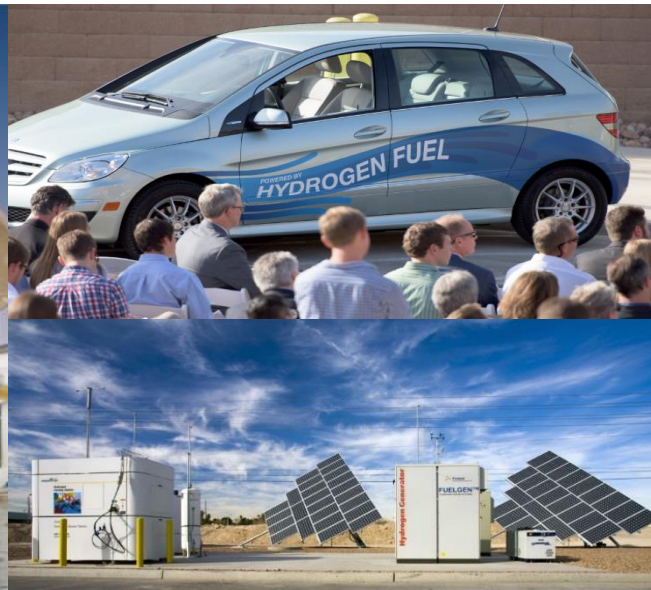


DOE Hydrogen and Fuel Cell Technologies Office Opening Remarks

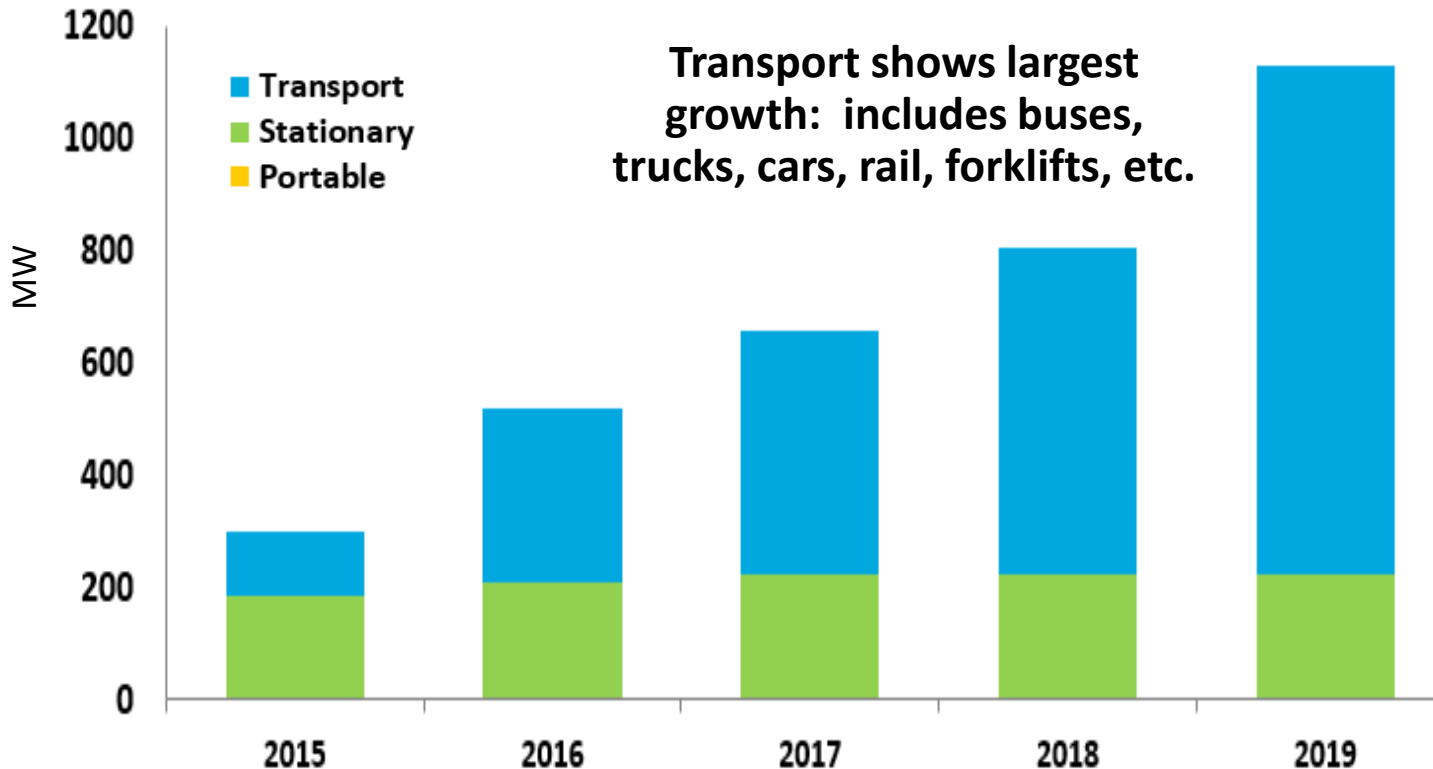
Dr. Sunita Satyapal, Director, Hydrogen and Fuel Cell Technologies Office

Green Hydrogen Visions for the West Virtual Conference
Green Hydrogen Coalition, NASEO and Western Interstate Energy Board
November 18, 2020



