U.S. DEPARTMENT OF
ENERGY
Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

2022 AMR Plenary Session

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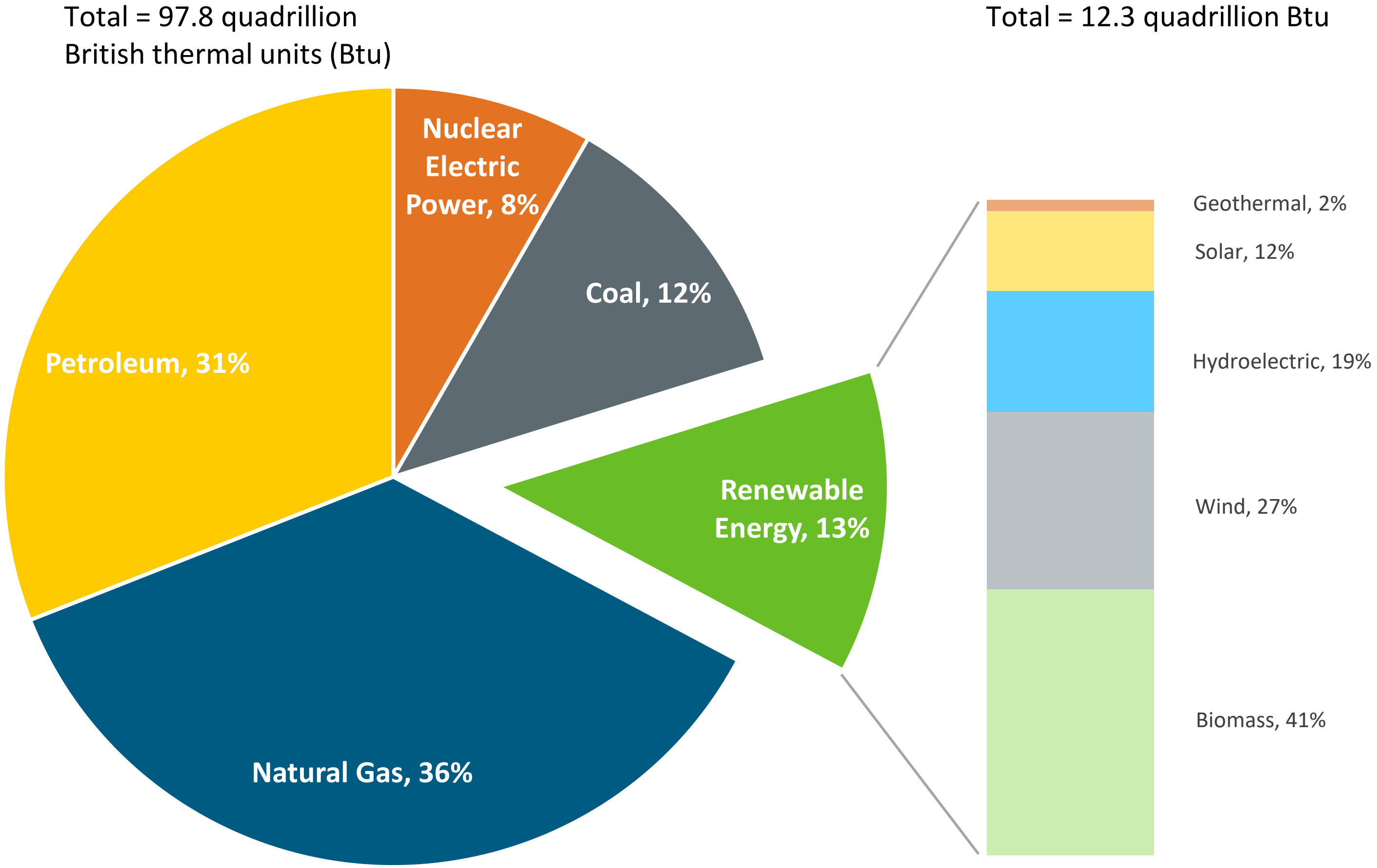
U.S. Department of Energy

June 6, 2022

Introduction – Energy, Market, and Policy Context

U.S. Energy Landscape and Key Goals

U.S. primary energy consumption by energy source, 2021



Note: Sum of components may not equal 100% because of independent rounding
Source: Data collected from U.S. Energy Information Administration, April 2022, *Monthly Energy Review,* preliminary data

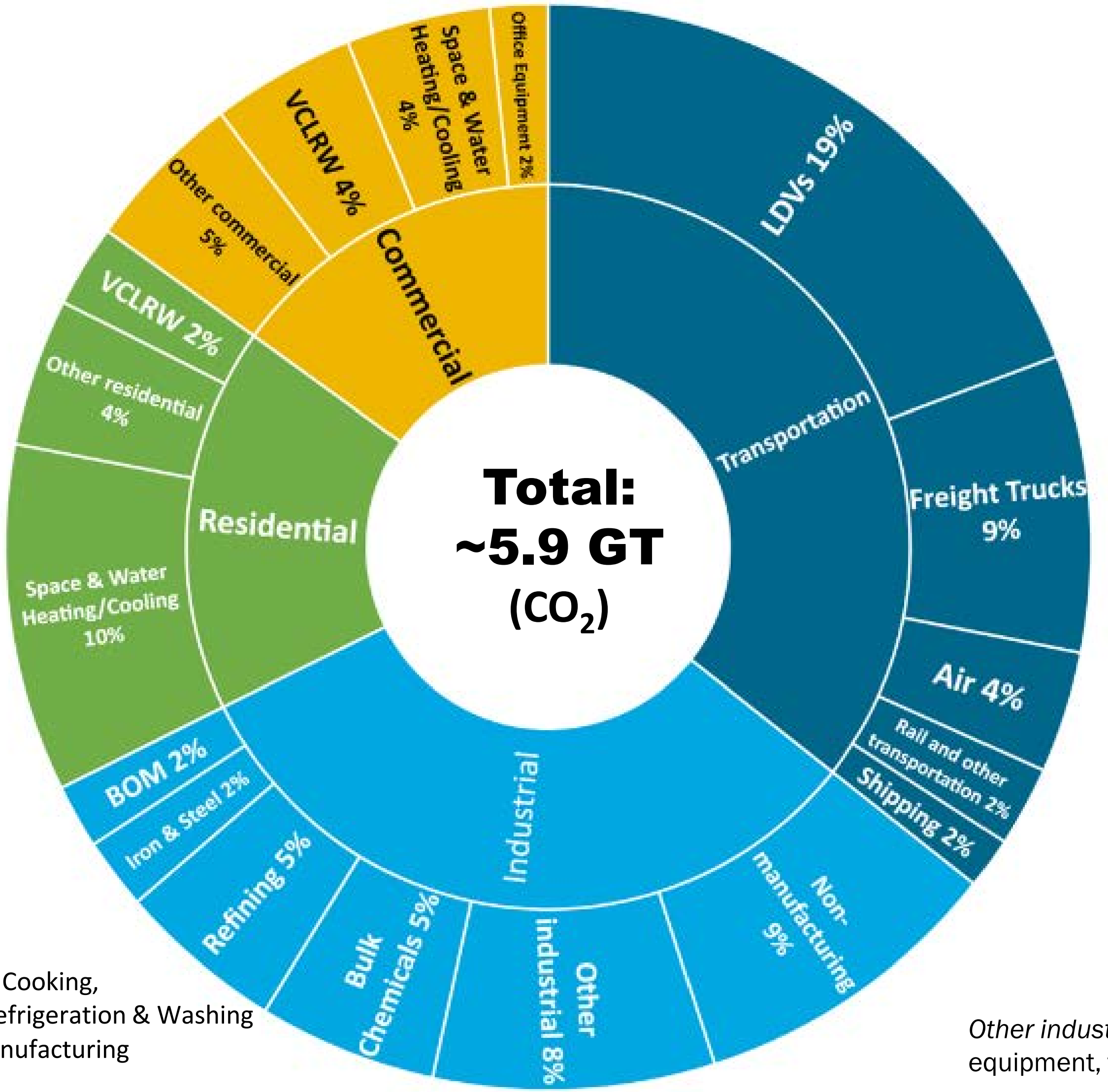
Administration Goals include:

- **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, EJ40: 40% of benefits in disadvantaged communities

EJ: Environmental Justice

U.S. Energy Related CO_2 Emissions by Sector End-Use



Need to address all sectors with a portfolio approach

Hydrogen can provide benefits particularly in hard to decarbonize sectors: industry, heavy duty transport and to enable energy storage

VCLRW - Ventilation, Cooking, Lighting, Refrigeration & Washing
BOM - Balance of Manufacturing

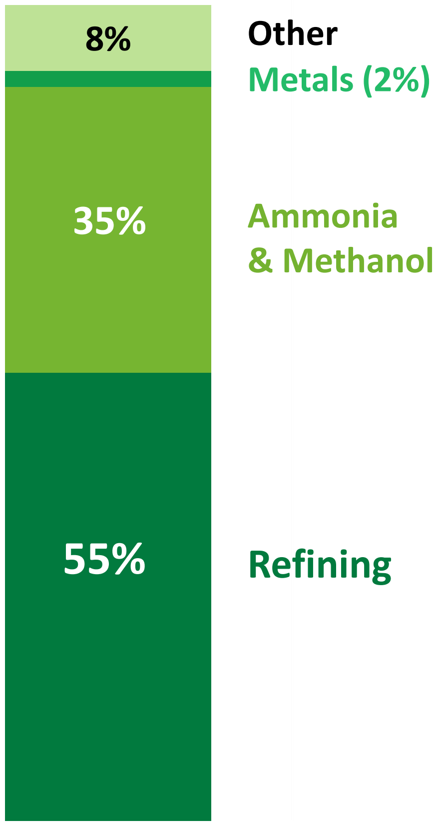
Other industrial: aluminum, cement and lime, construction, agriculture, plastics, wood, electrical equipment, transportation equipment, computing and electronics equipment, paper products, glass ,etc.

Note: Sum of sectors may not equal 100% due to independent rounding
Source: M. Koleva, DOE HFTO, NREL, adapted from EIA, 2020, U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

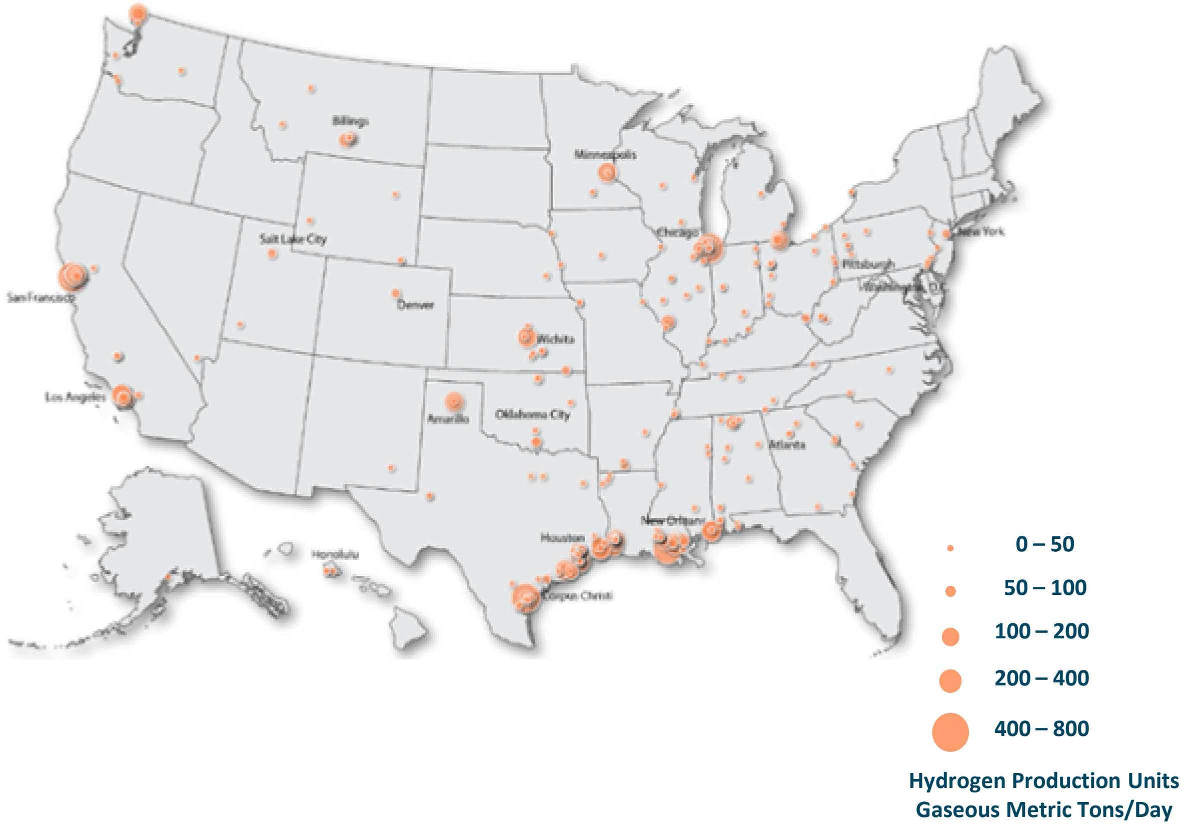
Snapshot of Hydrogen and Fuel Cells in the U.S.

- 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



Examples of Hydrogen Production Locations



Examples of Deployments

>500MW Backup Power

>50,000 Forklifts

>620 MW PEM* Electrolyzers

>80 Fuel Cell Buses

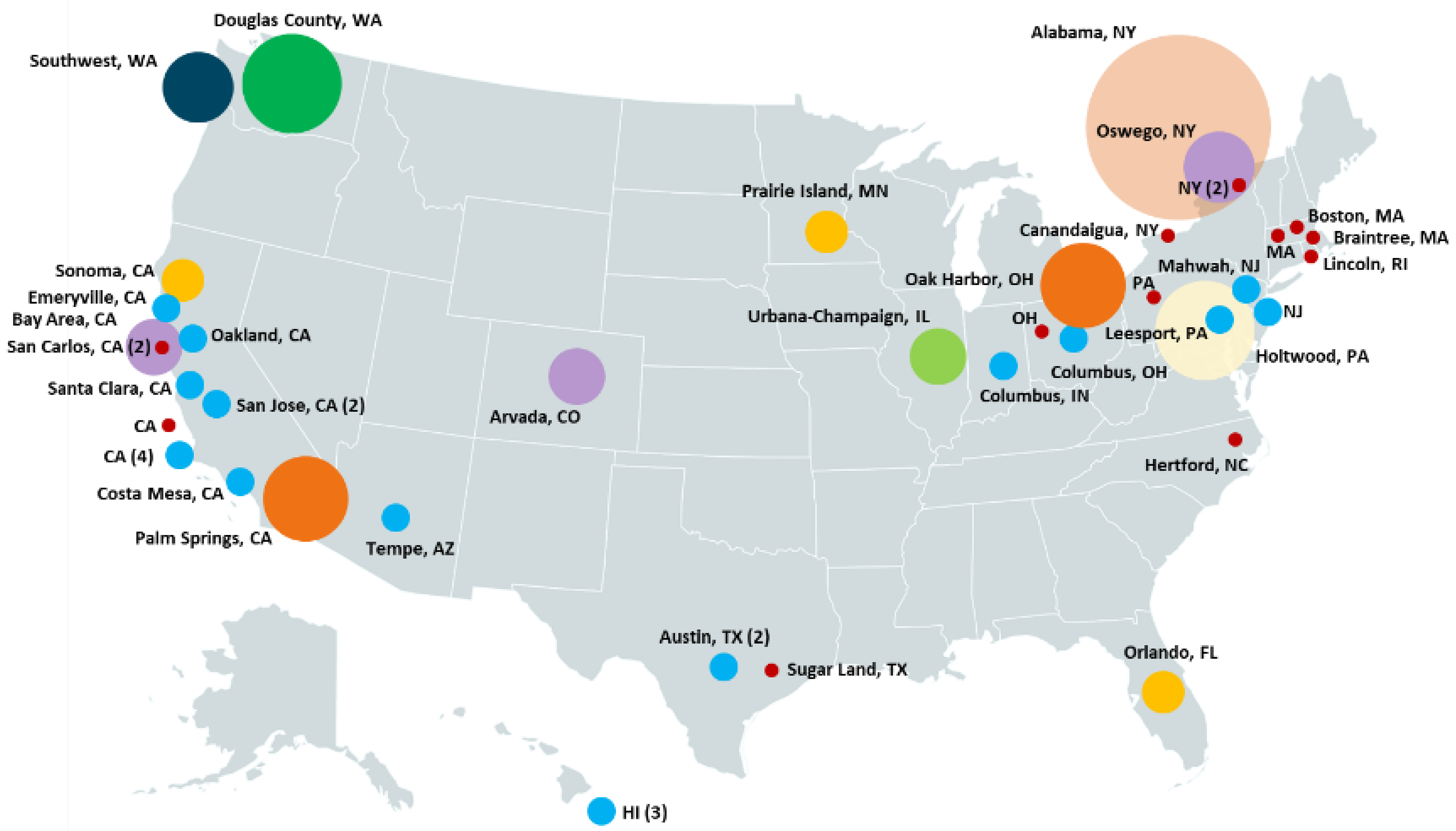
~50 H_2 Retail Stations

>13,000 Fuel Cell Cars

*Proton exchange membrane

PEM Electrolyzer Locations and Capacity – 2021 Snapshot

Operational and Under Construction: 172 MW Capacity



Electrolyzer Power Capacity
120 KW
180 KW
500 KW
1000 KW
1250 KW
1500 KW
2000 KW
5000 KW
30000 KW
120000 KW

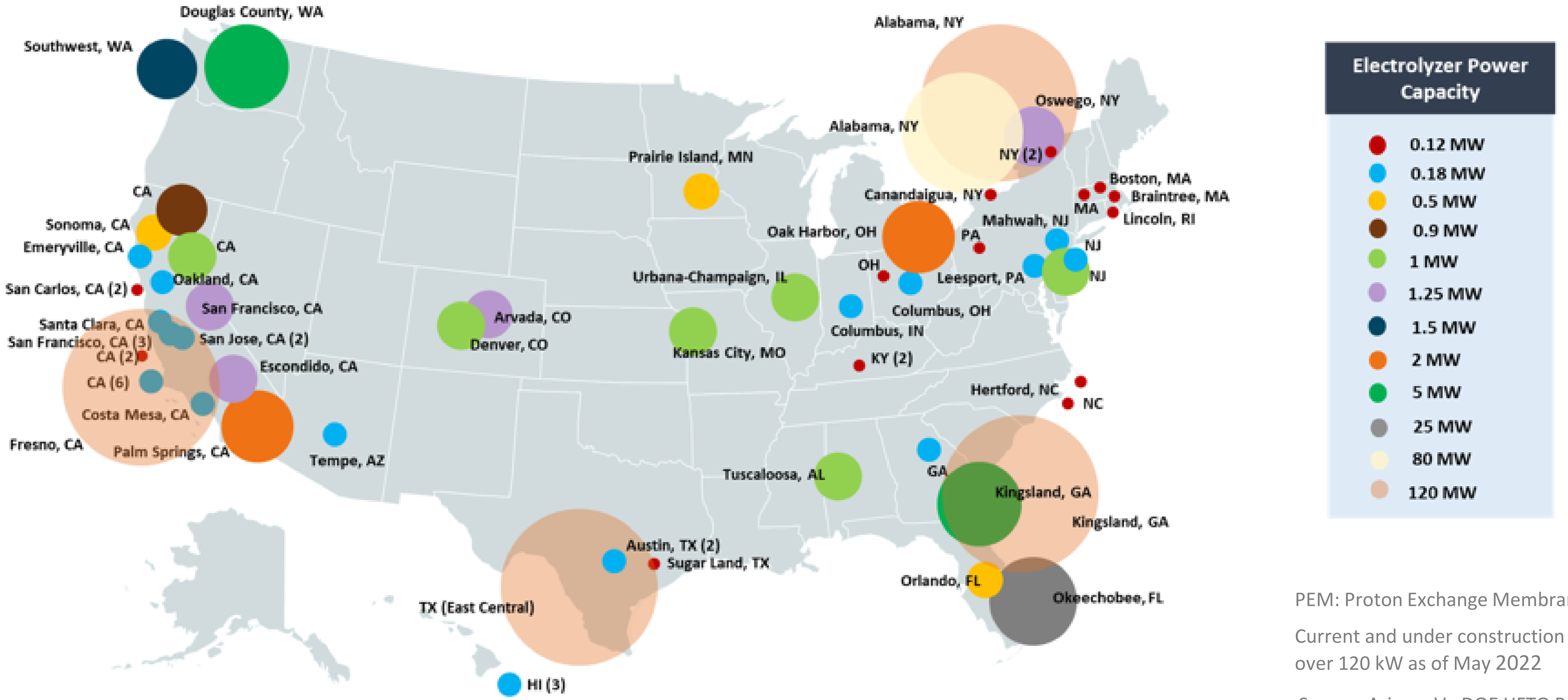
PEM: Proton Exchange Membrane

Current and under construction installations over 120 kW as of June 2021

Source: Arjona, et al, DOE HFTO Program Record 20009, June 2021 hydrogen.energy.gov/program_records.html

PEM Electrolyzer Locations and Capacity – 2022 Snapshot

Operational and Under Construction: > 620 MW Capacity



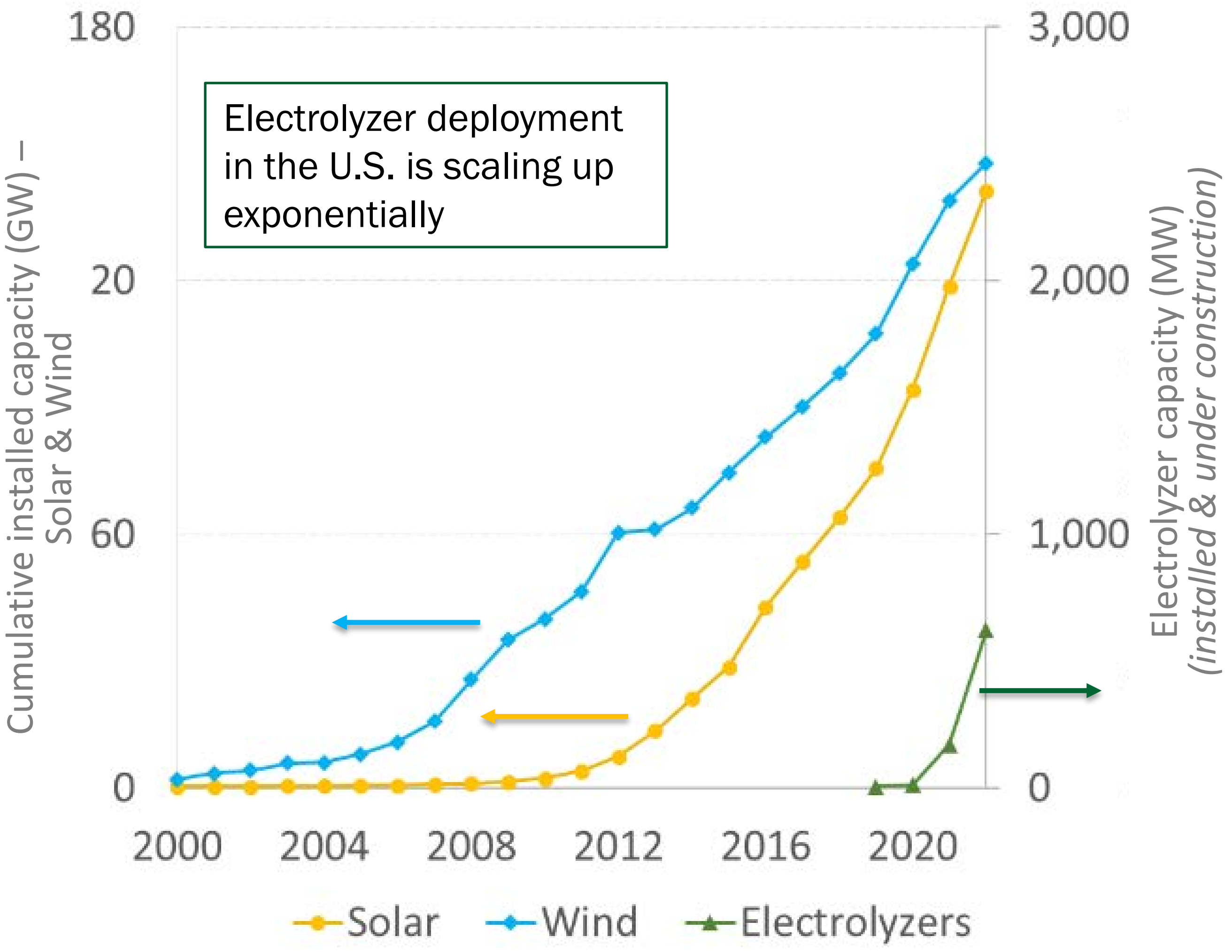
PEM: Proton Exchange Membrane

Current and under construction installations over 120 kW as of May 2022

Source: Arjona, V., DOE HFTO Program Record 22001 , June 2022

Cumulative Installed Capacities of Wind, Solar, and Electrolyzers in the U.S.

