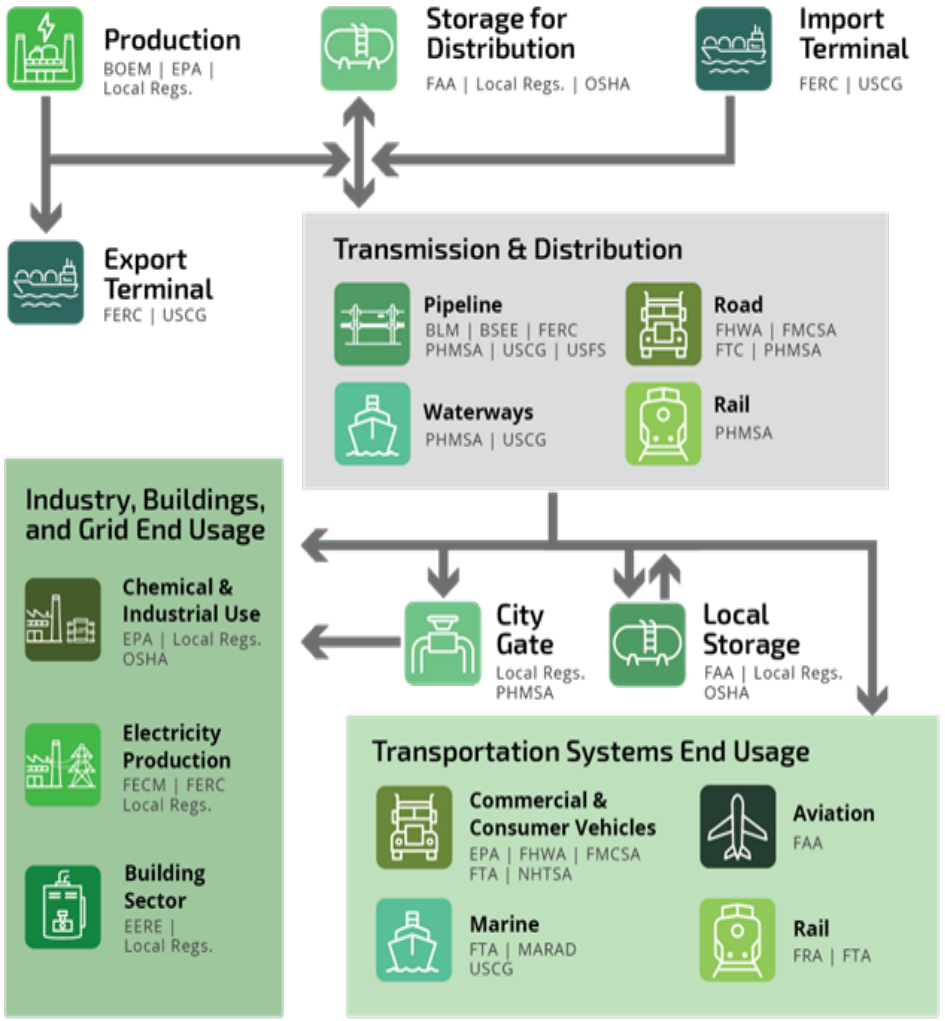
Crosscutting R&D Offices: Office of Science (SC) and ARPA-E

Fundamental Science and Advanced Innovative Concepts

Foundational research and innovation; user facilities and tools, materials and chemical processes (e.g., catalysis, separations), artificial intelligence/machine learning, databases and validation, high risk-high impact R&D, and other crosscutting activities.

OCED Regional Clean Hydrogen Hubs, OTT, LPO, OP, ED, IE, IA, and more

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

- Enabling large scale production and demand creation
- Financing, incentives, and compliance tools for commercial scale up
- Metrics for deployment and USG as offtaker
- Supply chains and resiliency (critical materials, strategic reserve)
- R&D to accelerate cost reductions and end use commercialization (JST interface)

Infrastructure, Siting, Permitting

- Siting, permitting, pipelines, storage, and infrastructure
- Harmonized codes and standards
- Interoperability and global standardization
- Safety, emissions (including secondary), sensors, risk mitigation, environmental impact
- Environmental review and best practices (NEPA, etc.)
- Pipeline and blending test facilities

Analysis and Global Competitiveness

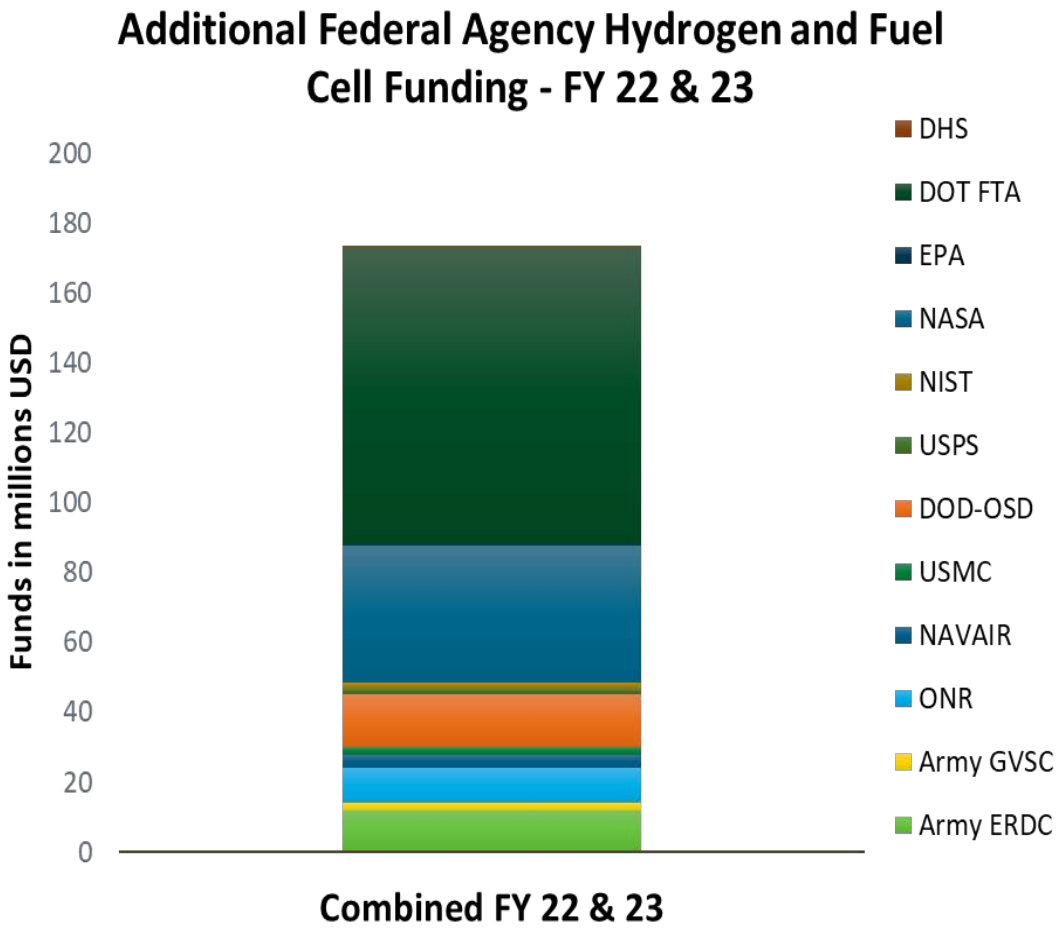
- National strategy and commercial liftoff analysis
- Impacts and gap assessments (technoeconomic analysis, incentives, resource/water availability, emissions, jobs, manufacturing, etc.)
- Intellectual property and global landscape assessment
- Export market analysis
- Systems integration and optimization

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

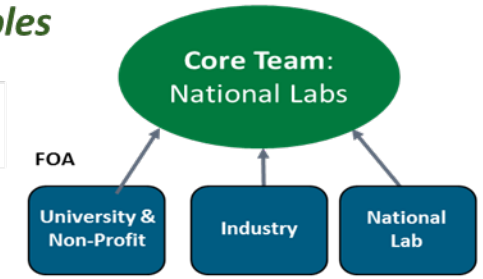
Research and Development

Basic and applied research through individual projects and consortia

Consortia Examples

HydroGEN Advanced Water Splitting Materials

H2NEW U.S. DEPARTMENT OF ENERGY



H-Mat Hydrogen Materials Compatibility Consortium

ElectroCat Electrocatalysis Consortium

HyMARC Hydrogen Materials Advanced Research Consortium

MILLION MILE FUEL CELL TRUCK

U.S. DEPARTMENT OF ENERGY

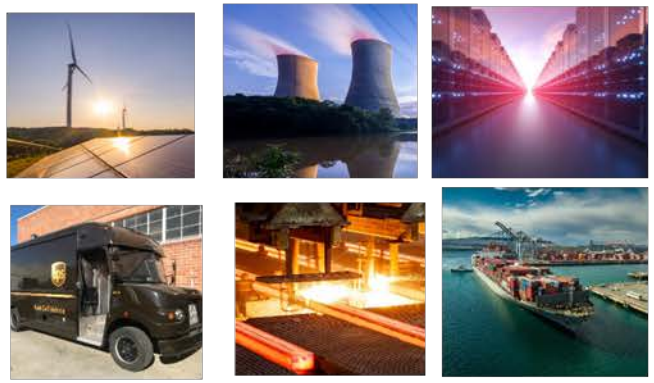
SHASTA Subsurface Hydrogen Assessment, Storage, and Technology Acceleration

Basic science user facilities, theory, modeling

Technology Integration, Validation, Demos

1st of a kind demonstrations and systems integration to de-risk deployments

Examples:



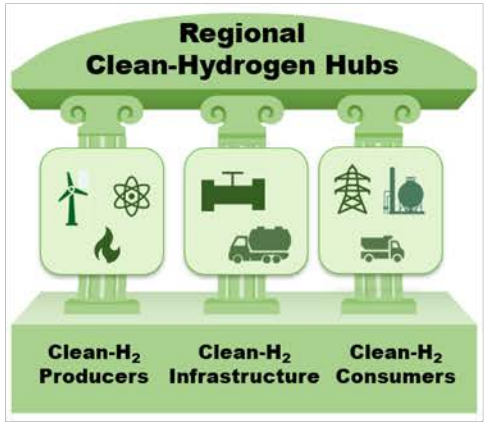
Renewables and nuclear to H_2, 15 delivery trucks in disadvantaged area, 3 Super Truck projects, data center, fueling for passenger ferry, energy storage, H_2 for steel

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_2 energy storage and power generation

Enabling Activities

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

H2EDGE Hydrogen Education for a Decarbonized Global Economy

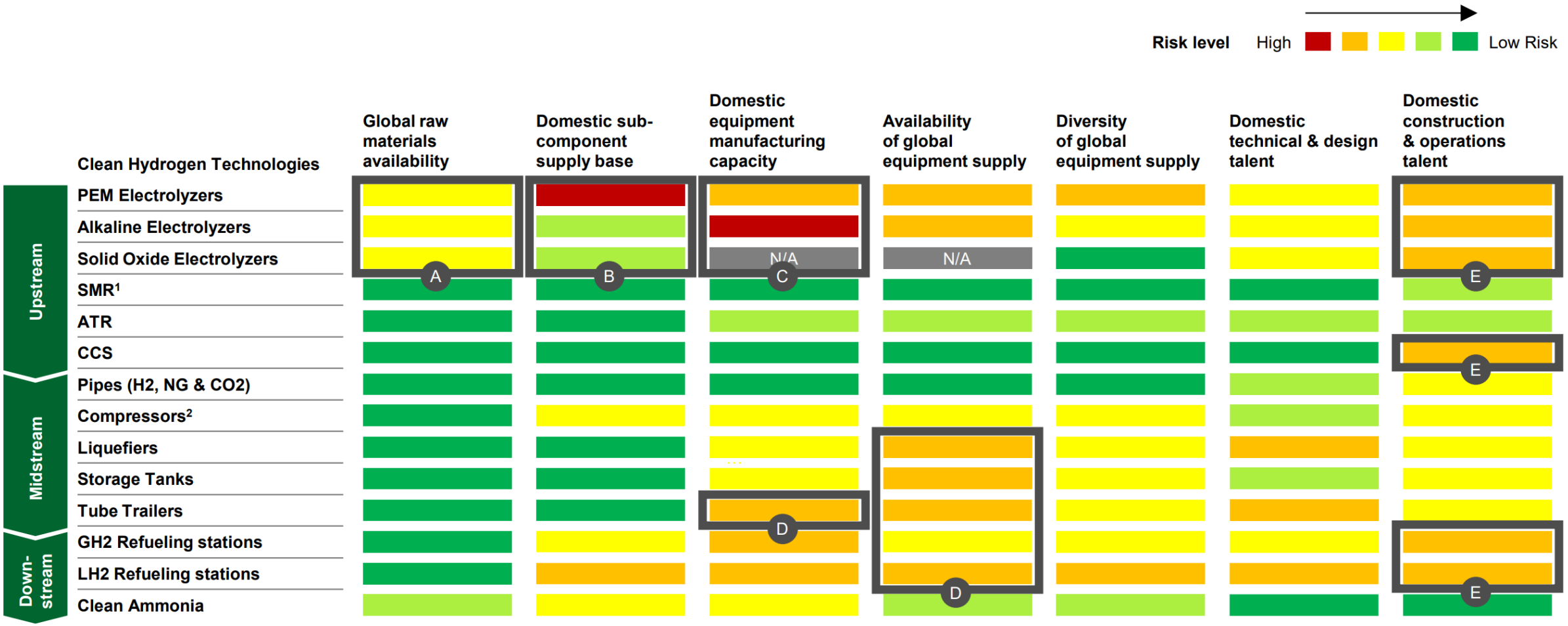
CENTER FOR Hydrogen SAFETY Connecting a Global Community

HyBlend U.S. DEPARTMENT OF ENERGY

H_2 Matchmaker

Assessments to Guide Priorities—Vulnerabilities across Value Chain

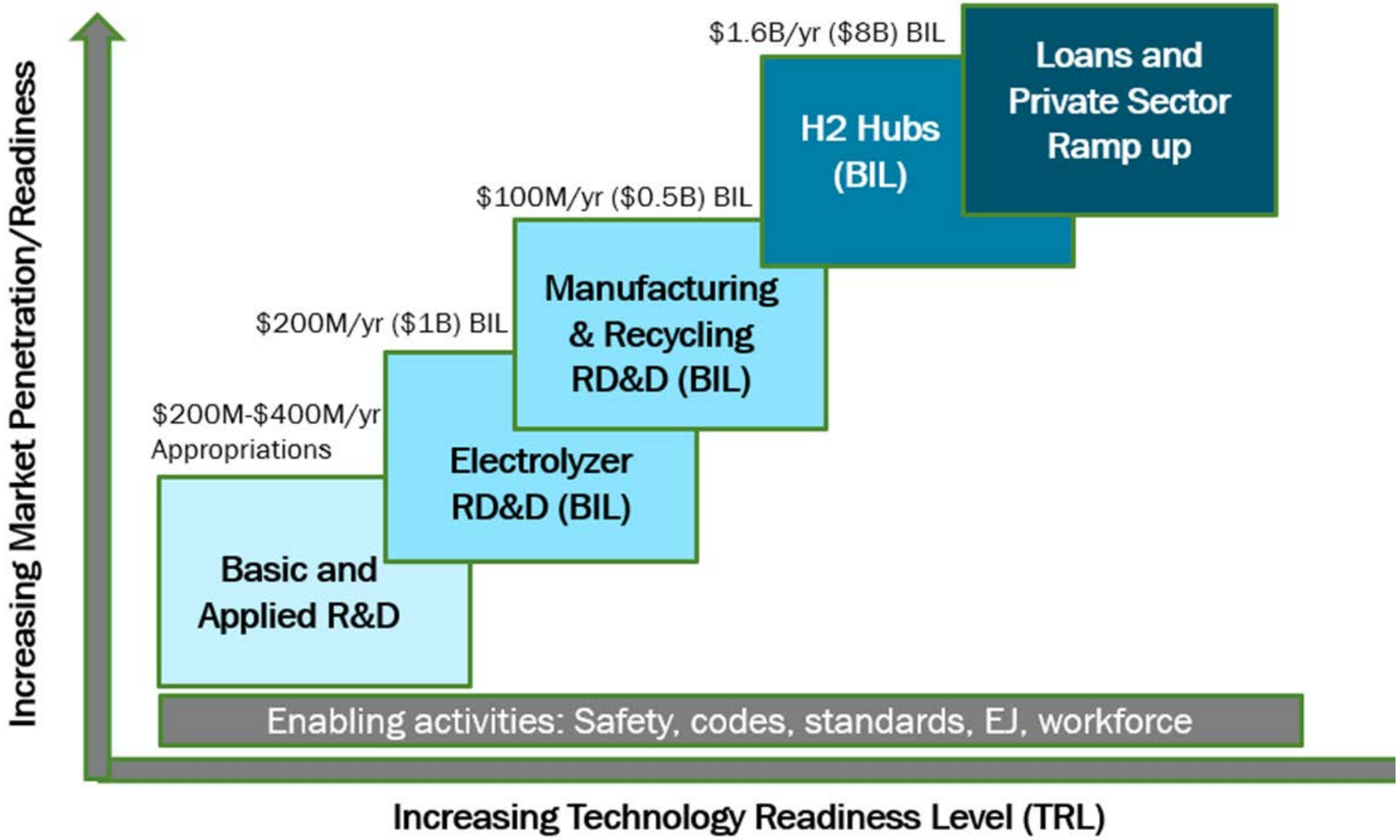
Potential supply chain vulnerabilities, 2025



