U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Department of Energy Hydrogen Update

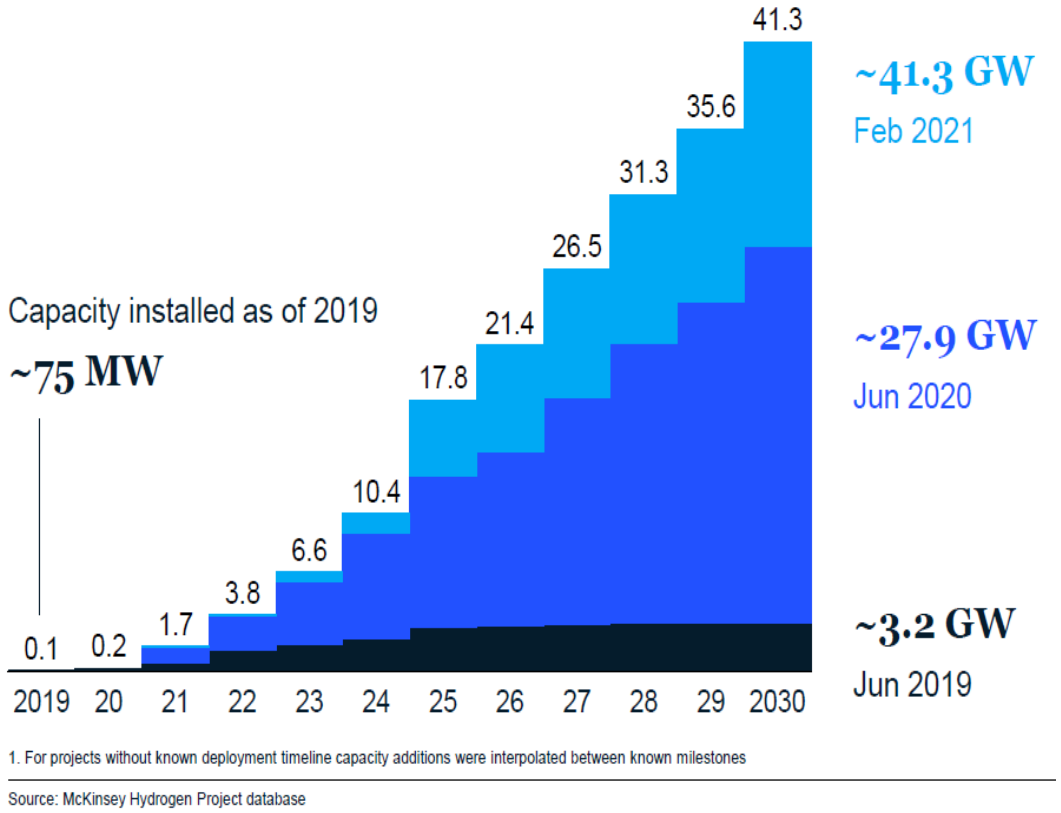
Dr. Sunita Satyapal, Director, U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office

July 1, 2021

Recent Increased Interest in Hydrogen: Global Drivers

- ✓ **Low-cost renewables** are now available
- ✓ **Countries see clean H_2 can help meet climate goals**
  - Hard to decarbonize sectors
  - Energy storage
  - Import/export opportunities

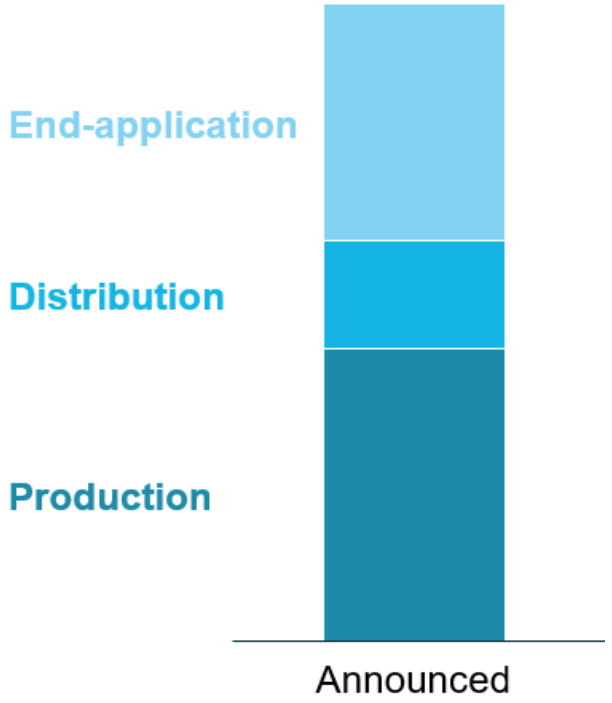
200-fold electrolyzer growth by 2030
Over 40 GW planned



1. For projects without known deployment timeline capacity additions were interpolated between known milestones

Source: McKinsey Hydrogen Project database

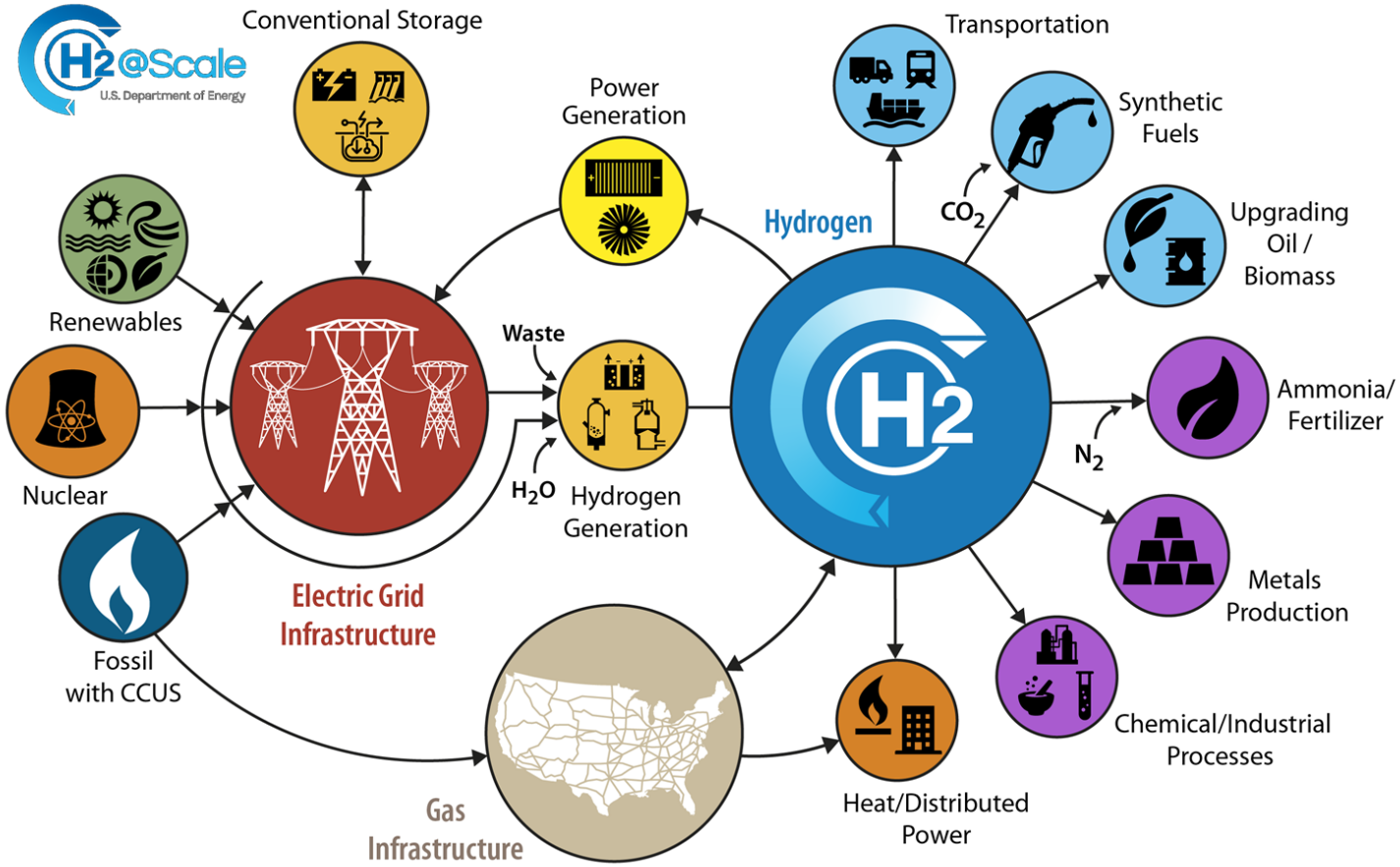
$80B Global Government Funding. 6X More with Private Sector through 2025



Source: McKinsey, H2 Council, Spring 2021

Studies show potential for 10 to 25% global GHG reduction using clean hydrogen. $2.5T Revenue. 30M Jobs.