Similar to solar and wind, electrolyzer deployments are scaling up rapidly



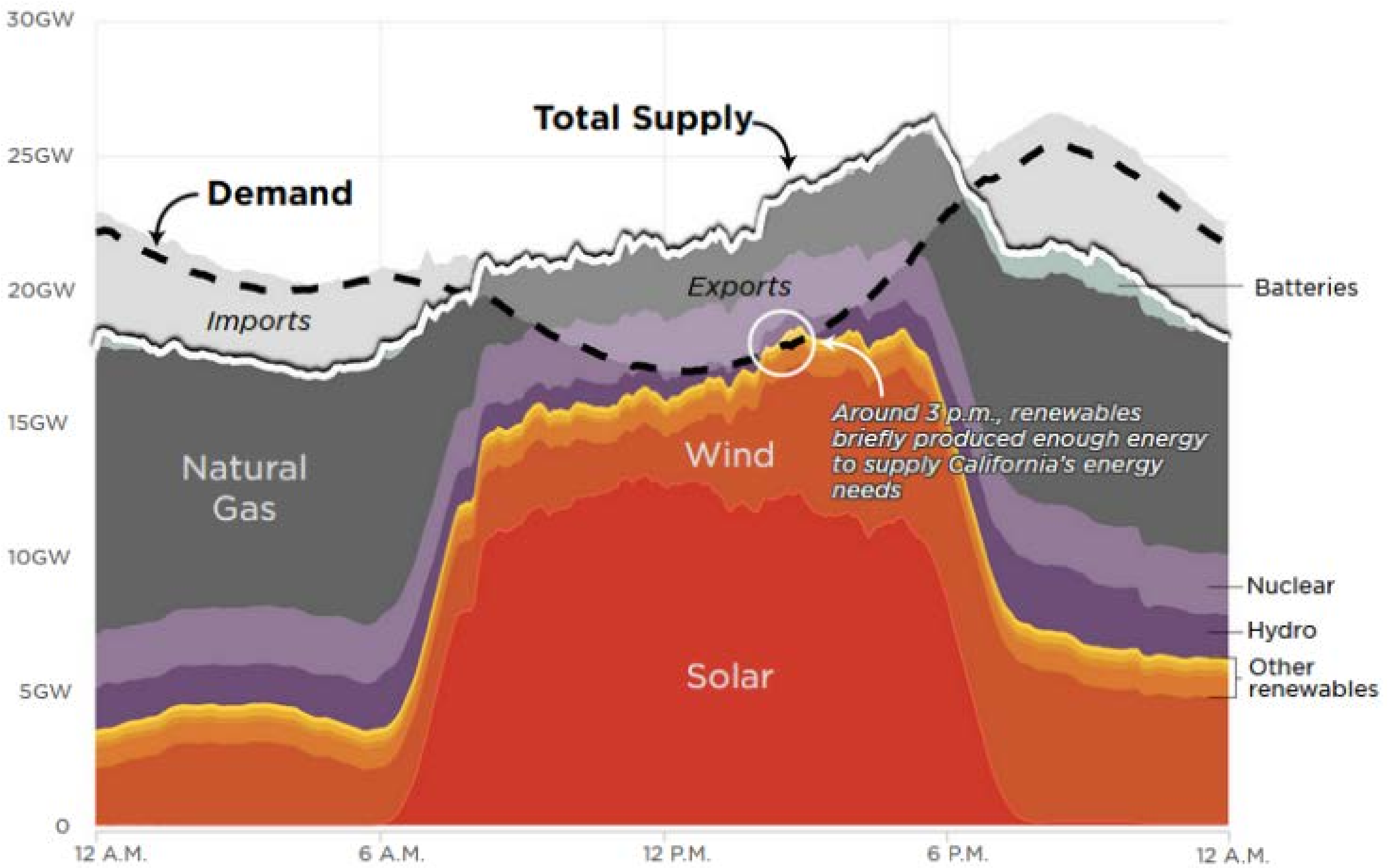
Global electrolyzer market estimates vary

Scenarios show over 60 GW by 2030

Sources: M. Koleva, HFTO/NREL, BNEF, 2021, Global Installed Capacity, IHS Markit, 2021, Hydrogen – CEH, Arjona, V. and Buddhavarapu, P., 2021, DOE Hydrogen Program Record. Electrolyzer Capacity Installations in the United States, Arjona, V., 2022, DOE Hydrogen Program Record. PEM Electrolyzer Capacity Installations in the United States, M. Klippenstein, CHFCA, EIA

Penetration of Renewables Drives the Need for Energy Storage

For the first time in history, in May 2022, renewable power in California exceeded demand



Source: California Independent System Operator

Credit: Daniel Wood and Lauren Sommer/NPR

Other renewables include geothermal, biomass, biogas and small hydroelectric power. Large hydroelectric and nuclear power are not considered renewable by the state of California. Total supply exceeds demand because some amount of electricity is lost in transmission and some is exported to other states.

Developing Our Strategy, Sharpening Our Goals


“Water the roots, not the leaves,
to grow the trees.”

U.S. DEPARTMENT OF ENERGY

DOE Hydrogen Program: Strategy & Overview

The U.S. DOE Hydrogen Program Spans Multiple DOE Offices

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

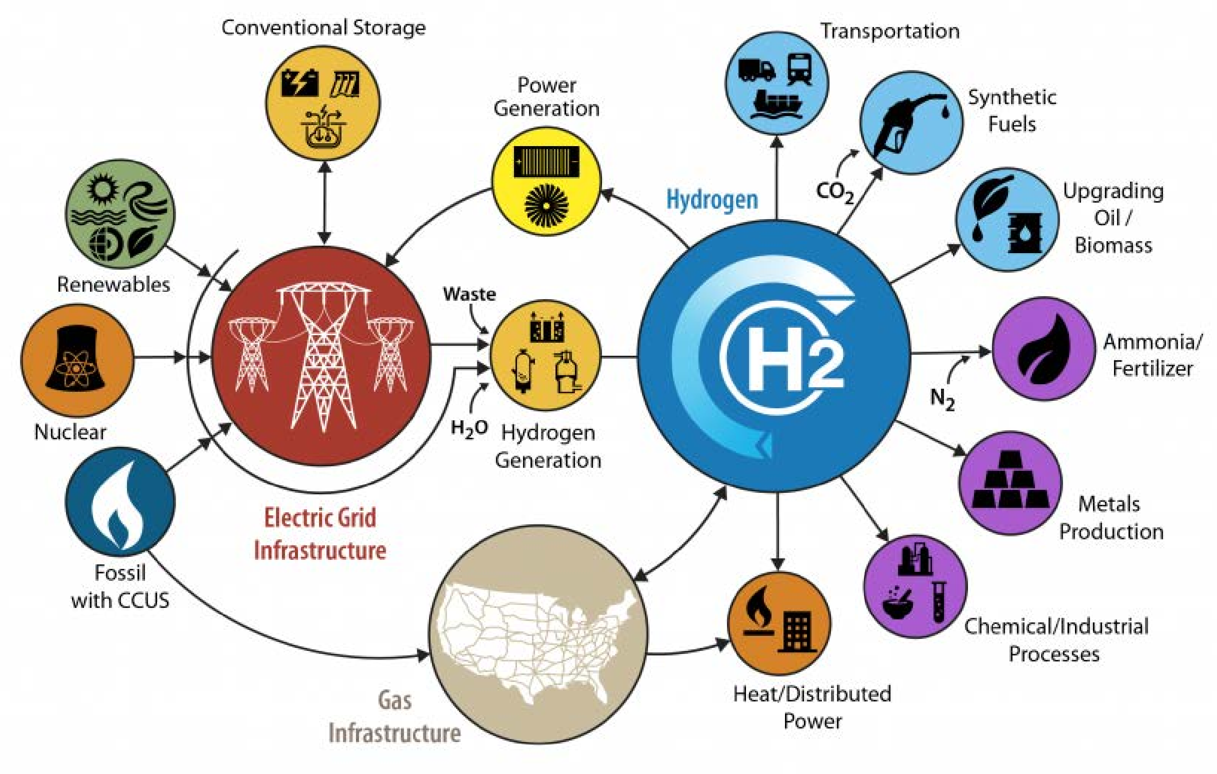
Hydrogen Program

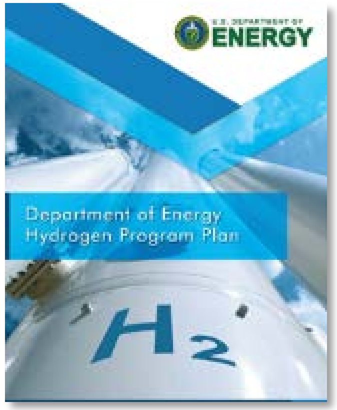
Coordinated across DOE

Focuses 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 all resources** (renewables, nuclear, and fossil + CCS)

H2@Scale provides a vision to guide how hydrogen can enable clean-energy pathways across applications and sectors in an increasingly interconnected energy system





DOE Hydrogen Program Plan (2020)

www.hydrogen.energy.gov

Comprehensive DOE Strategy Across the Hydrogen Value Chain

NEAR-TERM → **LONGER-TERM**

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

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

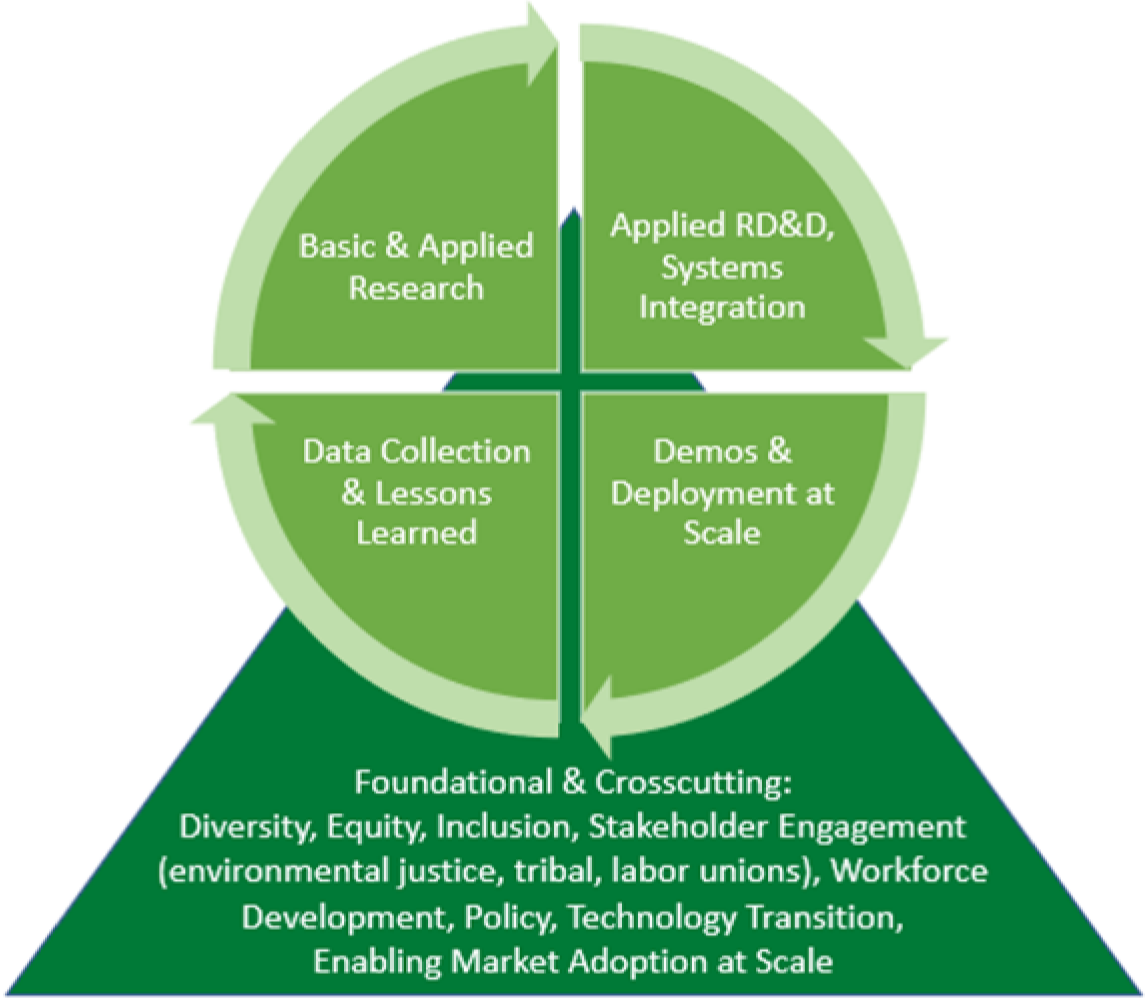
Storage
- Pressurized tanks (gaseous H_2)
- Geologic H_2 storage (e.g., caverns, depleted oil/gas reservoirs)
- Cryogenic vessels (liquid H_2)
- Cryo-compressed
- Chemical H_2 carriers
- Materials-based H_2 storage

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

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

Coordinated Strategy Across RDD&D

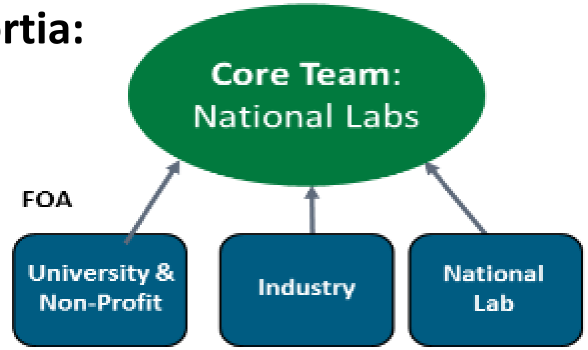
Includes more than **400 projects** with more than **200 companies & universities** and **15 National Labs**



Portfolio includes:

1) **Single project recipients & subrecipients**
2) **Consortia—leveraging national labs**
3) **Direct projects at/with labs**
4) **Small business innovation projects**

Consortia:



Examples

HydroGEN Advanced Water Splitting Materials

HyMARC

ElectroCat Electrocatalysis Consortium

H-Mat

H2NEW U.S. DEPARTMENT OF ENERGY

ACT U.S. DEPARTMENT OF ENERGY

MILLION MILE FUEL CELL TRUCK

Program Priorities and Key Initiatives to Address Them

Program Priorities	Key Initiatives to Address Priorities
1 Low-Cost Clean Hydrogen Production	H2NEW, HydroGEN, ElectroCAT, Hydrogen Shot Incubator Prize, H2 Demos
2 Safe, Low-Cost Delivery and Storage Infrastructure	H-Mat, HyBlend, HyMARC, SHASTA, C-Fiber Tanks, Liquefaction, Sensors
3 Low Cost, Durable, and Efficient Fuel Cells & Low-NO_x Turbines	M2FCT, ElectroCAT, Low-NOx Turbine RD&D
4 Enable End Use Applications at Scale	H2@Scale demos, Hydrogen Hubs, H2 Matchmaker

Examples from multiple offices across DOE

DOE Targets include:

Clean Hydrogen
- $1/kg production
- $2/kg delivery
- $9/kWh storage

Electrolyzers
- $150/kW
- 73% efficiency
- 80Khr durability

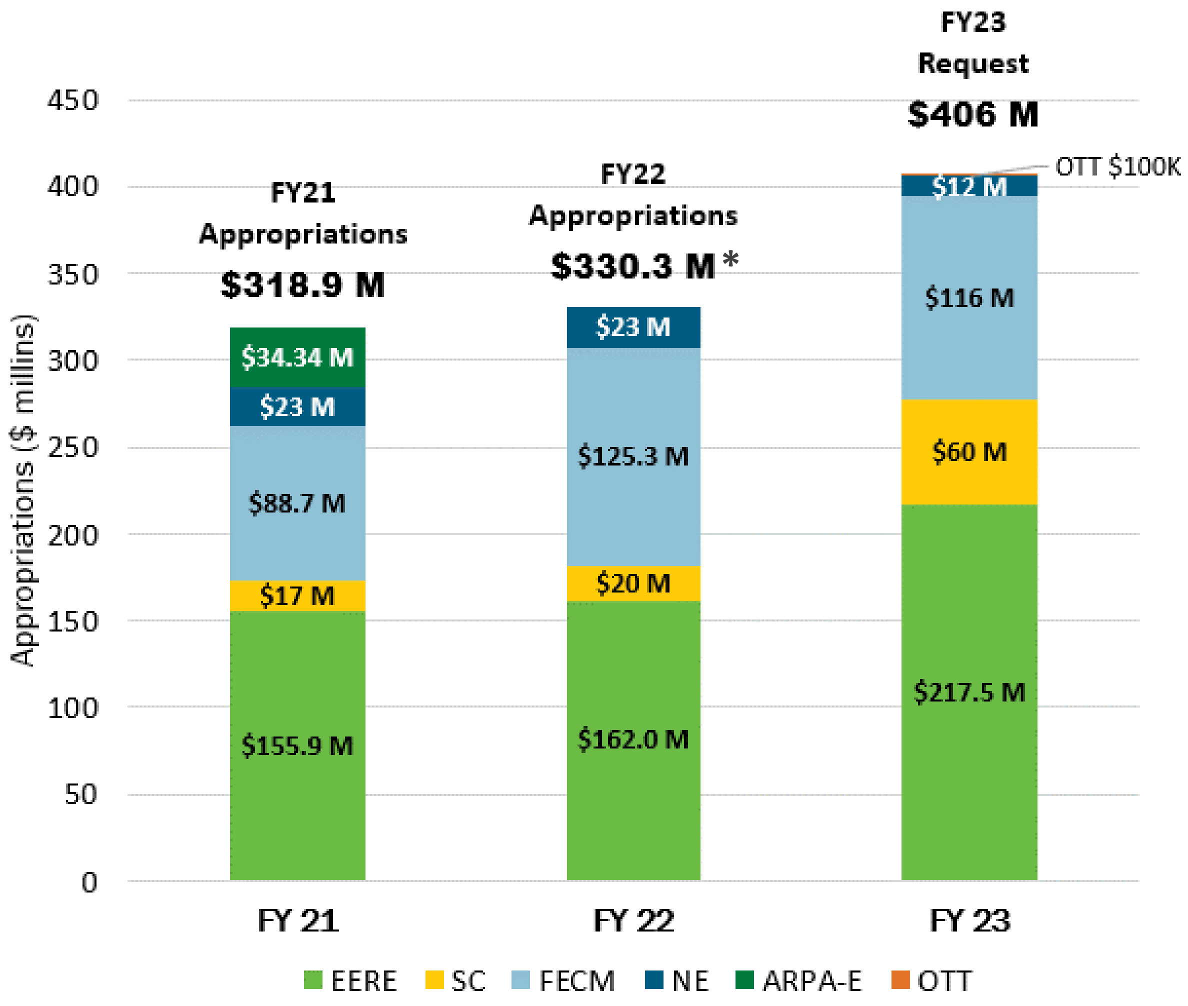
Fuel Cells for Heavy Duty Trucks
- $80/kW
- 25Khr durability

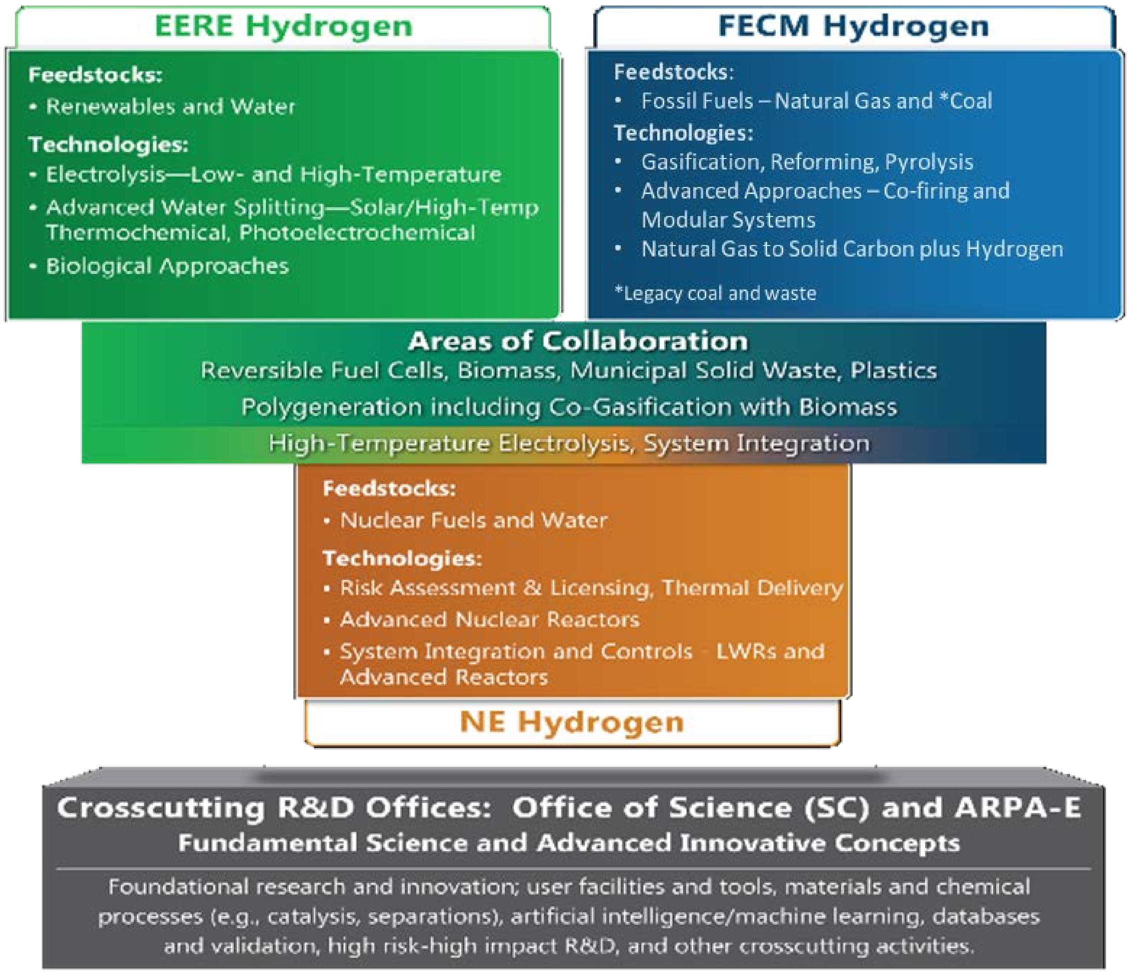
Enable EJ40 Priorities

DEI

DOE Hydrogen Program: Budgets & Plans

DOE Hydrogen Program Fiscal Year (FY) Funding across Offices





See: .www.energy.gov/sites/default/files/2022-05/doe-fy2023-budget-volume-2-crosscutting.pdf

*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 2023 is TBD.

The Hydrogen and Fuel Cell Technologies Office (HFTO)

Mission	Research, development and demonstration (RD&D) of hydrogen and fuel cell technologies to advance:	• Clean Energy and Emissions Reduction Across Sectors • Job Creation and a Sustainable and Equitable Energy Future

Budget Subprograms

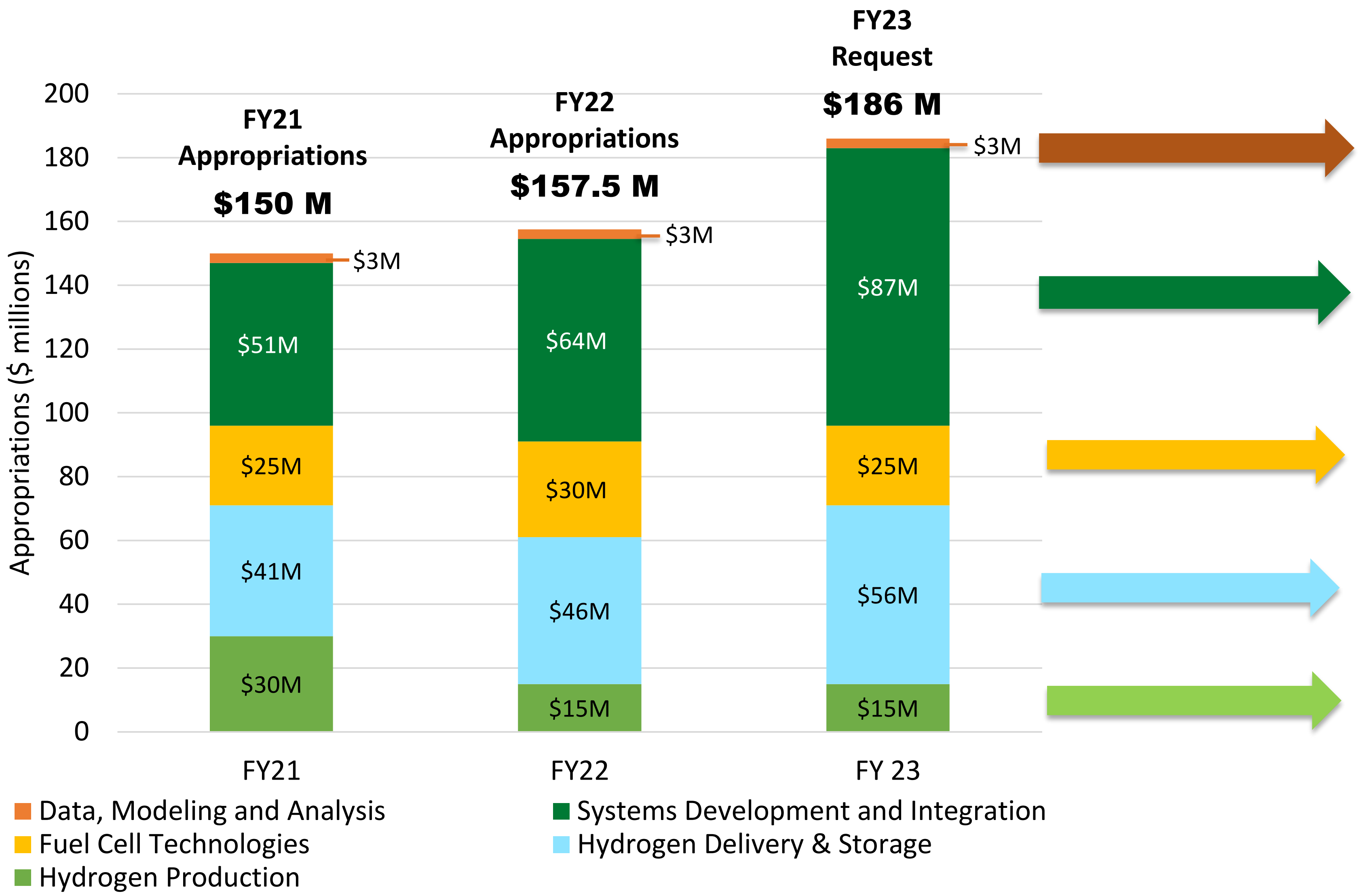
Hydrogen Technologies	Fuel Cell Technologies	Systems Development & Integration
Hydrogen Production Hydrogen Infrastructure and Storage	Materials & Components Systems	Transportation Industrial and Chemical Applications Grid Energy Storage and Power Generation Safety, Codes and Standards