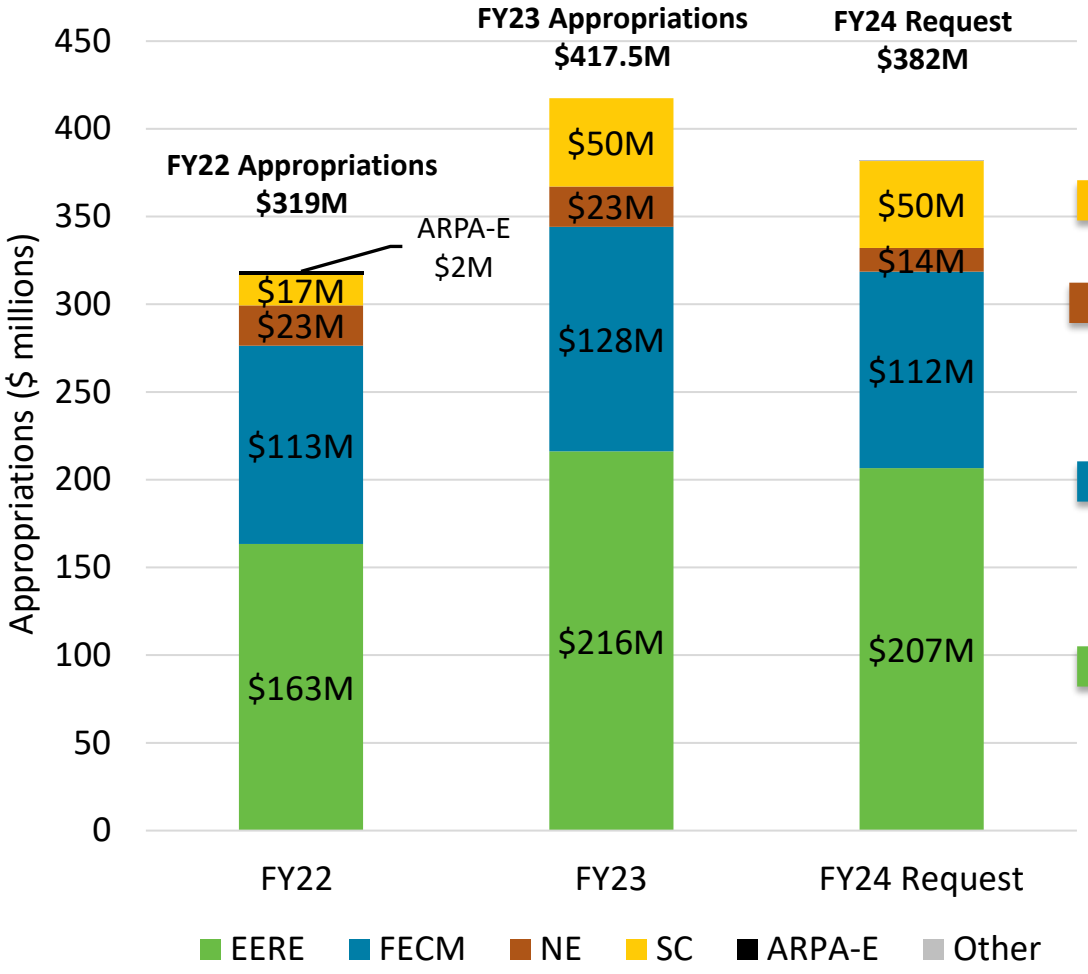
1: Includes large scale compressors at industrial and productions sites and compressors at refueling facilities | 2: No significant additional build out of Steam Methane Reformers anticipated
Source: Department of Energy Fuel Cells & Electrolyzers Supply Chain Report, ENS Interviews, NREL experts

DOE Pathways to Commercial Liftoff Report

Hydrogen Program RDD&D Portfolio across TRLs



DOE Hydrogen Program Fiscal Year (FY) Funding across Offices



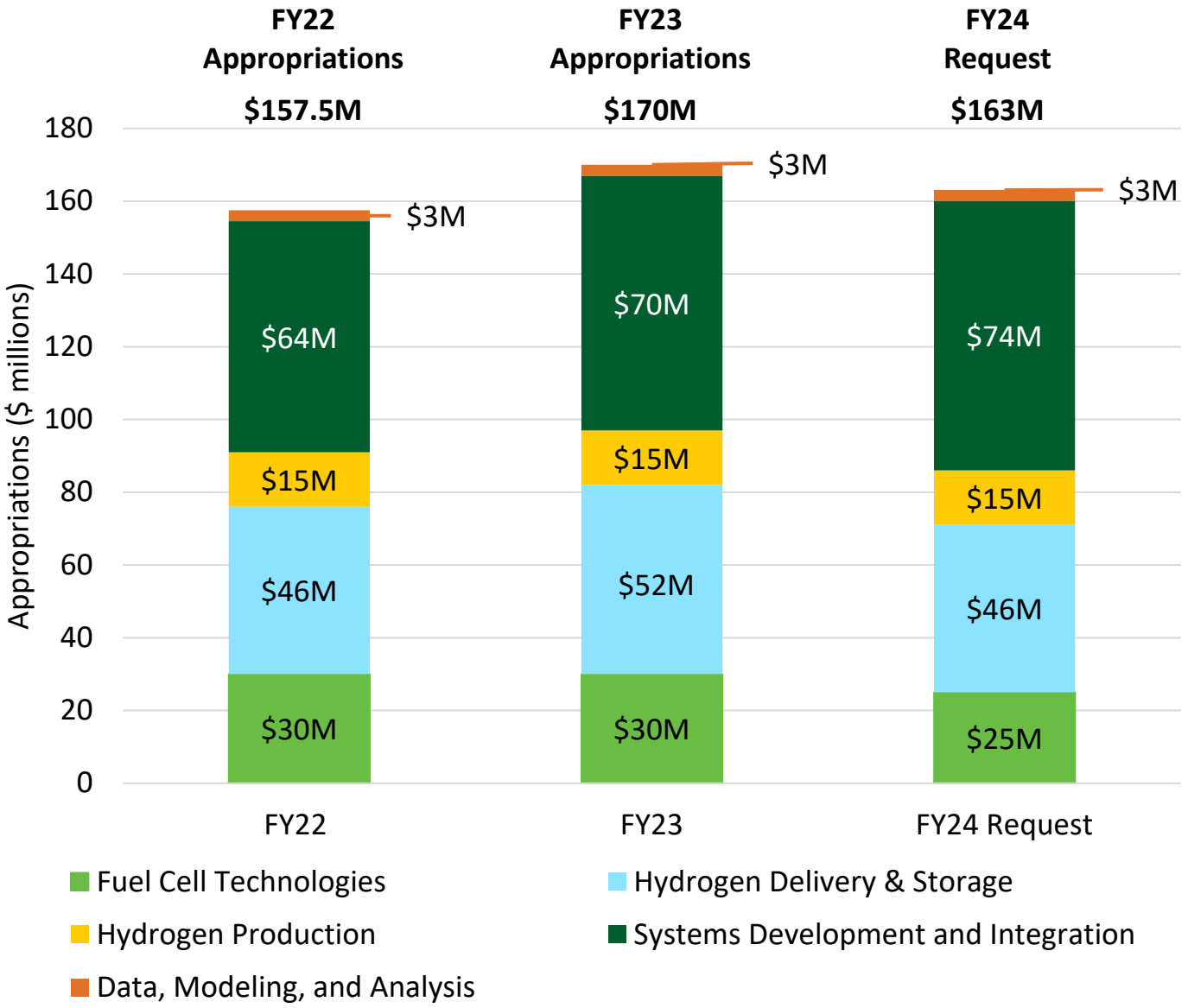
Focus Areas

- **Foundational knowledge & SOA capabilities supporting clean H_2, including EERCs**
- **Nuclear-powered production of H_2 and syn-fuels, including 1st-of-a-kind demos with thermal integration**
- **Co-gasification of wastes with CCS; combustion of H_2 and blends; SOFC for data-center backup power**
- **Production, storage, delivery, conversion, & end use of clean H_2 across sectors; focus on infrastructure for integration with renewables**

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



Focus Areas

- Guide and strengthen portfolio through rigorous analysis
- Validate first-of-a-kind systems across applications, de-risk technologies; includes safety, codes, standards, workforce development
- Supplement production RD&D with BIL funding (including $1B)
- Increase bulk storage, liquid, and delivery focus (e.g., carriers)
- Continue heavy-duty fuel cell RD&D, including supply chain

Note: Appropriations reflect Congressional direction

Key Activities Across DOE Addressing Program Priorities

Program Priorities	Key Initiatives to Address Priorities
1 Low-Cost Clean Hydrogen Production	H2NEW, HydroGEN, ElectroCAT, H2 Shot Incubator Prize, EERCs, EFRCs *(e.g., CEDARS)*, ARPA-E NH_3 Pyrolysis , CCUS
2 Safe, Low-Cost Delivery and Storage Infrastructure	H-Mat, HyBlend, HyMARC, SHASTA, C-Fiber, Liquid H_2, H_2 Carriers, HD Dispensing, Sensors
3 Low Cost, Durable, and Efficient Fuel Cells & Low-NO_x Turbines	M2FCT, ElectroCAT, Low-NOx Turbine RD&D, ARPA-E INTEGRATE, EFRCs *(e.g., CABES)*
4 Enable End Use Applications at Scale	H2@Scale Demos, Clean Hydrogen Hubs, NE Integrated Energy Systems, ARPA-E *(e.g., REEACH)*

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

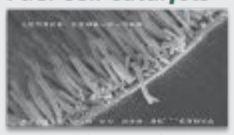
By private industry

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

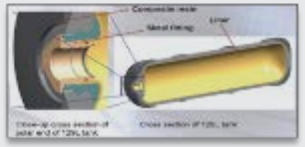
Class-1, -2, and -3 Forklifts
Plug Power (GenDrive FCs)