Hydrogen and Fuel Cell Technology Growth Worldwide

Global fuel cell shipments surpass 1 GW



Source: E4tech for DOE analysis project

25-fold increase in electrolyzers deployed in the last decade

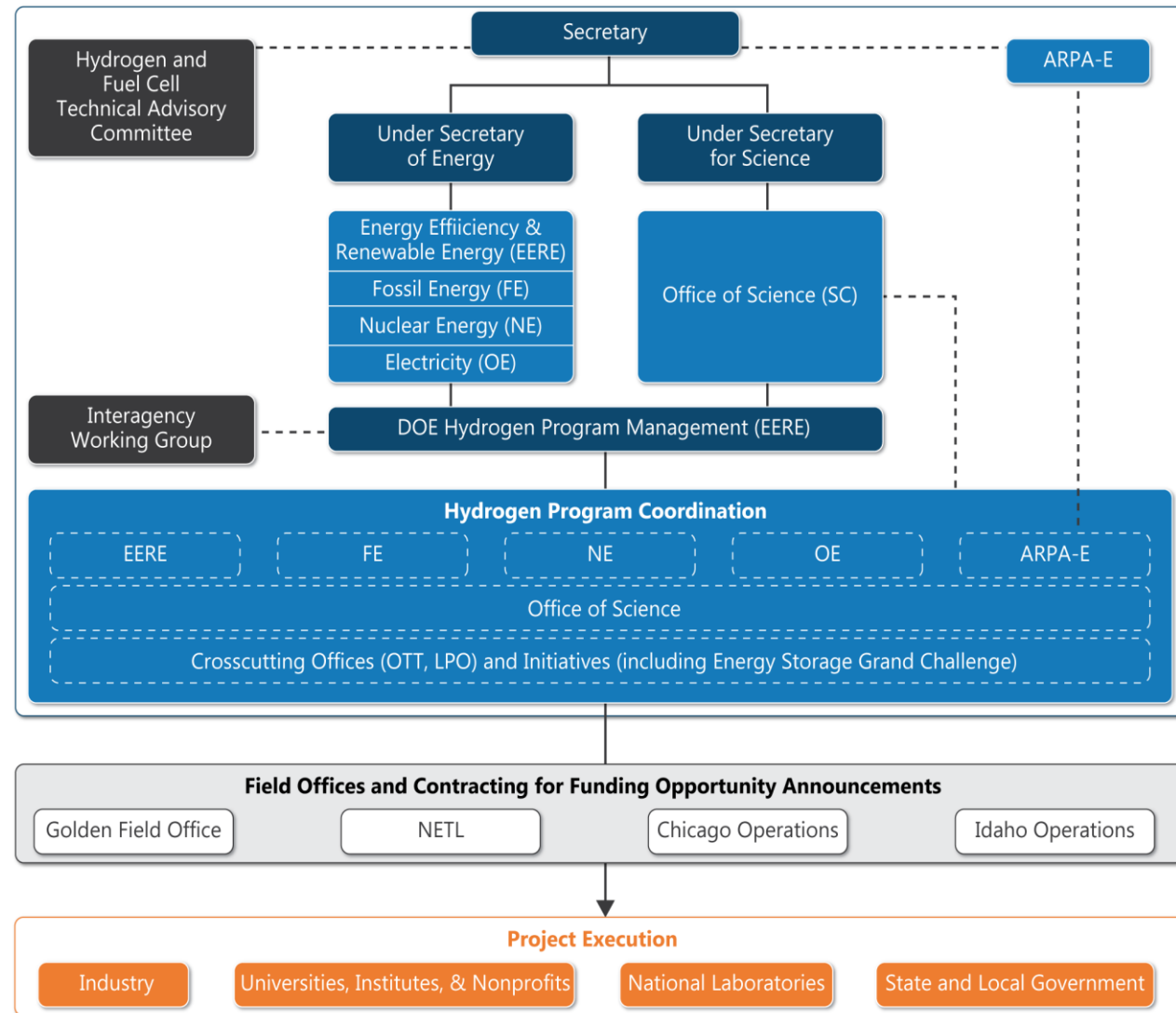
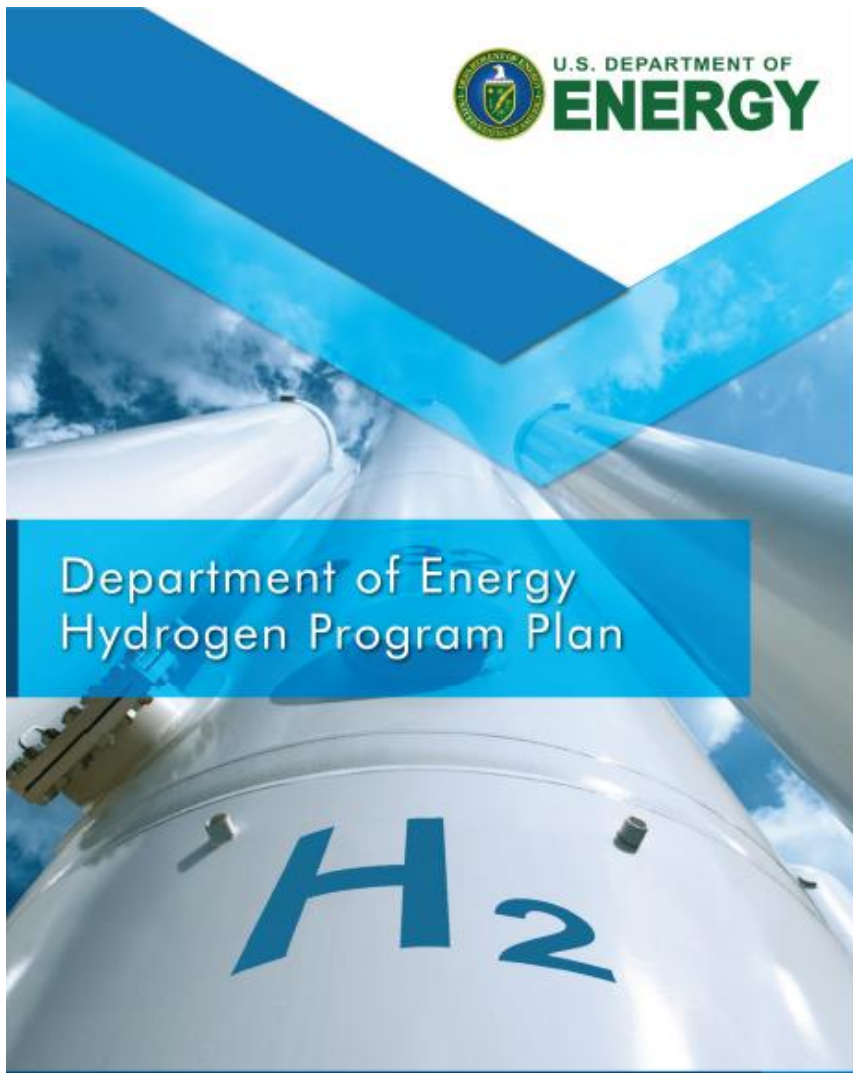
<1MW in 2010 to >25 MW by the end of 2019

Global FCEVs doubled to >25,200
>12.3K sold in 2019 vs. 5.8K in 2018

470 H₂ fueling stations worldwide
> 20% increase from 2018

Source: IEA (2020), *Hydrogen*, IEA, Paris, <https://www.iea.org/reports/hydrogen>

US DOE Integrated Hydrogen Program



Released November 2020 - www.hydrogen.energy.gov



Vision

The Program's vision is a prosperous future for the nation, in which clean hydrogen energy technologies are affordable, widely available and reliable, and are an integral part of multiple sectors of the economy across the country.