Data, Modeling, and Analysis

Enabling H2@Scale

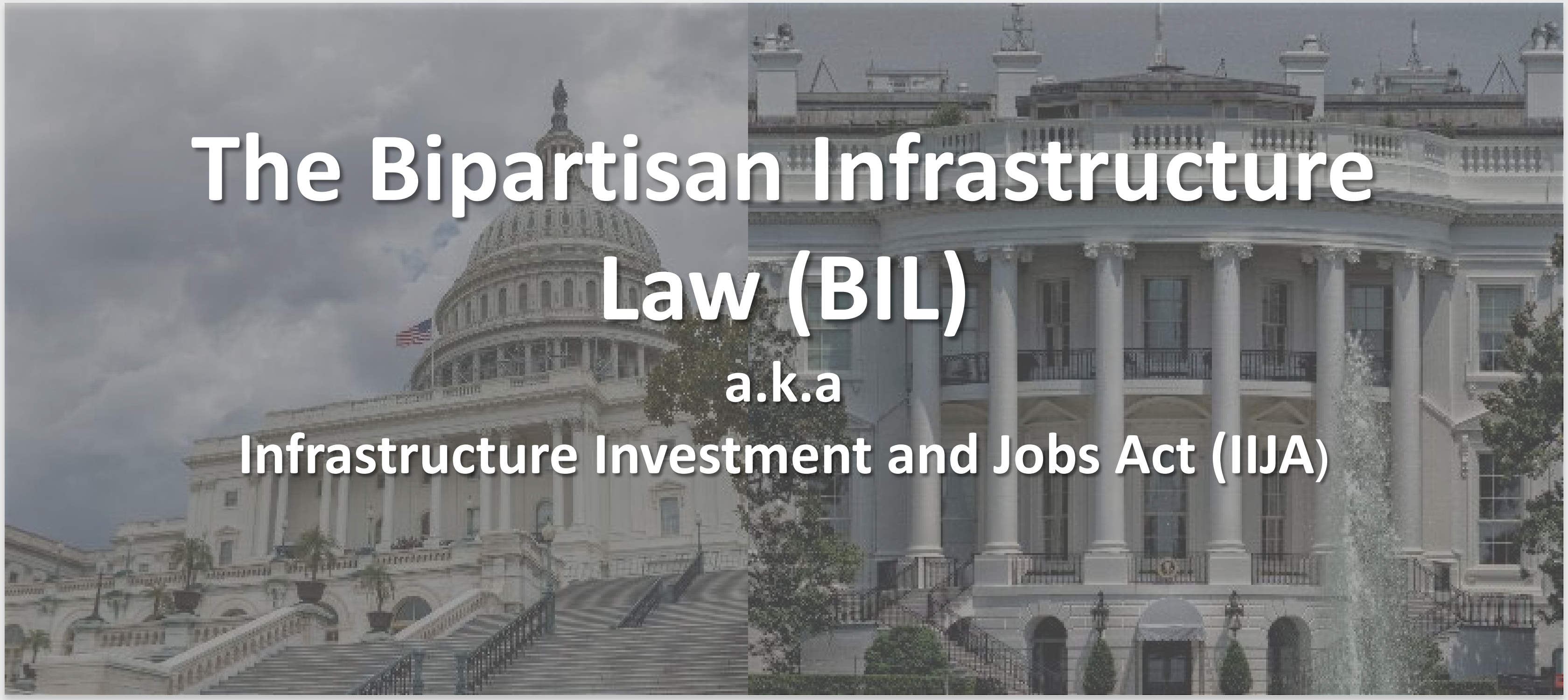
U.S. Department of Energy

Hydrogen and Fuel Cell Technologies Office Budget



Activities

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

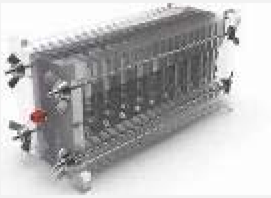

The Bipartisan Infrastructure Law (BIL)
a.k.a
Infrastructure Investment and Jobs Act (IIJA)

Bipartisan Infrastructure Law—Hydrogen Highlights

- **Includes $9.5B for clean hydrogen**:
  - $1B for electrolysis research, development, and demonstration
  - $500M for clean hydrogen technology manufacturing and recycling R&D
  - $8B for at least four regional clean hydrogen hubs
- **Aligns with Hydrogen Shot** priorities by directing work to reduce the cost of clean hydrogen to **$2 per kg by 2026**
- **Requires developing a National Hydrogen Strategy and Roadmap**

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

Key BIL Sec. 40314 Hydrogen Provisions—Overview



"Clean H_2 Electrolysis Program": BIL Includes research, development, demonstration and deployment (RDD&D) across multiple electrolysis technologies, compression, storage, drying, integrated systems, etc. Directly supports Hydrogen Shot

Sec. 40314 (EPACT Sec 816): Clean Hydrogen Electrolysis Program; **$1 Billion over 5 years. Goal $2/kg by 2026**

"Clean Hydrogen Manufacturing and Recycling"

Focus on manufacturing and end of life/recycling RD&D

Sec. 40314 (EPACT Sec 815): Clean Hydrogen Manufacturing & Recycling **$0.5 Billion over 5 years**

Regional Clean H_2 Hubs: At least 4 Hubs, geographic diversity, includes renewables, fossil + CCS, nuclear, for clean hydrogen production, multiple end use applications.

Sec. 40314 (EPACT Sec 813): Regional Clean Hydrogen Hubs; **$8 Billion over 5 years**

National Hydrogen Strategy and Roadmap: Includes working with EPA to develop an initial clean hydrogen production standard per Sec. 822: $\leq$ 2 kg CO_2e per kg H_2

Sec. 40314 (EPACT Sec 814): Strategy & Roadmap and **Sec. 40315 (EPACT Sec 822)**: Clean Hydrogen Production Qualifications)

DOE National Clean Hydrogen Strategy

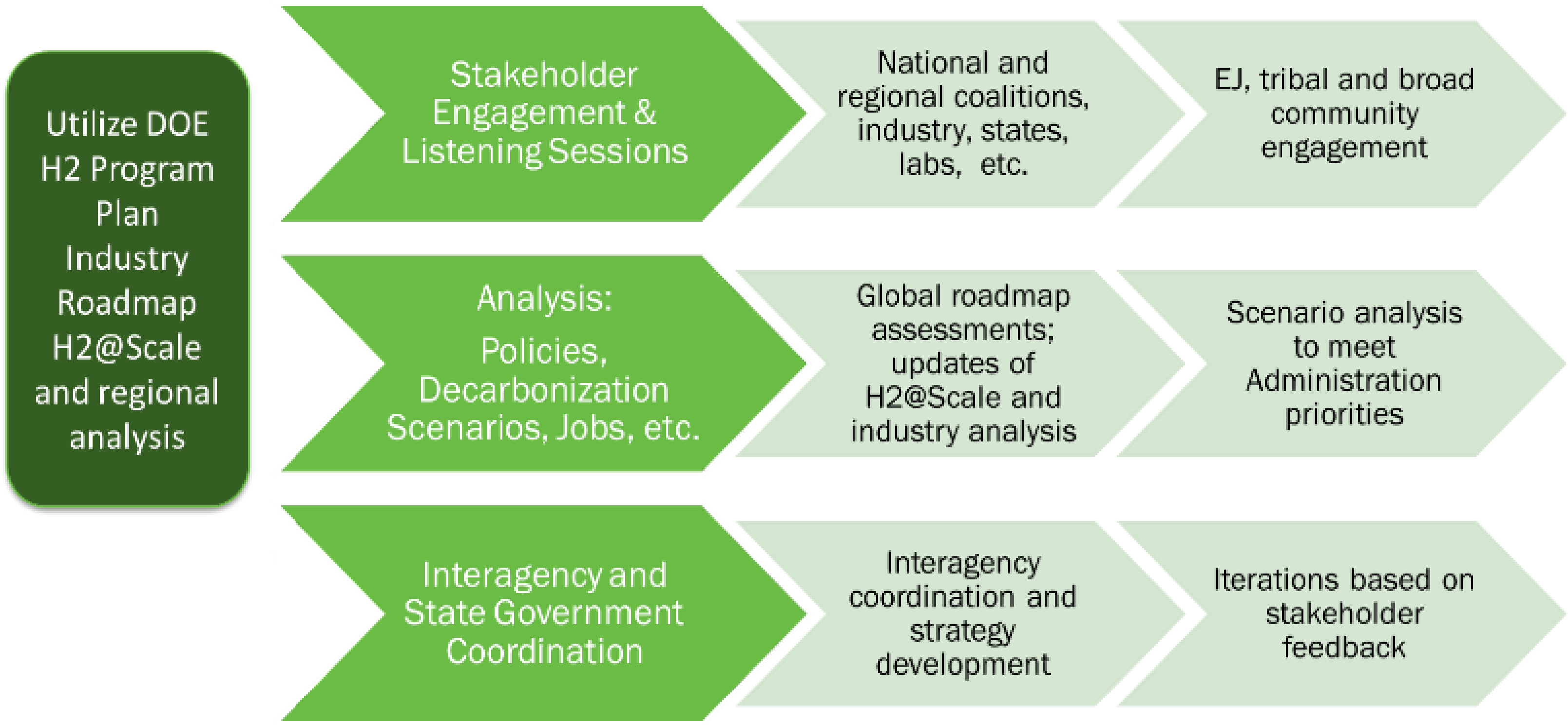
including

Hydrogen Shot

Internal and External Engagement

Broad Stakeholder Engagement included:

- **Interagency:** ~10 agencies
- **Webinars:** >1,700 participants
- **Industry:** >85 through industry coalitions
- **15 National Labs**
- **Tribal, Labor Union, EJ communities**
- **Environmental organizations**

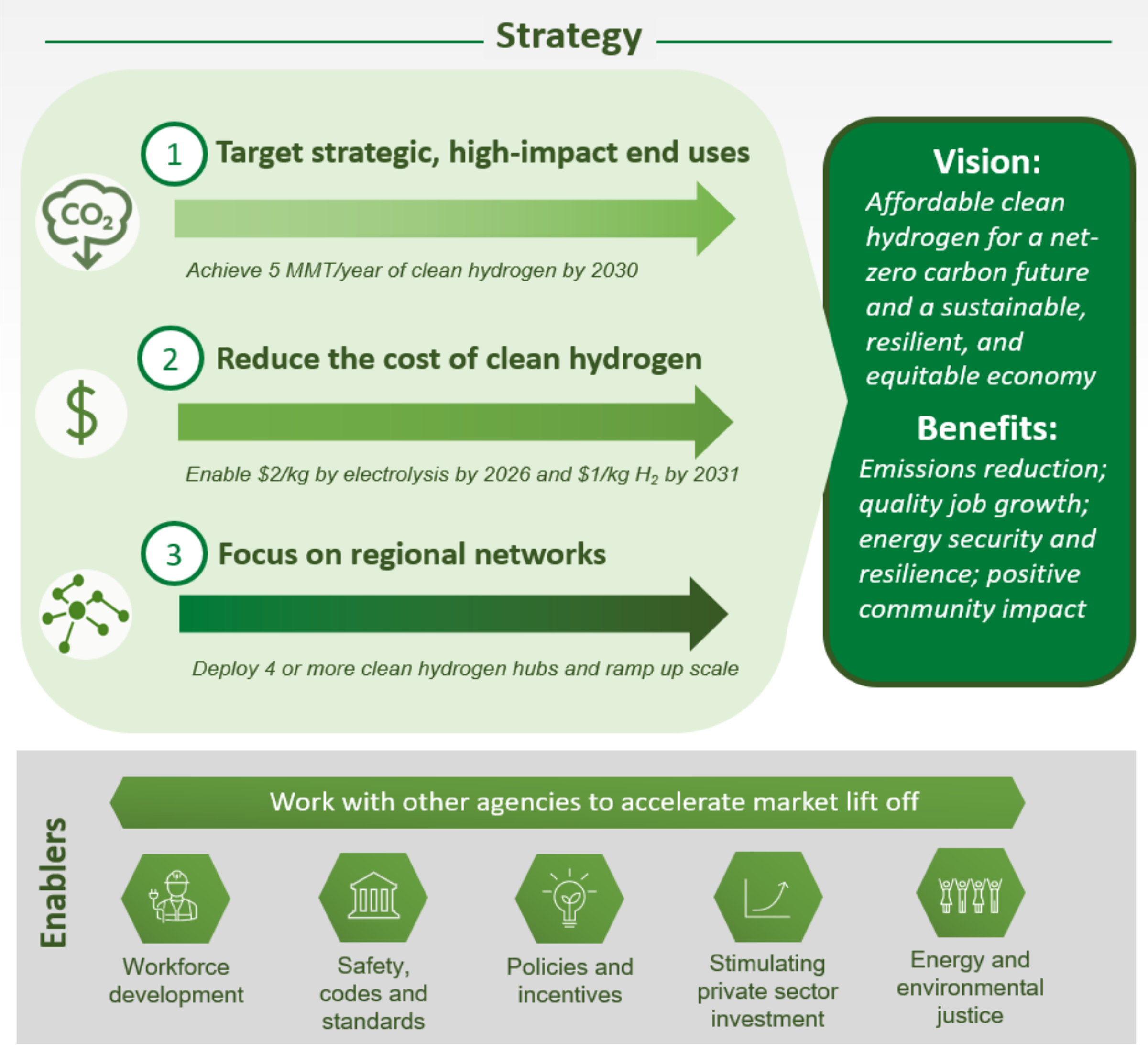


DOE: HFTO (lead) EERE, FECM, NE, SC, OTT, LPO, OE, OP, OCED, ED, IE, ELEP, and more (DOE Science and Energy Tech Team, “SETT”)

DOE National Clean Hydrogen Strategy Development

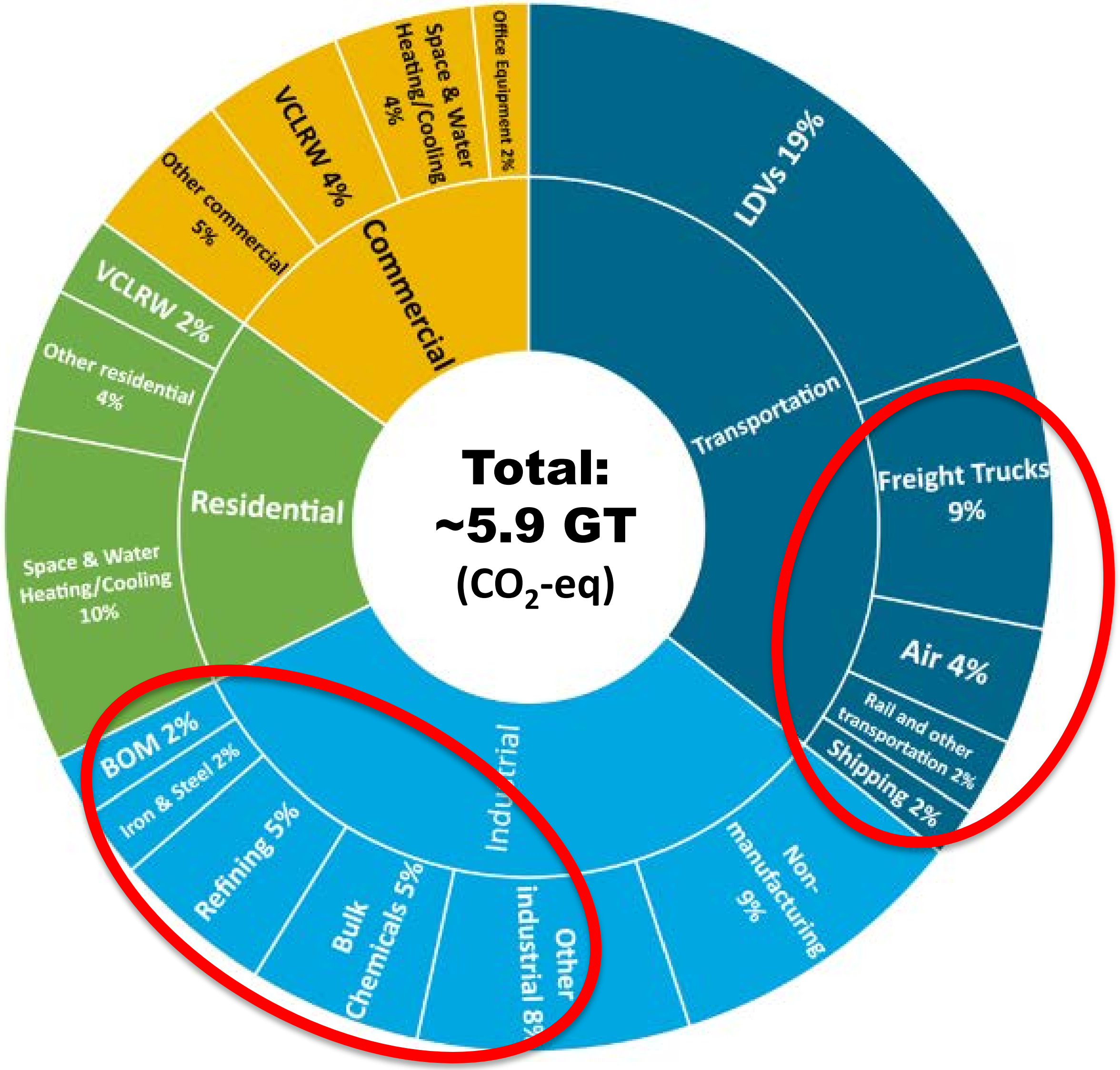
Guiding Principles include

- Enable Deep Decarbonization
- Catalyze innovation & investment
- Spur domestic manufacturing
- Grow sustainable jobs
- Foster diversity, equity & inclusion
- Advance environmental justice
- Enable affordability and versatility
- Approach holistically



Target Strategic, High-Impact Uses of Hydrogen

U.S. Energy Related CO_2 Emissions by Sector End-Use



Hydrogen can provide benefits particularly in hard to decarbonize sectors: industry, heavy duty transport and to enable energy storage

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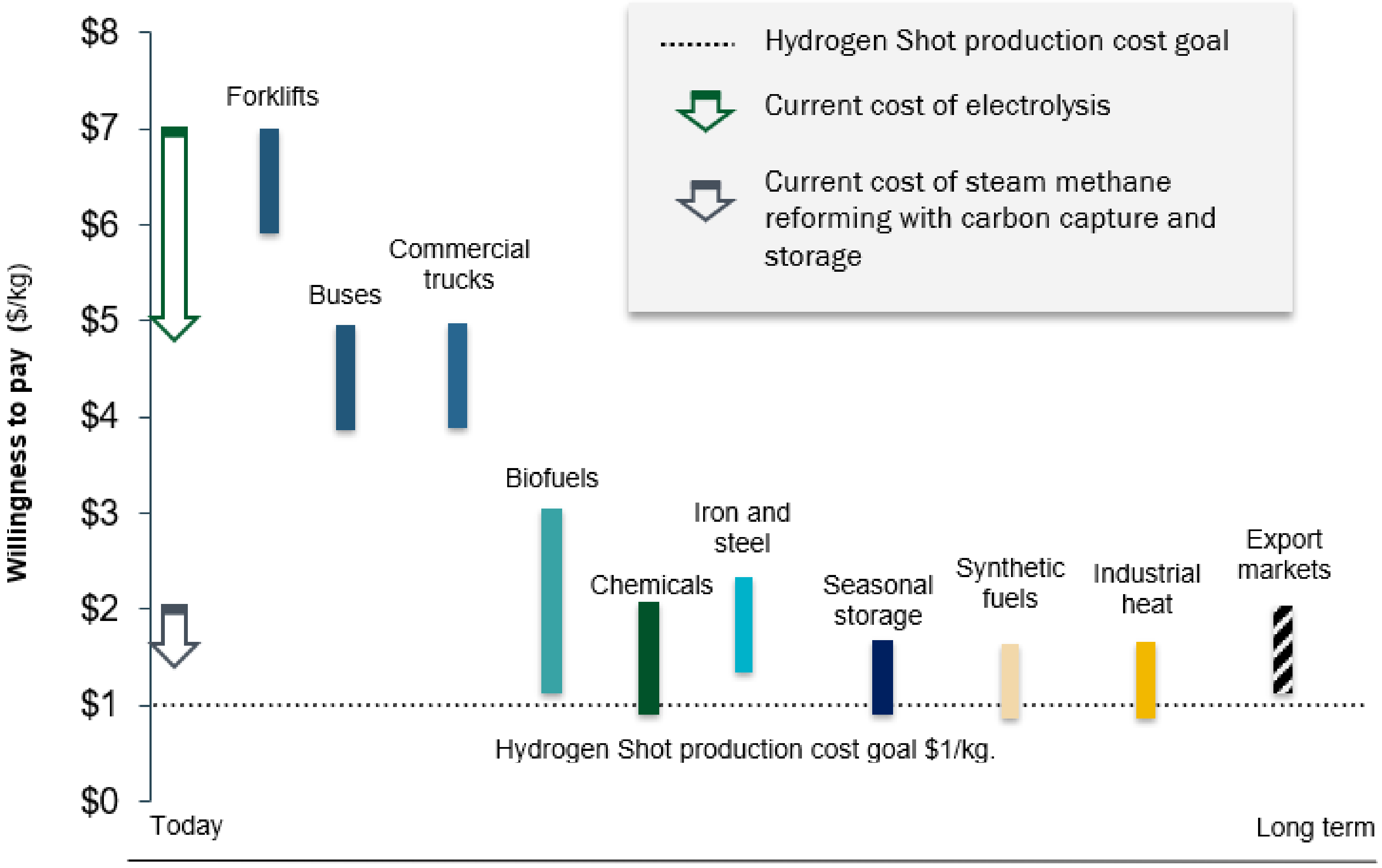
BOM - Balance of Manufacturing

Other industrial: aluminum, cement and lime, construction, agriculture, plastics, wood, electrical equipment, transportation equipment, computing and electronics equipment, paper products, glass ,etc.