Electrolyzers

Electrolyzer System
Proton Series

PEM Electrolyzer System
Giner

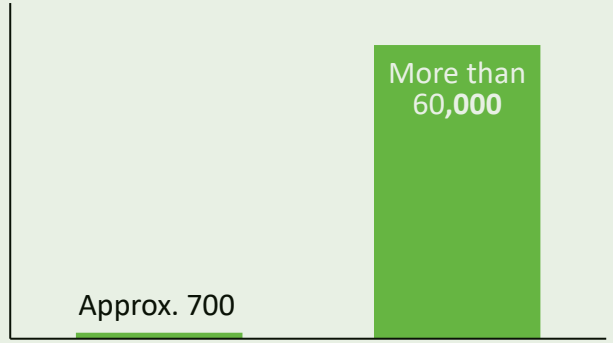
Hydrogen Tanks



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

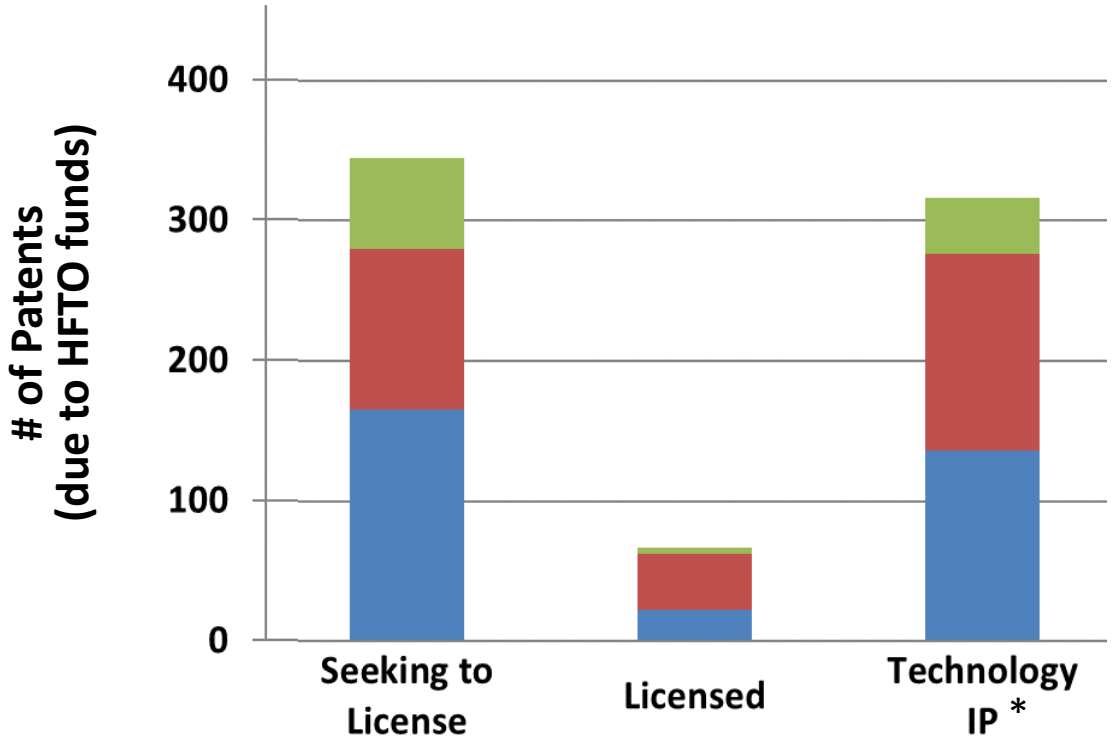
211 organizations received patents as a result of HFTO funding

~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

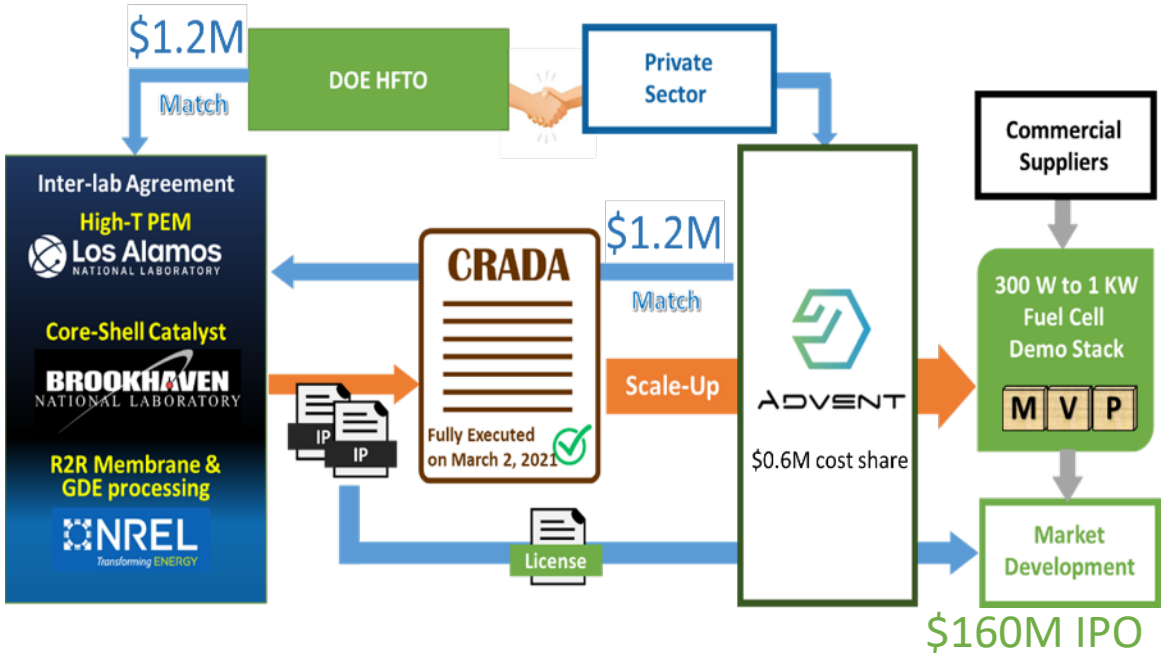


	Seeking to License	Licensed	Technology IP *
Storage	65	5	40
Production/Delivery	115	40	140
Fuel Cell	165	22	136
Total	345	67	316

* 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

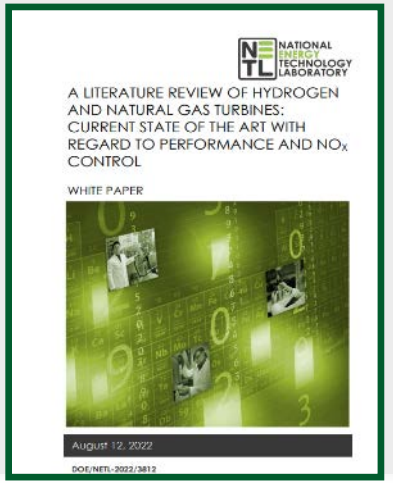
Examples of Recent Highlights – Just a Few!

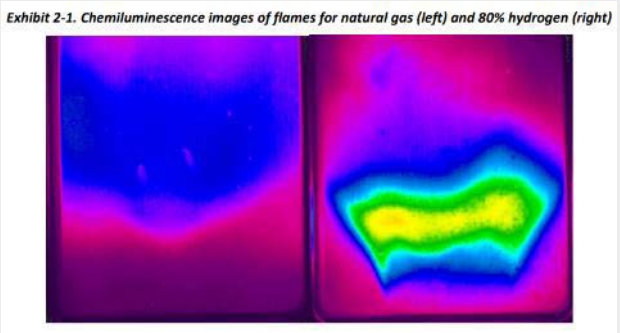
Nation's first integrated (behind the meter) 1.25MW PEM electrolyzer at a nuclear plant (Constellation)

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





NETL Review of H_2 and NG turbines

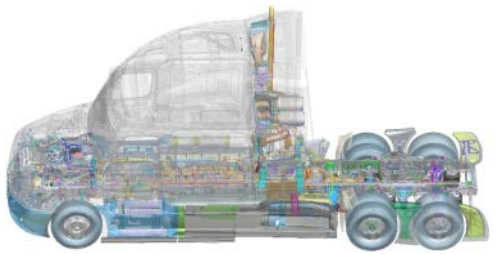
https://netl.doe.gov/sites/default/files/publication/A-Literature-Review-of-Hydrogen-and-Natural-Gas-Turbines-081222.pdf

Hydrogen Fuel Cell Heavy Duty Truck Projects

SuperTruck 3 Demonstrations include H_2 Fuel Cells (>75% GHG Reduction)

DAIMLER

Walmart, SCHNEIDER, Linde, MAHLE, MICHELIN, Argonne, NREL, Oak Ridge National Laboratory, Auburn University, Oregon State University



Goals:
- Demonstrate 2 total (Class 8) HD long-haul fuel cell electric trucks (B-sample & final truck demo)
- 6.0 mi/kg H2 fuel economy
- 600-mile range (onboard LH_2 storage)
- 65,000 pounds GVW

Fleet Operators: Schneider National, Walmart

general motors

Southern Company, nel, Argonne

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_2 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

FERGUSON, Consumers Energy, SoCalGas, FEV, NREL

Goals
- Demonstrate 5 total (Class 4-6) MD vocational trucks
- 300+kW net vehicle power, H_2 PEM FC + Li-Ion battery
- 300-mile range (700 bar H_2 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.