The Program works in partnership with stakeholders to:

- **Overcome technical barriers** through basic and applied research and development
- **Integrate, demonstrate, and validate** “first-of-a-kind” hydrogen and related technologies
- **Accelerate the transition of innovations** and technologies to the private sector
- **Address institutional issues** including safety concerns, education and workforce development, and the development of codes and standards
- **Identify, implement, and refine appropriate strategies** for federal programs to catalyze a sustainable market and concomitant benefits to the economy, the environment, and energy security

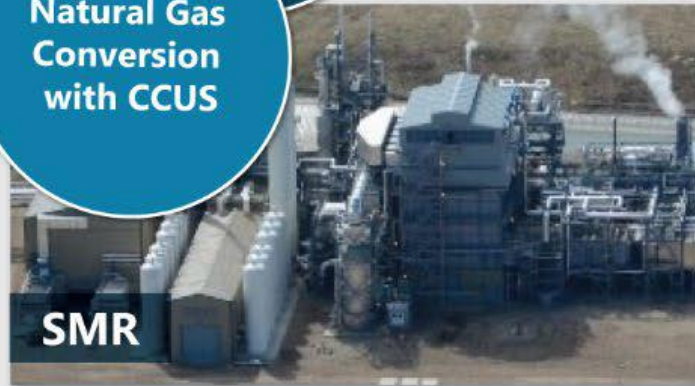
Portfolio Includes Hydrogen Production from Diverse Sources and Pathways

FOSSIL RESOURCES

- Low-cost, large-scale hydrogen production with CCUS
- New options include byproduct production, such as solid carbon

Coal Gasification with CCUS

Natural Gas Conversion with CCUS



SMR

BIOMASS/WASTE

- Options include biogas reforming and fermentation of waste streams
- Byproduct benefits include clean water, electricity, and chemicals

Biomass Conversion

Waste to Energy



ADG

H₂ SPLITTING

- Electrolyzers can be grid-tied, or directly coupled with renewables
- New direct water-splitting technologies offer longer-term options



STCH

Direct-Solar

High Temp. Electrolysis



PEM

Low Temp. Electrolysis



Electrolysis

Key Program Targets and Key R&D Office Activities



Examples of Key DOE Hydrogen Program Targets

DOE targets are application-specific and developed with stakeholder input to enable competitiveness with incumbent and emerging technologies. These targets guide the R&D community and inform the Program's portfolio of activities. Examples include:

- \$2/kg for hydrogen production and \$2/kg for delivery and dispensing for transportation applications
- \$1/kg hydrogen for industrial and stationary power generation applications
- Fuel cell system cost of \$80/kW with 25,000-hour durability for long-haul heavy-duty trucks
- On-board vehicular hydrogen storage at \$8/kWh, 2.2 kWh/kg, and 1.7kWh/l
- Electrolyzer capital cost of \$300/kW, 80,000 hour durability, and 65% system efficiency
- Fuel cell system cost of \$900/kW and 40,000 hour durability for fuel-flexible stationary high-temperature fuel cells

EERE Hydrogen

Feedstocks:

- Renewables and Water

Technologies:

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

FE 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

Areas of Collaboration

Reversible Fuel Cells, Biomass, Municipal Solid Waste, Plastics

Polygeneration including Co-Gasification with Biomass

High-Temperature Electrolysis, System Integration

Feedstocks:

- Nuclear Fuels and Water

Technologies:

- Electrolysis Systems for Nuclear
- Advanced Nuclear Reactors
- System Integration and Controls - LWRs and Advanced Reactors

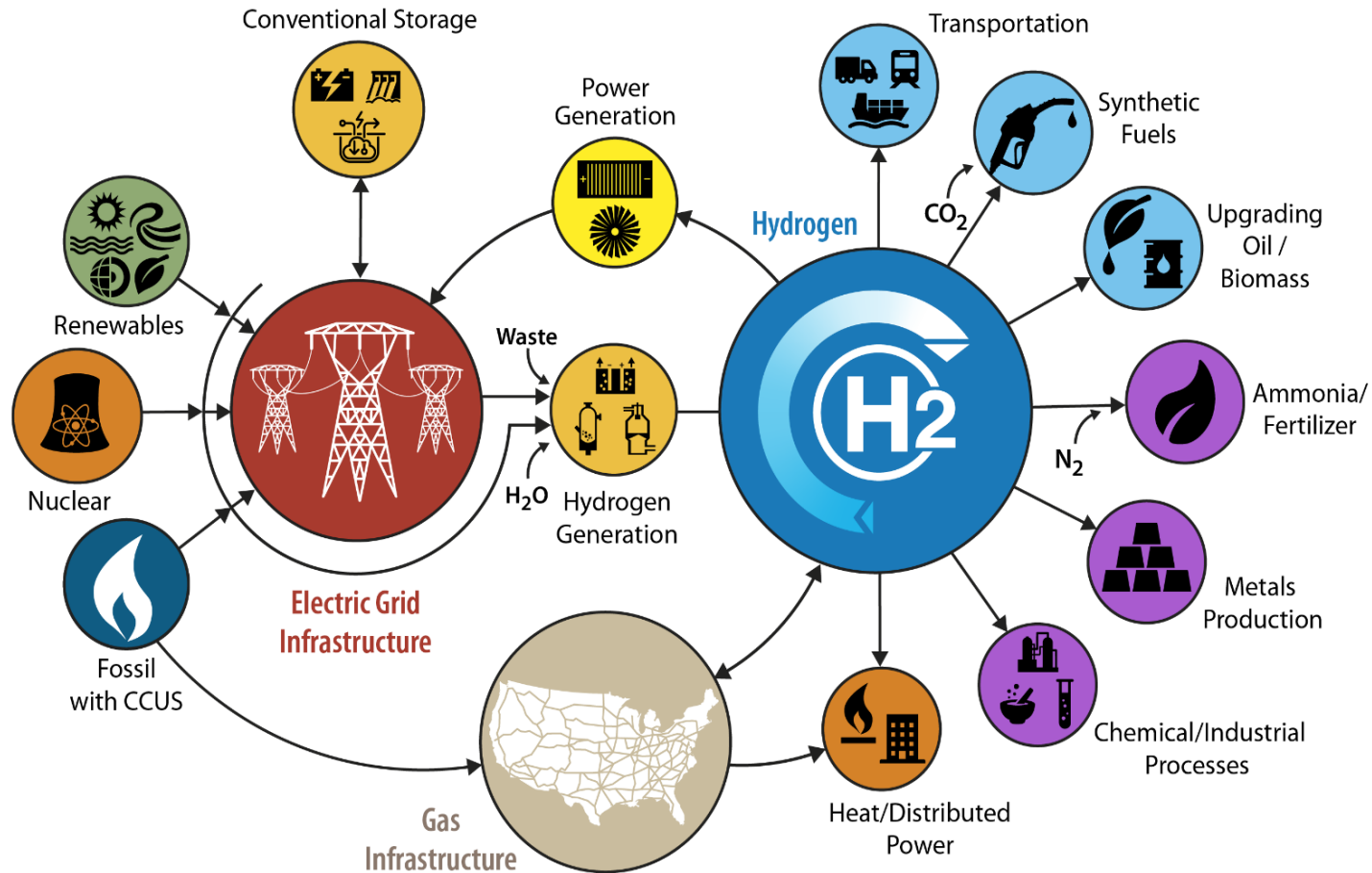
NE Hydrogen

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

Fundamental Science and Advanced Innovative Concepts

Hydrogen is one part of a Comprehensive Energy Portfolio

H2@Scale: Enabling affordable, reliable, clean, and secure energy across sectors



- Hydrogen can address specific applications across sectors that are hard to decarbonize
- Today: 10MMT H₂ in the U.S.
- Economic Potential: 2 to 4x more