Note: Sum of sectors may not equal 100% due to independent rounding
Source: M. Koleva, DOE HFTO, NREL, adapted from EIA, 2020, U.S. Energy Information Administration - EIA - Independent Statistics and Analysis

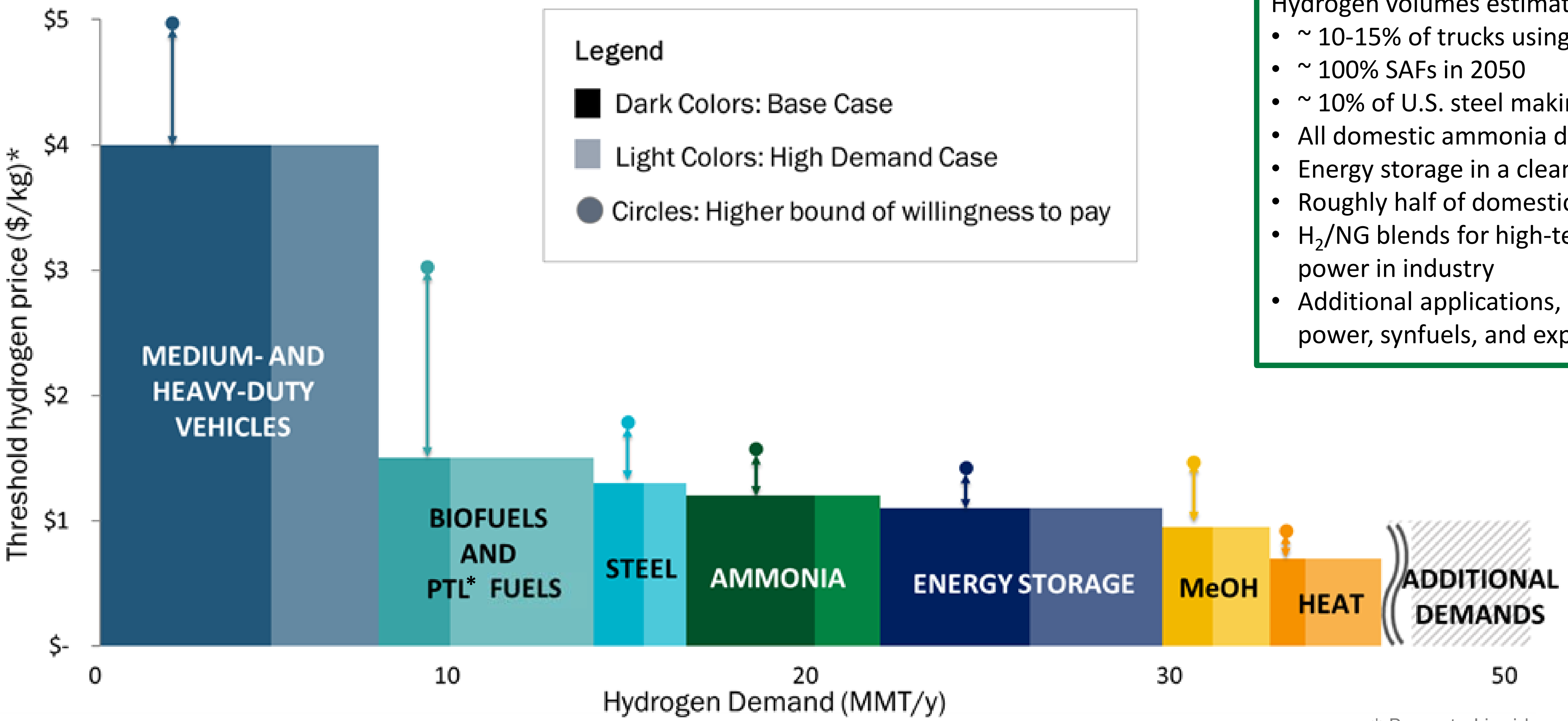
Threshold Costs for Hydrogen to be Competitive Across Sectors

Some applications can start to be competitive at a higher threshold cost and can jumpstart the market



Threshold cost for each application includes cost of production, delivery, storage, compression/processing/dispensing, as required, to the point of use for each application

Clean Hydrogen Demand and Costs for Market Penetration



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

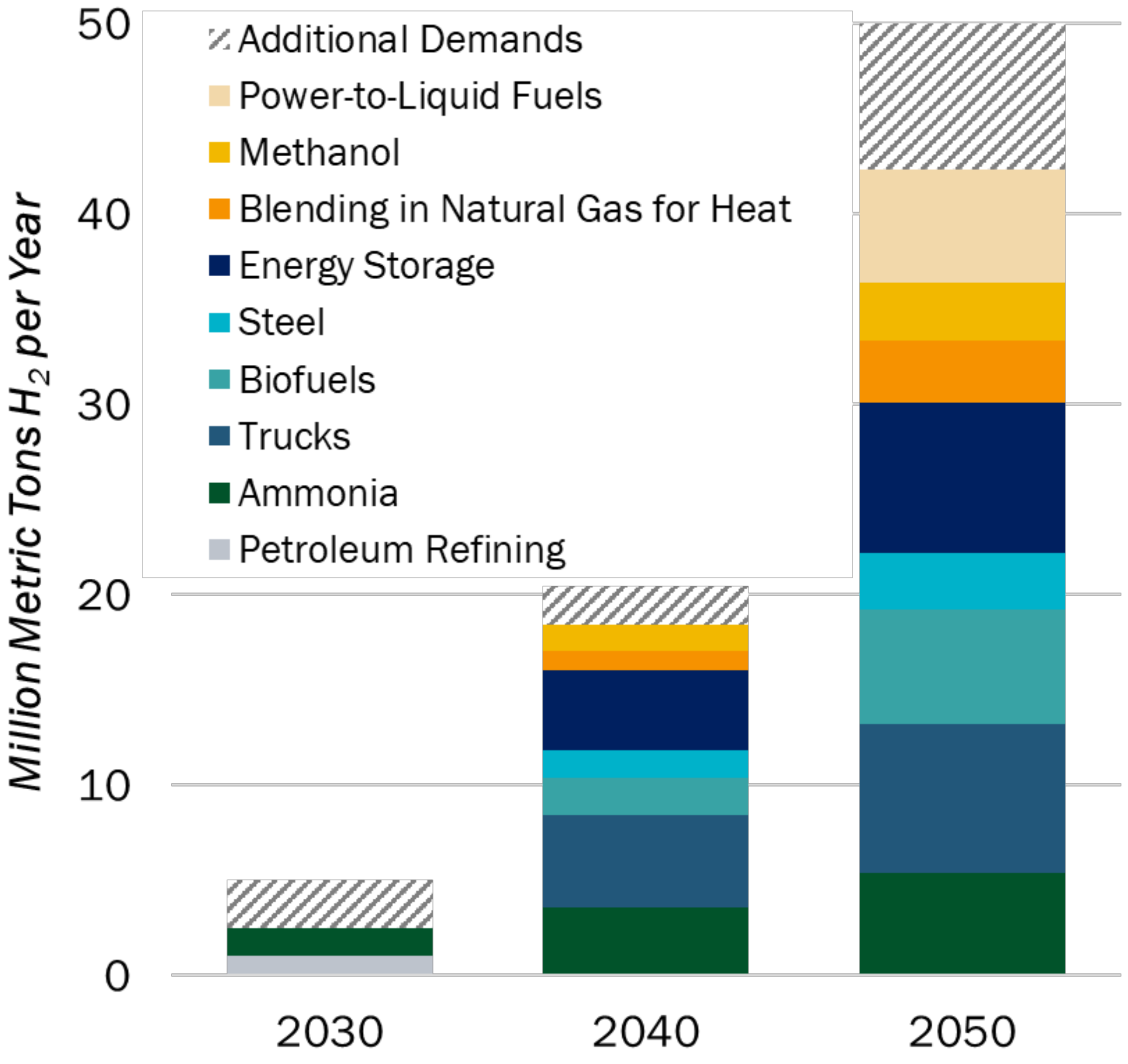
Scenario Analyses for H_2 Demand**

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

* Power to Liquid
** Volumes dependent on multiple variables

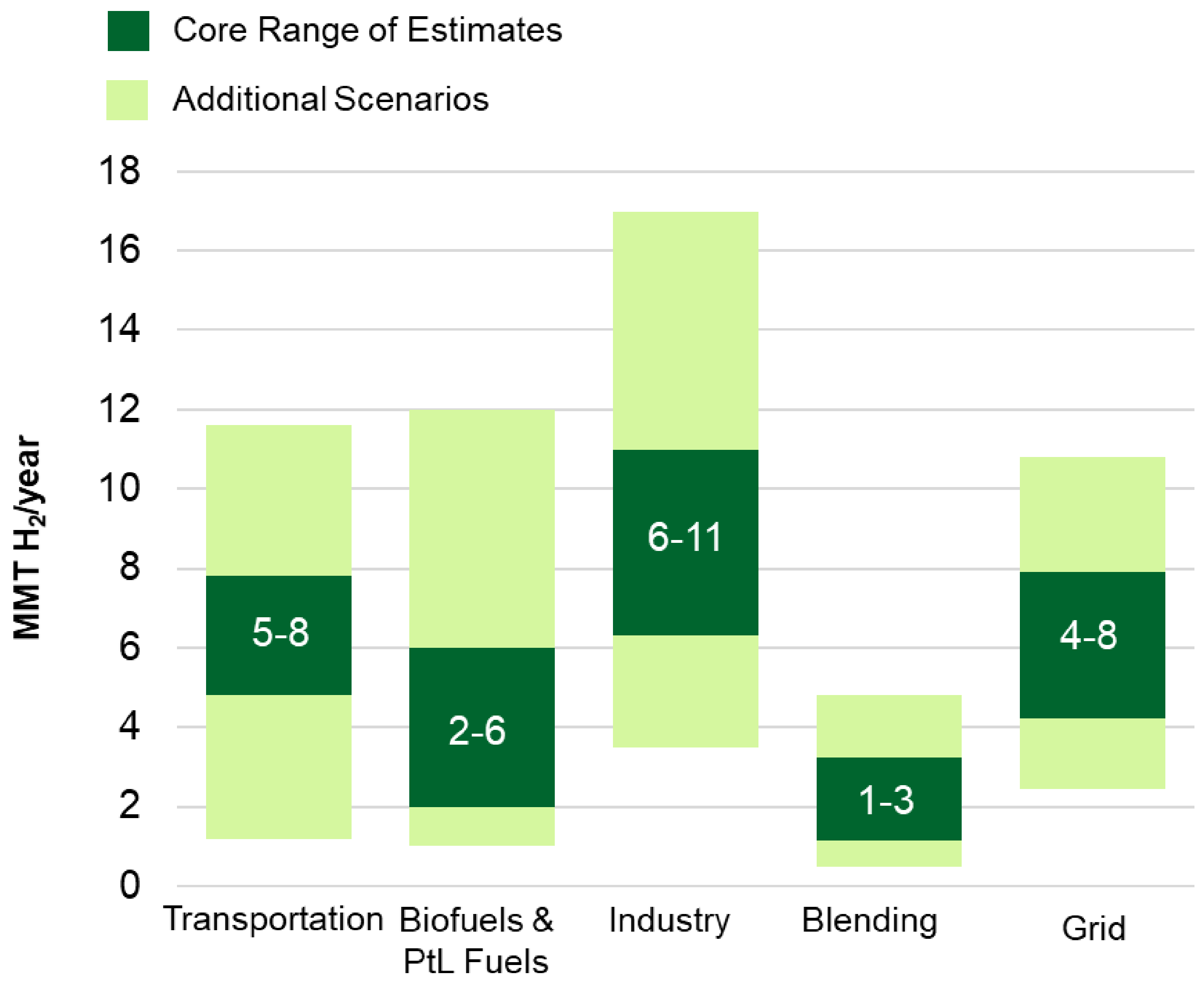
The Opportunity for Clean Hydrogen



Clean Hydrogen Use Scenarios

- Catalyze clean H_2 use in existing industries (ammonia, refineries), initiate use for sustainable aviation fuels (SAFs), steel, potential exports
- Scale up use for heavy-duty transport, industry, and energy storage
- Market expansion across sectors for strategic, high-impact uses

Range of Potential 2050 U.S. Clean Hydrogen Demand



- **Recognizes range of uncertainties**
- **Includes conservative and ambitious scenarios**
- **Core range: ~ 18–36 MMT H_2**
- **Maximum range: ~ 36–56 MMT H_2**

Potential Opportunities for:

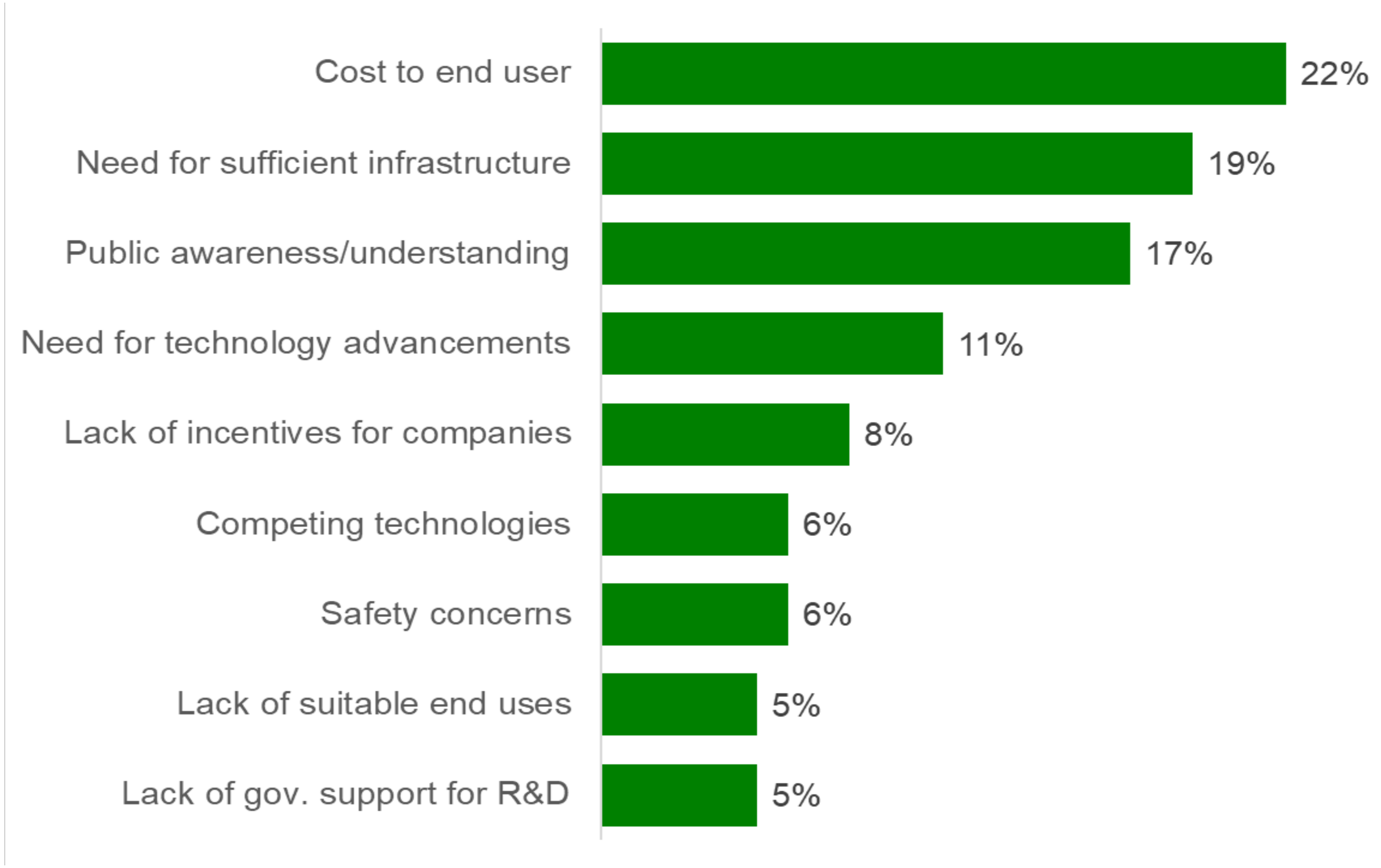
~ 5 MMT/yr by 2030

~ 20 MMT/yr by 2040

~ 50 MMT/yr by 2050

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

Stakeholder Reported Barriers to Hydrogen Market Adoption



- **4,900+ total registrants,**
- **3,200+ participants at Plenary**
- **34 countries**

Hydrogen Shot Summit Speakers included:

- **Secretary Granholm, DOE Leadership across offices**
- **Sec. John Kerry**
- **Bill Gates**
- Industry CEOs, VPs Congressional Members, Labs, Research and Academic Experts

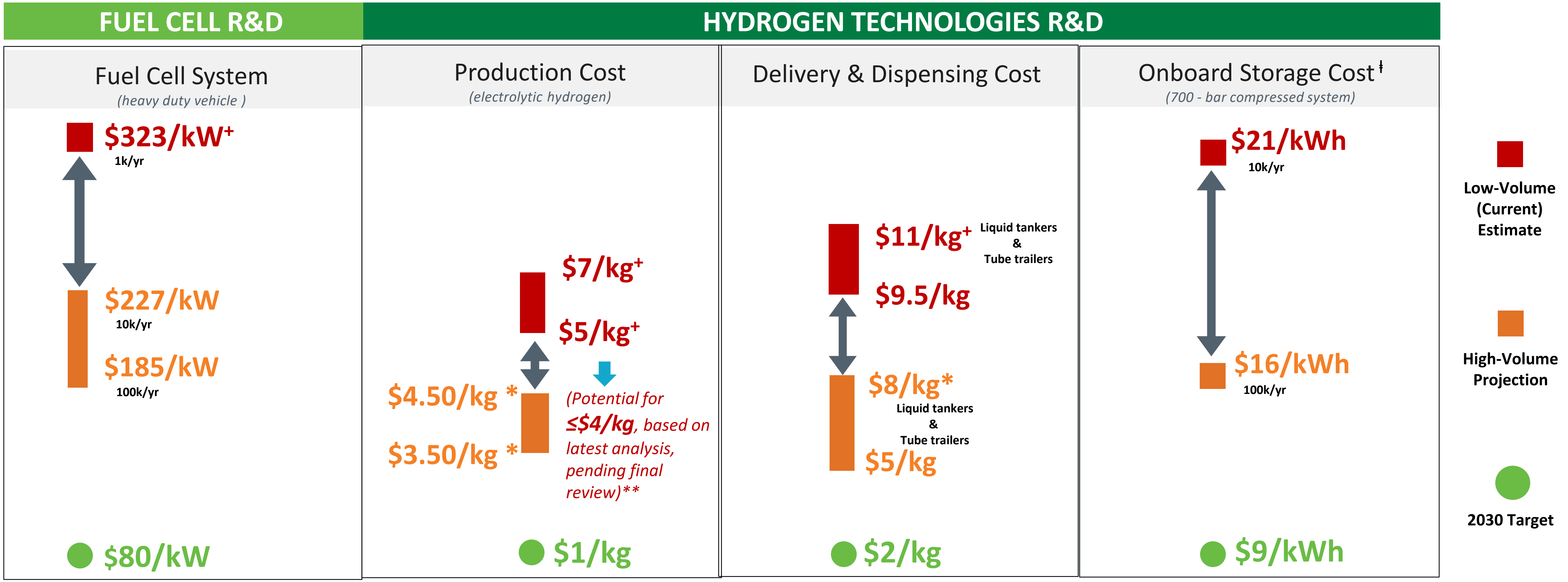
Source: Hydrogen shot summit, Sept 2021

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

Focus on Cost-Reduction

Technology Targets Guide RD&D Activities

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 (2021), adjusted to reflect cost of system that meets 25,000 hours durability

ǂ5 to 7 cents/kWh, 90% capacity factor at $1500/kW
*5 to 7 cents/kWh, 90% capacity factor at $460/kW
** See Hydrogen Technologies Plenary presentation for more information about pending Program Record

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

ǂStorage costs based on 2019 storage cost record

All costs based on $2016

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

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Hydrogen Energy Earthshot

“Hydrogen Shot”

“1 1 1”

$1 for 1 kg clean hydrogen in 1 decade

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

Strategy includes Hydrogen Shot

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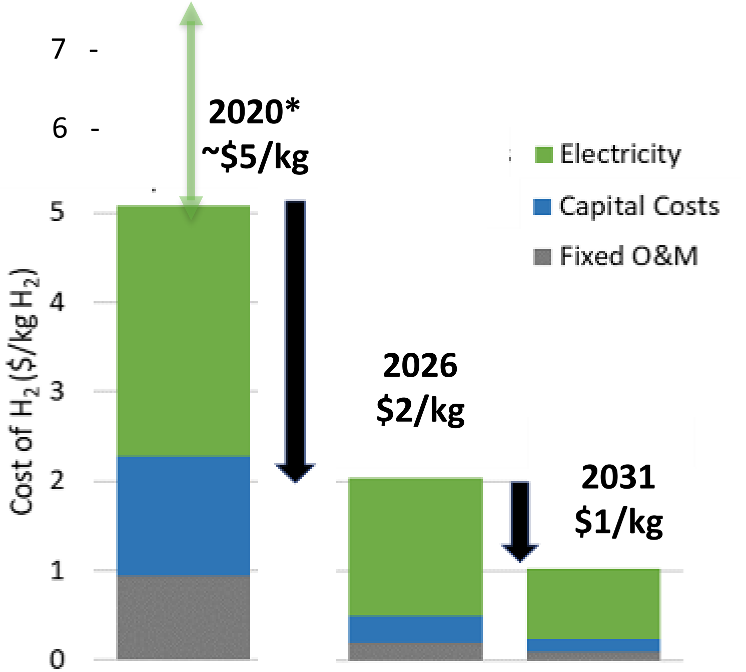
* Baseline 2020 cost: PEM $1,500/kW, $50/MWh, 90% capacity factor

How to reduce cost? Examples across multiple pathways

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

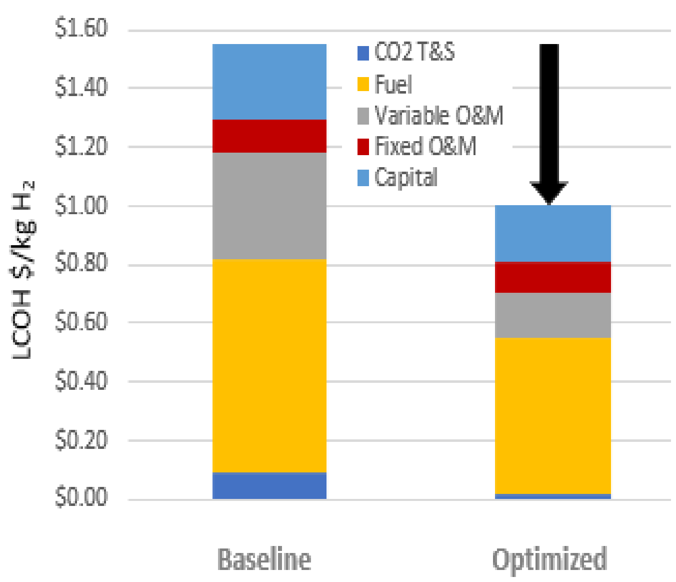
H_2 from Electrolysis



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

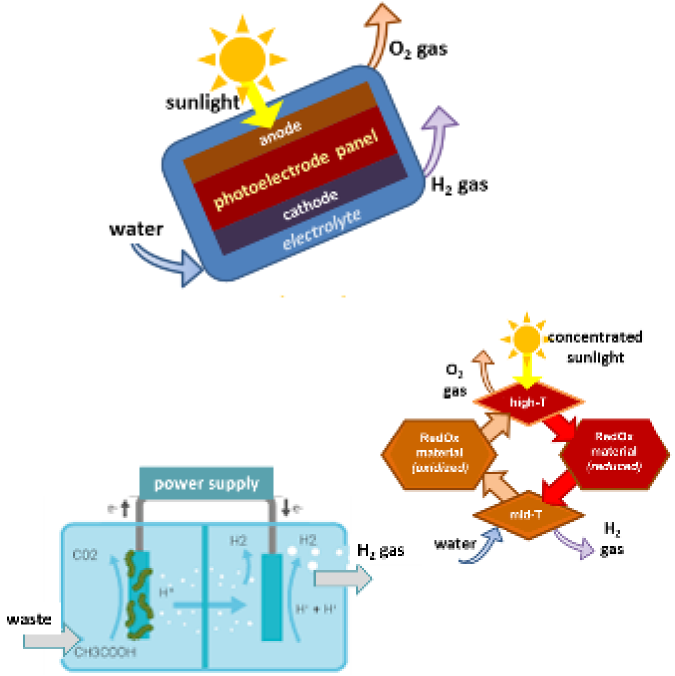
Thermal Conversion

Example: Natural Gas Conversion + CCUS



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

Advanced Pathways

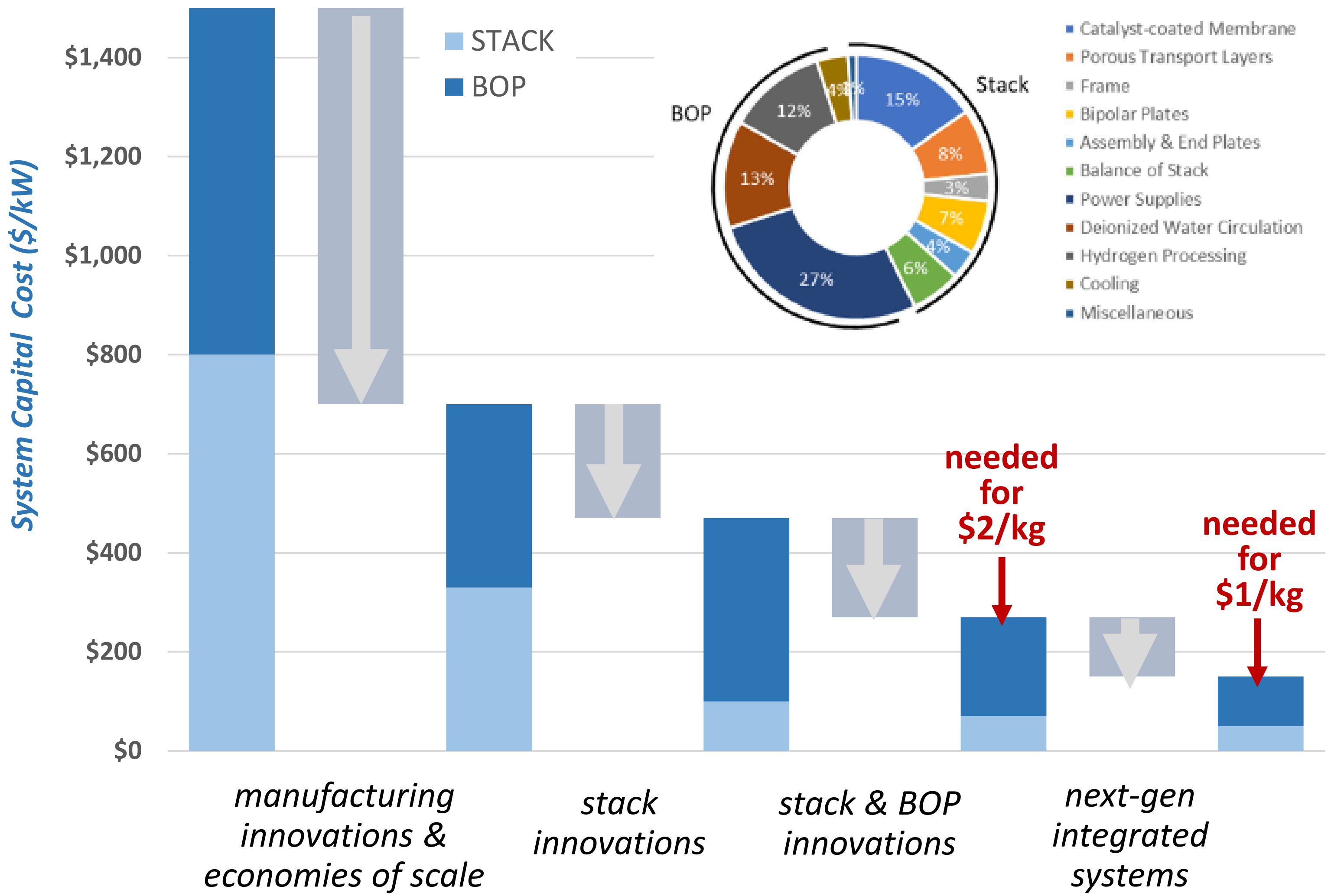


- Photelectrochemical (PEC), thermochemical, biological, etc.