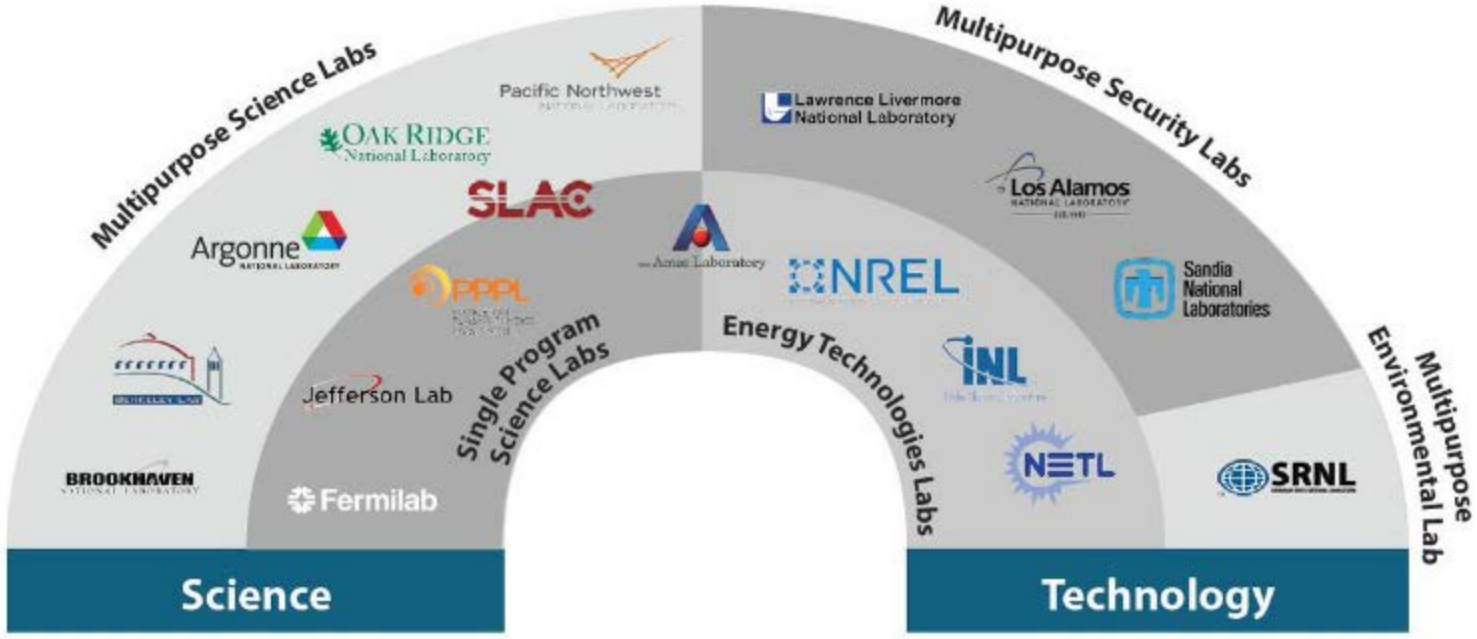
Government Team

Key Stats

- Kenworth Class 7 Truck
- 176 kg H_2 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

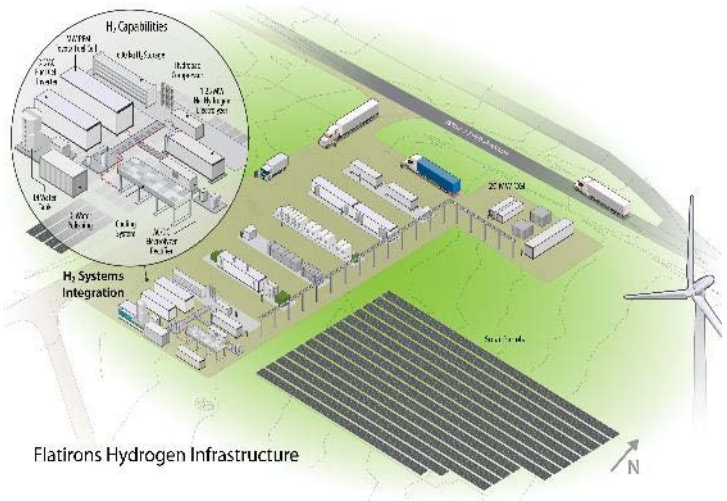


DOE National Laboratories across energy, science, and security:

- 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

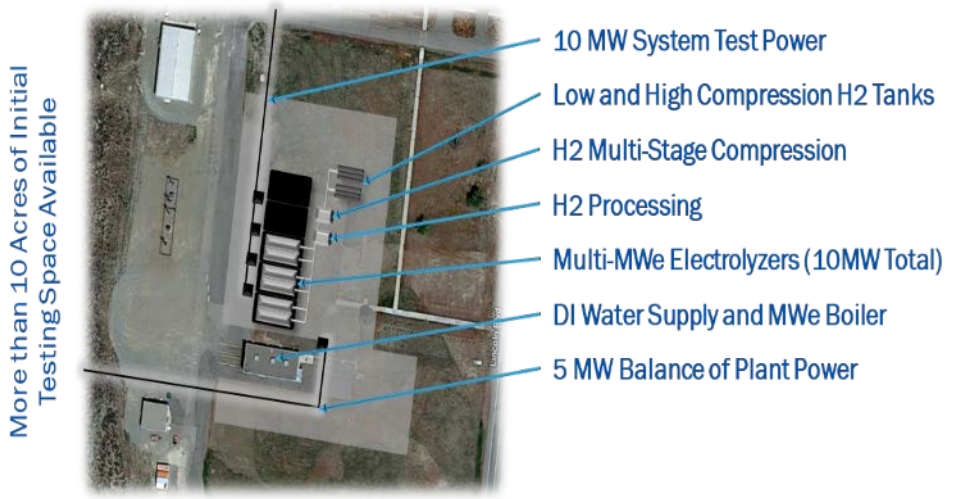
Low-Temperature Electrolyzers – NREL (P207)



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)

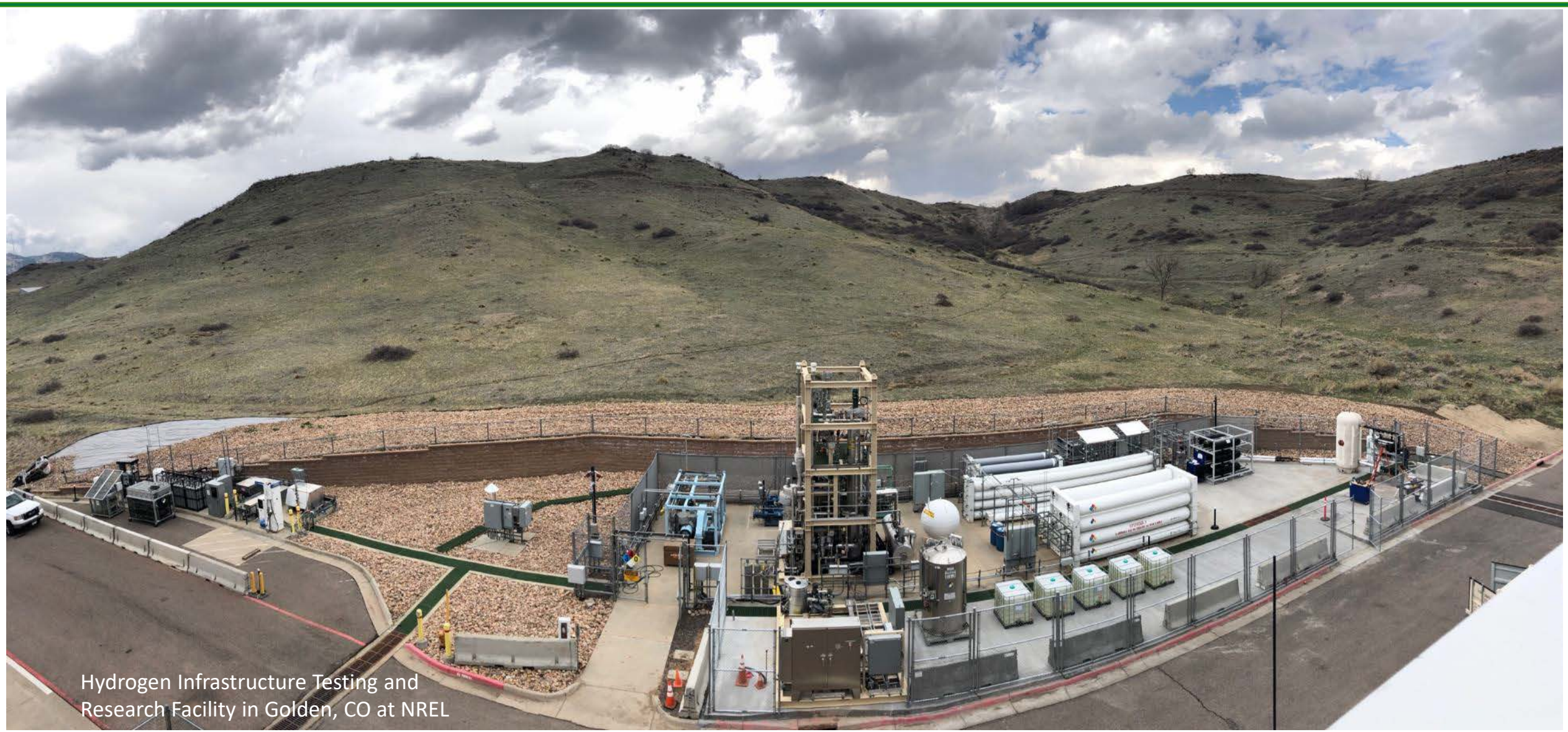
Enclosed/outdoor sensor deployment capability

Process Gas Characterization Apparatus (PGCA)

NEC-compliant apparatus for up to 100 vol% H_2 (or H2-NG Blends)

For more information, contact NREL Hydrogen Safety R&D: 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

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

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
For ongoing support in safety topics, please explore Center for Hydrogen Safety