Strategies

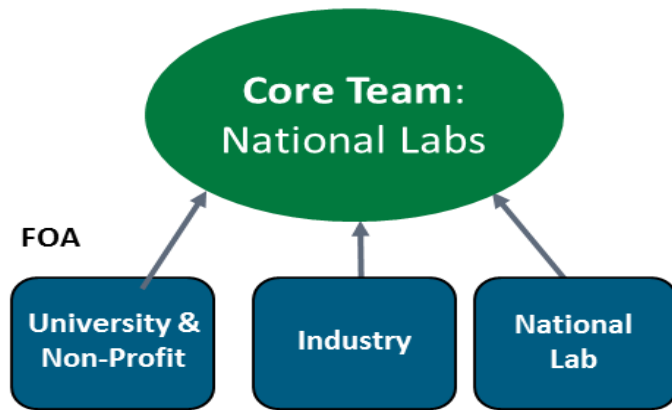
- Scale up technologies in key sectors
- Continue R&D to reduce cost and improve performance, reliability
- Address enablers: harmonization of codes, standards, safety, global supply chain, workforce development, sustainable markets

Source: U.S. DOE Hydrogen and Fuel Cell Technologies Office, <https://www.energy.gov/eere/fuelcells/h2scale>

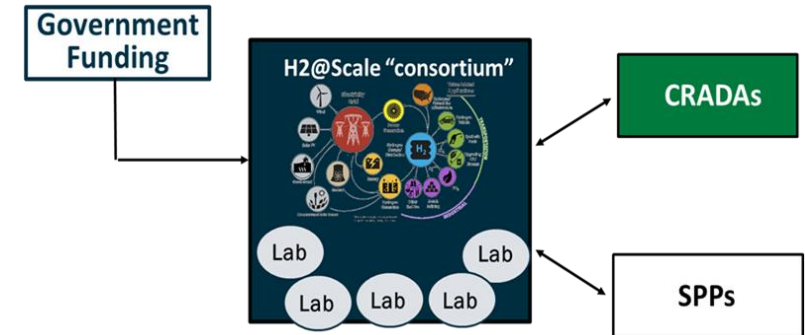
Key Programmatic Areas

Includes early stage R&D: Funding Opportunity Announcements (FOAs) for industry, universities and national labs, including consortia

And includes later stage RD&D: Leverages private sector for large-scale demonstrations and cost-shared RD&D. Demos in TX, FL, Midwest, CA and more



2 New Lab Consortia Just Announced: H2NEW and Million Mile Fuel Cell Truck Consortium



CRADA = Cooperative Research and Development Agreement
SPP- Strategic Partnership Project ('Work for Others')

Over 25 CRADA projects with private sector



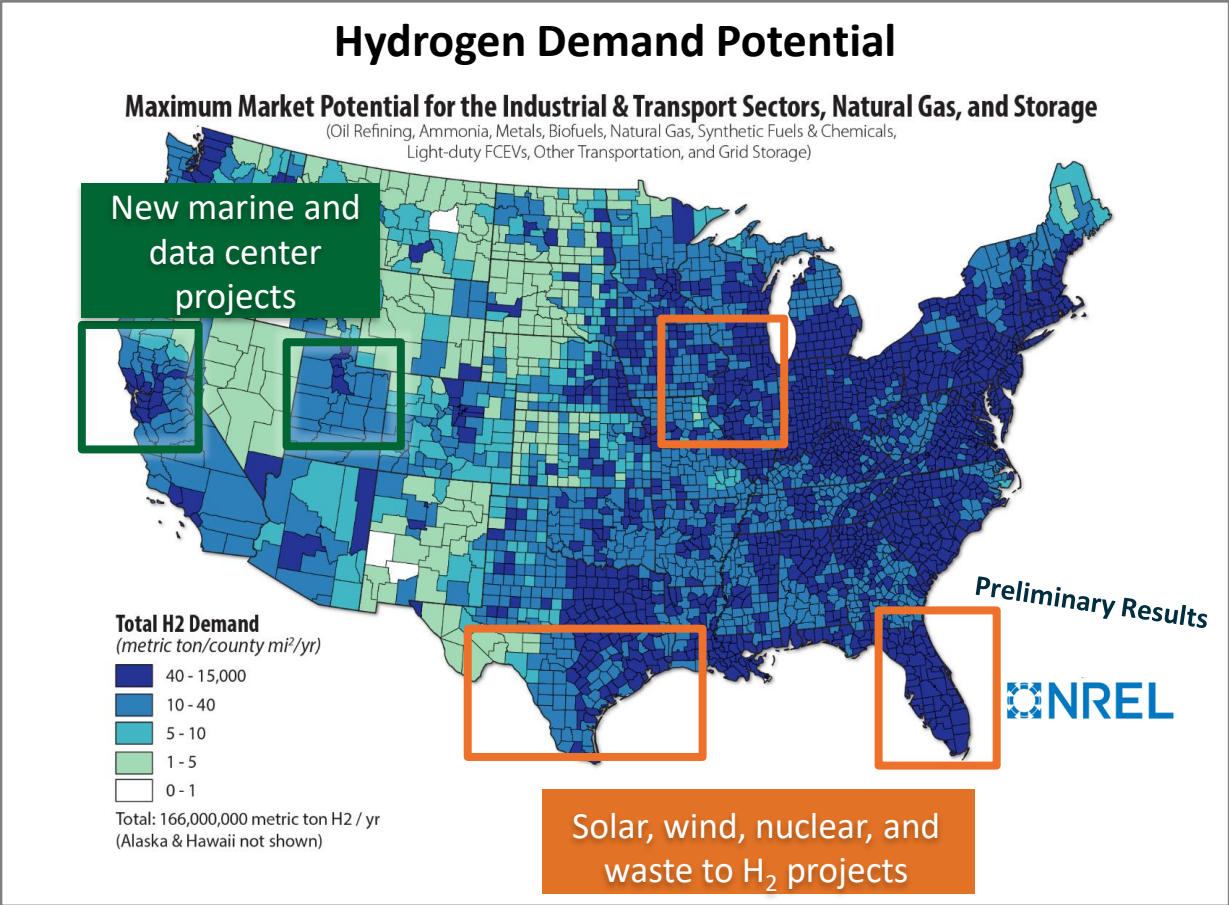
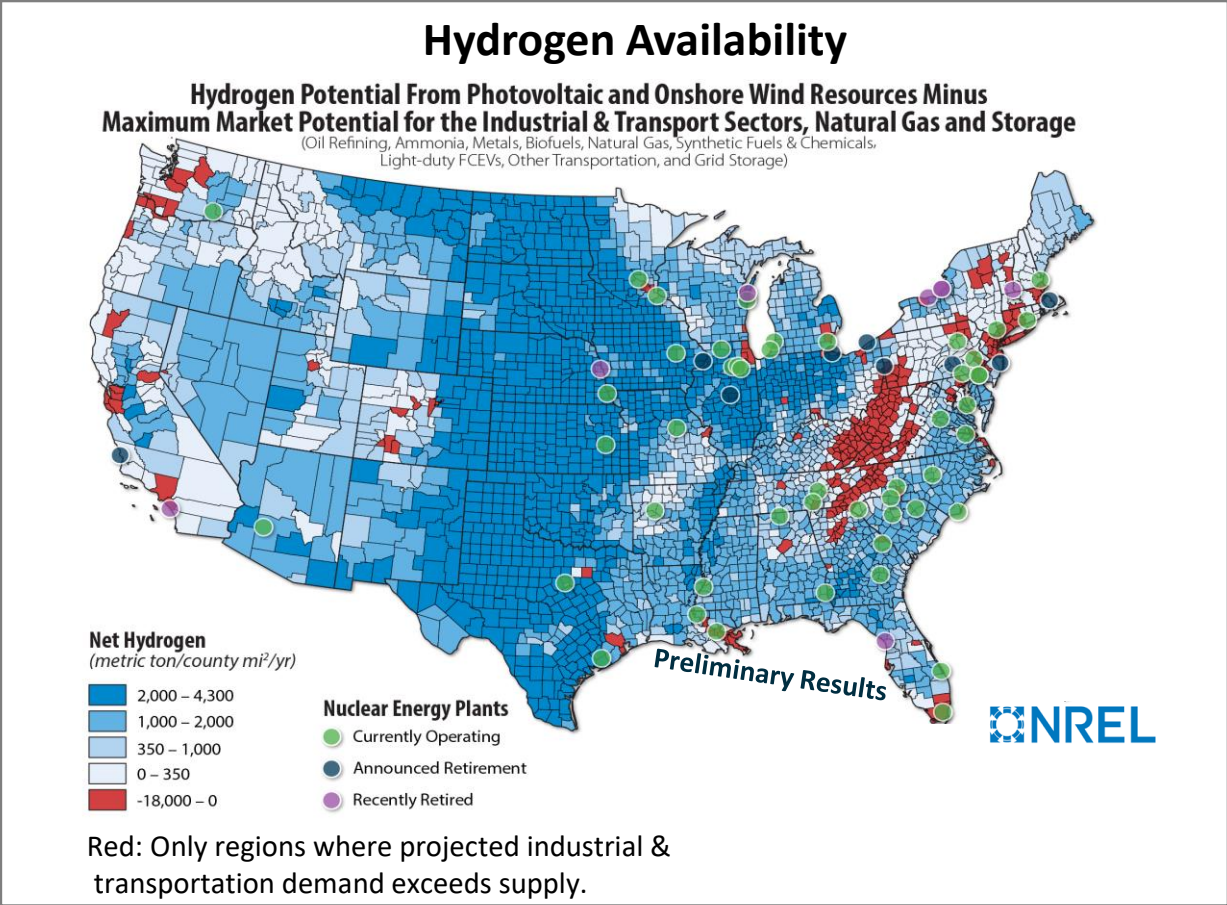
Just Announced: \$64M for 18 projects including R&D and demonstrations at ports and datacenters, and a workforce development program . Includes collaboration with Advanced Manufacturing Office and Vehicles Office in EERE