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

Scenario to Reduce PEM Electrolyzer Cost

Need Demonstrations & Deployments, together with Research & Development



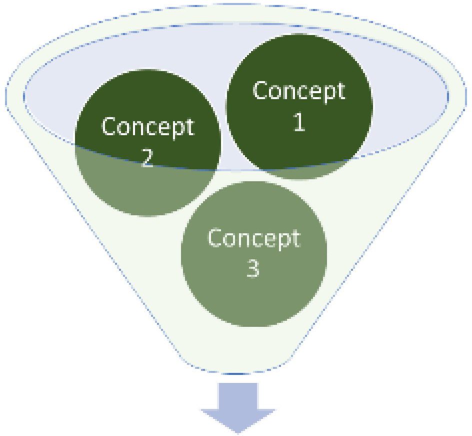
- **Increase manufacturing volume (multi-GW)**
- **Reduce capital cost <$300/kW by 2025, ~150/kW by 2030**
- **Maintain performance and durability while addressing stack and balance-of-plant (BOP) costs**

All Tools in the Toolbox Needed to Achieve Hydrogen Shot

Mechanisms for Innovation across the RDD&D Pipeline to achieve Hydrogen Shot

Hydrogen Shot Incubator Prize

Complements conventional FOAs



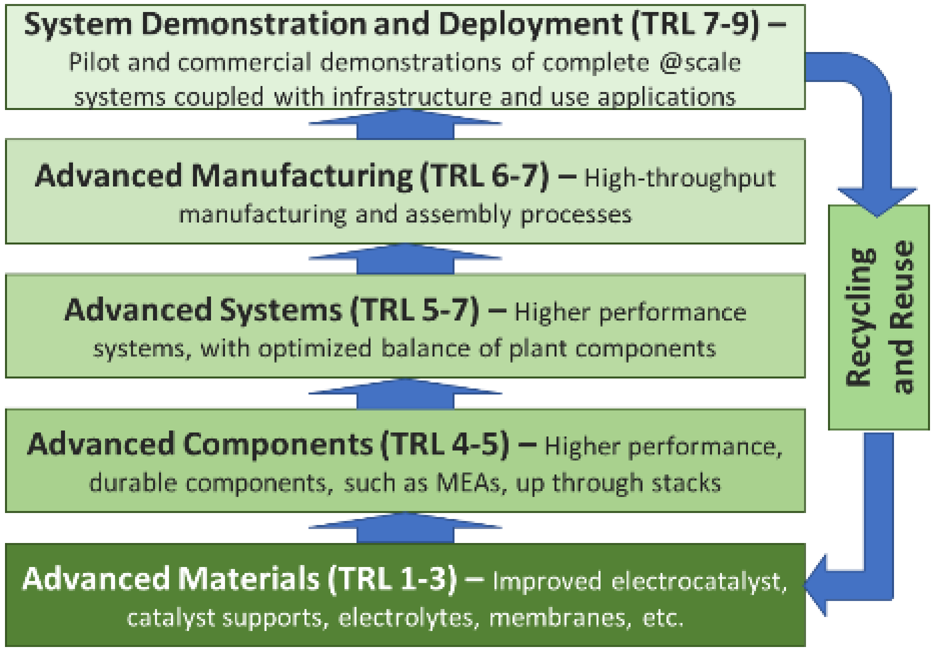
Hydrogen Shot Screener

Provide vouchers for entrepreneurs to use national lab experts for proof of concept

Pitch to investors or apply for future FOAs

FOAs, Consortia, Demos, H2 Hubs, Loan Guarantees

Feedback Requested on Industry Needs



AI and machine learning tools explored with AI Office
De-risk demos and validate integrated systems
Ramp up scale through demos and H2 Hubs

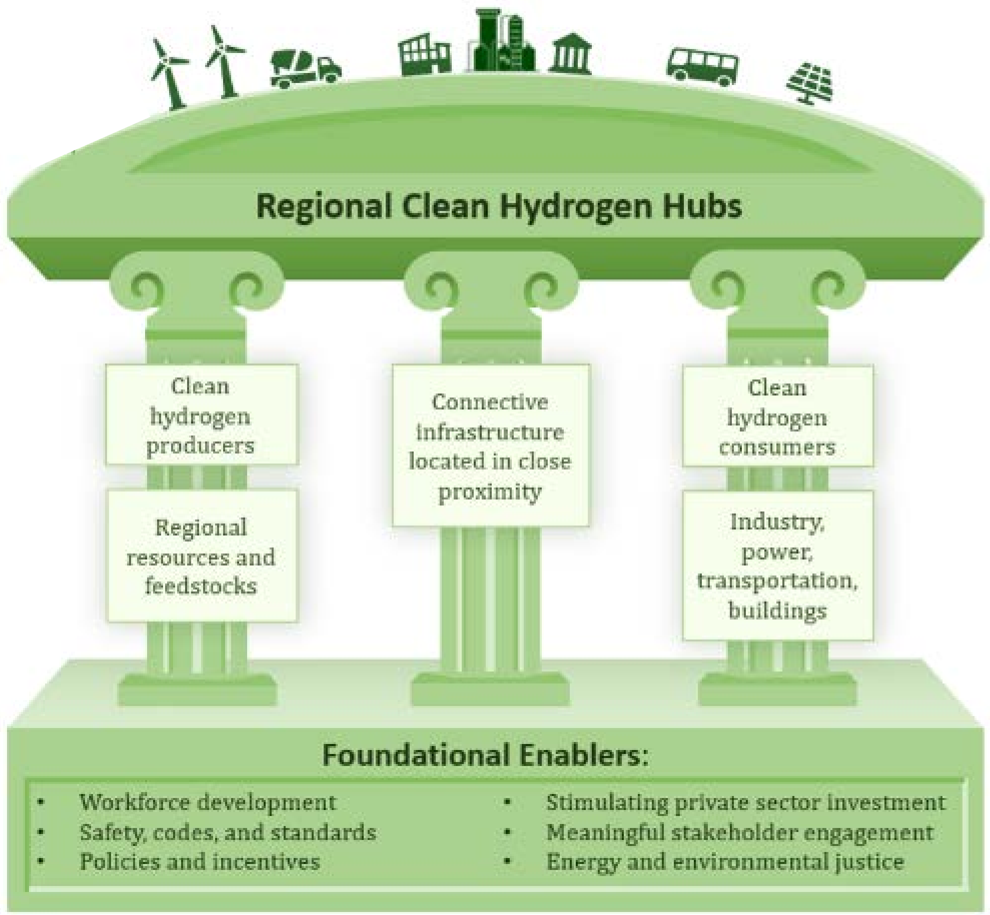
Hydrogen Shot Incubator Prize

Incentivize development of **innovative off-roadmap technologies** with the potential to produce clean hydrogen at $1/kg in one decade

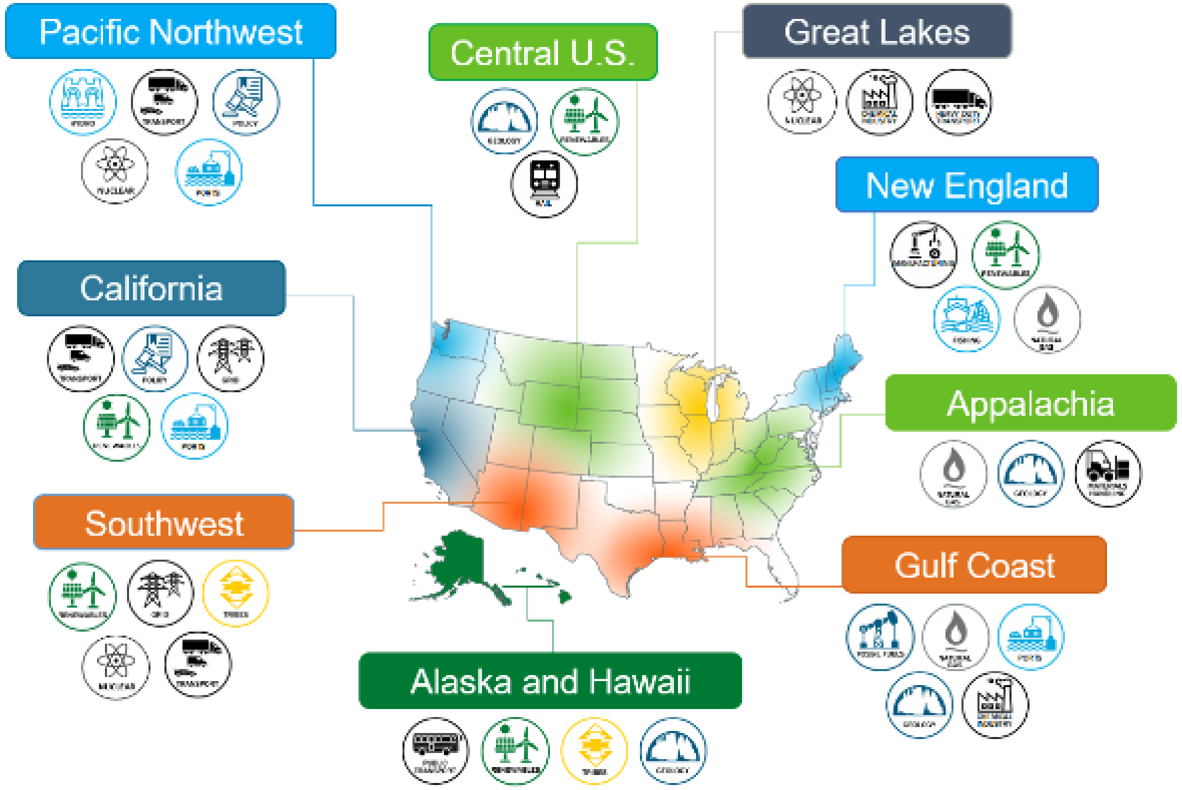
Learn More: www.herox.com/HydrogenShotPrize

Focus on Regional Networks

Build Regional Networks through "Clean Hydrogen Hubs"



Examples of Stakeholder and RFI Input



RFI findings: Regional clusters and geographic factors

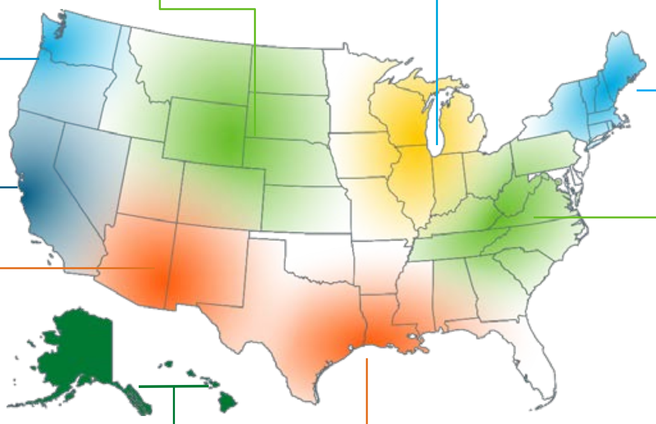
Pacific Northwest
- *Port communities*
- *Tribal communities*
- *Extensive renewables*
- *8 jobs per $1M invested in H_2*

California
- *Diverse populations*
- *Extensive infrastructure*
- *Emissions regulations*
- *40,000+ jobs*

Southwest
- *Tribal and Hispanic communities*
- *Underutilized solar*
- *Nuclear power*
- *Up to 2B tonnes/yr emission reduction potential*

Central U.S.
- *Ample wind*
- *Geological storage*
- *Railway transport*
- *Nuclear resources*
- *>630,000 tonnes/yr CO_2 reduction*

Great Lakes
- *Major national corridors*
- *Nuclear power*
- *60,000+ jobs*



Alaska and Hawaii
- *Extensive renewables – geothermal, solar, ocean*
- *Backup power*
- *Isolated communities*
- *86,000 tonnes/yr emission reduction*

New England
- *Offshore wind*
- *Fishing communities*
- *Backup power and winter heating*
- *~120K tons CO_2/year reduction*

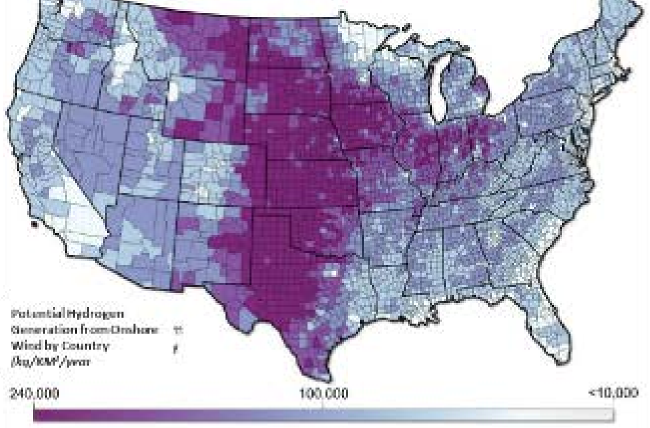
Appalachia
- *Retiring fossil plants*
- *Mining, refining transferable skills*
- *Carbon capture and sequestration*
- *70,000 tons/yr H_2 production*

Gulf Coast
- *Existing infrastructure*
- *Multiple opportunity zones*
- *Renewable resources*
- *1,000s of jobs*
- *Chemical industry*

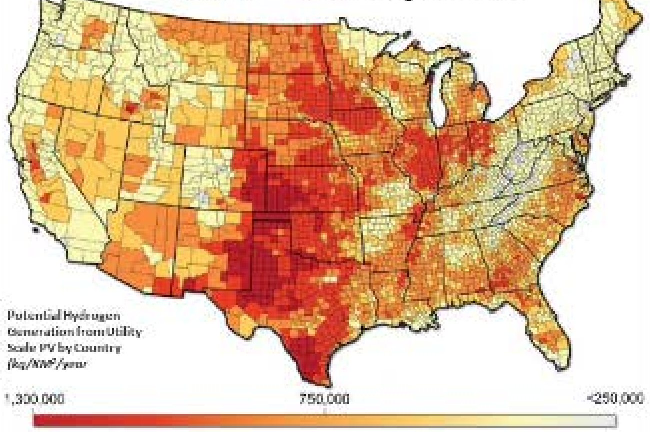
Resource Analysis Helps Identify Clean-Hydrogen Opportunities

Deployments are likely to vary regionally depending on availability of resources and CCS

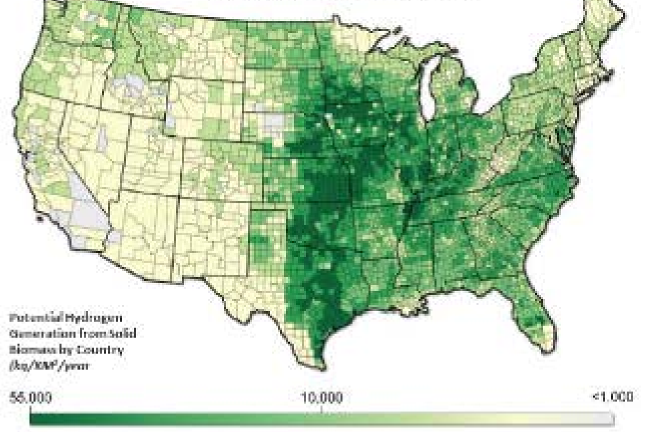
On-shore wind



Solar – Utility Scale



Solid Biomass

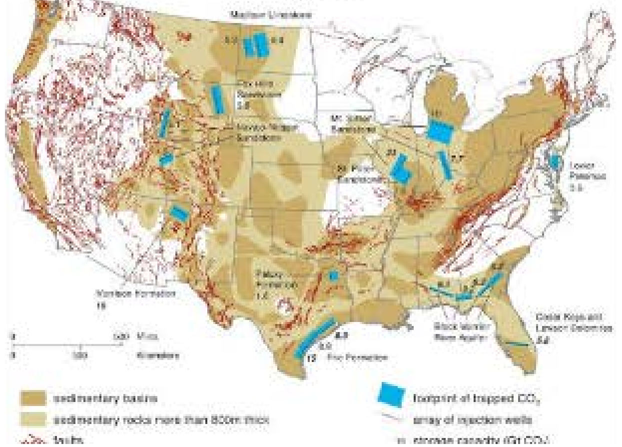


Nuclear

Natural Gas*

*Steam methane reforming facilities for most of the data points.

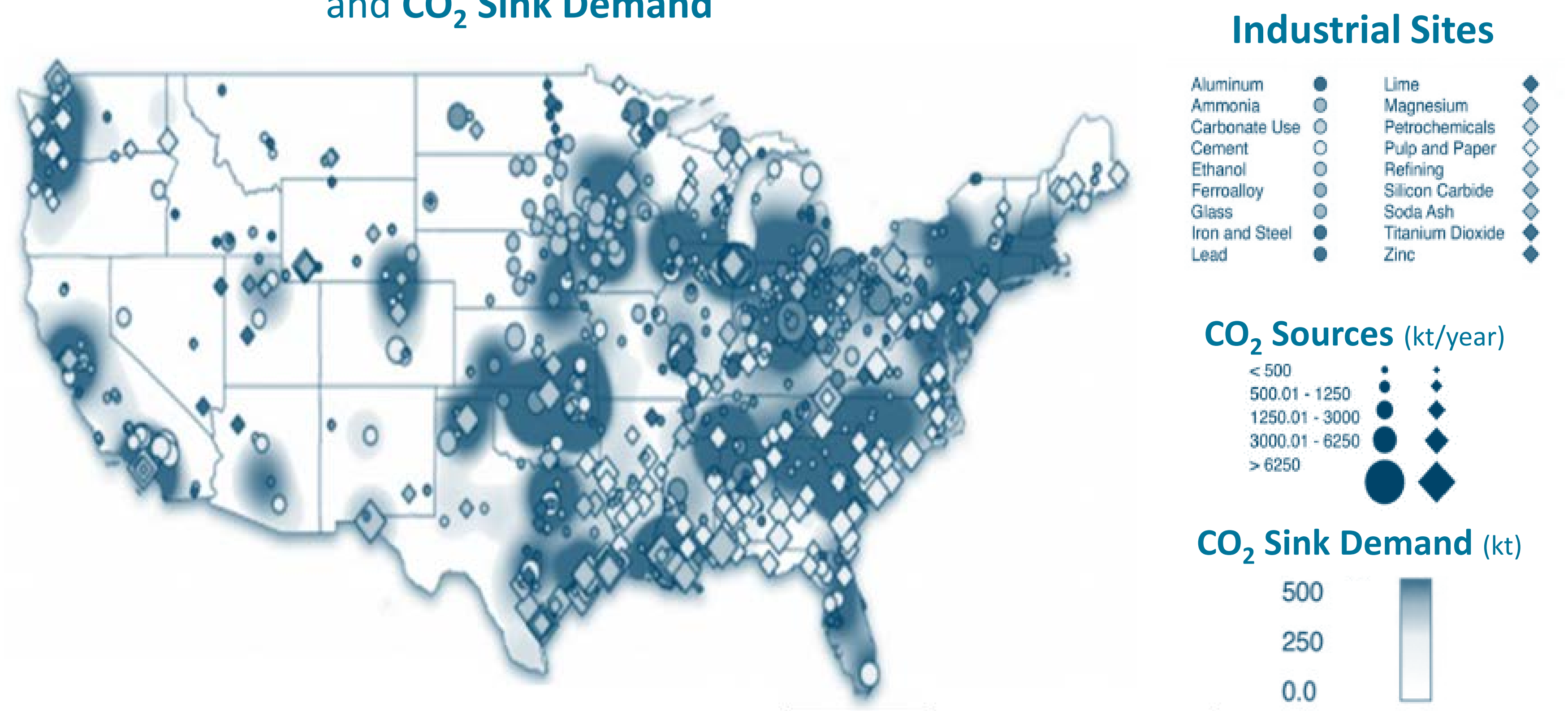
CCS



Industrial Clusters as Basis for Potential Hydrogen Hubs

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**

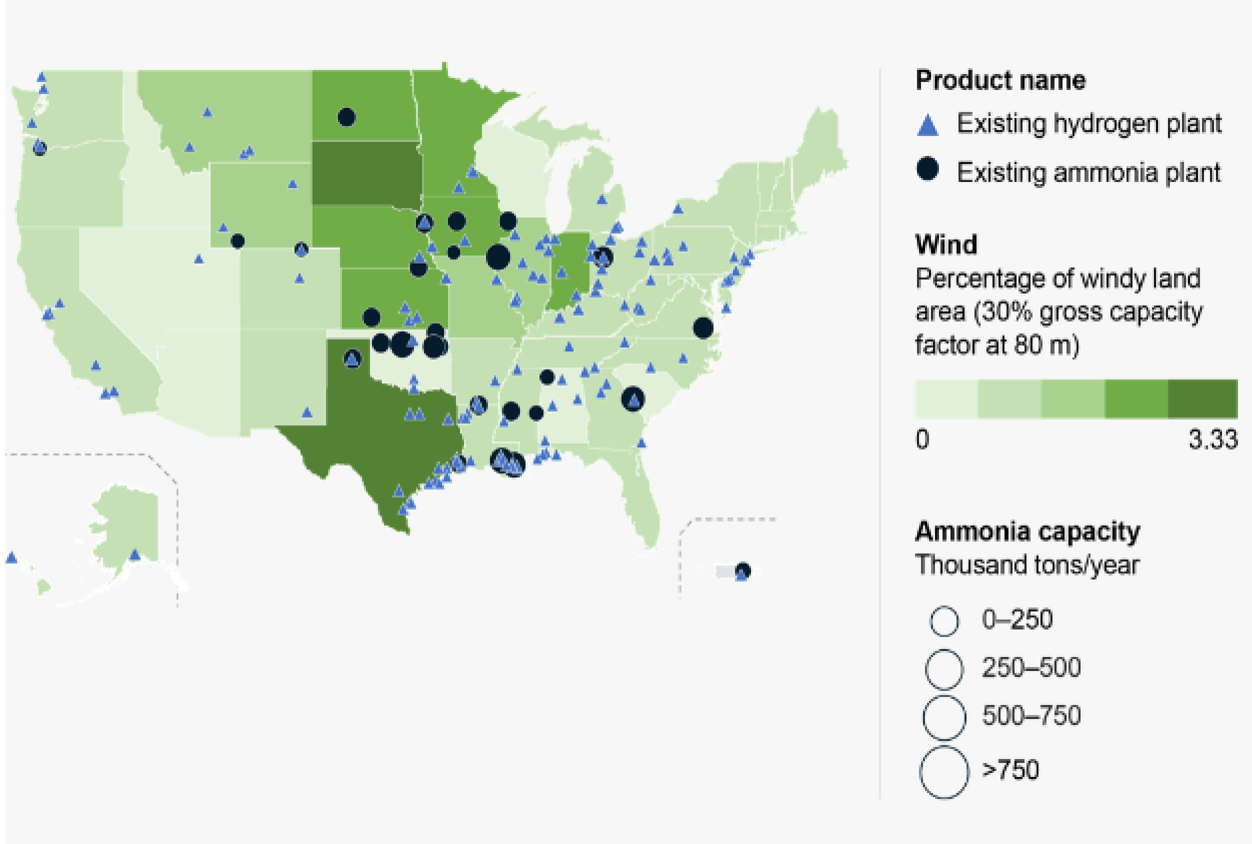


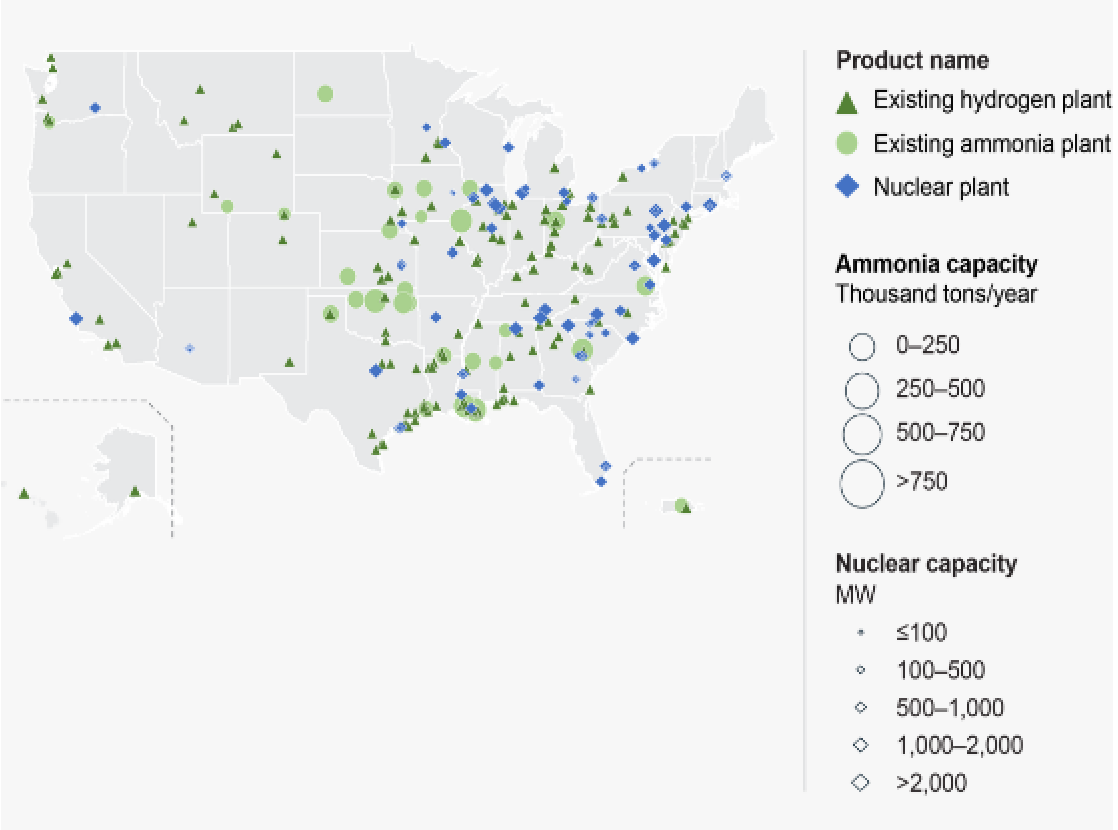
Mapping industrial sites to CO_2 sources and demands can help identify **industrial clusters for potential decarbonization hubs**

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

Example of Matching Supply and Demand: H_2 Potential and Ammonia Production Plants

Resource mapping helps identify regions with substantial resources of clean energy and hydrogen demand, to inform early deployments. Examples show hydrogen, ammonia, wind, and nuclear.