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



Potential

- 10 MMT of H_2/yr produced today with scenarios for ~5X growth
- 10 MMT H_2 would ~ double today's solar or wind deployment
- Industry study shows potential for $140B in revenue, 700K jobs, 16% GHG reduction. Analysis underway, including on export potential.

Contributes to Administration Goals including:

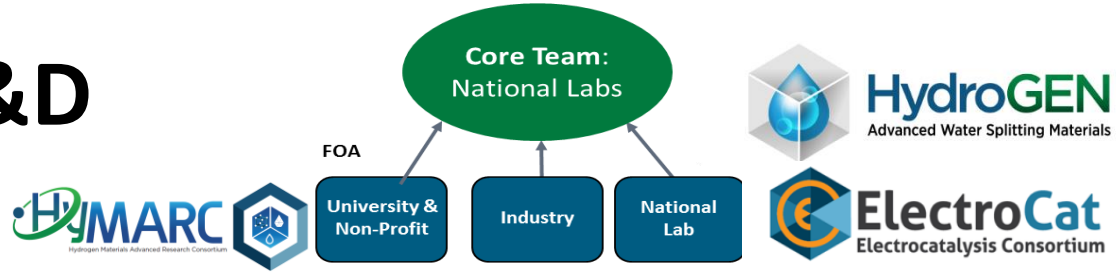
- **100% carbon-pollution-free electric sector by 2035**
- **Net zero emissions economy by 2050**

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

HFTO Comprehensive Strategy

Focused Consortia with labs, industry, universities

R&D



New: $100M/5yrs

H2NEW U.S. DEPARTMENT OF ENERGY

ACTE U.S. DEPARTMENT OF ENERGY

MILLION MILE FUEL CELL TRUCK

2016 2018 2020

D&D

Trucks, GSE

Infrastructure

CO_2+H_2

Renewables to H_2

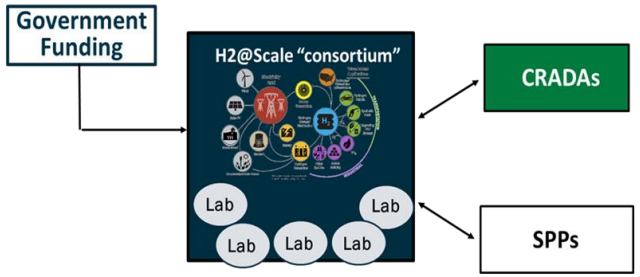
Data Center

Nuclear to H_2

New: Super Truck FOA and more…

Ammonia (ARPA-E)

Enablers



Comprehensive analysis, tools and models to accelerate progress

Safety, codes, standards, workforce development

Systems integration and validation

H2EDGE Hydrogen Education for a Decarbonized Global Economy

H-Mat Hydrogen Materials Compatibility Consortium

CENTER FOR Hydrogen SAFETY Connecting a Global Community

HyBlend U.S. DEPARTMENT OF ENERGY

Key 2030 Targets

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

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

Fuel Cells
- $80/kW
- 25Khr durability

Enable EJ40 Priorities, DEI

Deployment in collaboration with Loan Program Office

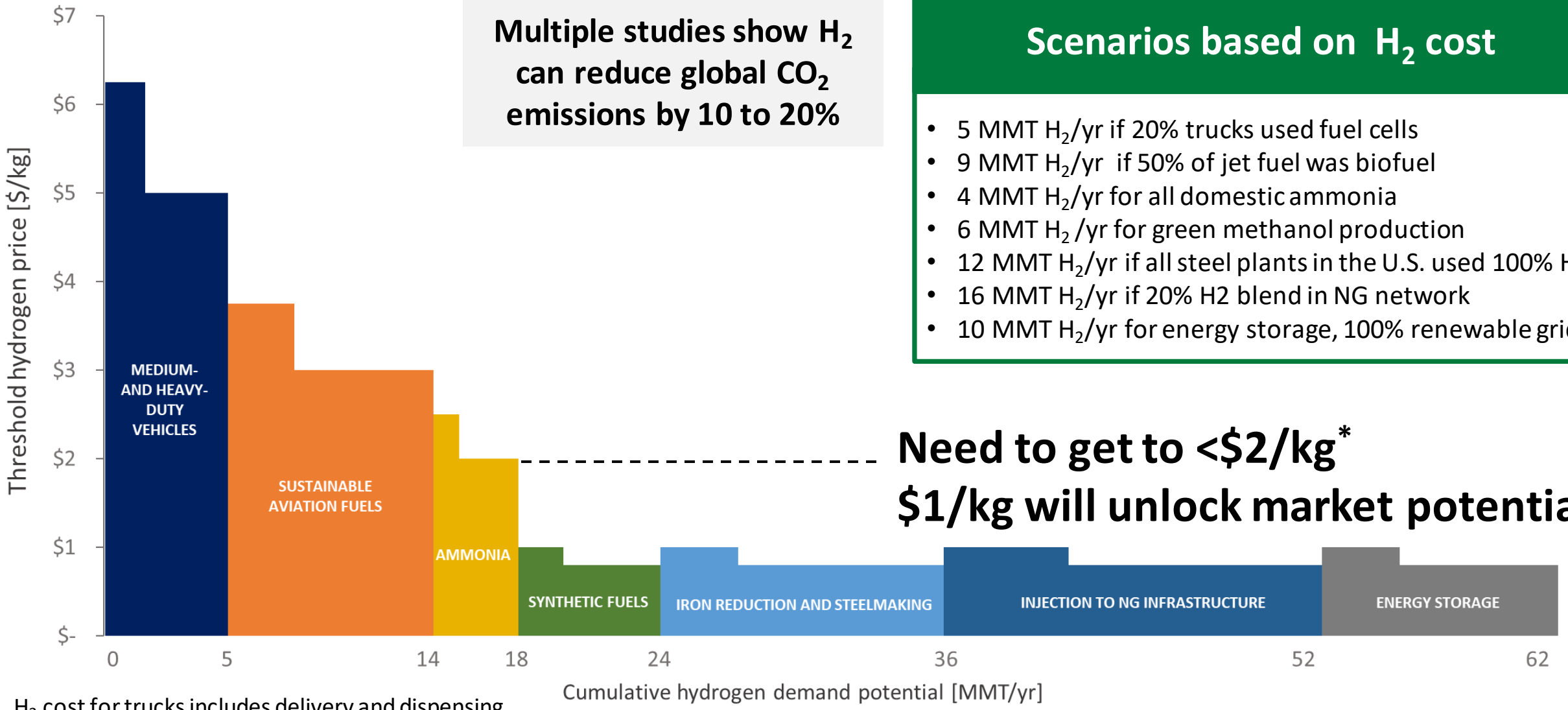
Examples shown, not exhaustive. Over 190 companies, 109 universities, 16 national labs in the last decade; CRADAs are Cooperative Research And Development Agreements

Analysis Determines Market Potential Scenarios

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

Scenarios based on H_2 cost

- 5 MMT H_2/yr if 20% trucks used fuel cells
- 9 MMT H_2/yr if 50% of jet fuel was biofuel
- 4 MMT H_2/yr for all domestic ammonia
- 6 MMT H_2 /yr for green methanol production
- 12 MMT H_2/yr if all steel plants in the U.S. used 100% H_2
- 16 MMT H_2/yr if 20% H2 blend in NG network
- 10 MMT H_2/yr for energy storage, 100% renewable grid