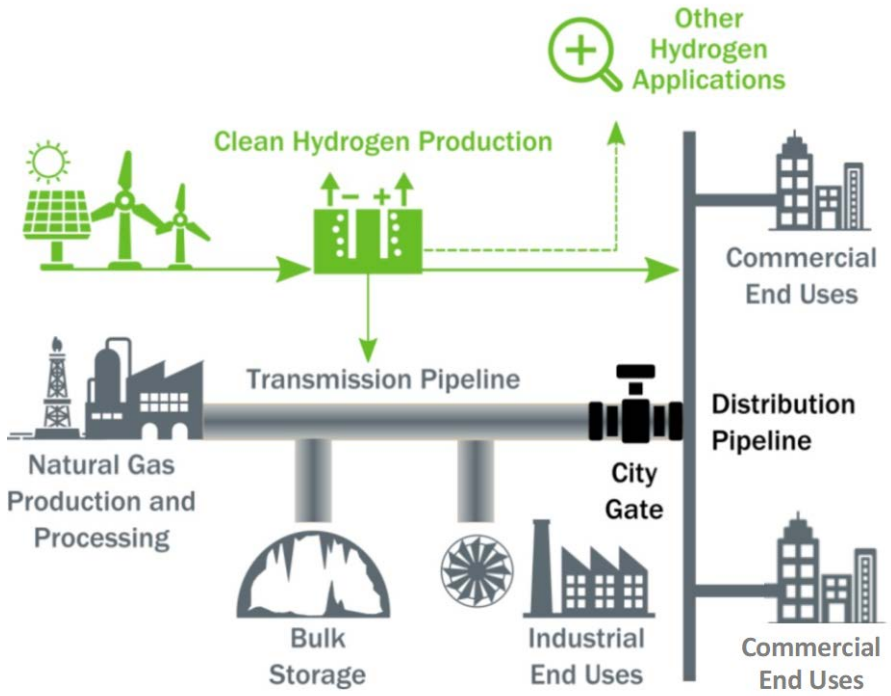
Stay tuned: Listening session webinar planned later this summer with FCHEA on permitting and siting to identify challenges and next steps

Hydrogen Blending in Natural Gas Pipelines

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_2 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_2 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 H2 **(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

Argonne NATIONAL LABORATORY GREET LIFE-CYCLE MODEL

GREET "Train the Trainer" Fellowships

www.zintellect.com

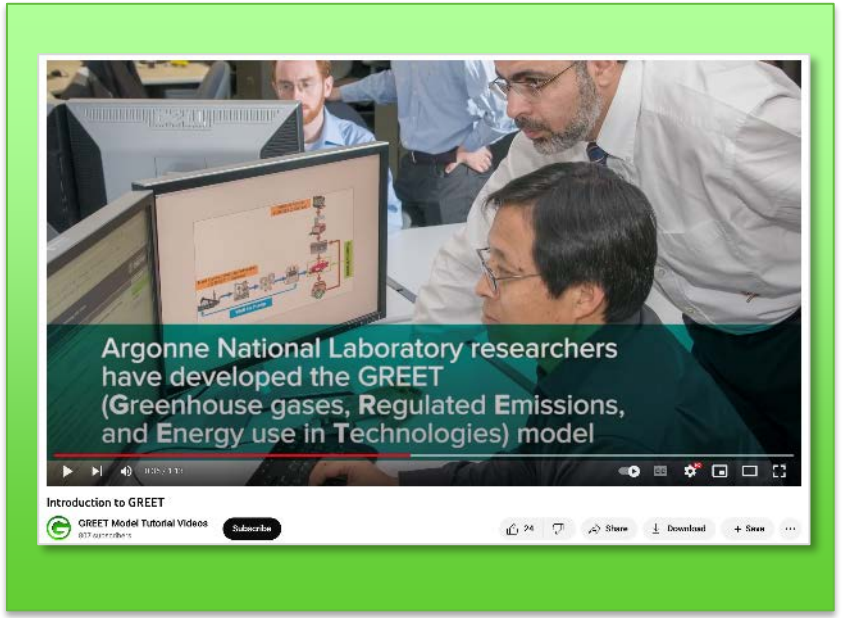
Apply Now! Key word: GREET Trainer

Become a GEM Fellow

www.gemfellowship.org

Focus on minority students

Learn how to use GREET Model



GREET Model Tutorial Videos

@greetmodeltutorialvideos5576 812 subscribers 27 videos

More about this channel >

YouTube

www.youtube.com/@greetmodeltutorialvideos5576

Partners include U. MN, GPI

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

Energy and Environmental Justice

Diversity, Equity, Inclusion, and Accessibility

Justice 40 & Disadvantaged Communities

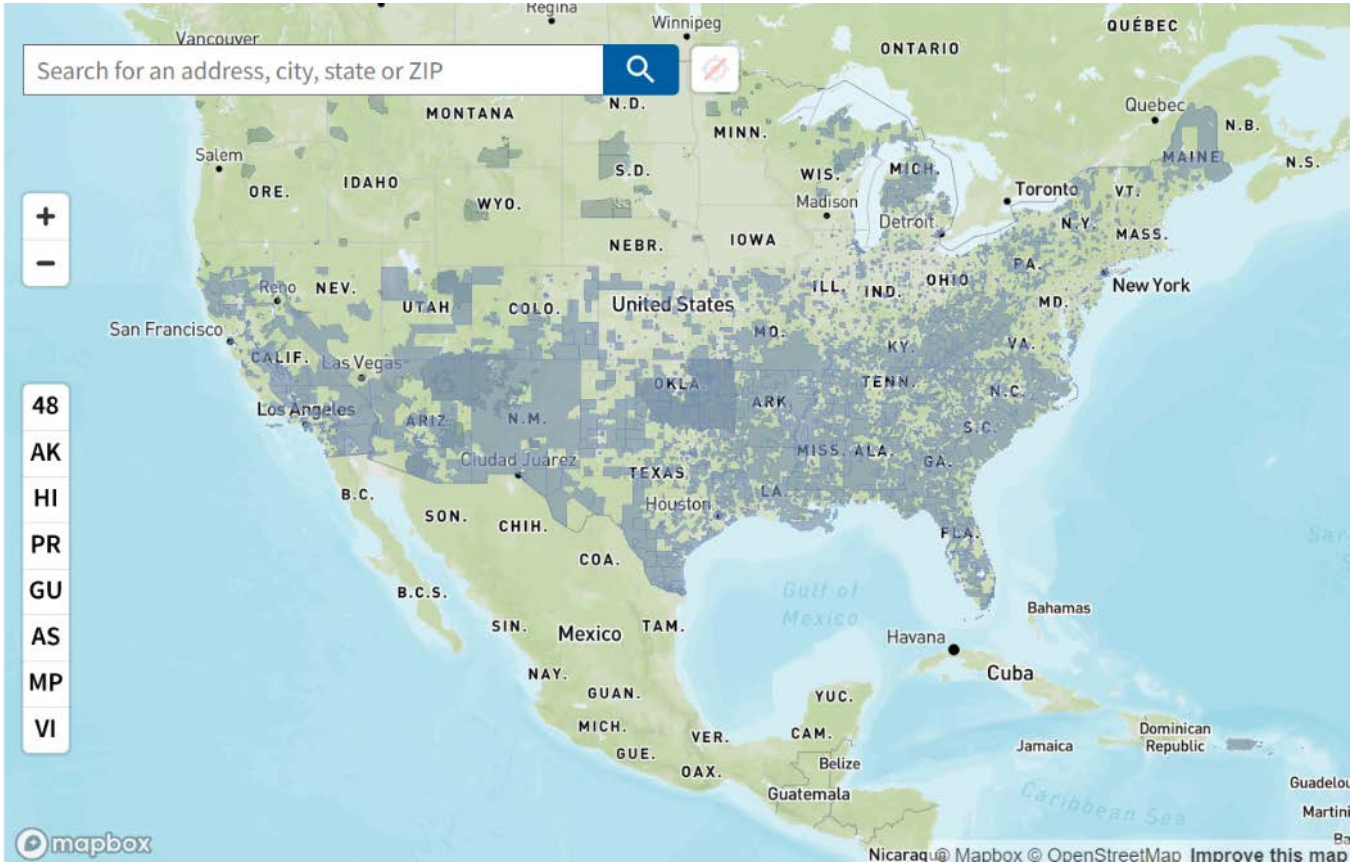
Communities are considered disadvantaged:

- 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

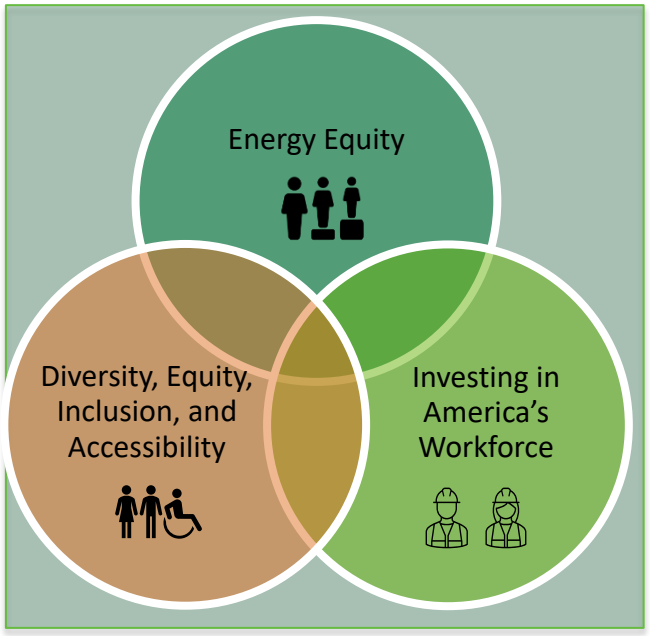
Distribution of census tracts identified as DACs

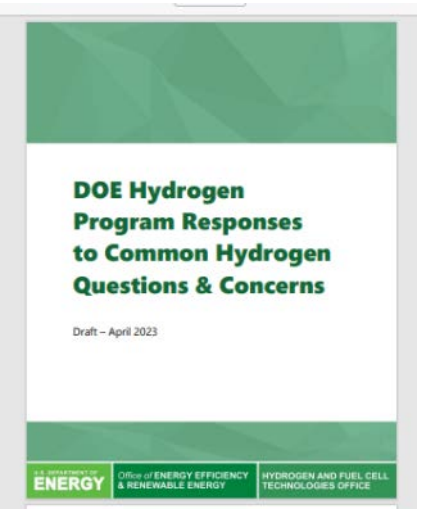


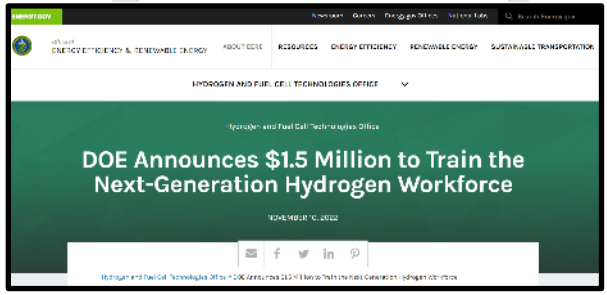
Census tracts that are overburdened and underserved are highlighted as being **disadvantaged** on the map. Federally Recognized Tribes, including Alaska Native Villages, are also considered disadvantaged communities.