Adapted from national lab, H2@Scale, and US Industry Hydrogen Roadmap

Ongoing Work and Accomplishments to Address Key Priorities

Program Enabled Accomplishments

Innovation

1,256 Patents

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

35% 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

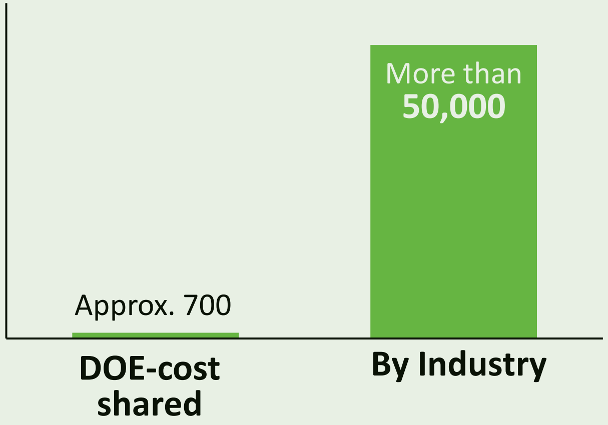
PEM Electrolyzer System
Giner

Hydrogen Tanks

Optimized 129L Tank
Quantum Technologies

Market Uptake

Hydrogen fuel cell forklifts in the U.S.



American-made small-scale hydrogen refueler

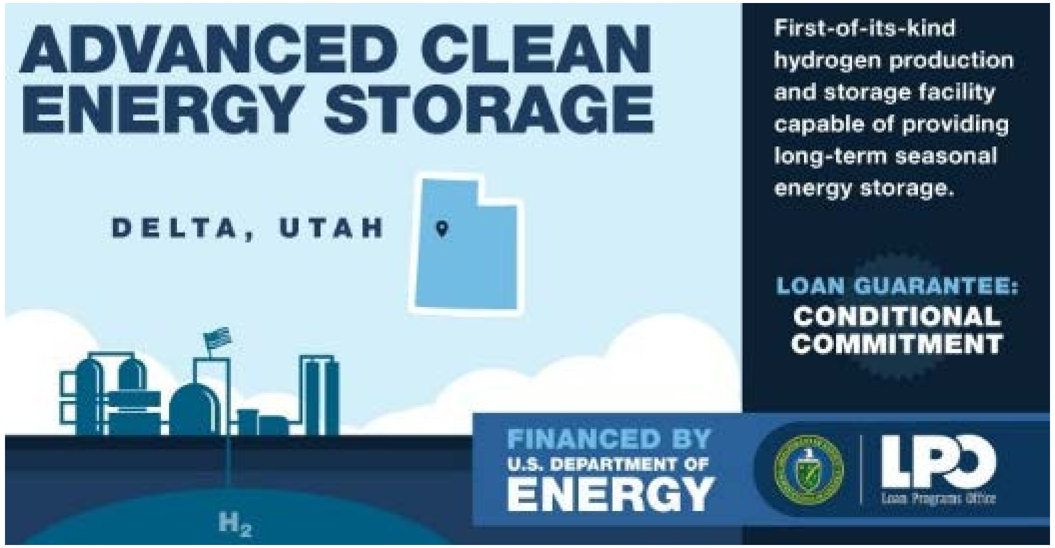
- Exported to Japan
- Uses electrolysis

Financing to Enable Deployment at Scale

Loan Programs Office (LPO) has $40 Billion in Available Debt Capital

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)

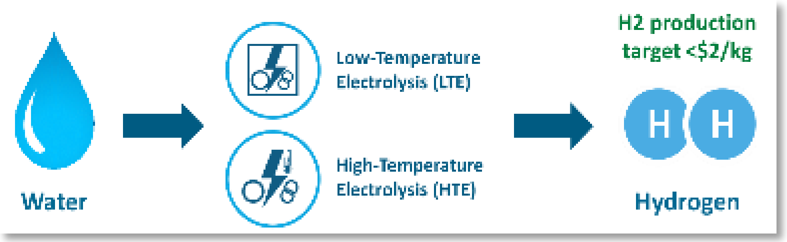


$504.4M for large-scale hydrogen energy storage, 220 MW electrolysis and turbine. Will enable up to 400 construction jobs and 25 operations jobs. (April 2022)

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

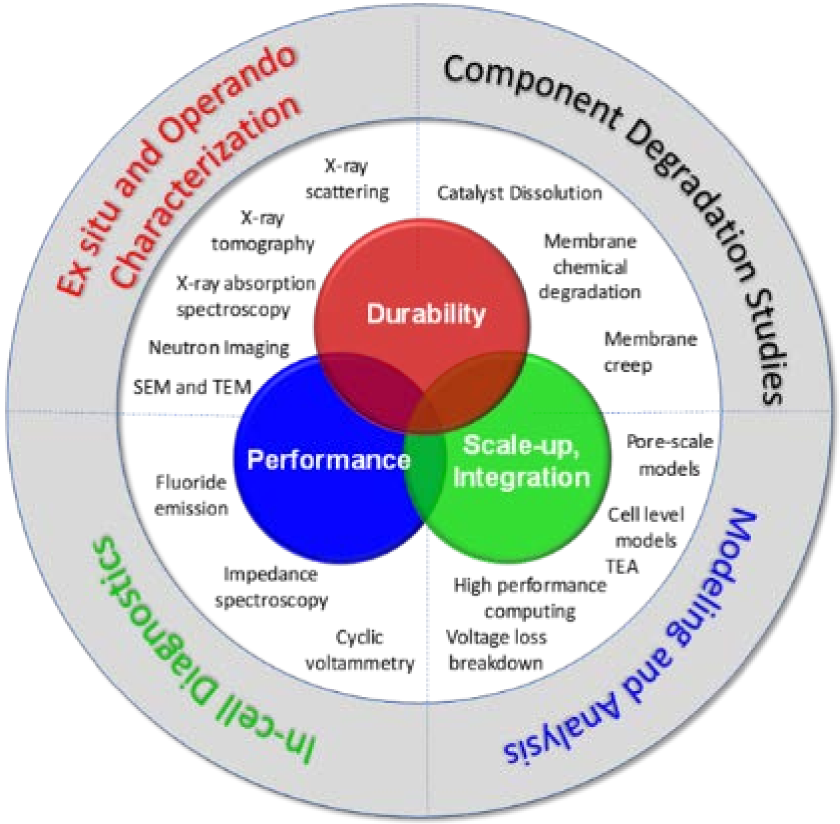
H2NEW Consortium to Accelerate Progress in Electrolyzers

H2NEW
U.S. DEPARTMENT OF ENERGY



Combines world-class experimental, analytical, and modeling tools

Electrolyzer Stack Goals by 2025		
	LTE PEM	HTE
Capital Cost	\$100/kW	\$100/kW
Elect. Efficiency (LHV)	70% at 3 A/cm^2	98% at 1.5 A/cm^2
Lifetime	80,000 hr	60,000 hr



Consortium Team

NREL, INL, Pacific Northwest, Argonne, Lawrence Livermore National Laboratory, NETL National Energy Technology Laboratory, Los Alamos, Oak Ridge National Laboratory, NIST, Berkeley Lab, Carnegie Mellon University, Colorado School of Mines, UC Irvine

Includes focus on durability to:

- → Improve understanding of degradation mechanisms
- → Develop and validate accelerated degradation processes to evaluate durability

Million Mile Fuel Cell Truck Consortium (M2FCT)

MILLION MILE FUEL CELL TRUCK
U.S. DEPARTMENT OF ENERGY

MISSION

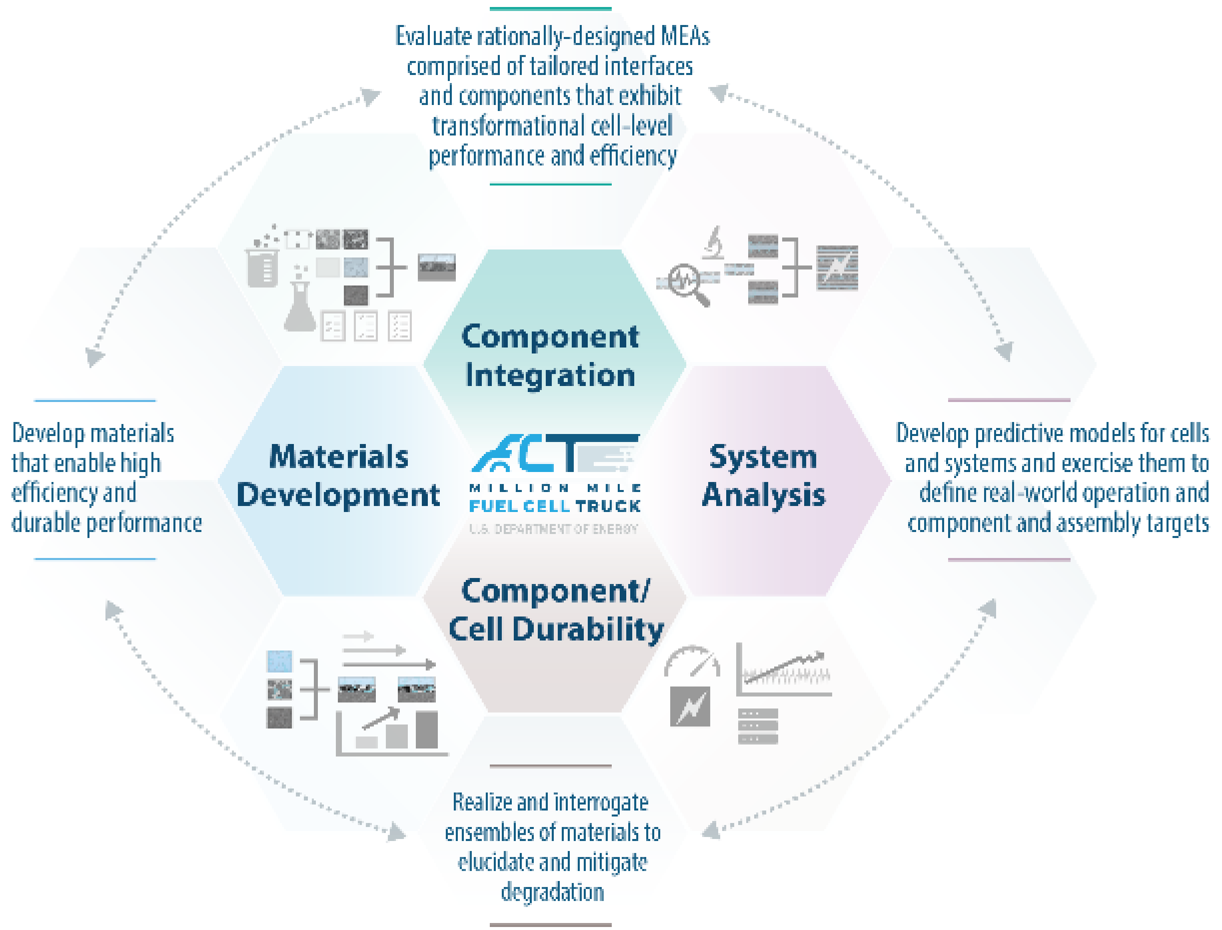
Advance efficiency and durability, and lower cost, of PEMFCs for heavy-duty vehicle applications

APPROACH

Pursue a “team-of-teams” approach with teams in analysis, durability, integration, and materials development

OBJECTIVE

Achieve MEA target :
2.5 kW/g_{PGM} power (1.07 A/cm^2 current density) at 0.7 V after 25,000 hour-equivalent AST



MEAs
gm, Carnegie Mellon University, NIKOLA

Membranes
Lubrizol, 3M, NIKOLA

Stacks
Cummins, plug

Bipolar Plates
Raytheon Technologies, NEOGRAF SOLUTIONS, TreadStone Technologies, Inc., gm, plug

Air Management
CATERPILLAR, EATON, R&D Dynamics Corporation, MAHLE Driven by performance

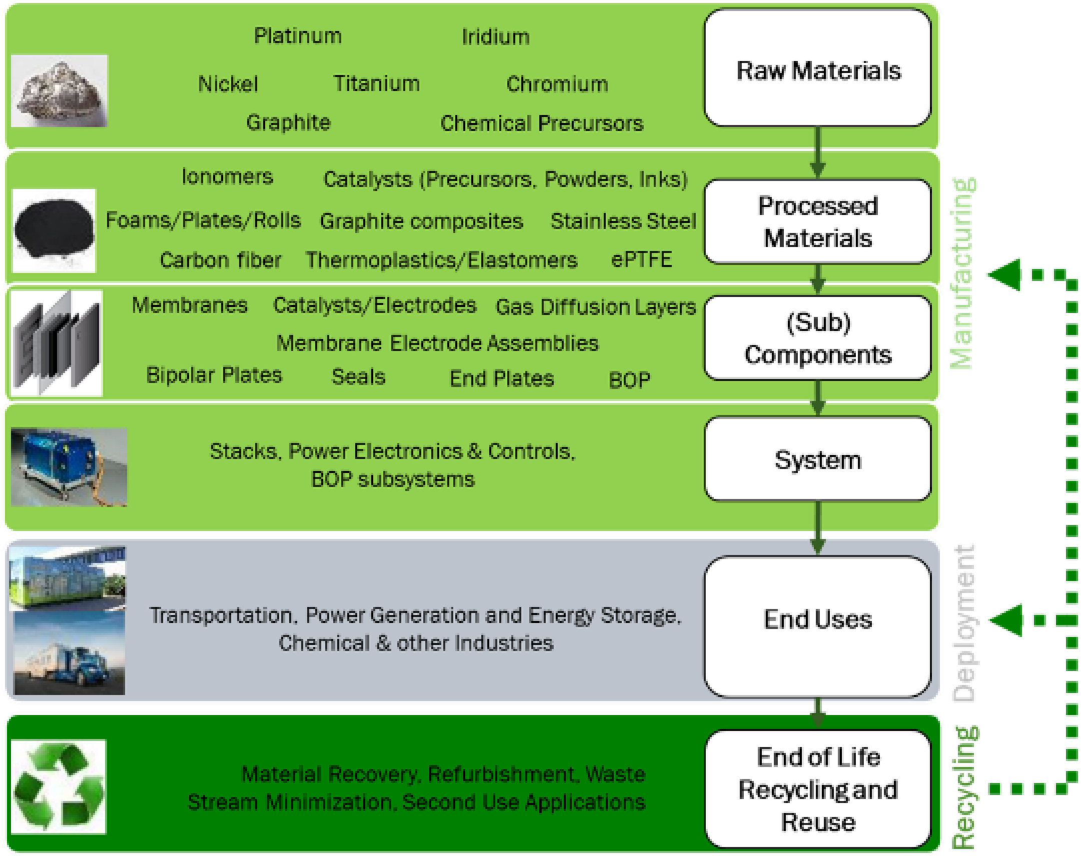
Main Laboratories
Los Alamos National Laboratory, Oak Ridge National Laboratory, Argonne National Laboratory, Berkeley Lab, NREL National Renewable Energy Laboratory

Affiliate Laboratories
Pacific Northwest National Laboratory, NIST National Institute of Standards and Technology, Brookhaven National Laboratory

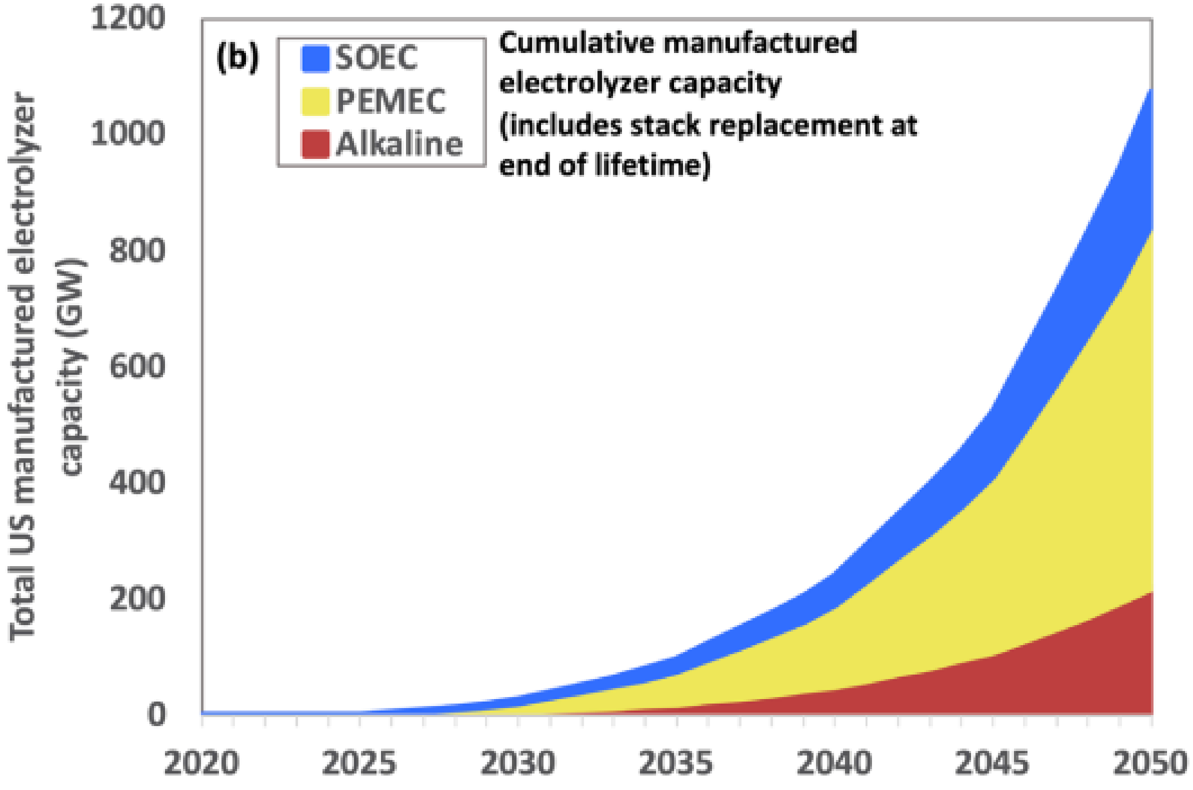
Released Supply Chain Report

Investigated key U.S. opportunities to enable the growth of electrolytic hydrogen and fuel cell markets

Example: PEM fuel cell & electrolyzer supply chain



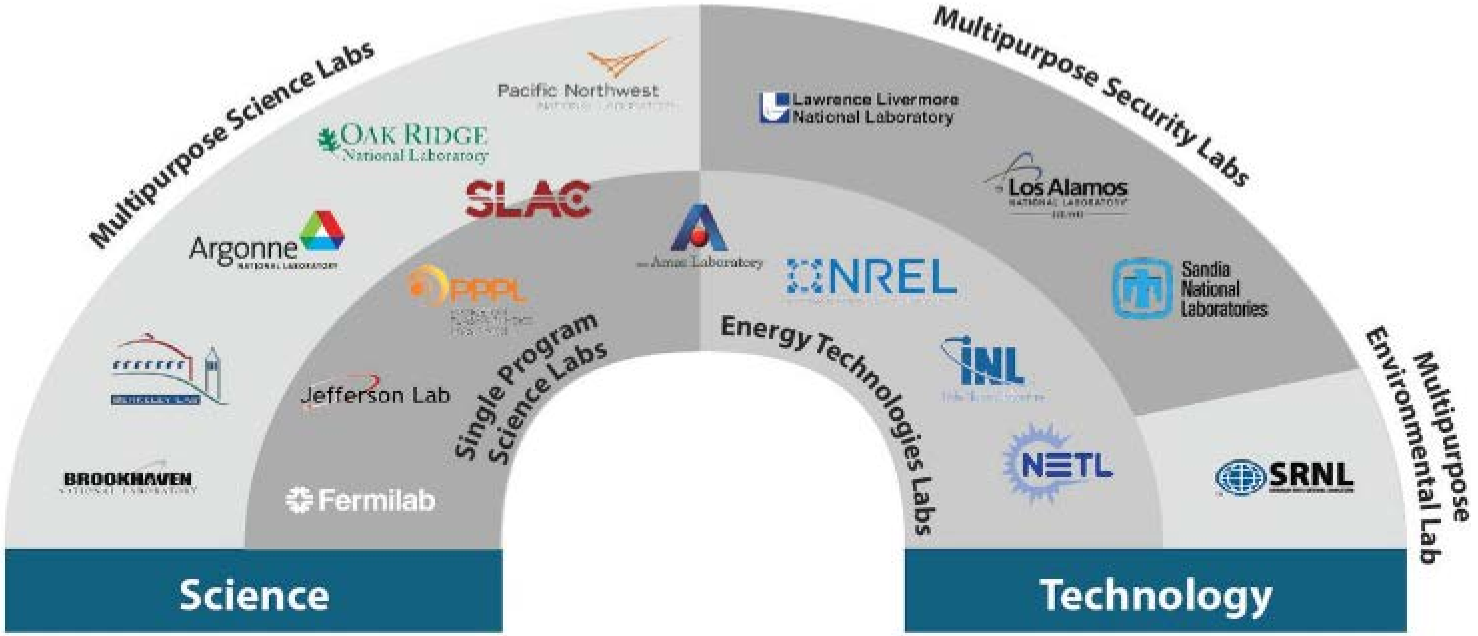
Example: Scenario for U.S. electrolyzer capacity



More information: www.energy.gov/eere/fuelcells/water-electrolyzers-and-fuel-cells-supply-chain-deep-dive-assessment

DOE National Laboratories

Strategy leverages DOE National Laboratories, partnering with industry and academia

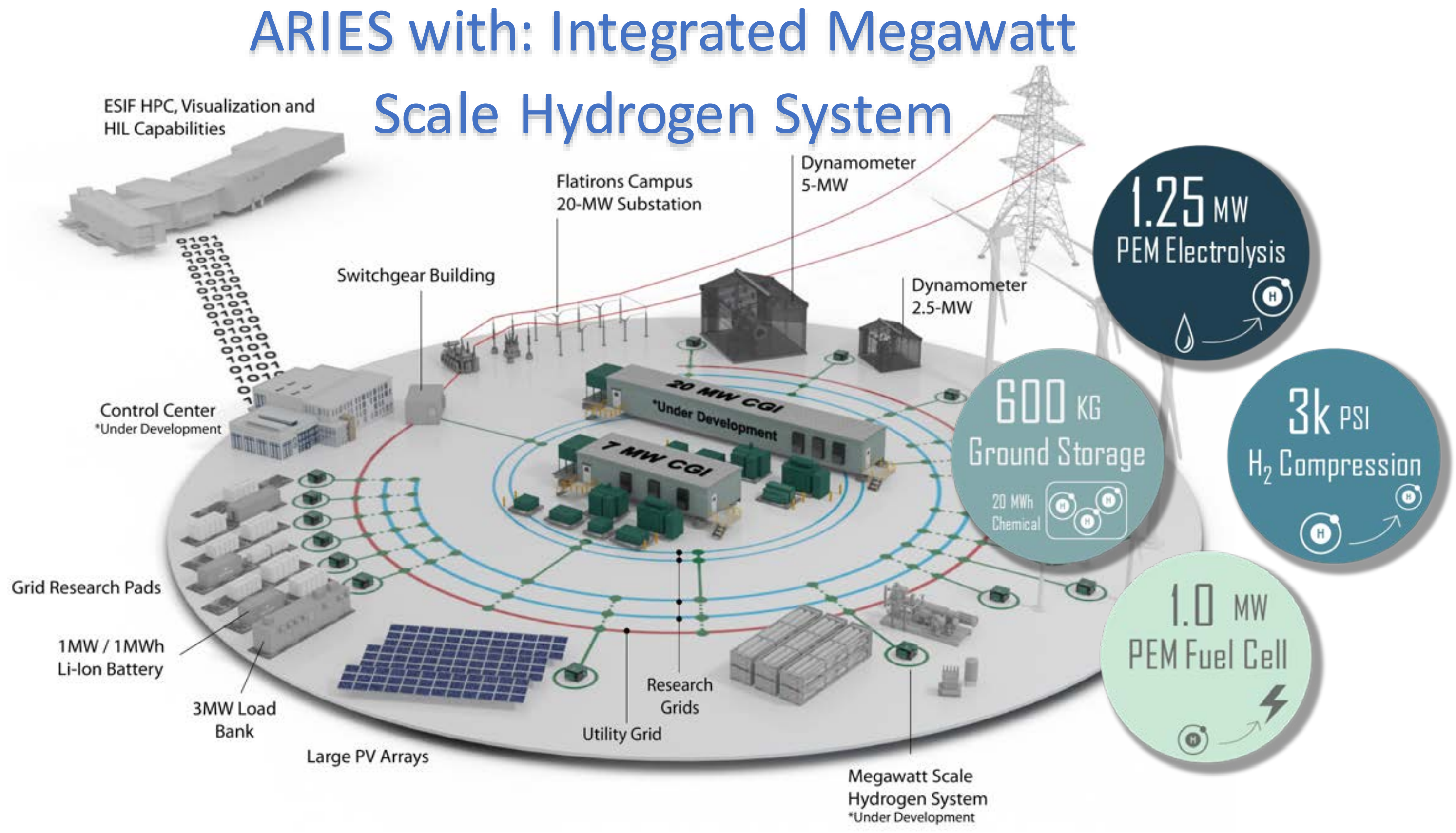


DOE National Laboratories across energy, science, and security:

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

2021 H2@Scale CRADA Call Results

Topic 1: H2@ARIES – Integrated Hydrogen Energy System Testing/Validation



Advanced Research on Integrated Energy Systems (ARIES)

- **NREL, SoCalGas, University of California Irvine:** Validation of interconnection and interoperability of grid-forming inverters sourced by H_2 technologies in view of 100% renewable microgrids (TA062)
- **NREL, GKN Powder Metallurgy, SoCalGas:** High Efficacy Validation Of HYdridE MEga Tanks at the ARIES Lab (HEVHY METAL) (TA063)
- **NREL, EPRI:** Hydrogen Production, Grid Integration, and Scaling for the Future (TA064)
- **NREL, GE Renewable Energy, Nel Hydrogen:** Optimal Wind Turbine Design for H_2 Production (TA061)

Additional Projects Supporting ARIES

Topic 2: Applied Risk Assessment and Modeling for H2@Scale Applications

- **PNNL, SNL, Seattle City Light, Port of Seattle:** Large-Scale Hydrogen Storage – Risk Assessment Seattle City Light and Port of Seattle
- **SNL, Wabtec:** Risk Assessments of Design and Refueling for Hydrogen Locomotive and Tender (SCS033)


ARIES H_2 System at NREL Flatirons Campus


ARIES H_2 System at NREL Flatirons Campus

Topic 3: Next-Generation Sensor Technologies (wide-area H2 sensors)

- **NREL, NETL, GTI, EPRI, Paulsson Inc., Renewable Innovations, Inc., Boyd Hydrogen LLC, Element One:** Next Generation Hydrogen Leak Detection – Smart Distributed Monitoring for Unintended Hydrogen Releases

https://www.energy.gov/eere/articles/doe-announces-nearly-8-million-national-laboratory-h2scale-projects-help-reach

HyBlend and H-Mat Consortia—Opportunities Available

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

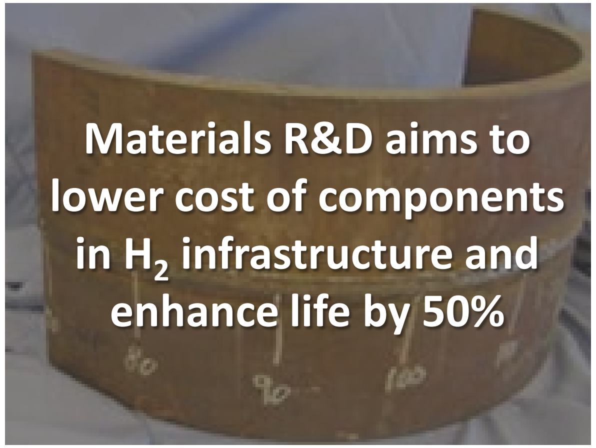
H-Mat Hydrogen Materials Compatibility Consortium

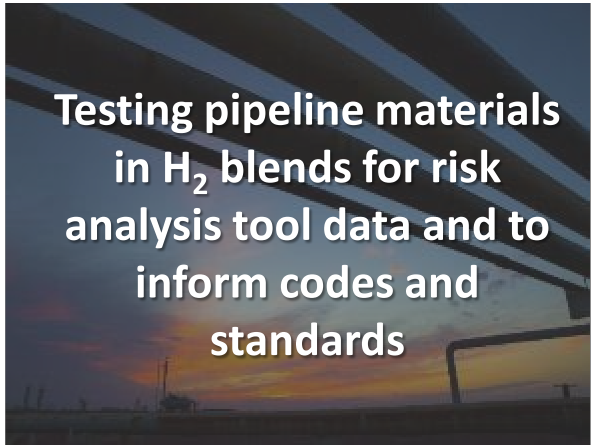
National lab consortium to assess and improve performance and reliability of materials in hydrogen, reduce costs, and inform codes and standards

HyBlend U.S. DEPARTMENT OF ENERGY

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

Over 30 partners





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

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

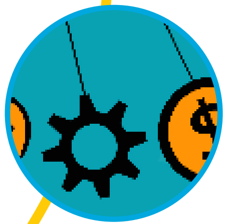
First-of-a-kind Hydrogen Business Case Prize—Links Students with Experts

Concept

Development of user-friendly computational tools that characterize regional value propositions for hydrogen in multiple applications, including co-locating supply and demand

Goals

Educational opportunities through mentoring sessions and potential internships



Inform stakeholders about investment opportunities

Winners

- ***1st place:* Super Hydrogen Family** – USC, U of S. Florida, U of Central Florida (see #SA185)
- ***2nd place:* Bend Hydrogen** – Oregon State (see #SA182)
- ***3rd place:* Pure Hydrogen** – UC Berkeley (see #SA183)
- ***4th place:* H24SCR** – U of Oklahoma

Coordinated by,
Masha Koleva

Hydrogen Business Case Prize Mentors

Jamie Randolph

Andrew Martinez

THANK YOU, MENTORS!