**Need to get to <$2/kg*
$1/kg will unlock market potential**

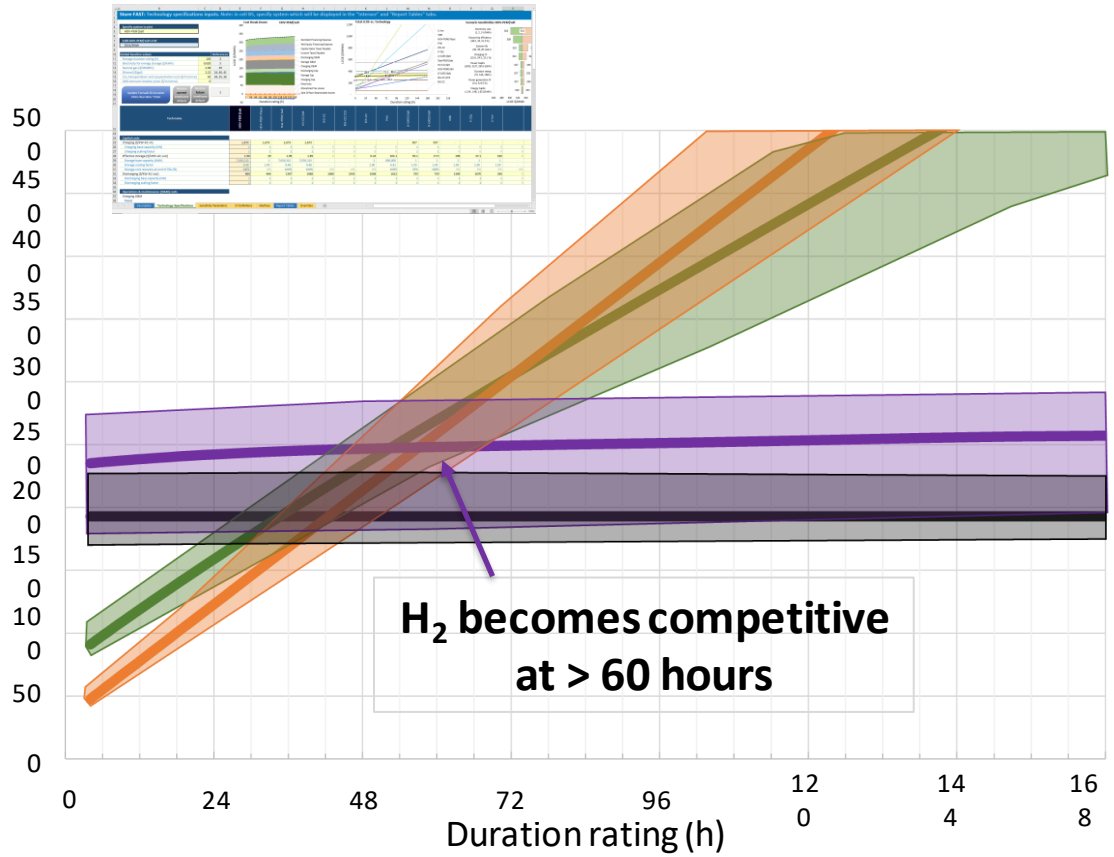
H_2 cost for trucks includes delivery and dispensing

* H_2 could compete at $1 to $2/kg higher cost with a carbon price

Results based on preliminary analysis

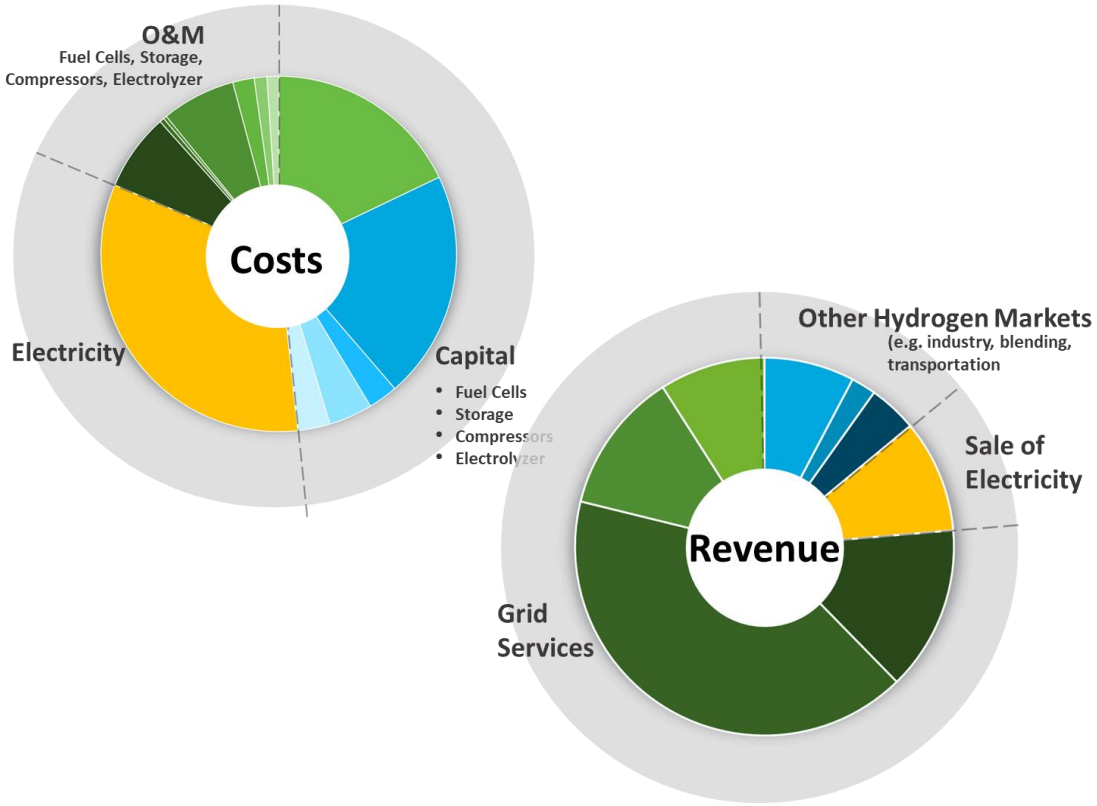
New Tools Developed: Long Duration Energy Storage & Value Proposition Tool

Newly released StoreFAST model assesses cost of long duration energy storage



Available at: https://www.nrel.gov/storage/storefast.html (NREL)

New tool to assess cost and revenue potential of grid-integrated hydrogen energy storage systems



Co-funded by HFTO and OE, now in beta testing at: https://eset.pnnl.gov (PNNL)

Hydrogen Energy Earthshot

“Hydrogen Shot”

Launched June 7, 2021

President Biden and Energy Secretary Granholm at Climate Summit

"…I've asked the Secretary of Energy to speed the development of critical technologies to tackle the climate crisis. No single technology is the answer on its own because every sector requires innovation to meet this moment."

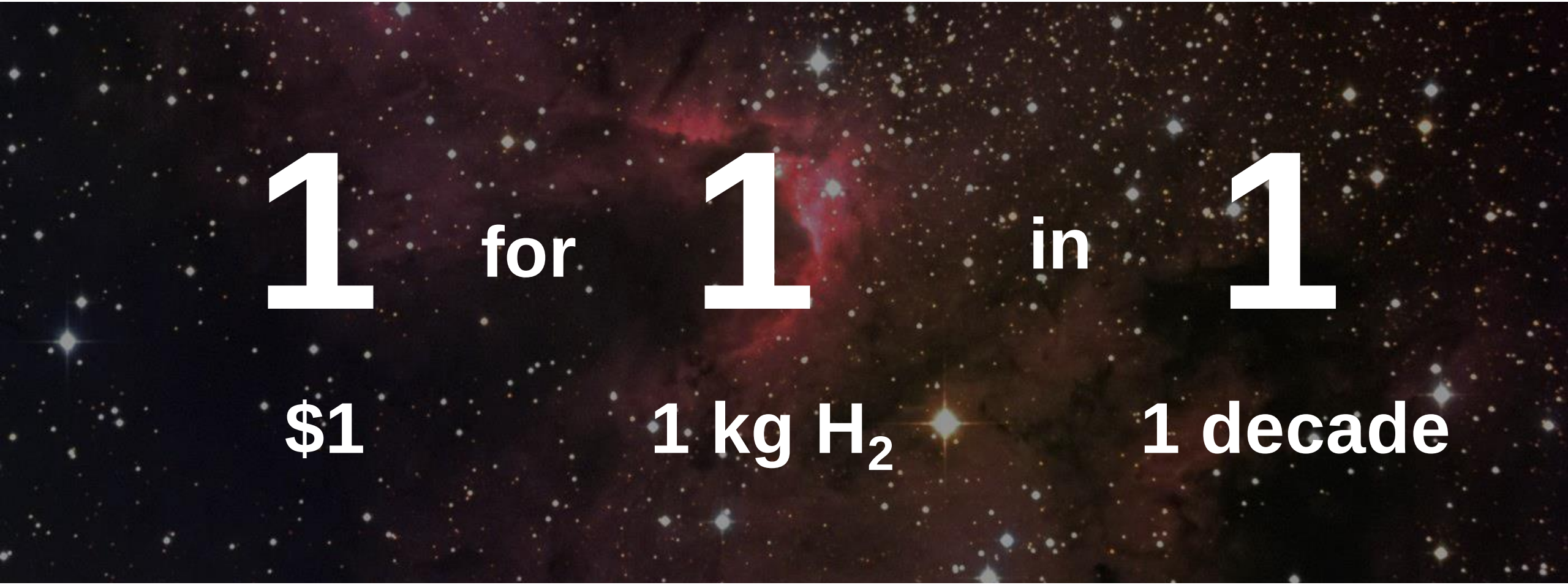
President Joseph R. Biden
April 23, 2021

Launch of Hydrogen Energy Earthshot
First of the Energy Earthshots
June 7, 2021
at DOE Hydrogen Program Annual Merit Review