Examples of H2@Scale Analysis and Demonstration Projects

Assessing resource availability.
Most regions have sufficient resources.

New H2@Scale demonstration projects cover range of applications

*Includes 1 project by Office of Nuclear Energy



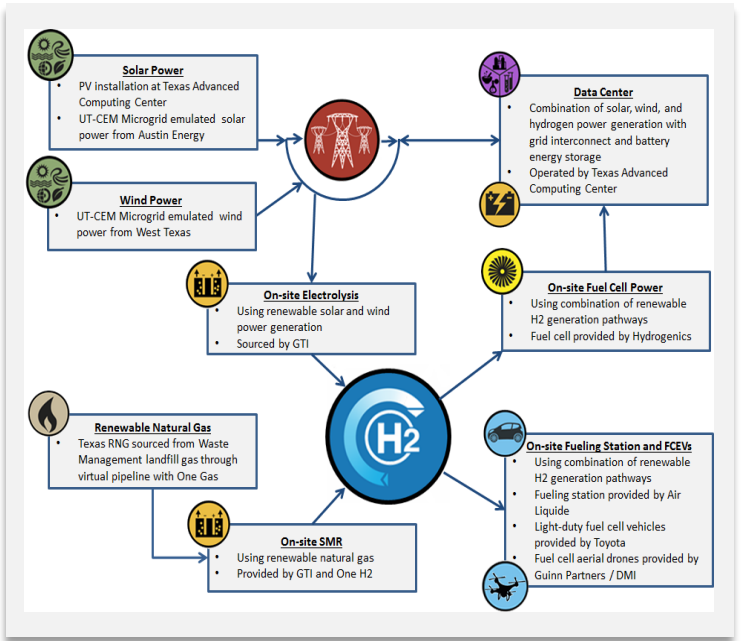
Example of H2@Scale Demonstration Projects