Yuri Freedman

Kaz Nagasawa

Kun Zhang

Misho Penev

Freddie Briggs

Beth Carter

Kareem Afzal

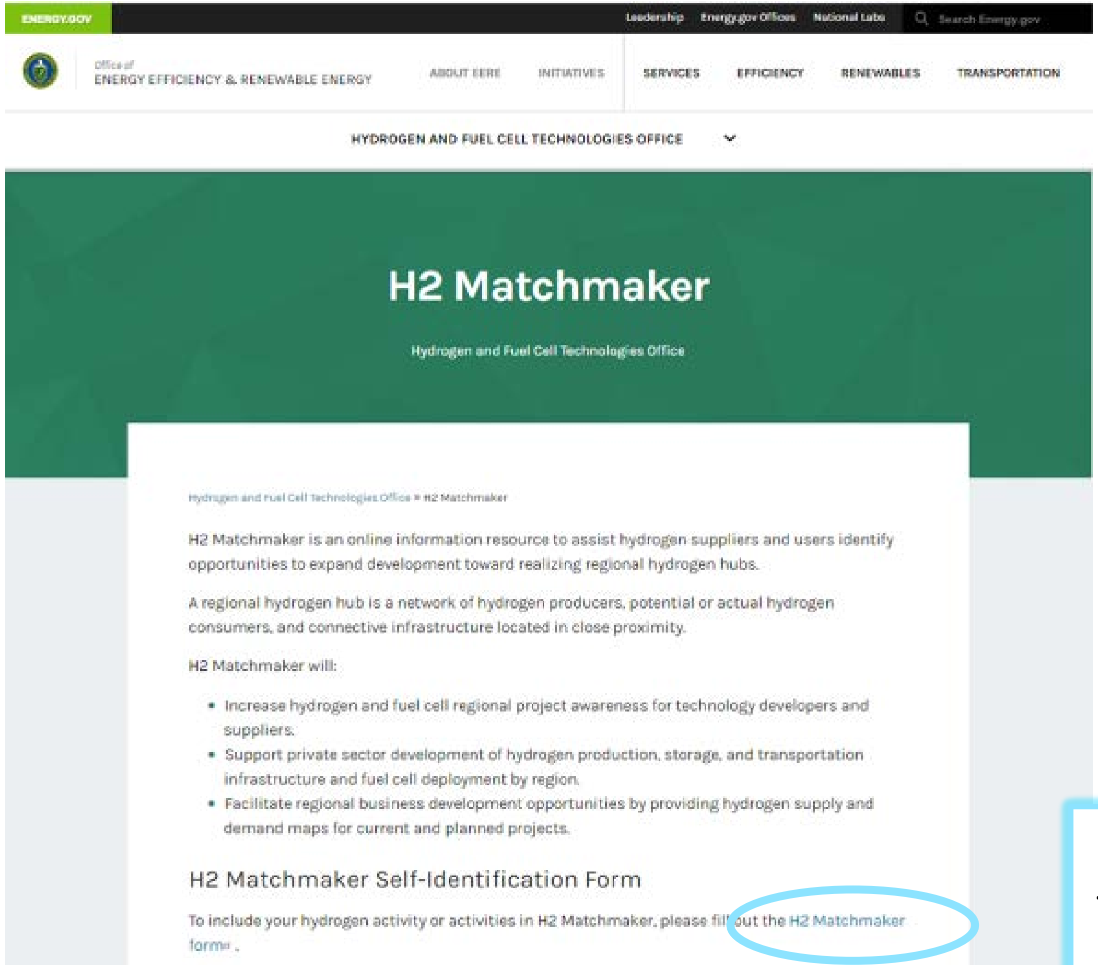
Growing Connections, Strengthening Networks

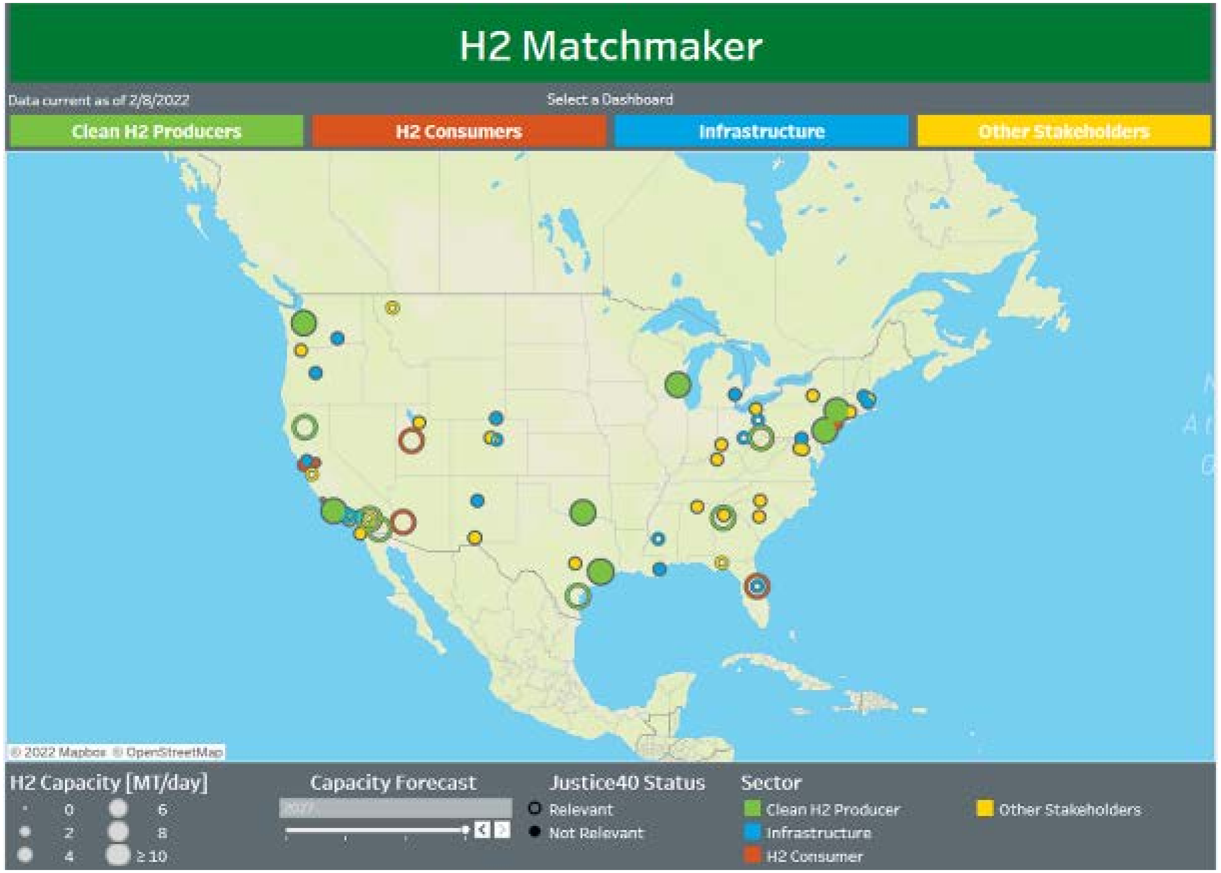
The redwoods are the tallest trees on earth—growing tall and enduring long dry spells—on harsh terrain and despite shallow roots.

They are able to do this through the collective strength of their roots which are an interwoven system, where each tree supports—and is supported by—the trees around it.

Developed and Launched H2 Matchmaker to facilitate H2 Hub Partnerships

Available at: www.energy.gov/eere/fuelcells/h2-matchmaker





This link will open the H2 Matchmaker self-identification form.

Promoting Safety includes Center for Hydrogen Safety (CHS) Activities

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

Over 80 members from industry, government, and academia—and growing!

CENTER FOR Hydrogen SAFETY Connecting a Global Community
FUNDAMENTAL
HYDROGEN SAFETY CREDENTIAL

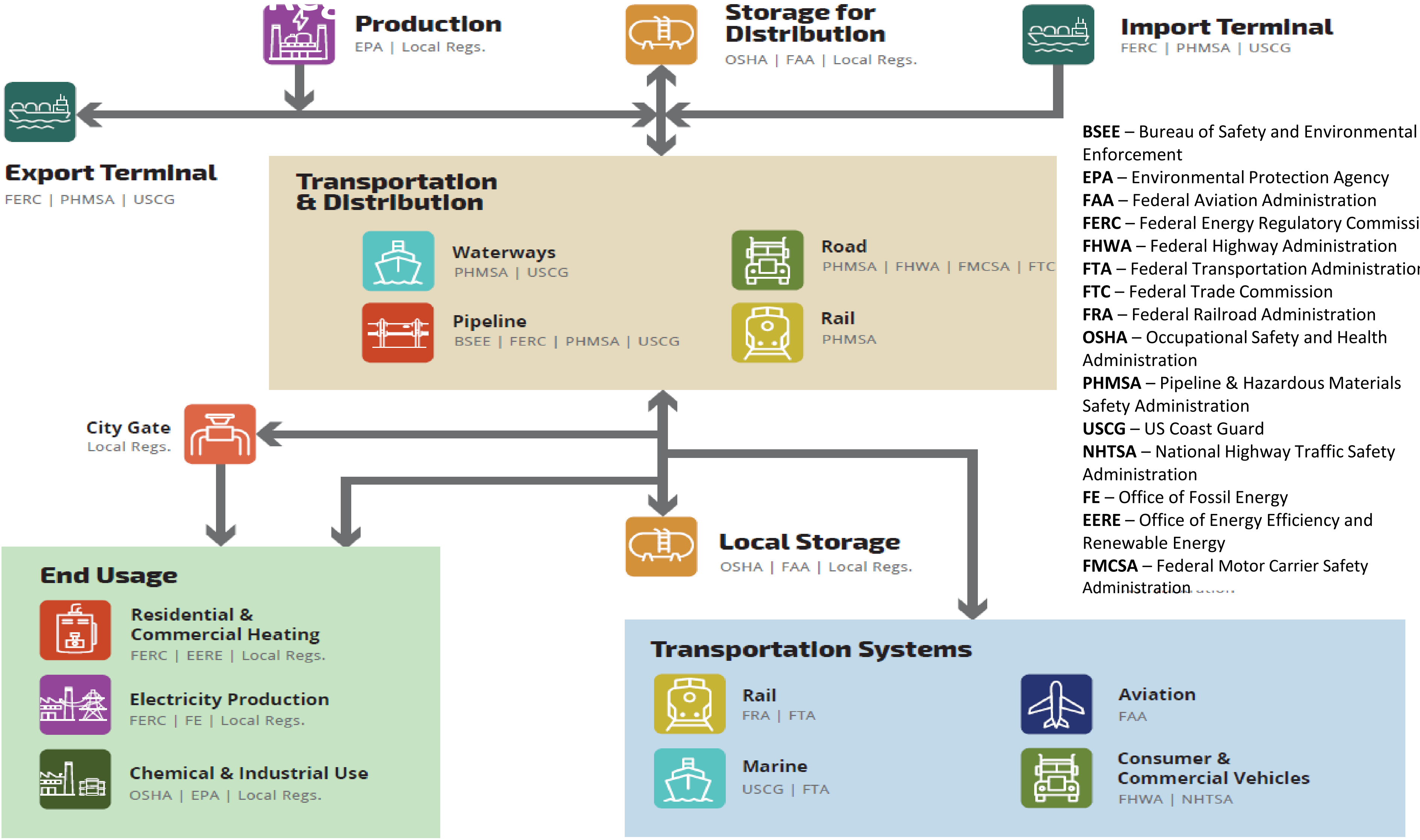
New Hydrogen Safety Credential!

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

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

www.aiche.org/CHS

Enabler: Developed Federal Regulatory Map & Identified Gaps



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

Gaps Identified

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

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

Interagency Working Group on Hydrogen and Fuel Cell Technologies

Partners	Examples of Collaborations & Focus Areas
DOE, DOT	Pipelines, buses, rail, marine, air, infrastructure
DOE, DOD across services	H2Rescue Truck for disaster relief, vehicles and infrastructure, Unmanned Underwater Vehicles (UUVs), microgrids and resiliency, and more
DOE, USPS	FC lift trucks and hydrogen infrastructure
DOE, NASA NSF	Cryogenic hydrogen systems, fuel cells, electrolyzers, storage (NASA), DOE consortia (NSF)
DOE, DOC, NIST	Metering, diagnostics, supply chain
DOE, EPA	Clean hydrogen standard, emissions analysis

IWG members share RDD&D information on their programs and collaborate through joint projects and gap analysis

H2Rescue Truck; DOE, DOD, FEMA

POC: Pete Devlin, HFTO, EERE

H2 Twin Cities Initiative Launched at COP26

Connecting Communities Around the World to Deploy Clean Hydrogen Solutions

Phase 1: November 10 – December 29, 2021

Phase 2: January 3 – March 18, 2022

Selections WG will evaluate proposals

Applicants self-identify and self-pair on the H2 Twin Cities website

A single, joint application is prepared

Open submission

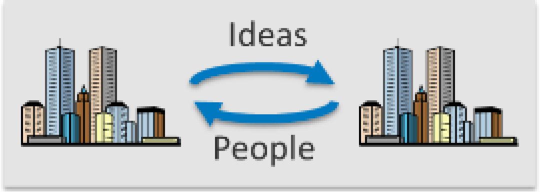
Deadline extended to July 25

OFFICIAL APPLICATION GUIDELINES

H2 Twin Cities 2021

Pairing Types

Sibling Cities



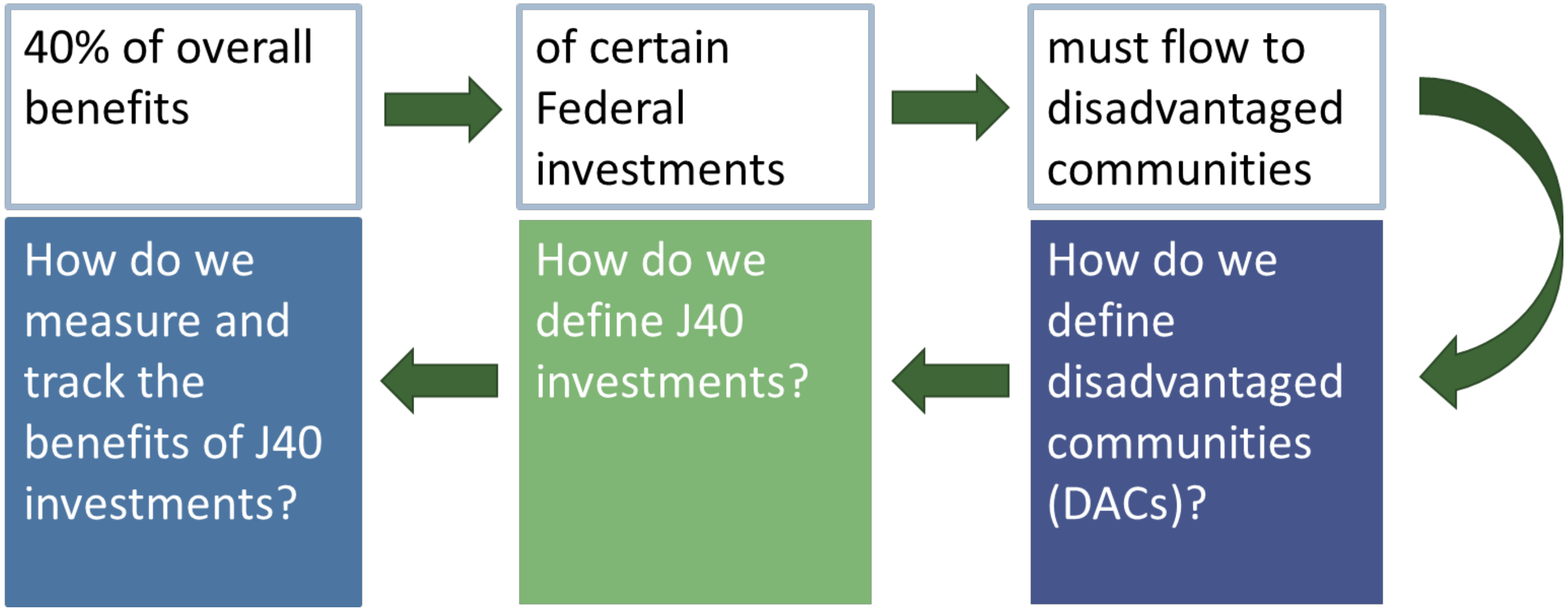
Mentor - Mentee

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


Diversity, Equity, and Inclusion
Environmental Justice
Workforce Development

Primary Elements of DOE Justice40

E.O. 14008, s. 223 - 40% of the overall benefits of certain Federal investments must flow to disadvantaged communities.
Interim Implementation Guidance for the Justice40 Initiative. https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf



See Feb 2022 HFTO H2IQ Webinar
https://www.energy.gov/eere/fuelcells/2022-hydrogen-and-fuel-cell-technologies-office-webinar-archives#02242022

DOE Interim DACs Definition

Disadvantaged communities

Current Thoughts:

- Census Tract Level
- 36 Indicators

VULNERABIILITY

FOSSIL DEPENDENCE

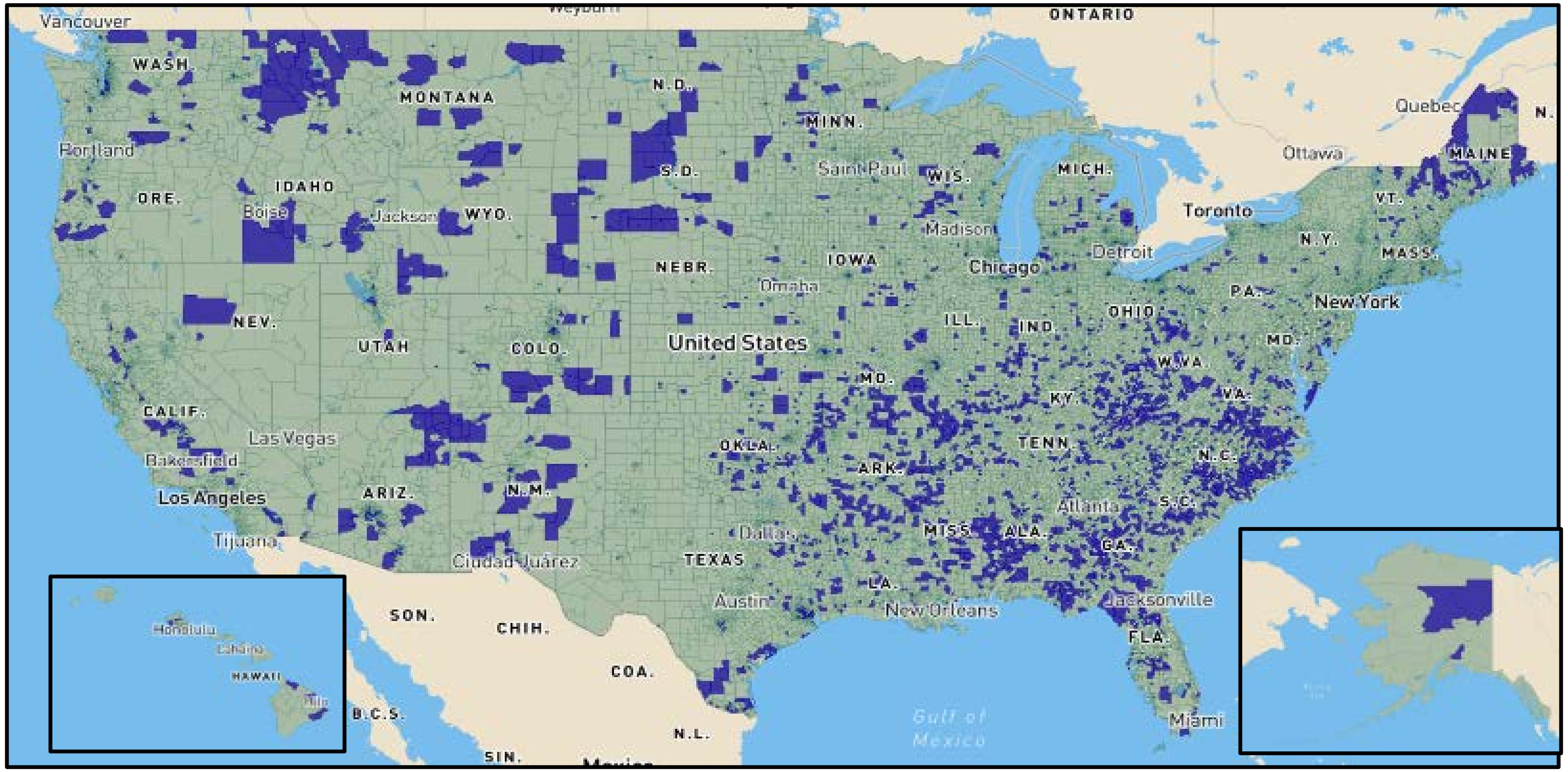
ENERGY BURDEN

ENVIRONMENTAL HAZARDS

Can also identify non-geographic DACs – groups that share a common characteristic

Distribution of census tracts identified as geographic DACs

DAC

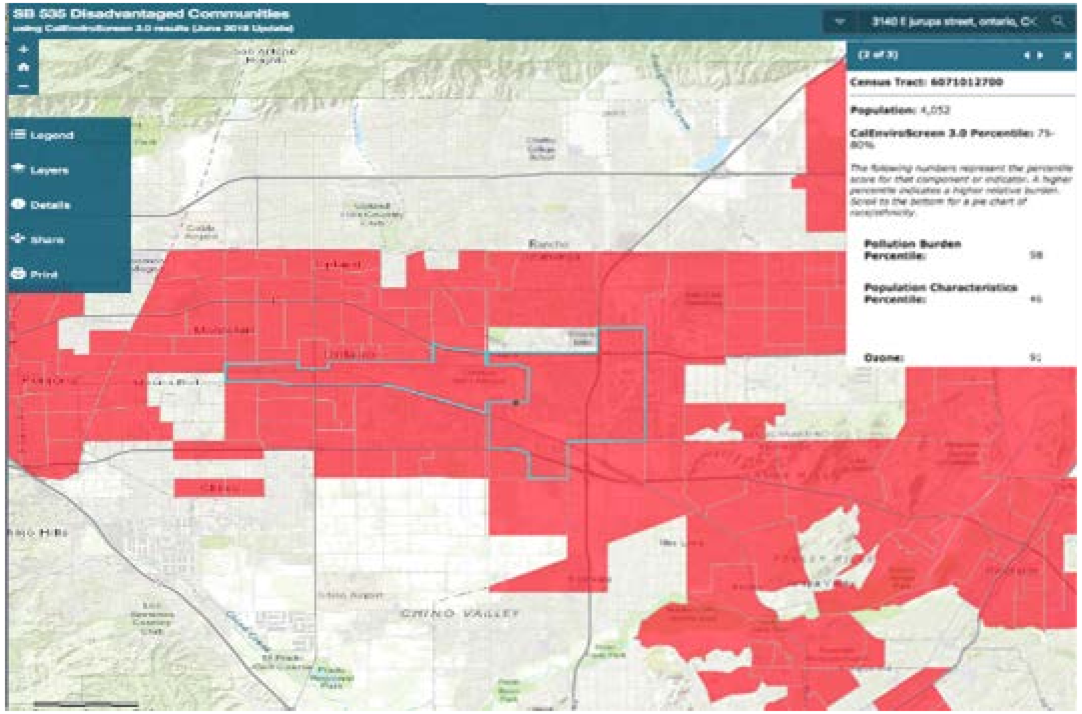


See Feb 2022 HFTO H2IQ Webinar https://www.energy.gov/eere/fuelcells/2022-hydrogen-and-fuel-cell-technologies-office-webinar-archives#02242022

Emphasis is on Benefits in Underserved & Disadvantaged Communities

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

Trucks will be demonstrated in disadvantaged community in Ontario, CA



Key Accomplishments:

- 10 trucks built with validation testing complete; 5 more in assembly
- Operations have begun in disadvantaged community out of UPS Service center in CA

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

Project impact per year: Savings of

- 285 metric tons of CO_2e
- 280,000 grams of criteria pollutants
- 56,000 gallons of diesel

Examples of Tribal Engagement

Engagement with Tribes included:

- Hydrogen Shot Summit
- Listening Sessions
- Engagement on potential BIL activities, such as Sec. 815 which includes direction to:

  A. Support **domestic supply chains** for materials and components;
  B. Identify and incorporate nonhazardous **alternative materials** for components and devices;
  C. Operate in partnership with tribal energy development organizations, Indian Tribes, Tribal orgs., Native Hawaiian community-based organizations, or territories or freely associated States; or
  D. Are located in **economically distressed areas** of the major natural gas-producing regions of the US

Collaboration with DOE Office of Indian Energy

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

Example: HBCU/MSI Funding Opportunity and Topic Overview

HFTO partnered with FECM and added topics to educate and train the next generation of engineers and scientists at HBCUs/MSIs, and increase investments in traditionally underrepresented and disadvantaged communities in the U.S.