Secretary Jennifer Granholm
June 7, 2021

ENERGY earthshots
U.S. DEPARTMENT OF ENERGY

Hydrogen

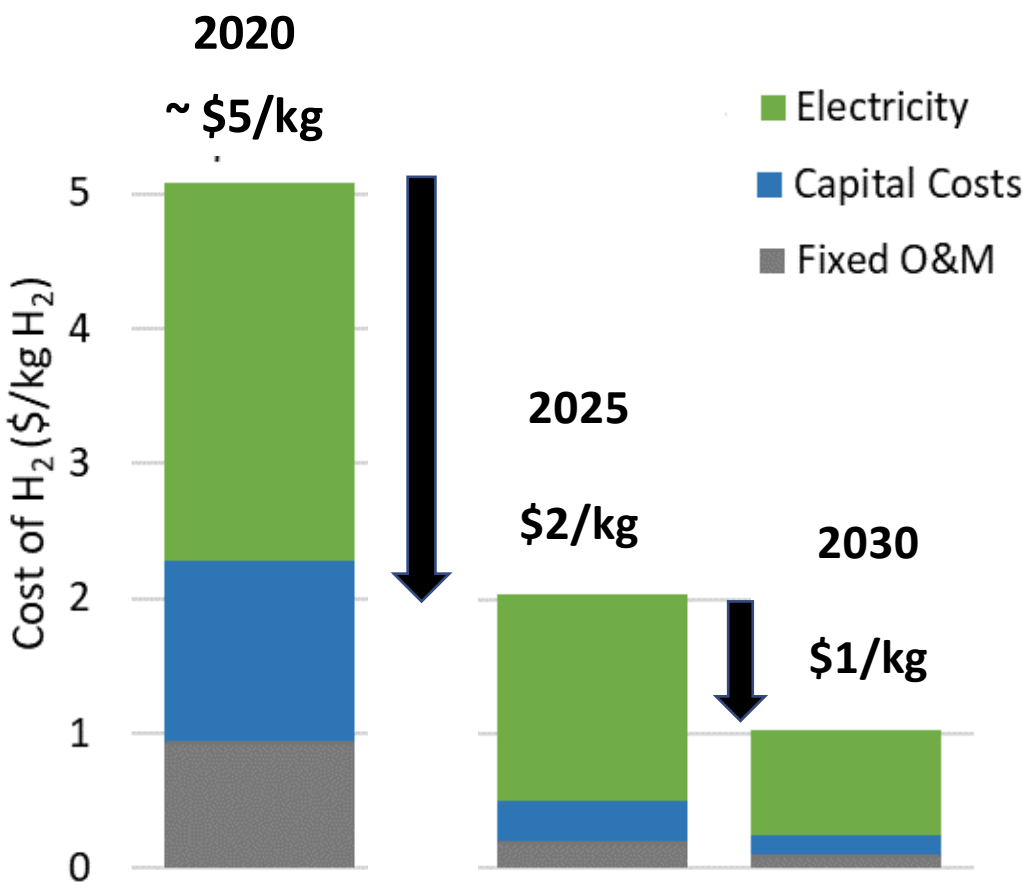


Request for Information on hydrogen demonstrations to support the Hydrogen Shot:
www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office-funding-opportunities

Hydrogen Shot: "1 1 1"
$1 for 1 kg in 1 decade for clean hydrogen

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

Example: Cost of Clean H_2 from Electrolysis



One of several pathways

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

All pathways for clean hydrogen included: Thermal conversion (fossil/waste + CCS), advanced water splitting, biological approaches, etc.

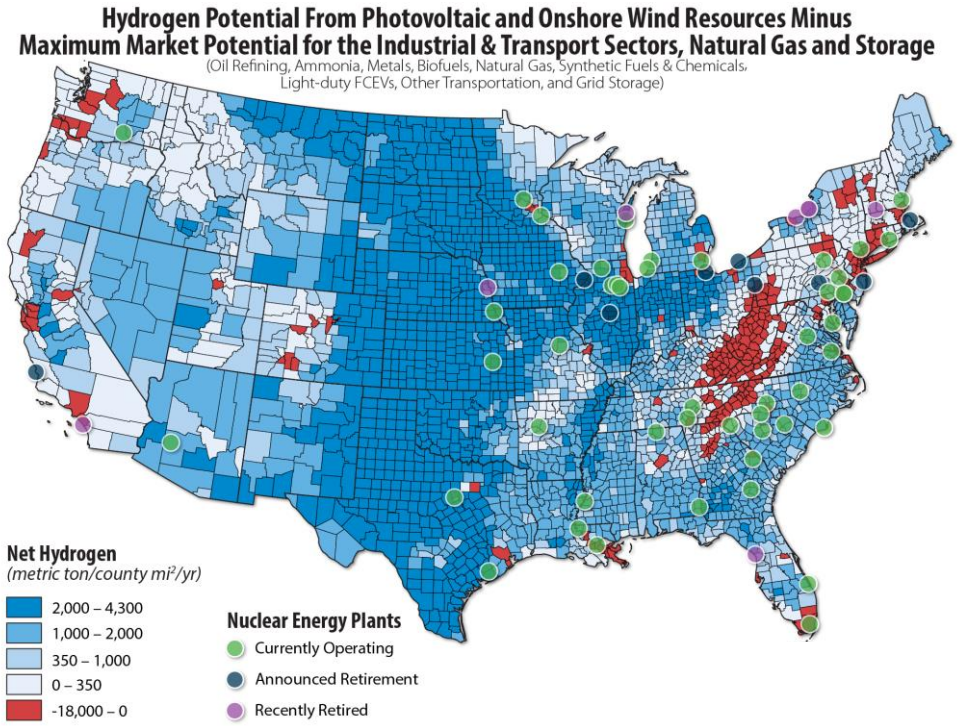
Emphasis: Getting to Scale

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

Request for Information (RFI) released – Due July 7, 2021

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

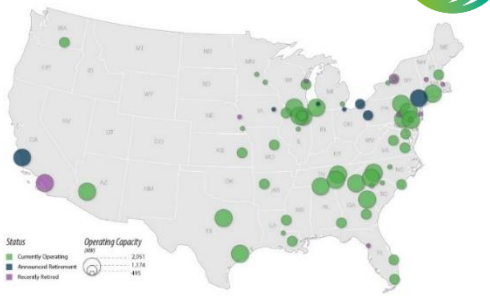
Renewables



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

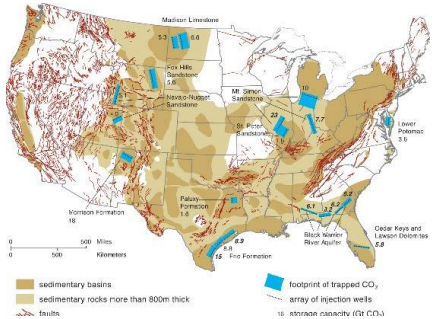
Hydrogen Shot Summit and Stakeholder Engagement Planned

Nuclear



Natural Gas (SMR)

CCS



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

DEI: Diversity, Equity and Inclusion
EJ: Environmental Justice

Hydrogen Shot Stakeholder Engagement and Next Steps

Stakeholder Engagement Planned

Industry, National Labs, Universities, Regional Coalitions, Labor Groups, Associations, Supply Chains, Federal and State Agencies, SBIRs/STTRs, Technology Commercialization Fund, Investors, International, Codes & Standards, Workforce Development and EJ Communities, and more

Timeline

- Announce Hydrogen Shot and RFI – June 7
- RFI Responses Due – July 7
- Office of Science Round Table- August
- Hydrogen Shot Summit
- Regional Analysis Preliminary Results – Fall
- Follow on Event – Oct 8: Hydrogen and Fuel Cell Day
- Stay tuned for more details

hydrogen.energy.gov

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

ENERGY earthshots U.S. DEPARTMENT OF ENERGY | Hydrogen

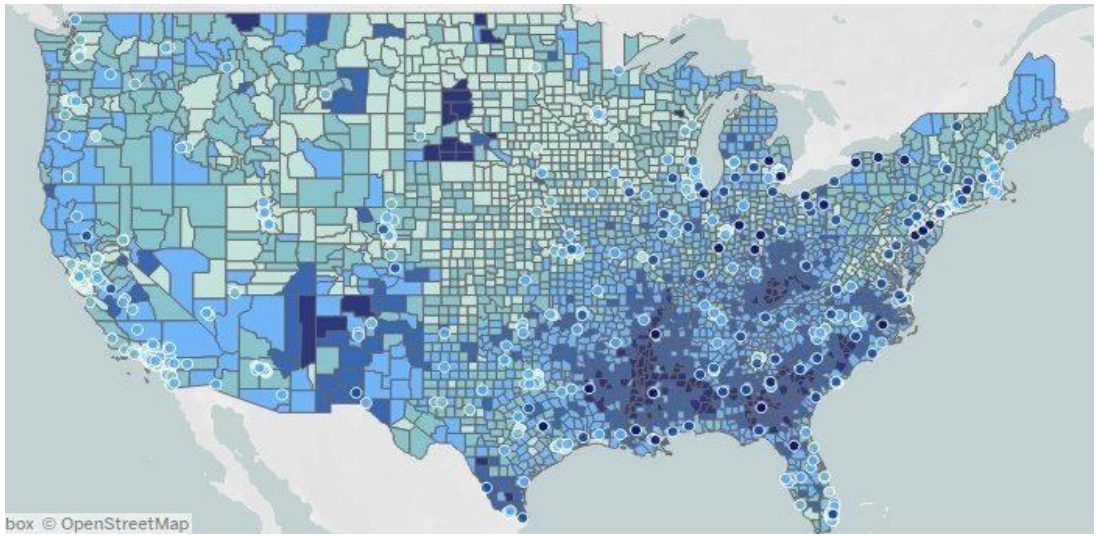
Save the Date

The Hydrogen Shot Summit – Aug. 31 to Sept. 1

- Two-day summit **bringing together stakeholders from industry, research, academia and government to identify pathways to meet the Hydrogen Shot** in the next decade
- **Technical breakout sessions to cover multiple hydrogen production pathways** and other topics including:
  - Electrolysis
  - Thermal conversion with CCS
  - Advanced pathways
  - Deployment and financing
- More info available coming soon at **www.energy.gov/eere/fuelcells/hydrogen-shot**


