U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office and Global Perspectives

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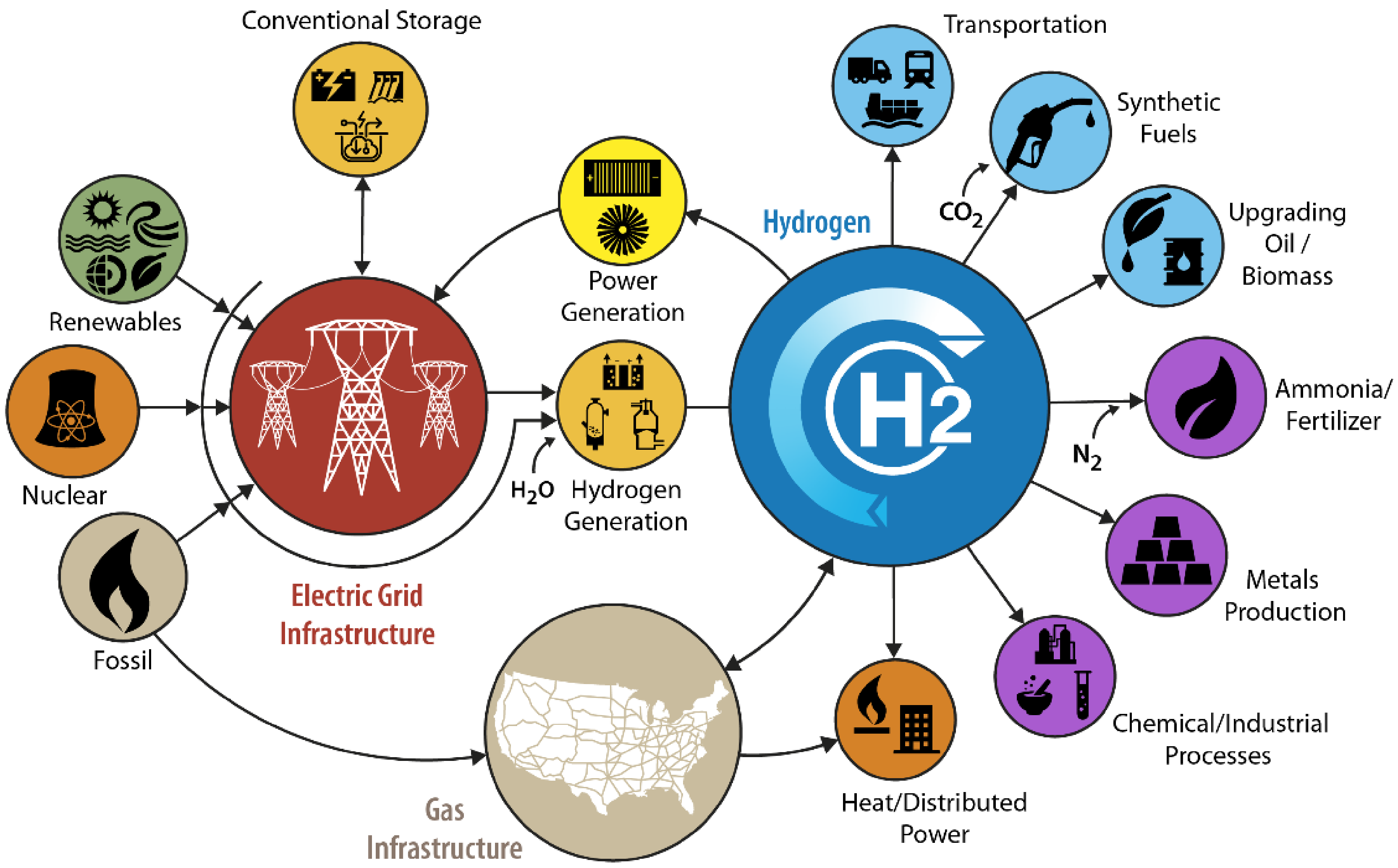
ICEF 7th Annual Meeting – September 28, 2020