Demonstration of H2@Scale: Different regions, hydrogen sources and end uses

Texas

Total Budget
\$10.8M

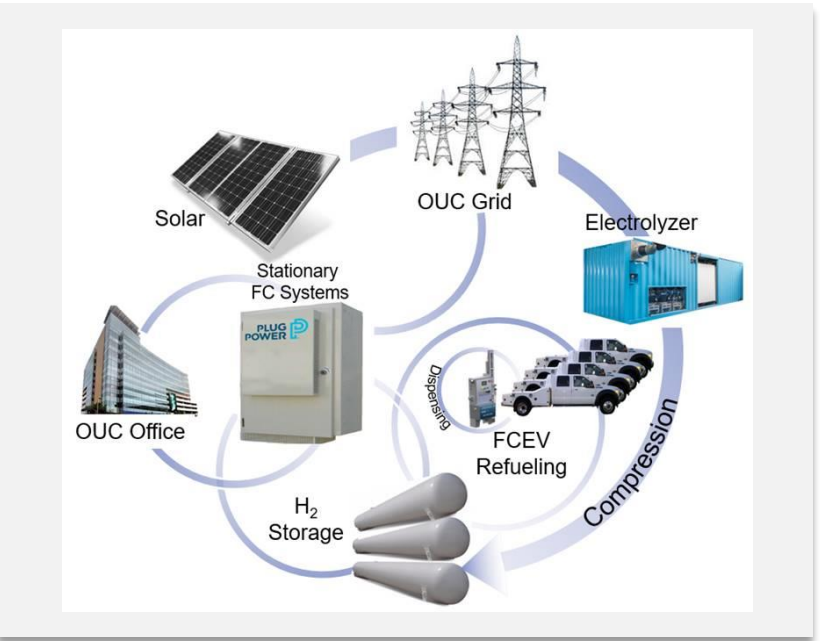
Wind, Solar, RNG/Waste



Florida

Total budget
\$9.1M

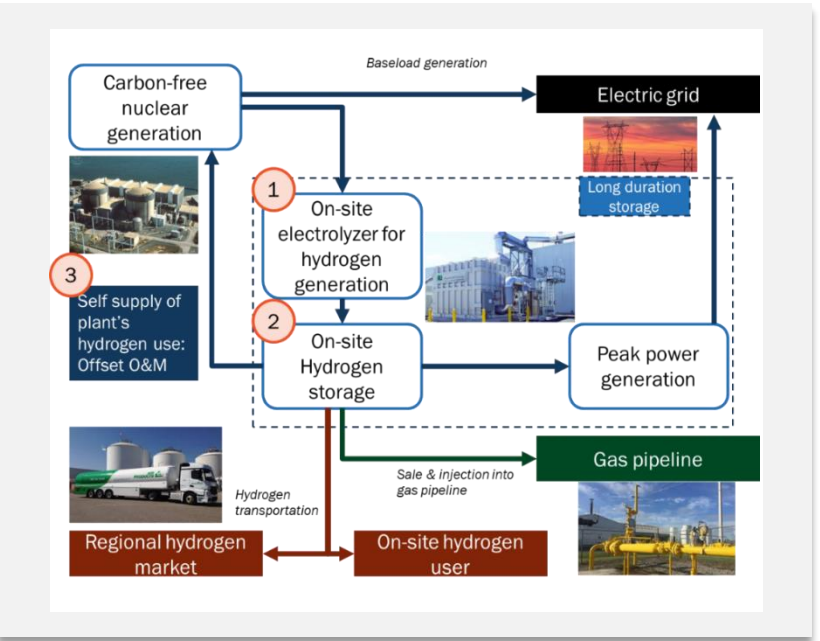
Solar-to-H₂ with End Uses



Site selection in process

Total Budget
\$7.2M

Nuclear-to-H₂ for at-Plant Use



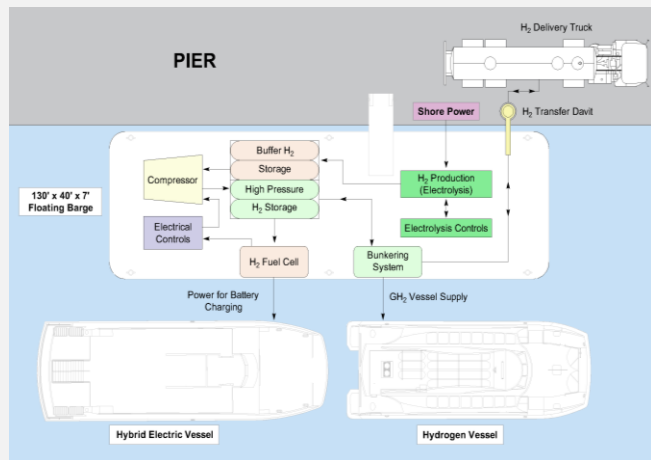
Examples of H2@Scale Demonstration Projects -2020