Explore the map - Climate & Economic Justice Screening Tool (geoplatform.gov)

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

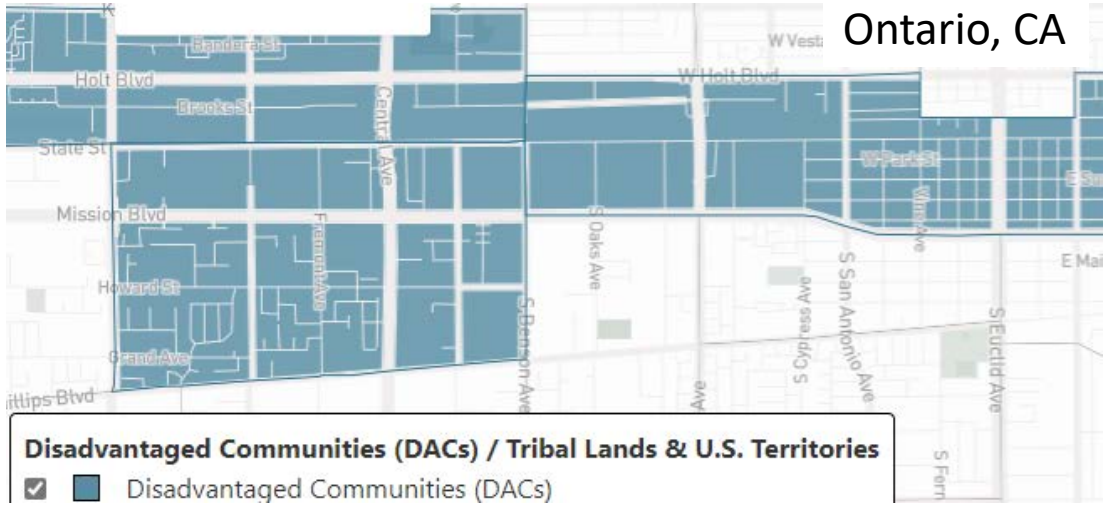
Planning Tribal Regional Roundtables for Autumn 2023

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

See: www.energy.gov/indianenergy/office-indian-energy-policy-and-programs

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!

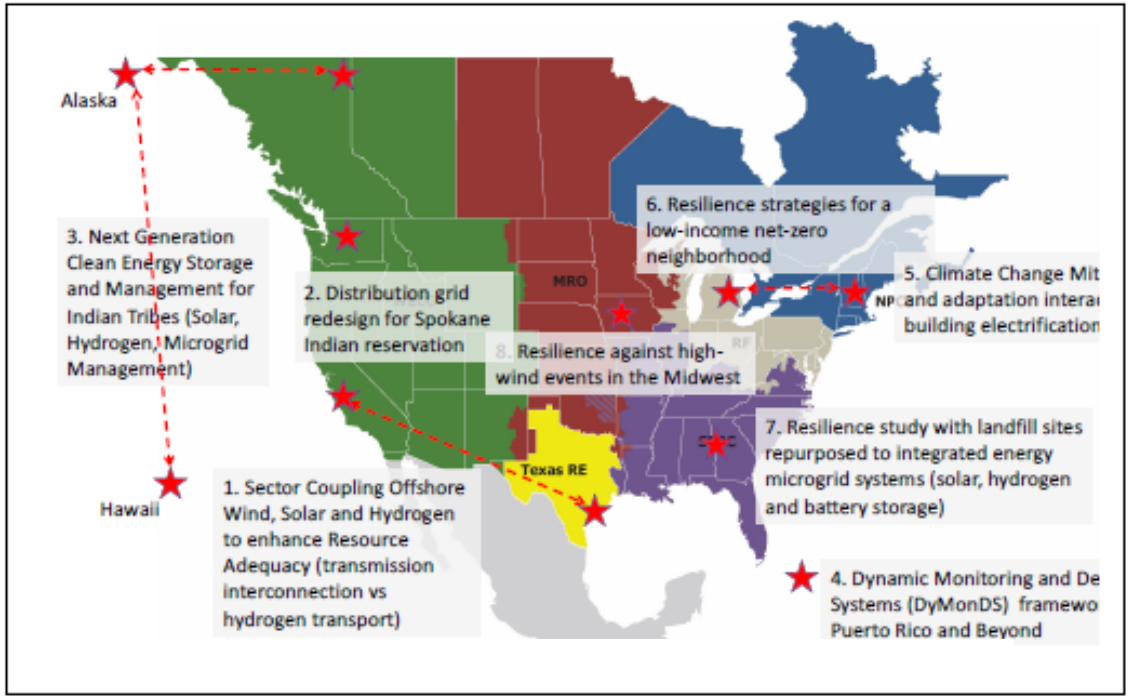
New Selection: The University Research Consortium for Grid Resilience

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



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[1]

Recent Activities to Measure H_2 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_2 cycle modeling, better understand rates of H_2 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

[1]Workshop technical report: https://publications.jrc.ec.europa.eu/repository/handle/JRC130362

Call to Action: Join the Center for Hydrogen Safety!

IPHE

AIChE
The Global Home of Chemical Engineers

Hydrogen Council

Pacific Northwest NATIONAL LABORATORY

hySafe
INTERNATIONAL ASSOCIATION FOR HYDROGEN SAFETY

CENTER FOR Hydrogen SAFETY
Connecting a Global Community

www.aiche.org/CHS

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!

- **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

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

The International Partnership for Hydrogen and Fuel Cells in the Economy

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

H_2 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

Breakthrough Agenda in collaboration with other partnerships is mapping activities across global H_2 initiatives to identify gaps, focus areas, and prioritized workstreams

Mapping of International Hydrogen Initiatives and Collaborations Underway

Hydrogen Breakthrough – Overview of the Priority Actions for 2023

BREAKTHROUGH AGENDA
a joint project of CEM & MI

Priority International Action	Coordinating initiative(s) To date
H.1: Standards & Certification Accelerate the development of standards for clean hydrogen	IPHE, IEA's Hydrogen TCP, IRENA's Collaborative Framework on Green Hydrogen
H.2: Demand Creation & Management Coordinate internationally to drive demand for clean hydrogen	First Movers Coalition, Clean Energy Ministerial Hydrogen Initiative, Mission Innovation Clean Hydrogen Mission
H.3: Research & Innovation Expand the number and scope of innovative clean hydrogen projects	Mission Innovation Clean Hydrogen Mission
H.4: Finance & Investment Scale and facilitate access to financial & technical assistance, particularly for developing countries	World Bank & UNIDO
H.5: Landscape Coordination 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

HYDROGEN AMERICAS 2023

SUMMIT & EXHIBITION

2 – 3 OCTOBER 2023

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

CONNECTING THE WORLD'S SENIOR HYDROGEN LEADERS WITH THE AMERICAS

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

Year in Review Highlights

~$8Billion in Funding Announced in 2023!

June 2022

- Clean H_2 Production, Storage, Transport, & Utilization

Aug 2022

- FOA for Clean H_2 Technologies & Decarbonize Grid
- IRA Passed
- Draft National Clean H_2 Strategy & Roadmap Released

Oct 2022

- H2Hubs FOA
- FOA for Nuclear-Coupled H_2 Production & Use
- Phase-One Winners of Incubator Prize
- $1.5M to Train the H_2 Workforce at MSIs

Dec 2022

- H2TwinCities Winners Announced
- Lab Call for Technology Commercialization Fund
- $47M for Affordable Clean H_2 Technologies

Feb 2023

- $7.4M for Zero-Emission M&HD Vehicles, Expansion of EV Charging in Underserved Communities
- $750M FOA Electrolysis, Manufacturing, & Recycling
- Pathways to Commercial Liftoff: Clean H_2

April 2023

- Nine Mile Point Begins H_2 Production
- $4.5M for Turbine Efficiency Research
- President Biden Visits Cummins Power Generation Facility

June 2023

- $60M to Advance Clean H_2 Tech & Improve Power Grid
- National Clean H_2 Strategy & Roadmap Released

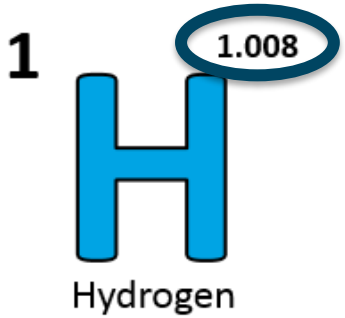
Resources and Opportunities for Engagement