Topic Area	Expected # of Awards	DOE Funds per Award ($K)
Hydrogen Storage Materials Development	Up to 6	up to $300
PGM-free Catalysts and Electrodes for Fuel Cells and Electrolyzers	Up to 6	up to $300
Hydrogen Materials Compatibility – RD&D	Up to 6	up to $300
Hydrogen Materials Compatibility – Gap Analysis	Up to 1	up to $250k
Total	**Up to 7**	up to $2M total

Facilitating knowledge sharing & student training opportunities through cooperative research partnerships with HFTO's consortia:

HyMARC Hydrogen Materials Advanced Research Consortium

ElectroCat Electrocatalysis Consortium

H-Mat Hydrogen Materials Compatibility Consortium

Goals: Build the talent pipeline and expand knowledge in hydrogen with a focus on materials R&D

- Uses established HFTO consortia and provides partnership opportunities
- Offers students the opportunity to travel to national laboratories
- Provides opportunity for creative partnership models with industry and pipeline

https://www.energy.gov/eere/fuelcells/articles/apply-funding-train-next-generation-hydrogen-workforce Closed May 31, 2022

HBCU: Historically Black Colleges and Universities.
MSI: Minority Serving Institutions

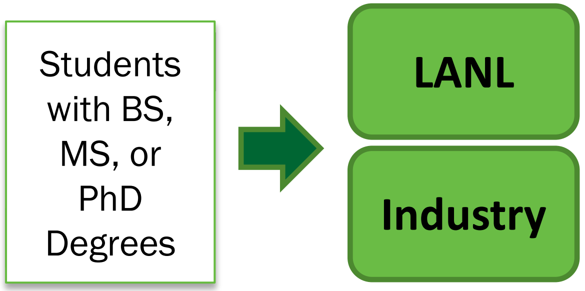
Promoting DEI, bridging academia, labs and industry

Pajarito Powder and LANL host Industry day
Discuss research opportunities and host facility tour
Building an alliance for MSI industry internships

LANL and Pajarito Powder Establish Collaboration with Minority Serving Institutions (MSIs)

Project Goals include:

- Develop a mutually beneficial relationship between LANL, Industry Partners, and MSIs through HFTO support
- Provide opportunities for MSI scholars to perform cutting-edge fuel cell research at LANL
- Encourage MSI scholars to pursue advanced degrees and enter the Hydrogen and Fuel Cell Workforce



Example: Workforce Development

Industry-led project on Hydrogen Education for a Decarbonized Global Economy (H2EDGE)

See: EPRI project (SCS028)

Key Accomplishments:

- **Professional short courses** in development include:

  Basic H_2 science, end uses, storage, delivery, safety, electrolyzer technology trends.
- **Oregon State University:** New sustainable engineering course on H_2 economy basics, challenges, barriers. Student projects with industry sponsors.
- **University of Delaware:** Developing laboratory course on PEM fabrication, gas separation, electrochemical compression.

Goals:

- Develop and deliver professional training courses and university curriculum content
- Collaborate with industry and university partners to develop certifications, credentials, qualifications, and standards for training

Next Steps:

- Conduct gaps assessments of professional training activities and university curriculum requirements
- Begin delivering professional training through short courses
- Develop new courses at a third partner university
- Advance the university engagement network by adding Affiliate Universities

Hydrogen Shot Fellowship

Hydrogen

The U.S. Department of Energy (DOE) is looking for talented, bright, early career professionals to partner with DOE Hydrogen Program Managers working to achieve the Hydrogen Energy Earthshot goal of $1 per 1 kilogram in 1 decade (“1 1 1”).

Are you graduating soon or just starting your career in hydrogen?

Do you want to help make clean hydrogen affordable for all?

The Hydrogen Shot Fellowship might be the opportunity you’re looking for!

Apply today at: www.zintellect.com Keyword: Hydrogen Shot

IPHE Early Career Network

Chair
Christine Watson (USA)

Co-Chair
Regional Director of Asia, Middle East, USA
Gaurav Shukla (India)

Co-Chair
Kendall Parker (USA)

Calling all hydrogen-enthusiast **STUDENTS** (undergrad & grad), **POST-DOCS**, and **EARLY CAREER PROFESSIONALS** worldwide!

Connect with peers, mentors, scientific researchers, industry professionals, and policymakers!

Join 230+ members from over 37 countries!

Join now & fill out our survey on YOUR career needs and interests:
www.iphe.net/early-career-chapter

Special Events Director
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(Denmark)

Regional Director of Europe
Thilo Krechlak
(Germany)

Regional Director of Africa
Faan Du Preez
(South Africa)

Education & Outreach Directors
Qingwang Yuan (USA)
Bikram Roy Chowdhury (USA)

Communications & Social Media Director
Yangwei Liu
(USA)

Community Manager
Ander Martinez Alonso
(Belgium)

IPHE Comm. Liaison
Ted Kwon
(Korea)

Examples of International Collaborations

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

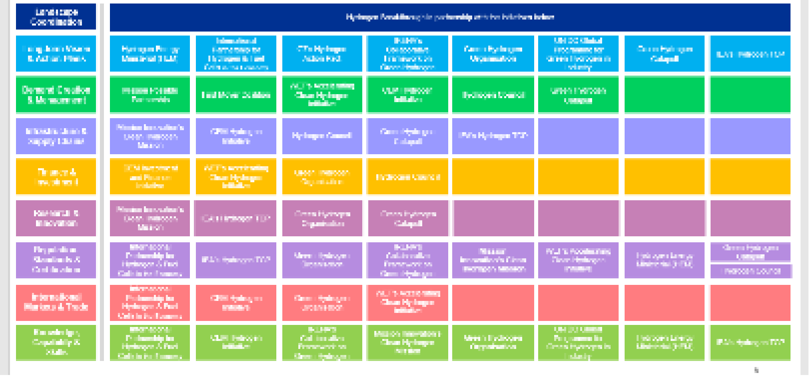
The International Partnership for Hydrogen and Fuel Cells in the Economy
Enabling the global adoption of hydrogen and fuel cells in the economy

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

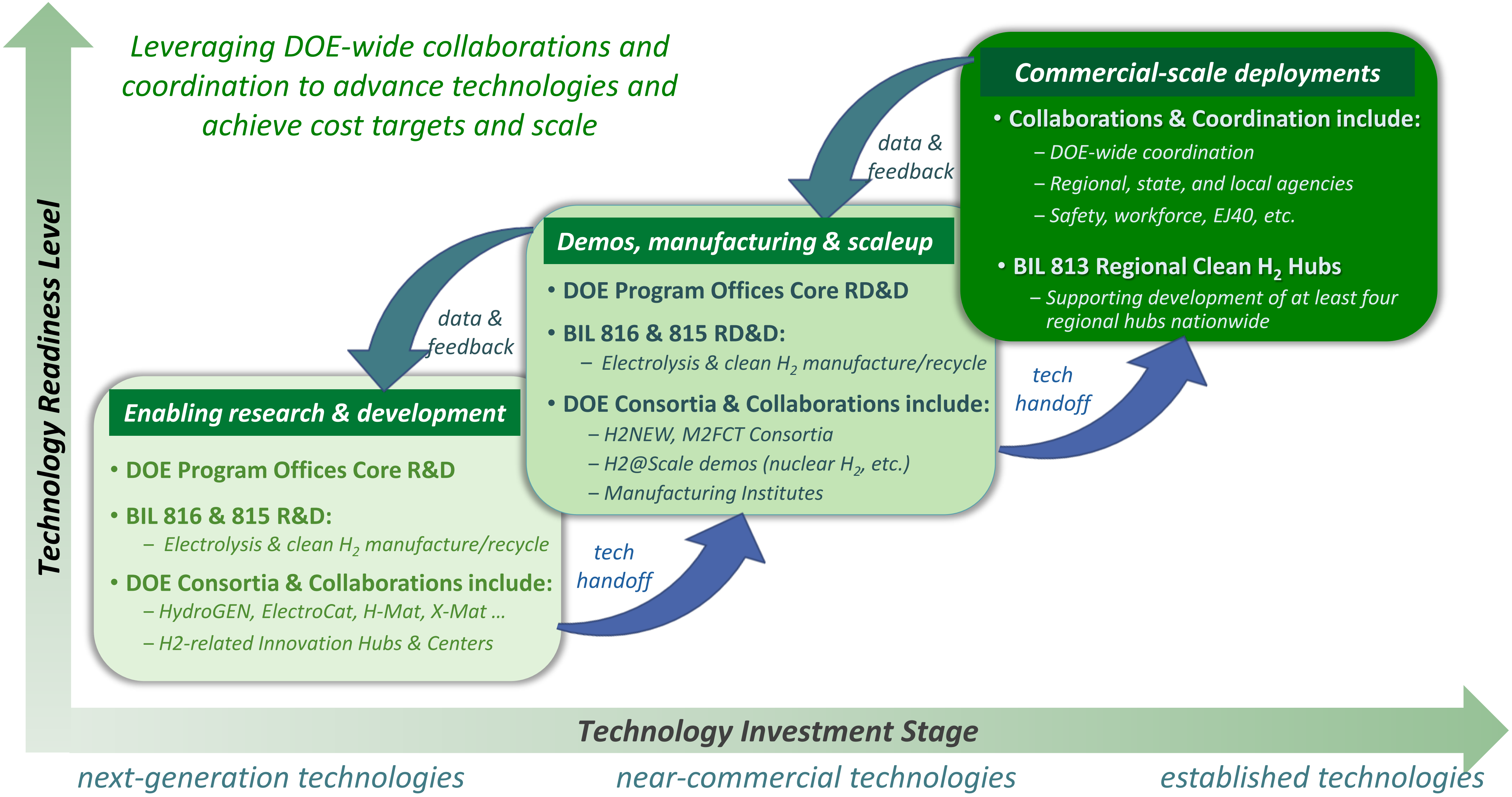
www.iphe.net

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



Building Momentum

Strategic RDD&D Portfolio



Year in Review Highlights

Launched Hydrogen Shot

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Hydrogen Shot Summit

$8M National Lab H2@Scale Projects

President Signs BIL

>8 workshops, webinars, stakeholder feedback (5,000 pgs.)

Two BIL RFIs Announced

HBCU & MSI Talent Pipeline

Issue H2 Hub NOI

Launch H2 Shot Incubator Prize

June 2021 — Sept 2021 — Dec 2021 — March 2022 — June 2022

SuperTruck3 Awards

Ford, gm, DAIMLER

RFI Issued for H_2 Demonstration Opportunities

$52.5M to fund 31 Projects for H_2 Tech including EERE and FECM

$20M for Clean H_2 From Nuclear (EERE and NE)

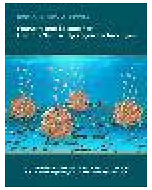
Launched H2 Twin Cities at COP26

H2 TWIN CITIES

Launched H2 Matchmaker

Clean Energy Supply Chain Report

Science Roundtable Report



EC Workshop on GWP

ARPA-E ReFuel-IT NH_3 project demo

Actions to Catalyze, Accelerate and Enable Scale

	2022-2025		2026-2029		2030-2035
Clean Hydrogen Production	Catalyze RD&D in electrolysis, thermal conversion, & new pathways to meet Hydrogen Shot	Demonstrate replicable, scalable production from renewables, nuclear, & fossil and waste with CCS	Deploy gigawatt-scale electrolyzers and develop domestic supply chains	Scale up electrolyzer manufacturing and recycling/reuse capacity	Achieve 5 MMT production capacity and $1/kg target
Delivery and Storage Infrastructure	Identify and prioritize barriers to infrastructure roll out	Initiate supporting infrastructure for regional hubs	Demonstrate advanced and efficient infrastructure components	Develop sustainable regional clean hydrogen networks	Deliver hydrogen at scale
End Uses and Market Adoption	Engage regulators to lay groundwork for strategic adoption across sectors	Initiate transition for hard to decarbonize industries	Deploy at least four regional clean hydrogen hubs	Deploy technologies that lower pollution and provide resiliency	Scale up hydrogen hubs and prepare export opportunities
Enablers	Engage stakeholders; address safety codes and standards; develop critical supply chains	Use and expand workforce, talent pools, and apprenticeship programs	Ensure 40% of benefits accrue to disadvantaged communities in hub regions	Demonstrate business cases and attract private capital	Achieve Justice 40, create good-paying jobs, and ensure public health & safety

Target table will be provided to meet BIL deliverable on targets for 2, 7, 15 years

Regional Clean Hydrogen Hubs Notice of Intent (NOI) Released Today!

NOI (DE-FOA-0002768) available at https://oced-exchange.energy.gov/

DOE Office of Clean Energy Demonstrations (OCED) anticipates issuing a Funding Opportunity Announcement in collaboration with the Hydrogen and Fuel Cell Technologies Office (HFTO) and the DOE Hydrogen Program

DOE Issues H2 Hub NOI—June 6, 2022

☆ Initial Application
◇ Go/No-Go Decisions

	Application	☆ Phase 1: Detailed Plan	◇ Phase 2: Develop, Permit, Finance	◇ Phase 3: Install, Integrate, Construct	◇ Phase 4: Ramp-Up & Operate
	Pre - DOE funding	**Up to $10M DOE Funding , Non-Federal Cost Share ≥ 50%, 12-18 Months**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-3 Years**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-4 Years**	**TBD DOE Funding, Non-Federal Cost Share ≥ 50%, 2-4 Years**
Engineering, Procurement, Construction, Operations	• Conceptual Design • Technical Readiness • Project Schedule • Total Project Cost Estimate	• Engineering & Design Documents • Technical Maturation Plans • Integrated Project Schedules	• Mature Engineering & Design • Technical Risk Management • Execution ready schedule & cost estimate, PM Tools • Operations Plan	• Ongoing execution reporting • Interim Go/No-Go reviews	• Ongoing performance Reporting • Technical risk updates, tracking • Final TPC accounting
Business Development & Management	• Business Strategy • Team Description • Workforce Plan • Finance Plan • Market potential analysis	• Project Management Plan • Risk Management Plan • Financial modelling • Site selection	• Finalized project structure, management, financing • Ongoing risk management • Final legal, workforce, procurement agreements • Feedstock & Offtake Plans	• Ongoing execution reporting • Ongoing risk management	• Updated financial analyses • Revised growth plans • Updated Risk Management
Permitting & Safety	• Safety history/culture description • Regulatory approval timeline overview	• Initial Hydrogen Safety Plan (HSP) & Site Safety Plan • Physical, Information, Cyber Security Plans • Environmental & Regulatory preparations	• Execution ready HSP and security plans • Permits & approvals in place for construction	• Ongoing permit, environmental, safety reporting • Permits & approvals in place for operations	• Ongoing permit, safety, and security reporting
Community Engagement & Impacts	• Initial Equity Plan addressing community engagement, Justice40, community consent or benefits agreements, job quality, workers rights, etc.	• Stakeholder engagement and Community Consent or Benefits Agreement drafts	• Finalized Equity Plan, Agreements • Community development targets identified, tracking plans	• Ongoing reporting on Equity Plan activities	• Revised community engagement plans for operations • Ongoing reporting and evaluation
Technical Data & Analysis	• Lifecycle Analysis • Techno-economic Analyses	• Project Production Model • Updated Lifecycle and Technoeconomic Analysis	• Final Lifecycle & Technoeconomic Analyses • V&V and Project Completion Testing Plans	• Periodic analyses updates • V&V data collection • Project completion testing and performance ramp V&V	• Validated performance model • Finalize lifecycle and technoeconomic analyses • Dissemination of analyses, lessons learned

Issued by OCED in collaboration with HFTO and DOE Hydrogen Program, all relevant offices

NOI (DE-FOA-0002768) available at https://oced-exchange.energy.gov/

H2Hub project phases, including examples of likely activities and deliverables in each phase, subject to change prior to the FOA release.

Highlights and Milestones Summary

FY2021	FY2022	FY2023
Awarded first-of their-kind demo projects, including: Large Scale Fuel Cell Powered Data Center, Renewable H_2 Production on Refueling Barge, Two H_2 for Steel projects	BIL signed into law	Issue BIL FOAs for Sec. 813 and 815- Electrolysis and Manufacturing & Recycling
Launched Hydrogen Shot	Issued Request for Information for BIL sections 813, 815, and 816	Issue Annual FOAs
Launched H2NEW, Million Mile Fuel Cell Truck consortium and HydroGEN 2.0	Held multiple workshops and webinar including on BIL H_2 Provisions and RFIs	Select at least four H_2 Hubs (OCED in collaboration with HFTO and DOE Hydrogen Program)
Launched H2EDGE Workforce Development Project	Released Hub NOI in collaboration with OCED	Select Hydrogen Shot Incubator ***Propose!* Phase** Winners
Developed H_2 energy storage financial assessment tool	Selected over $51M in new projects	Complete milestones for current RD&D projects
Launched HyBlend Project and 5 CRADA projects on HD fueling	Selected (3) SuperTruck III Projects Focused on M/HD H_2 Fuel Cell Trucks	Complete coordinated, prioritized action plan with other agencies
Released SuperTruck III FOA	Launched Hydrogen Shot Incubator Prize	Complete coordinated workstreams and international architecture for global hydrogen partnerships
	Issue FY22 FOAs	
	Complete DOE National Clean Hydrogen Strategy and Clean Hydrogen Standard guidance	

Acknowledging HFTO's Collaboration Network

Collaboration and coordination to accelerate progress and advance environmental justice

Project Partners

- *14 National Labs*
- *190 Companies*
- *109 Universities*

Cross-Office work with Multiple DOE Offices

EERE *(Solar, Wind, Vehicle Tech., Advanced Manufacturing, Bioenergy, Building Tech., Water Power);* ***ARPA-E; Fossil Energy & Carbon Management; Nuclear Energy; Office of Science, and more***

DOE Crosscutting Initiatives

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

Interagency Collaboration & Coordination

Including ***DOD, DOT, DHS, EPA, NASA, NSF, NIST*** among others

International Collaboration

IEA, IPHE, CEM, HEM, MI, IRENA, CH-JU, 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.

Hydrogen and Fuel Cell Technologies

Will be hiring several Feds

Open to U.S. Citizens

Senior Advisor
Eric Miller

Director
Sunita Satyapal

Operations Includes Katie Randolph, Shawna McQueen, Vanessa Arjona

System Analysis
Neha Rustagi *

Will be Hiring

Hydrogen Production including Clean H_2 Electrolysis
Ned Stetson (Acting)

Hydrogen Infrastructure & Storage Technologies including Clean H_2 Manufacturing & Recycling
Ned Stetson

Fuel Cell Technologies including Clean H_2 Manufacturing & Recycling
Dimitrios Papageorgopoulos

Technology Acceleration including H_2 Hubs in Collaboration with OCED:
Jesse Adams

*Also supports H_2 Technologies

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

Upcoming Opportunities for Engagement

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Save the date!

2023 DOE Annual Merit Review and Peer Evaluation Meeting
June 5-8, 2023

Hydrogen and Fuel Cells Day October 8

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

1 H 1.008
Hydrogen

INCREASE YOUR H_2IQ

Join Monthly
H2IQ Hour Webinars

Download
H2IQ For Free

Visit H2tools.Org For Hydrogen Safety And Lessons Learned

https://h2tools.org/

CENTER FOR Hydrogen SAFETY
Connecting a Global Community

www.aiche.org/CHS

Sign up to receive hydrogen and fuel cell updates

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

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

HFTO is Hiring!

If you are interested in applying to be part of our team, please submit resumes to the ***DOE Applicant Portal*** *and email* ***hftoinquiries@ee.doe.gov*** *to let us know you have submitted your resume. Include* ***"Clean Energy Corps Applicant"*** *in the subject line of the email.*


"It is the long history of humankind (and animal kind, too) that those who learned to collaborate and improvise most effectively have prevailed.”
– Charles Darwin

Thank you

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

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

Additional Information

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

HFTO Project Partners: Labs, Universities, and Industry

3M Company
Air Products and Chemicals
Ames Laboratory
Argonne National Laboratory
Army Corps Engineers
Brookhaven National Laboratory
Carnegie Mellon University
Caterpillar Inc.
Center for Transportation and the Environment
Clemson University
Collaborative Composite Solutions Corporation
Colorado School of Mines
Cummins Inc.
C-Zero, LLC
DOT National Highway Traffic Safety Administration
Drexel University
Electric Power Research Institute Inc
Electricore Inc.
Exelon Corporation
Frontier Energy, Inc.
FuelCell Energy, Inc.
Gas Technology Institute
General Motors LLC
Georgia Institute of Technology

Giner ELX, Inc.
Greenway Energy, LLC
Hornblower Energy
Hy-Performance Materials Testing, LLC
Idaho National Laboratory
Ivys, Inc.
Lawrence Berkeley National Laboratory Lawrence
Livermore National Laboratory Liox Power, Inc.
Los Alamos National Laboratory
Lubrizol
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
ORAU
Oregon State University
Pacific Northwest National Laboratory
Pennsylvania State University
Plug Power Inc.
Proton Energy Systems, Inc.
Raytheon Technologies Research Center
Redox Power Systems, LLC
Rensselaer Polytechnic Institute
Saint-Gobain Ceramics and Plastics, Inc.
Sandia National Laboratories
Savannah River National Laboratory
Shell
Skyre, Inc.
SLAC National Accelerator Laboratory
Southern Company Services
Strategic Analysis, Inc.
The Chemours Company FC, LLC
The University of Alabama
The University of Tennessee, Space Institute
The University of Toledo

Treadstone Technologies, Inc.
U.S. Naval Research Laboratory
United Technologies Research Center
University of California, Irvine
University of California, San Diego
University of Colorado
University of Colorado, Boulder
University of Connecticut
University of Delaware
University of Florida
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 Virginia
Vanderbilt University
Washington State University
West Virginia University

Collaborative H_2 Projects between HFTO and other EERE Offices

Advanced Manufacturing (AMO)

- **Manufacturing electrolyzer stacks** *NexTech Materials, Ltd,* **$4.2M**
- **Electrolyzer cell and stack assembly** *Cummins, Inc,* **$7.2M**
- **Low-cost PEM electrolysis at scale** *Proton Energy Systems,* **$5.5M**
- **Integrated MEAs & scale-up** *Giner ELX, Inc.,* **$5.8M**
- **Advanced manufacturing for PEM electrolyzer components** *3M,* **$6.1M**

Bioenergy Technologies (BETO)

- **Upgrading bio & renewable natural gas** *Production Summit Utilities*, **$5M**

Solar Energy Technologies (SETO)

- **Clean H_2 to jet fuel using CSP** *Dimensional Energy*, **$3.4M**
- **Solar thermo-electrochemical process for H_2** *Arizona State University,* **$0.5M**

Water Power Technologies (WPTO)

- **Energy storage options for non-powered dams,** *INL, PNNL* **$5M**

Wind Energy Technologies (WETO)

- **FlexPower: PV-wind-storage hybrid energy systems including H_2** *NREL, INL, SNL***,** *NETL* **$5.5M**
- **Wind to H_2 modeling and optimization** *NREL,* **$0.15M**

Offshore Wind to H_2 (SBIR)

- **Offshore wind and PEM electrolysis** *Giner Inc.,* **$1.1M**
- **Offshore wind and AEM electrolysis** *Alchemr, Inc.,* **$1.1M**
- **Optimizing wind technology for H_2 production** *NREL, GE, Nel,* **$0.5M**