Demonstration of H2@Scale: Different regions, hydrogen sources and end uses

Marine Application

Total Budget
\$16M

Electrolyzer and fuel cell for marine application

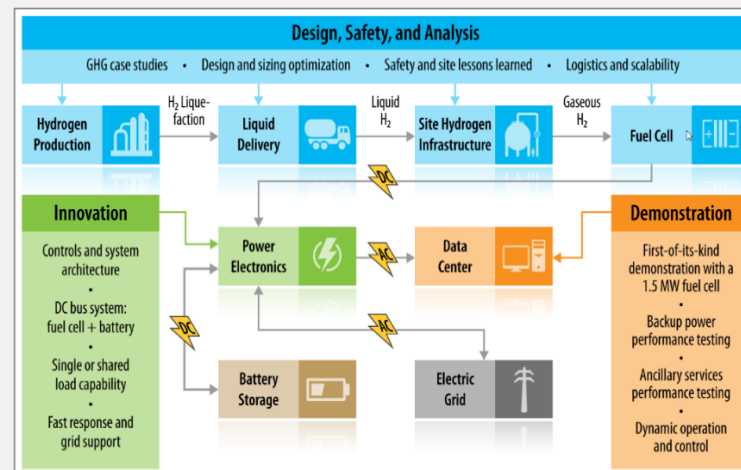


1st-of-its-kind maritime H₂ refueling on floating barge - up to 530 kg H₂ /day

H₂ for Data Center

Total Budget
\$13.7M

PEM fuel cell for data center power

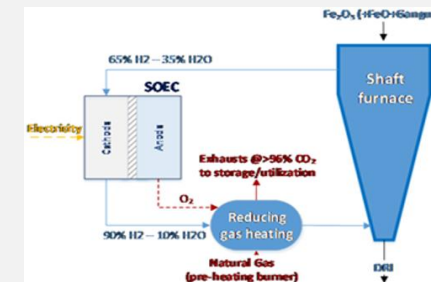


1.5MW fuel cell to meet data center requirements and future scale up

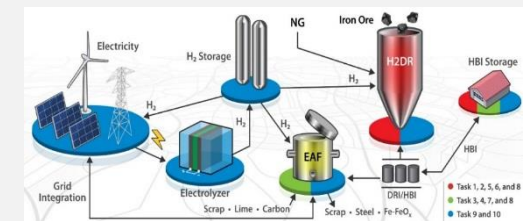
H₂ for Steel Production

Total Budgets
\$5.7M & \$7.2M

DRI-process and grid-interactive steelmaking



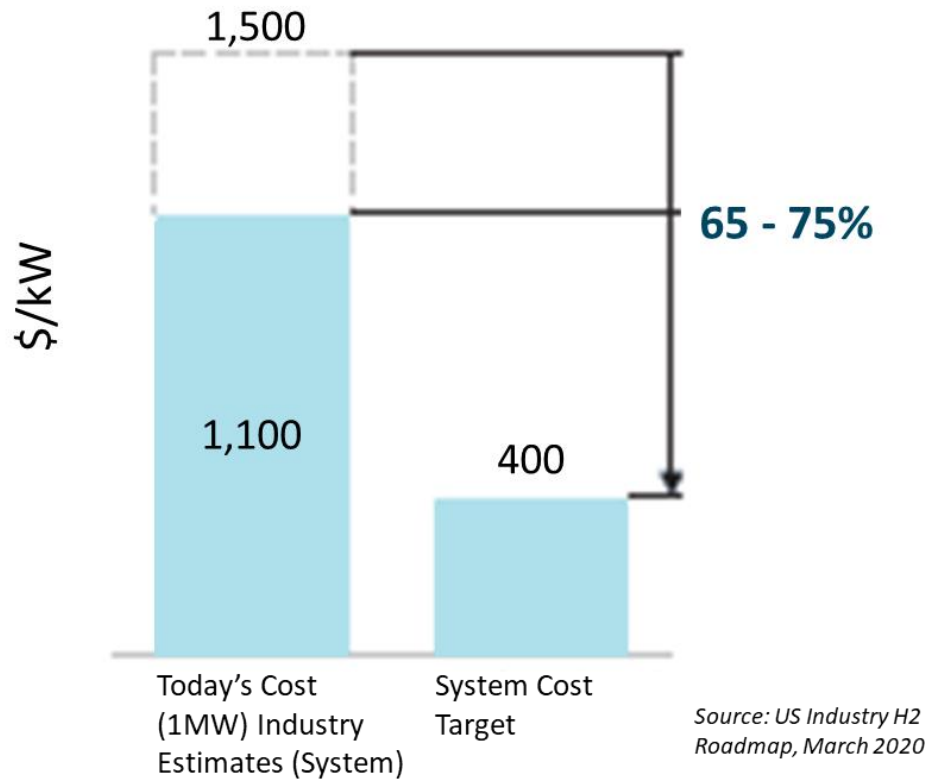
Reduction of 30% in energy and 40% emissions vs conventional DRI processes



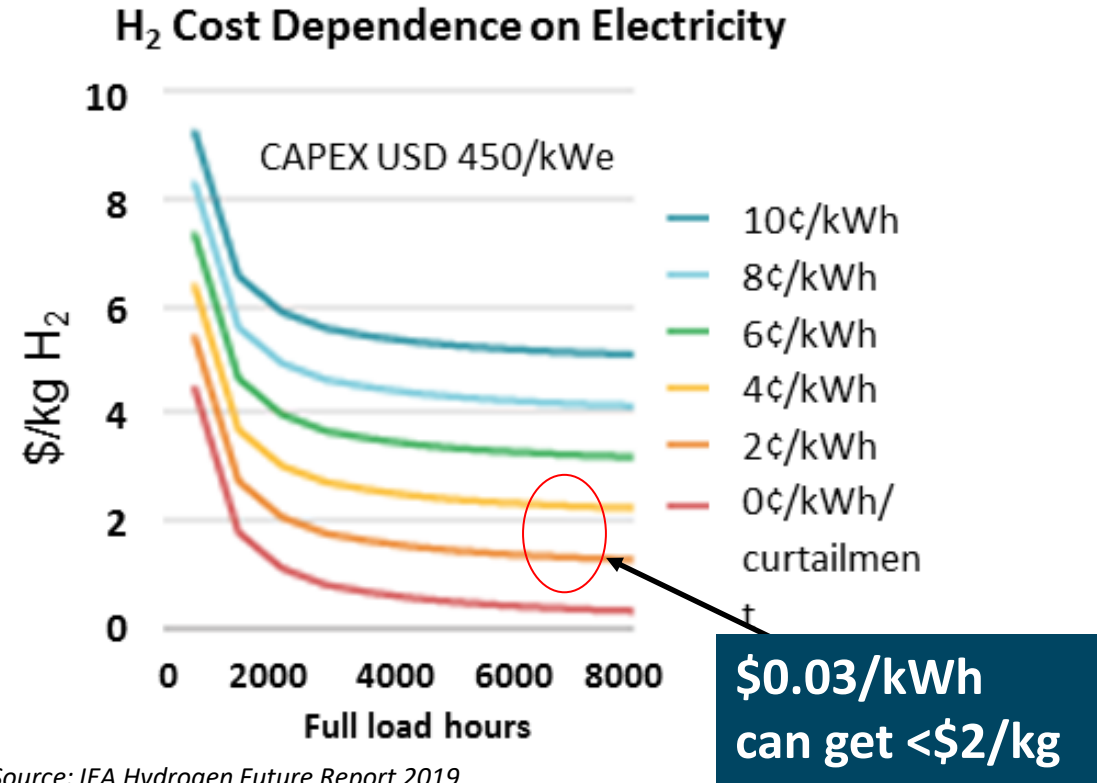
1 ton/wk iron prod.; scaled to 5,000 ton/day

Electrolysis Cost – Recent Independent Analyses

Today's Polymer Electrolyte Membrane (PEM) electrolyzers require 65-75% cost reduction