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 H2IQ
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

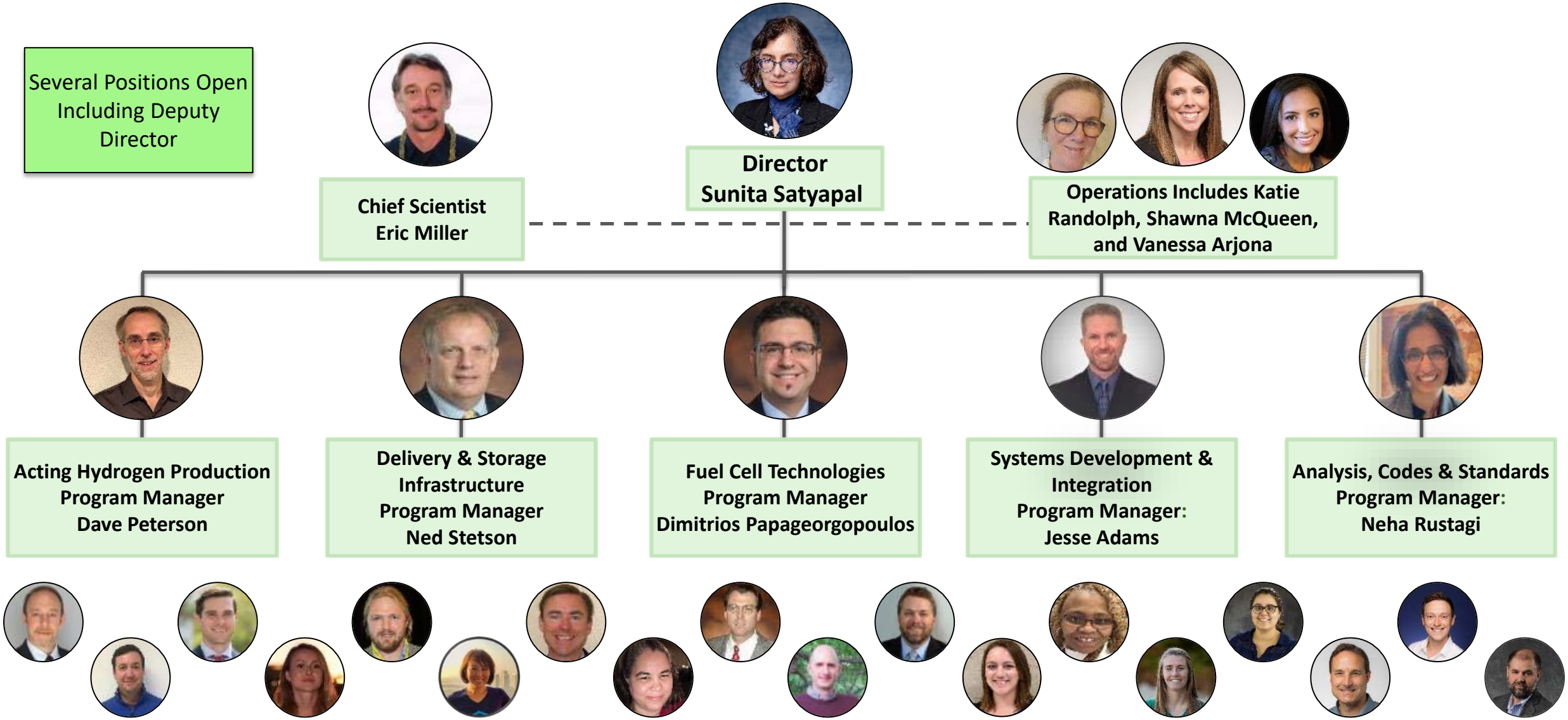
www.aiche.org/CHS

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

Acknowledgements: Hydrogen and Fuel Cell Technologies Office



DOE Clean Energy Corps Applicant Portal: **www.energy.gov/applicant-portal**

Champions #1 for Element #1

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
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

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

** 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

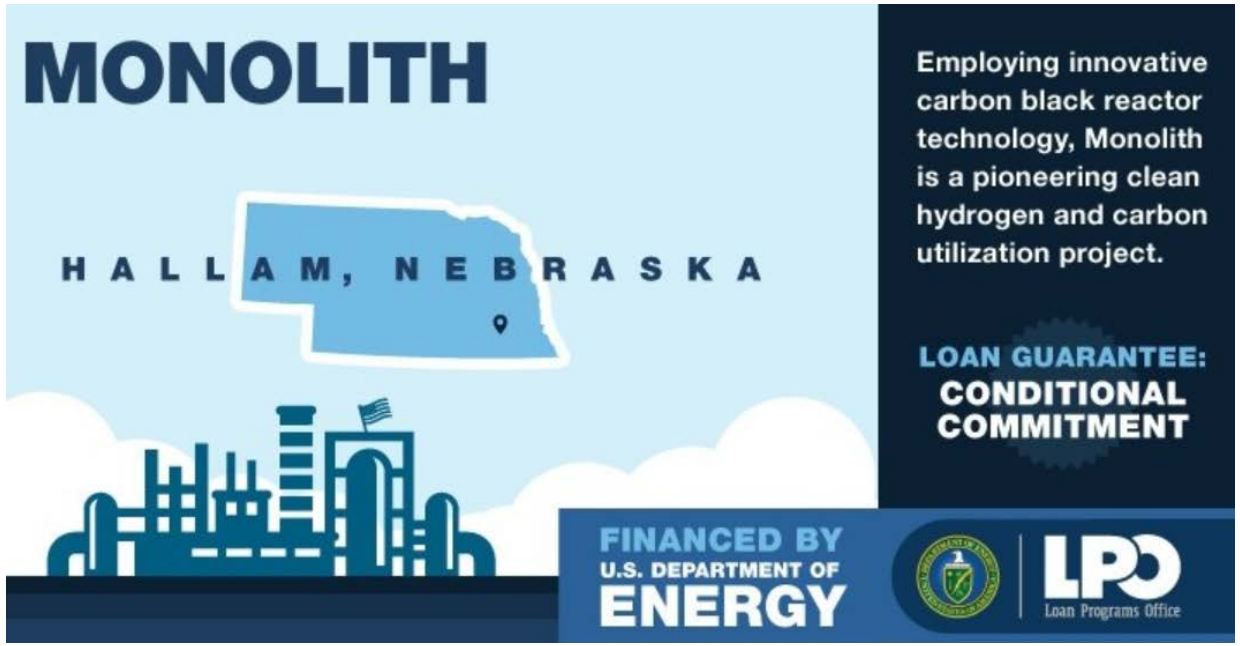
DOE Hydrogen Program FOAs/Lab Calls

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

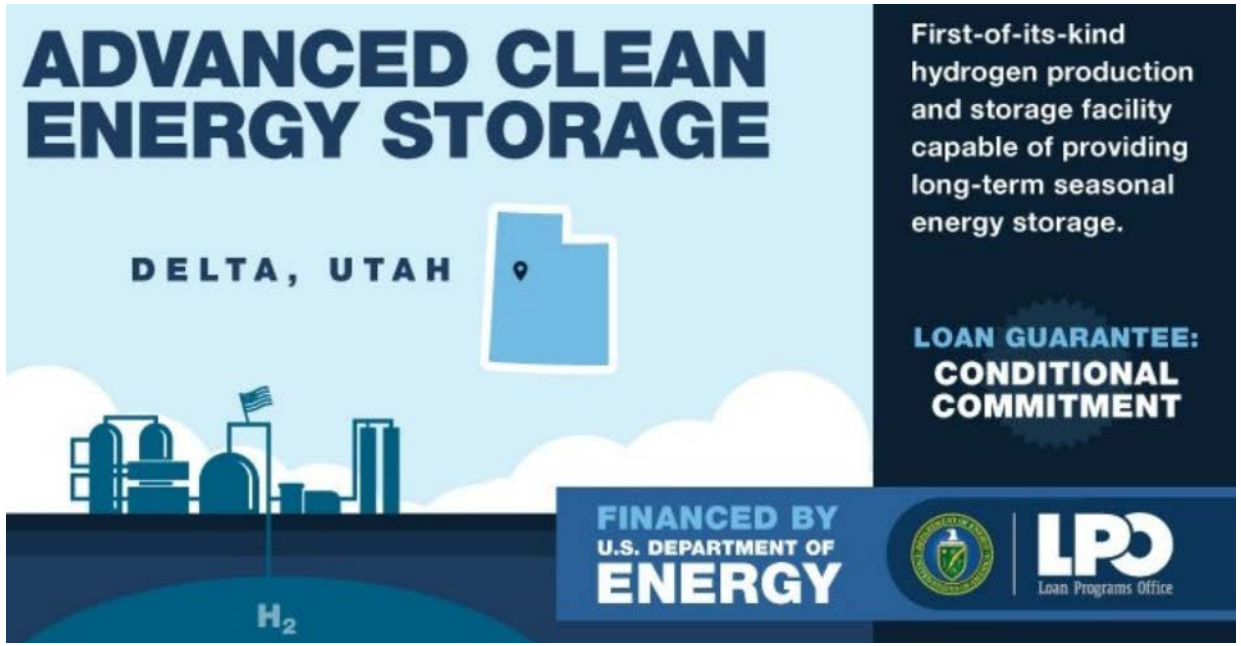
Financing to Enable Deployment at Scale

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

LPO announced loan guarantee conditional commitments for 2 clean hydrogen projects



$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)



$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