Collaboration
Diversity, Equity, Inclusion

Focus on Benefits in Underserved & Disadvantaged Communities



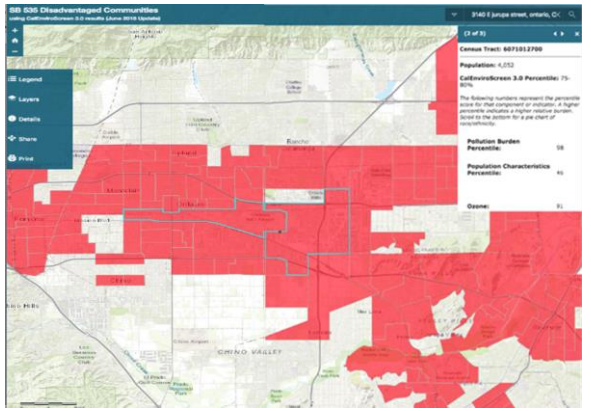
[New index ranks America's 100 most disadvantaged communities | University of Michigan News (umich.edu)]

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

- HFTO, NNSA, LANL Collaboration to engage with HBCU Students
- Bob Rose Fellowship* established 2019, in partnership with UT-ORNL Workforce Development Program. Contact: ORI@tennessee.edu

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

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



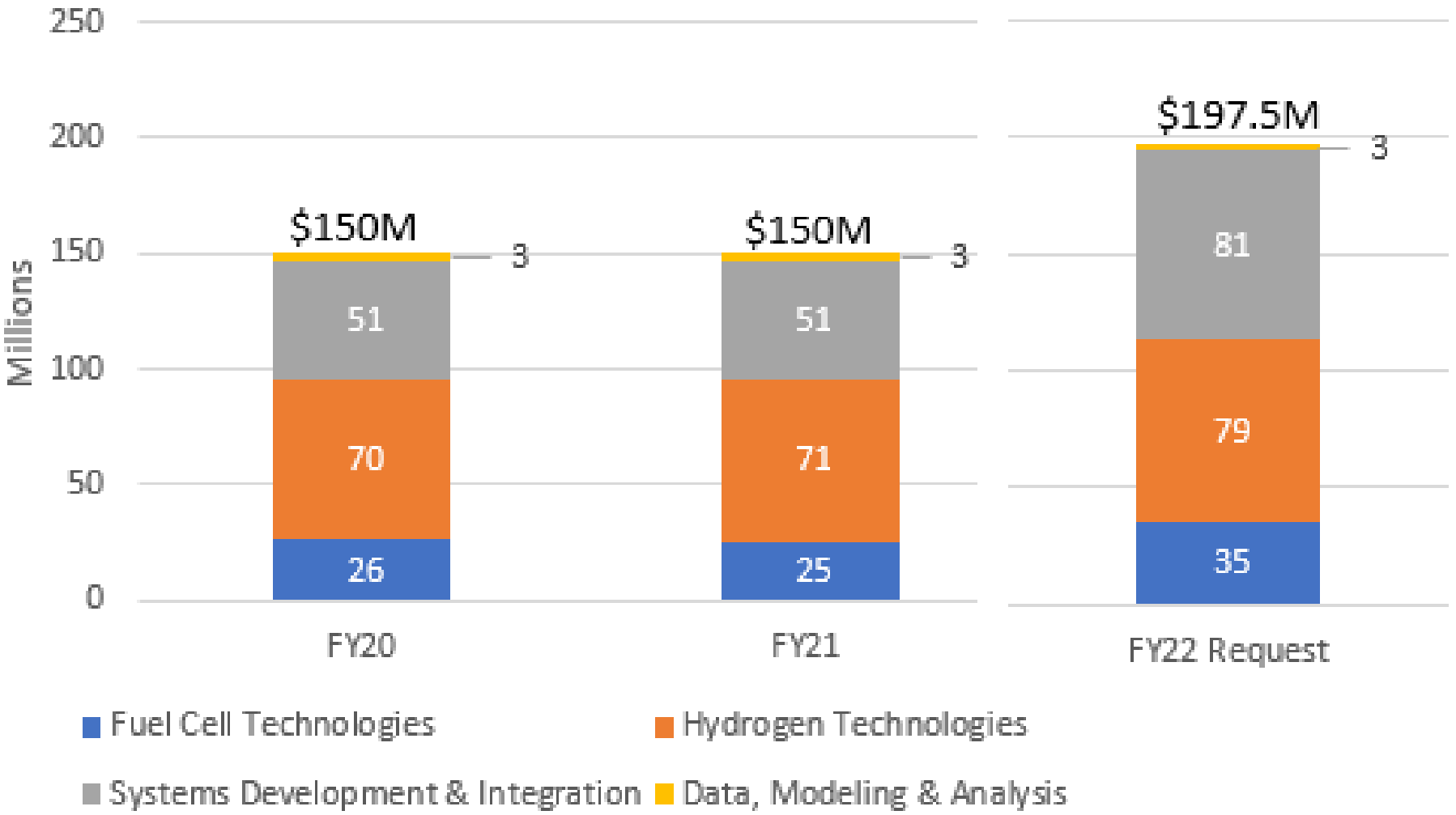
Trucks will be demonstrated in Ontario, CA- disadvantaged community

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

Project impact per year: Savings of

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

Funding for Hydrogen and Fuel Cell Technologies Office



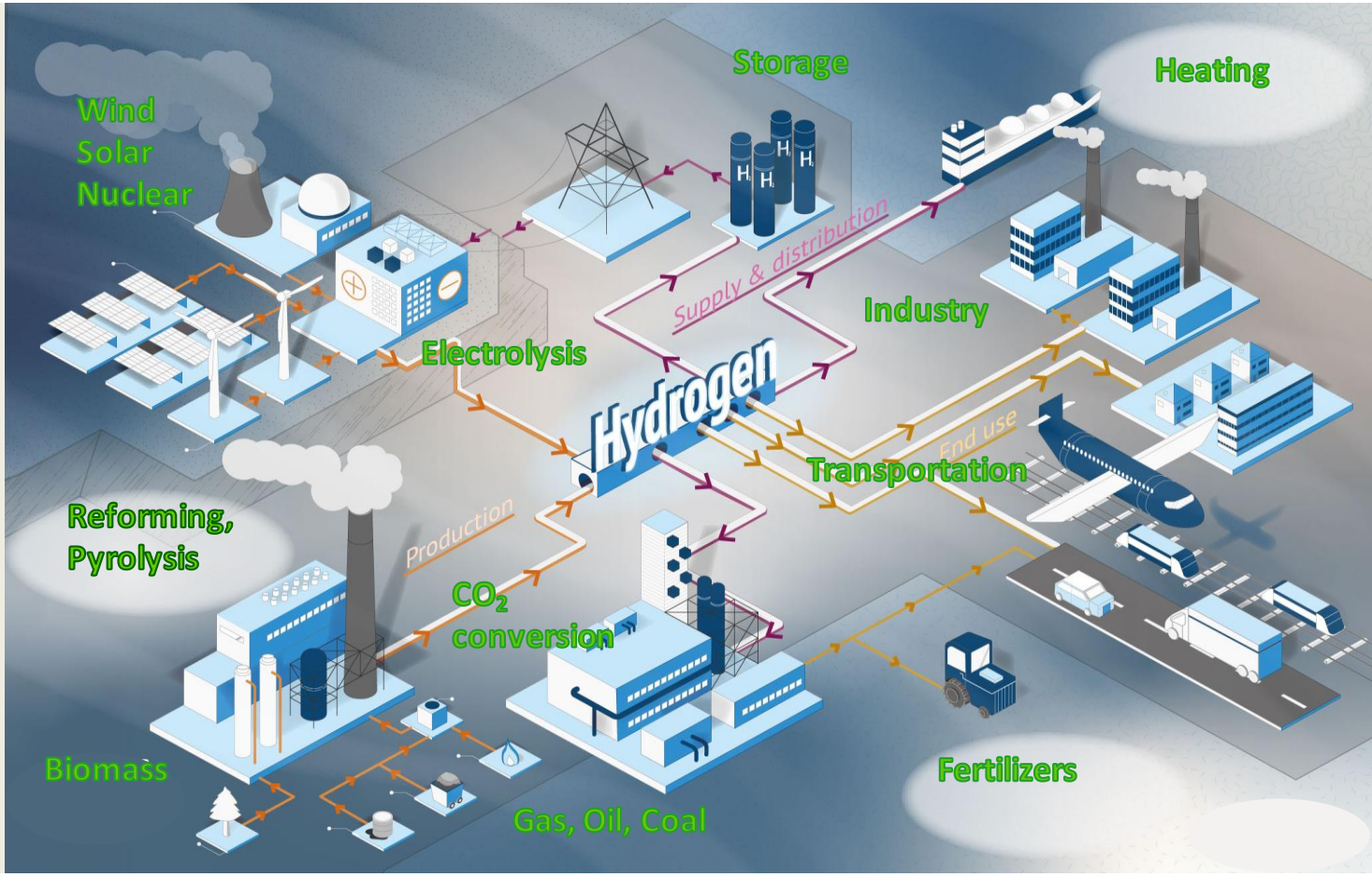
FY22 HFTO Request:

$197.5M

HFTO has funded over 190 companies, 109 universities, and 16 National Labs across 40 States over the last decade

Summary: Strategy and Next Steps

1) **Accelerate R&D to reduce cost**
2) **De-risk demonstration and enable deployments**
3) **Strategic scale up**
   - **Clusters**: co-locate supply and demand (e.g., at ports) and enable infrastructure
   - **RFI feedback** and regional analysis will guide activities



Identify jobs, EJ, and workforce development opportunities (e.g., transition from fossil fuel to H_2, ports, etc.)

Thank You

Sunita Satyapal
Director
Sunita.Satyapal@ee.doe.gov

Save the Date

for next year's AMR
June 6 to 9, 2022
We hope in person!

Looking for more info?
#H2IQ

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

Additional Information

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

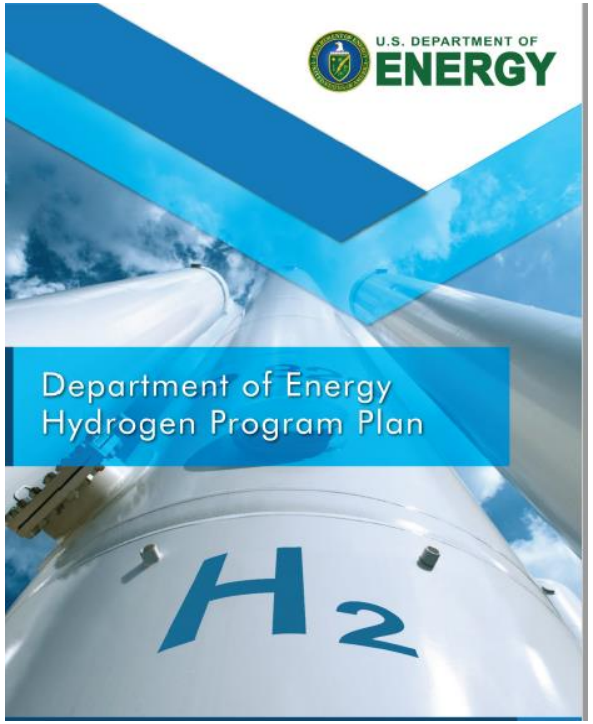
Acknowledgements: Recent HFTO Funded Recipients

3M
Automated Dynamics
Advent Technologies, Inc.
Air Products and Chemicals
Army Corps of Engineers
Caterpillar, Inc.
Chemours Company FC, LLC
Center for Transportation and the Environment
Collaborative Composite Solutions Corporation
Cummins, Inc.
C-Zero, LLC
DOT National Highway Traffic Safety Administration
Electricore Inc.
Electric Power Research Institute, Inc.
Exelon Corporation
FedEx
Ford
Frontier Energy, Inc.
FuelCell Energy, Inc.
Gas Technology Institute
General Motors
Giner ELX / Plug Power
GLWN
Greenway Energy, LLC
Hexagon R & D LLC
Hornblower Yachts
Ivys, Inc.
Mercedes-Benz
National Institute of Standards and Technology
Ohio Fuel Cell Coalition
Pajarito Powder
Redox Power Systems, LLC
Proton Energy Systems Inc
Saint-Gobain Ceramics and Plastics, Inc.
Skyre, Inc.
Southwest Research Institute
Strategic Analysis Inc.
Treadstone
United Technologies Research Center
Lubrizol Corporation
Liox Power, Inc.
Hy-Performance Materials Testing, LLC
NASA
Nikola Motor Company
Ames Lab
Argonne National Lab
Brookhaven National Lab
Idaho National Lab
Lawrence Livermore National Lab
Los Alamos National Lab
National Energy Technology Lab
National Renewable Energy Lab
Oak Ridge National Lab
Pacific Northwest National Lab
Sandia National Laboratories
Savannah River National Lab
SLAC National Accelerator Lab
U.S. Naval Research Lab
Arizona State University
California Institute of Technology
Carnegie Mellon University
Clemson University
Colorado School of Mines
Drexel University
Georgia Institute of Technology
Indiana University Purdue University Indianapolis
James Madison University
Leland Stanford Junior University
Massachusetts Institute of Technology
Missouri University of Science & Technology
Montana State University
Northeastern University
Oak Ridge Associated Universities
Oak Ridge Institute for Science & Education
Oregon State University
Penn State University
University of Michigan
Rice University
Rutgers University
The University of Alabama
The University of Toledo
University of Delaware
University of Hawaii
University of Illinois at Urbana-Champaign
University of Kansas
University of Kentucky
University of Oregon
University of South Carolina
University of Southern California
University of California, Irvine
University of California, San Diego
University of Colorado
University of Connecticut
University of Tennessee Space Institute
University of Texas at Austin
University of Virginia
Vanderbilt University
University of Tennessee-Knoxville
Washington State University
West Virginia University
Washington U (IIT)

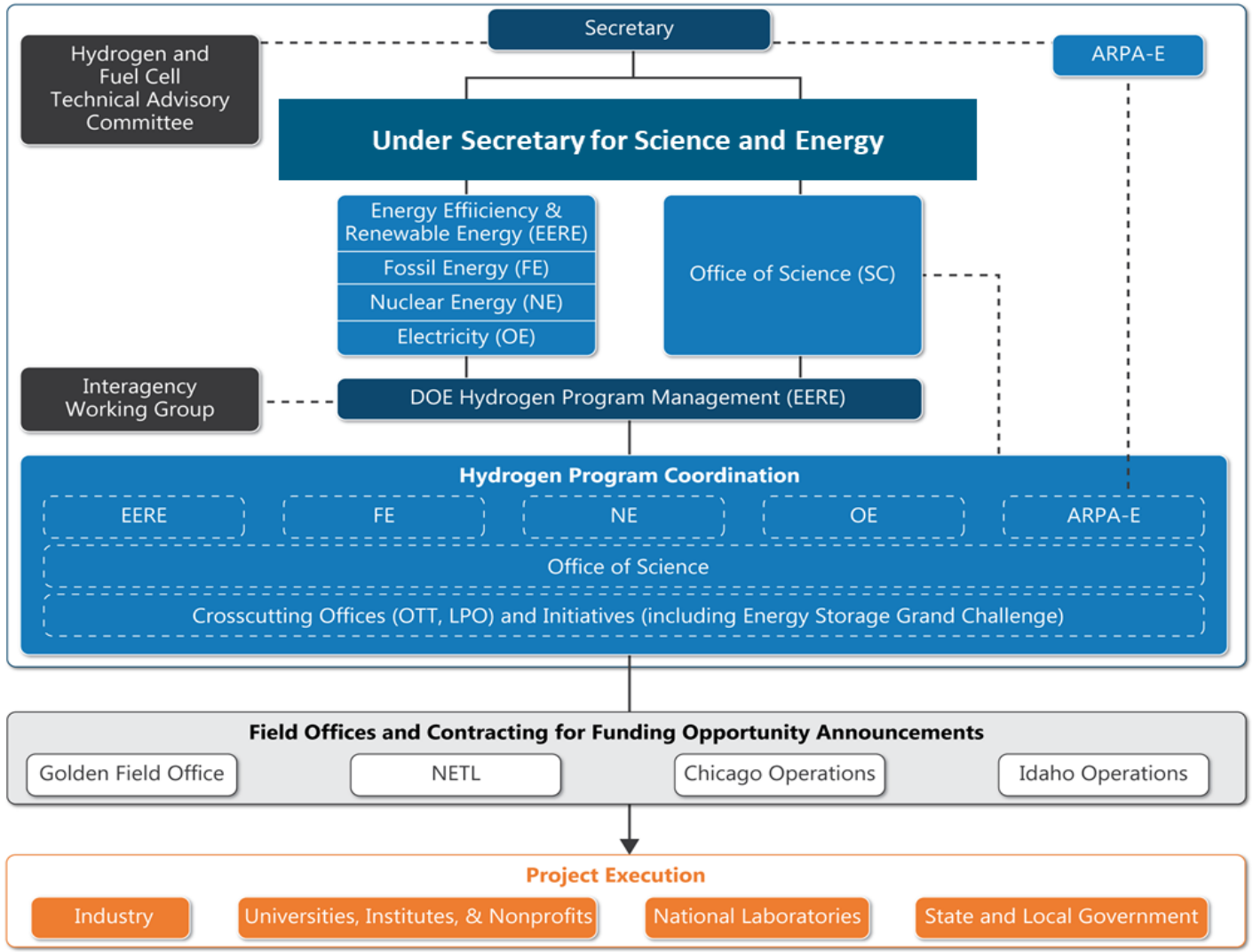
The U.S. DOE Hydrogen Program Released November 2020