Hydrogen is one part of a Comprehensive Energy Portfolio

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



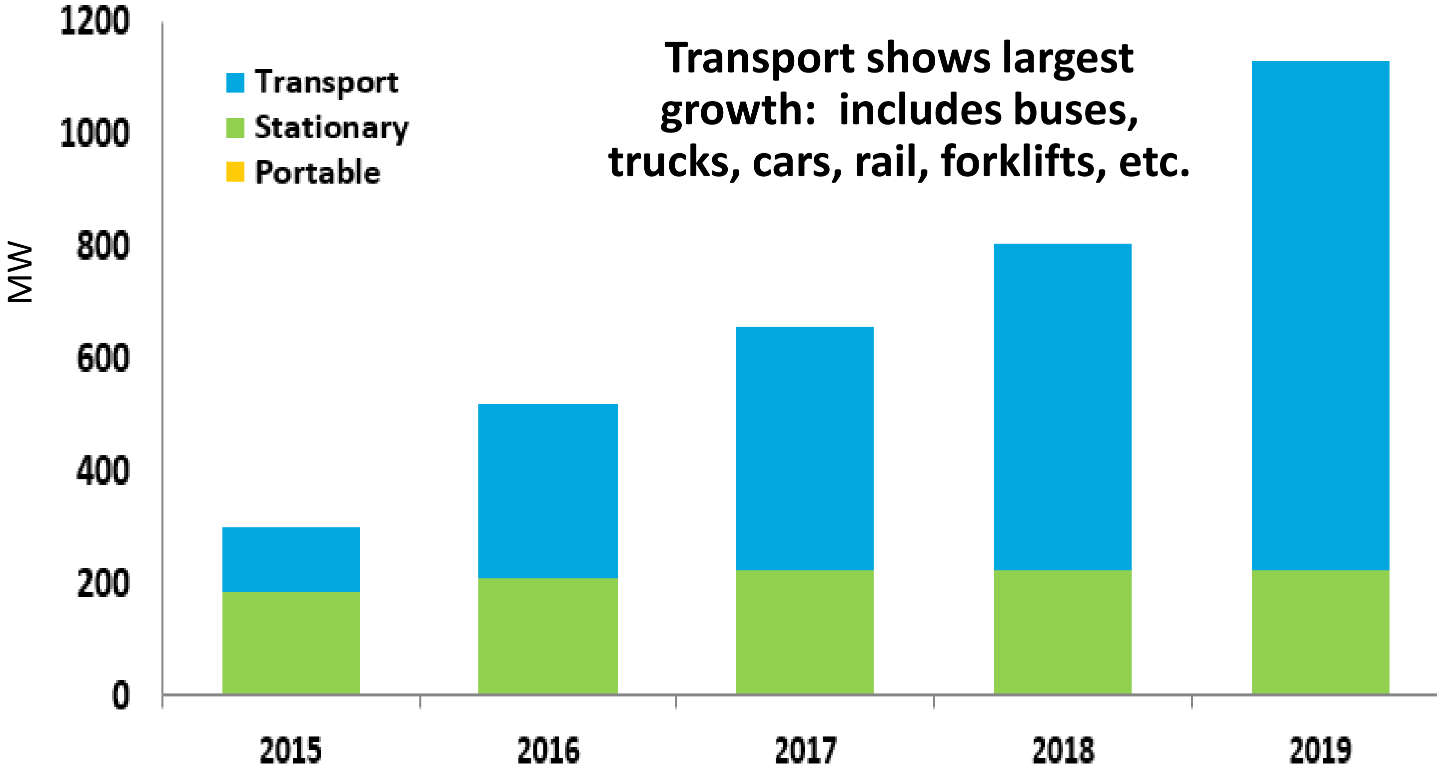
Hydrogen can address specific applications across sectors

Today: 10MMT H_2 in the U.S.

Economic Potential: 2 to 4x more

Hydrogen and Fuel Cell Technology Growth Worldwide

Global fuel fell 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 end of 2019