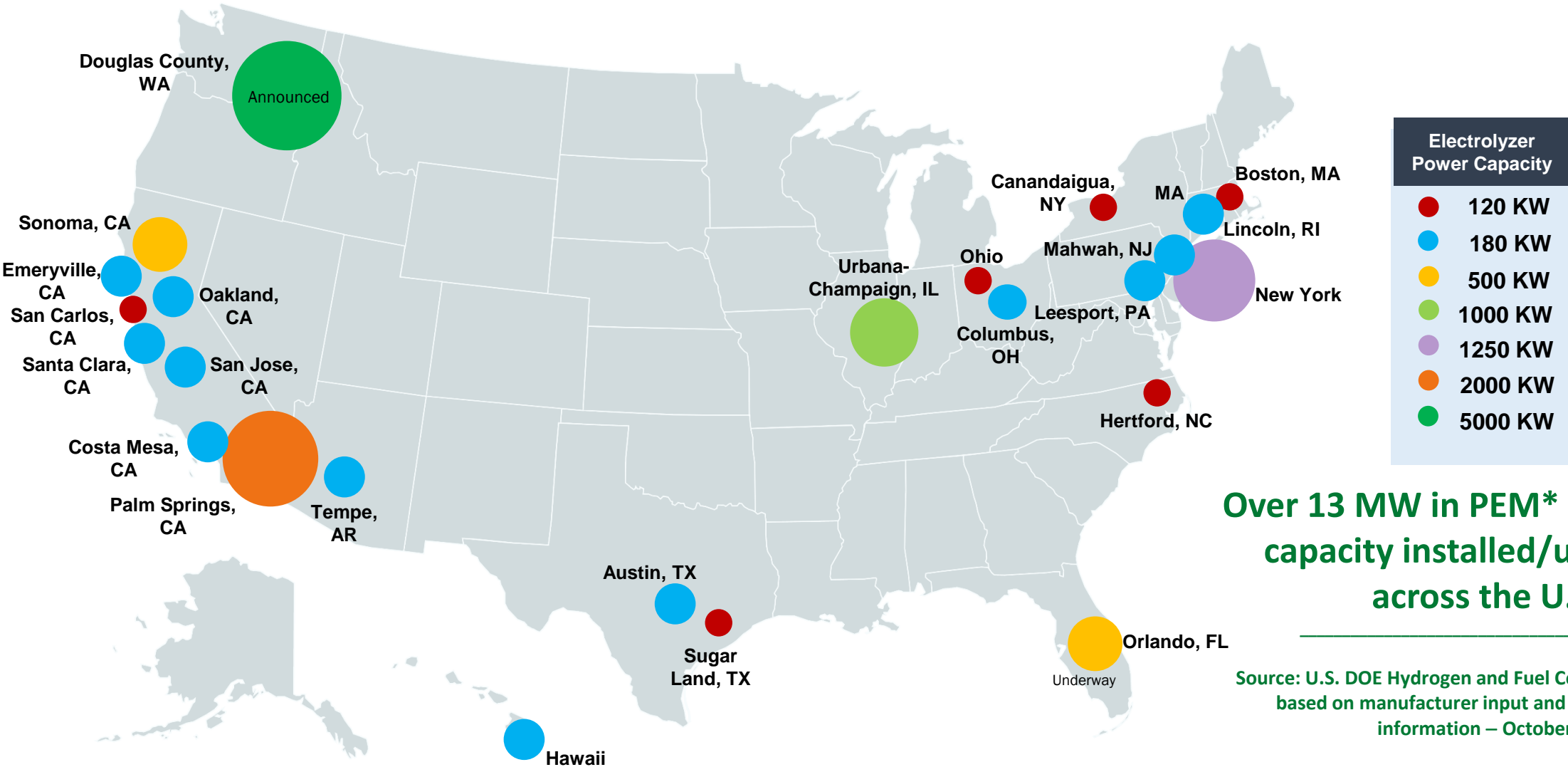


\$2/kg H₂ is achievable at about \$0.03/kWh electricity cost and high utilization



Today's hydrogen cost from PEM electrolyzers: ~ \$5 to \$6/kg at \$0.05 to \$0.07/kWh

U.S. Hydrogen Electrolyzer Locations and Capacity (KW)



Over 13 MW in PEM* electrolyzer capacity installed/underway across the U.S.

Source: U.S. DOE Hydrogen and Fuel Cell Technologies Office based on manufacturer input and publicly available information – October 2020

* Polymer electrolyte membrane

A top-down view of several hands of different skin tones clasped together in a circle, resting on a green grassy surface. The hands are arranged in a supportive grip, with fingers interlocking. Two hands have gold rings on the ring fingers. The overall tone is warm and collaborative.

Collaboration

“No one can whistle a symphony. It takes a whole orchestra to play it.”

- H. Luccock

Examples of Global Collaboration

Coordinating across global partnerships: IPHE, Ministerials, Mission Innovation, IEA, etc.
 Global Center for Hydrogen Safety established to share best practices, training resources and information



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



Elected Chair and Vice-Chair, 2018

New Chair: Dec 2020: The Netherlands
 Vice Chairs: U.S. Japan
www.iphe.net

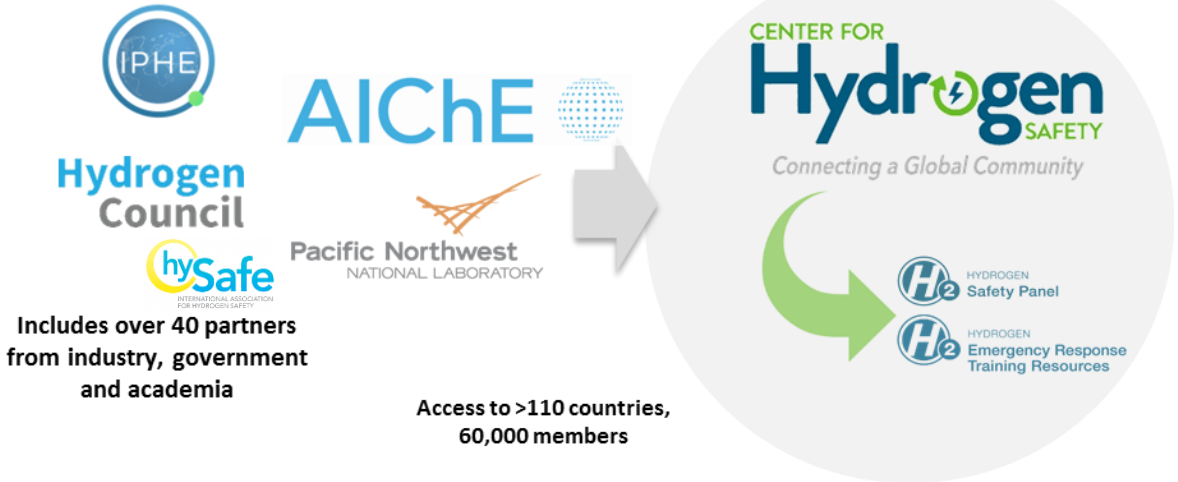


Formed in 2003 Over 20 countries

Key Activities: Harmonization of codes & standards, Information sharing on safety, policies, regulations, analysis, education.
Task force on developing H₂ production analysis methodology to facilitate international trade, global RD&D monitoring

- Hydrogen and Clean Energy Ministerials
- Mission Innovation Hydrogen Challenge
- International Energy Agency

www.aiche.org/CHS



Resources and Events

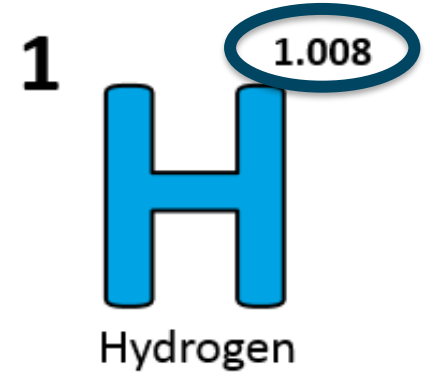
Save the Date

June 8-10, 2021 Annual Merit Review and Peer Evaluation Meeting for the Hydrogen and Fuel Cells Program in Arlington, VA



Oct 8 - Hydrogen and Fuel Cells Day

(Held on its very own atomic weight-day)



Resources



Join Monthly
H2IQ Hour Webinars

Download
H2IQ For Free

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

[energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource](https://www.energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource)



Visit H2tools.Org For Hydrogen Safety And Lessons Learned

<https://h2tools.org/>



Learn more:

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](https://www.energy.gov/eere/fuelcells) AND www.hydrogen.energy.gov

Thank You

Dr. Sunita Satyapal, Director

Hydrogen and Fuel Cell Technologies Office

Sunita.satyapal@ee.doe.gov

<https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office>

www.hydrogen.energy.gov