The Energy Policy Act (2005) Title VIII and Energy Policy Act of 2020 provide key authorization

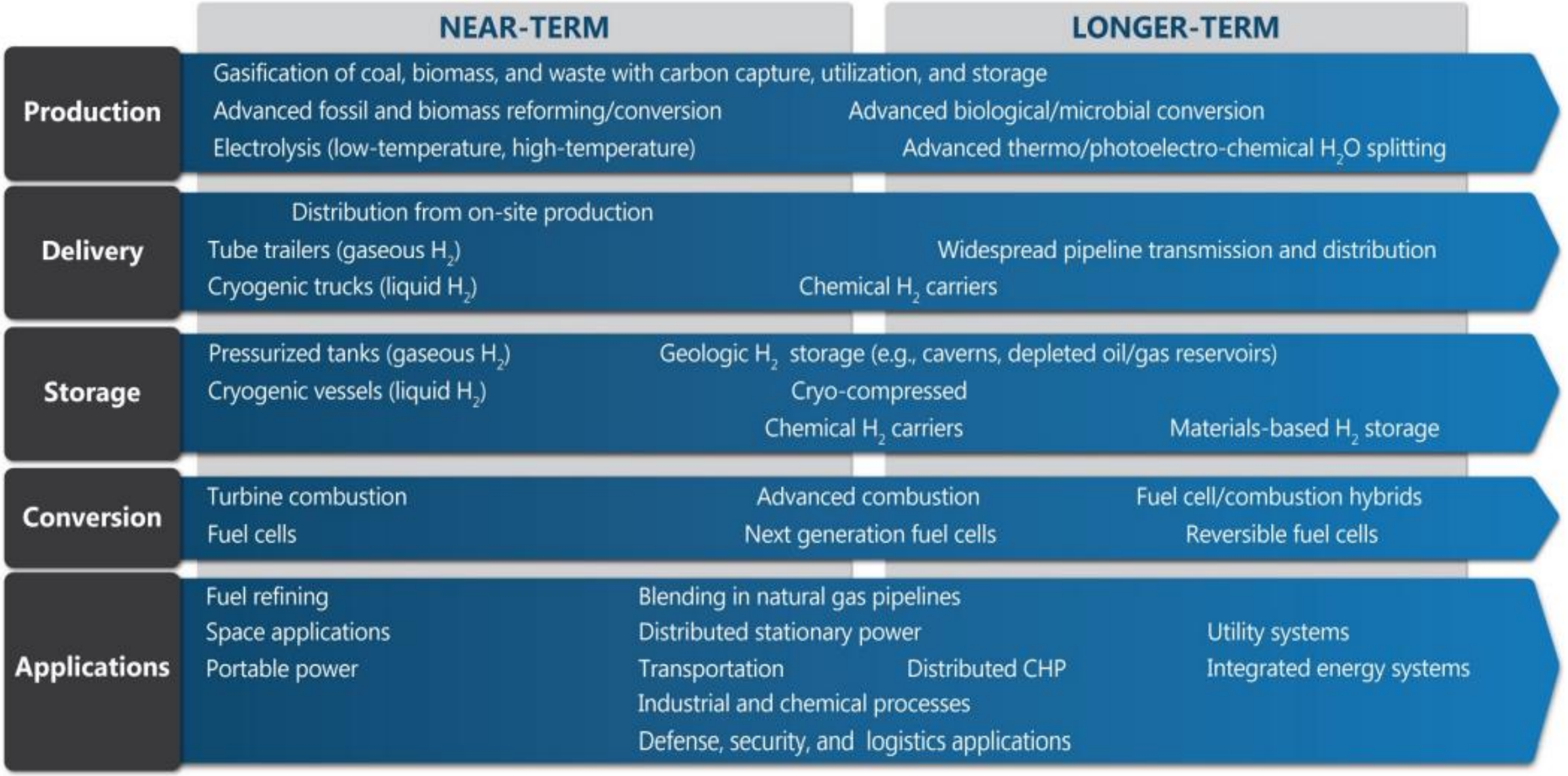
Hydrogen is one part of a broad portfolio of activities



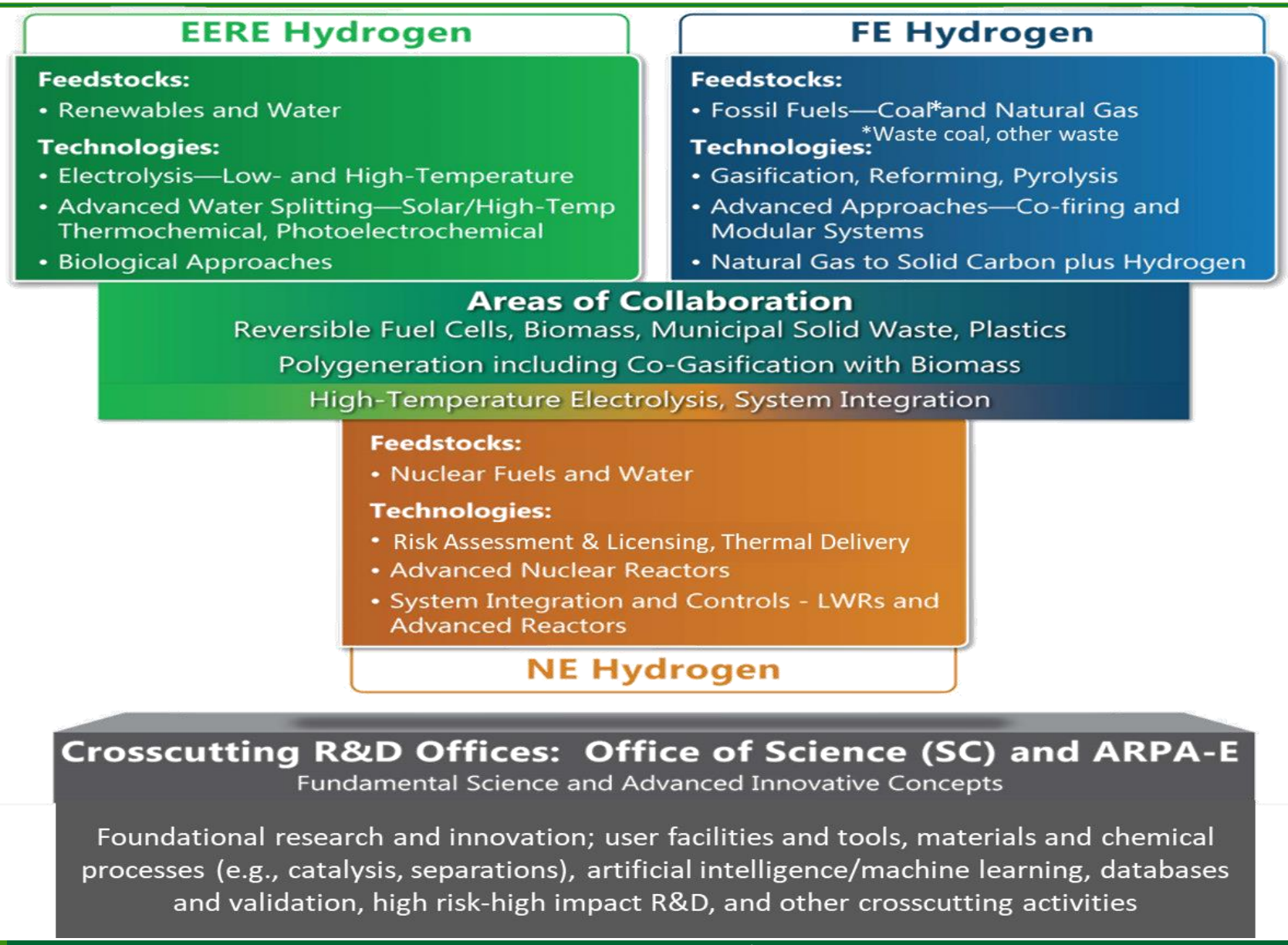
www.hydrogen.energy.gov



Comprehensive Strategy Across the Hydrogen Value Chain



DOE Hydrogen Program – Collaboration



EERE: Office of Energy Efficiency and Renewable Energy
FE: Office of Fossil Energy
NE: Office of Nuclear Energy

Hot Off the Press: CRADA Call Released June 7, 2021

Total Funding: up to $12M over 3 years*

- $500k - $2M per project, dependent on topic area
- Up to 14 projects total
- 30% cost share including 10% cash in
- National Lab leads w/ partners from industry, state & local govt, universities, and more

Topics

1) Integrated Hydrogen Energy System Testing & Validation
2) Applied Risk Assessment and Modeling for H2@Scale Applications
3) Next-Generation Sensor Technologies

Proposals due July 19, 2021

CRADAs are Cooperative Research And Development Agreements

*Pending Appropriations

www.nrel.gov/hydrogen/h2-at-scale-crada-call.html

HyBlend and H-Mat Consortia – Opportunities Available

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

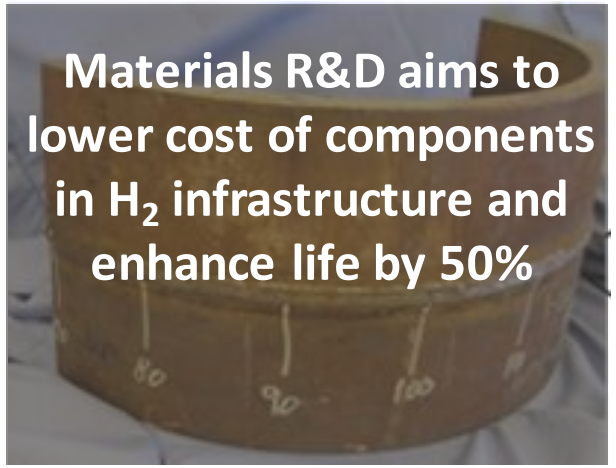
H-Mat Hydrogen Materials Compatibility Consortium℠

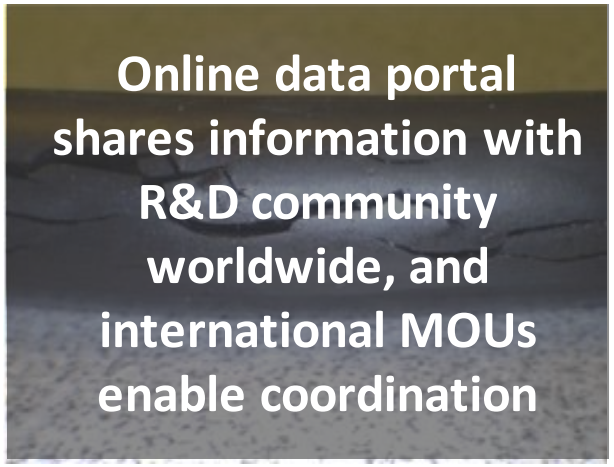
National lab consortium to assess and improve performance and reliability of materials in hydrogen, reduce costs, and inform codes & standards.

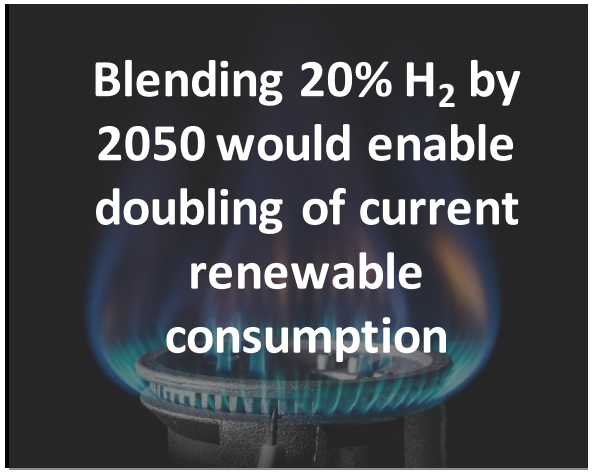
HyBlend U.S. DEPARTMENT OF ENERGY

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

Over 40 partners







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

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

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

Examples of Applications Deployed

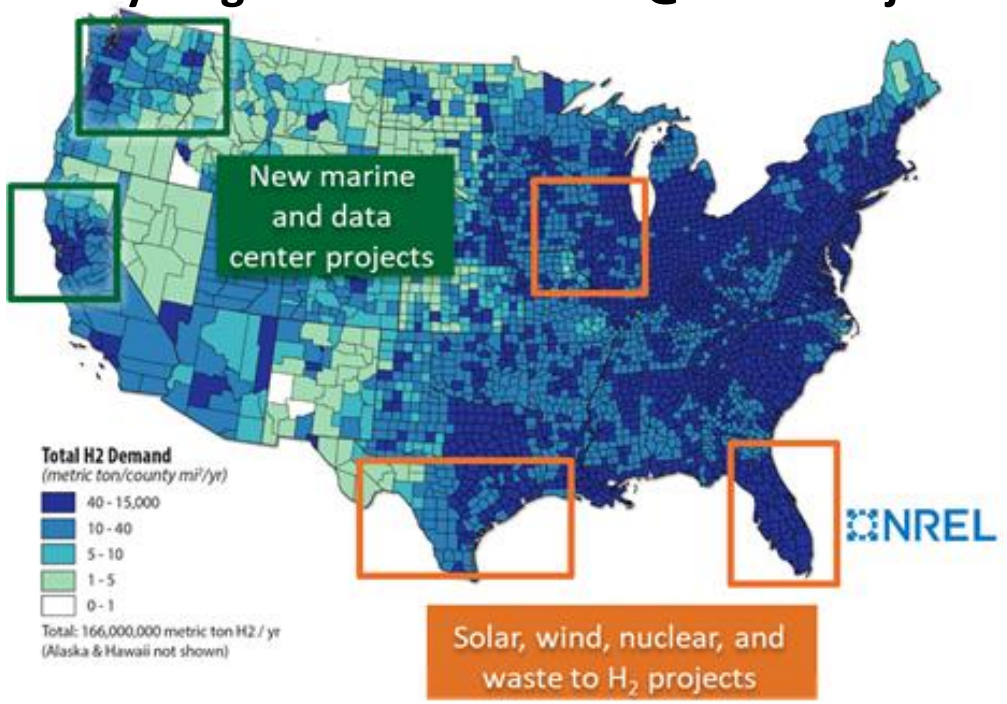
- **>500MW** Backup Power
- **>40,000** Forklifts
- **>172 MW** PEM* Electrolyzers
- **>60** Fuel Cell Buses
- **>45** H_2 Retail Stations
- **~10,000** Fuel Cell Cars

*Polymer electrolyte membrane

Major Hydrogen Production Sites

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

Hydrogen Demand and H2@Scale Projects



Hydrogen Stations Plans Across States

California
200 Stations Planned California Fuel Cell Partnership Goal

Northeast
12 – 20 Stations Planned

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

H2@Scale Projects to Demonstrate Technology and Train Future Workforce

Different regions, hydrogen sources, end uses & educational opportunities

H_2 for Marine Application

California

1st-of-its-kind maritime H_2 refueling on floating barge - up to ½ ton H_2 /day

H_2 from Renewables

Texas

Integrates wind, solar, RNG from waste with onsite electrolysis and multiple end-uses

H_2 for Data Center

Washington

Integrates a 1.5MW fuel cell with a data center to provide reliable and resilient power

H_2 for Steel Production

Missouri

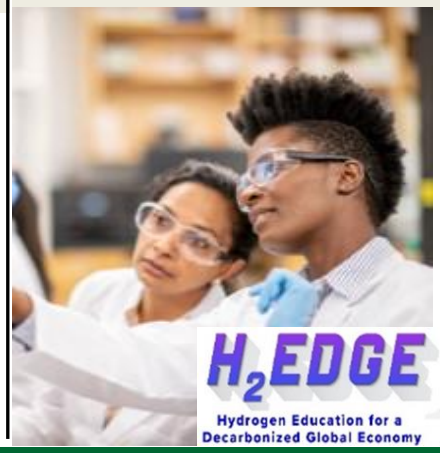
Reduction of 30% in energy and 40% emissions vs. conventional processes

H_2 from Nuclear

New York

Demonstrates a MW electrolyzer with a nuclear plant (collaboration with Nuclear Office)

Workforce Development



Multi-state

A Training, education and recruiting program to build skills needed in the H_2 industry