Global FCEVs doubled to >25,200

>12.3K sold in 2019 vs. 5.8K in 2018

470 H_2 fueling stations worldwide

> 20% increase from 2018

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

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

Examples of Applications

>500MW
Stationary Power

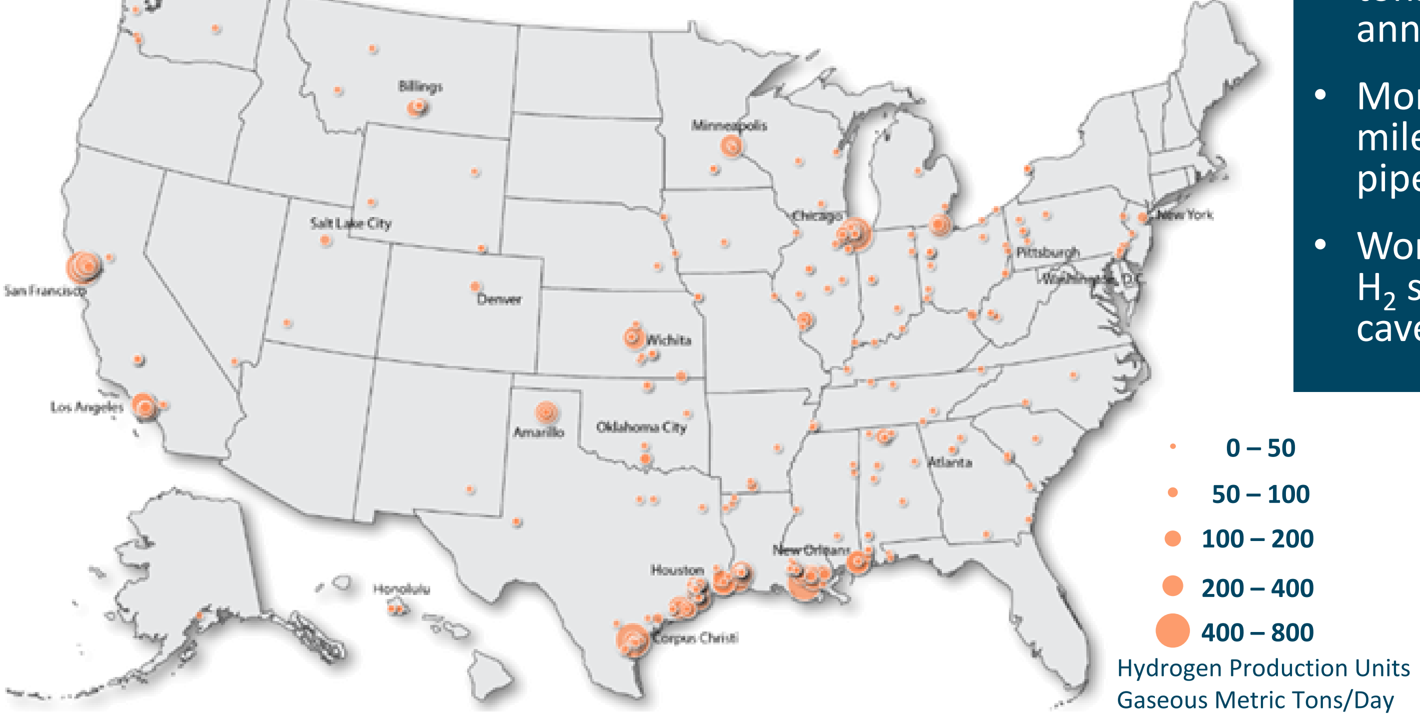
>35,000
Forklifts

>60
Fuel Cell Buses

>45
H_2 Retail Stations

>8,800
Fuel Cell Cars

Hydrogen Production Across 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

Hydrogen Stations: Examples of Plans Across States

California
200 Stations Planned
CAFCP Goal

Northeast
12 – 20
Stations Planned

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

Roadmaps and Plans have Common Strategies

Drivers include: Energy security, energy efficiency & resiliency, economic growth, innovation & technology leadership, and environmental benefits

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

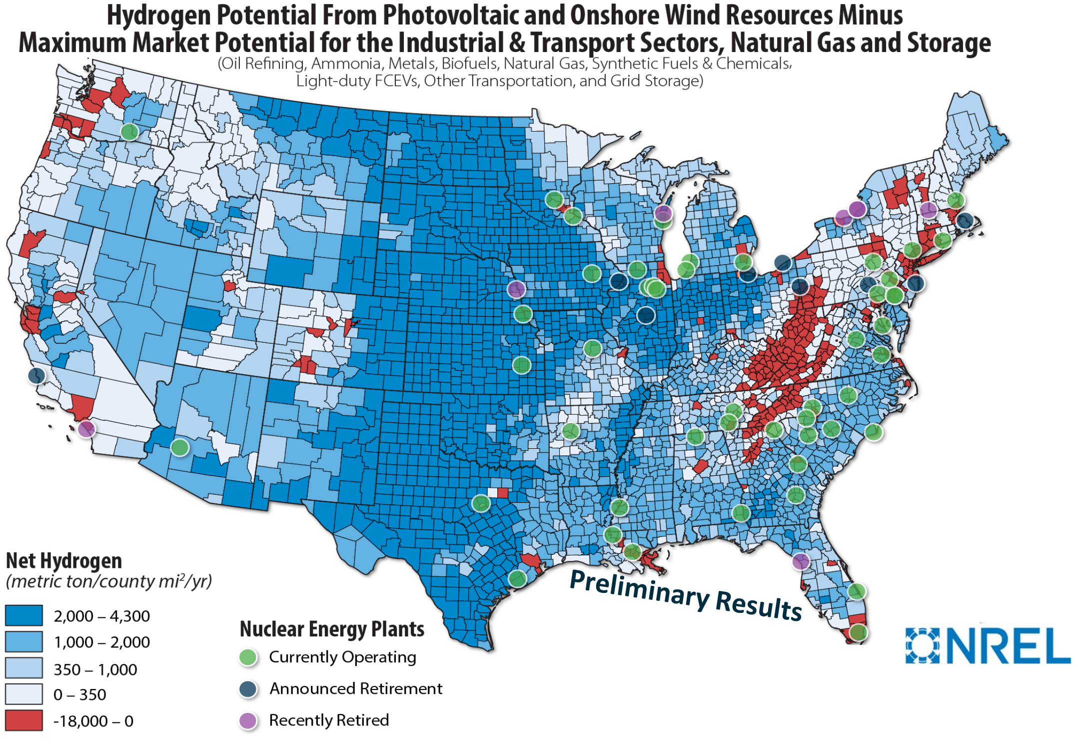
Examples of H2@Scale Analysis and Demonstration Projects

Assessing resource availability.
Most regions have sufficient resources.

New H2@Scale demonstration projects cover range of applications

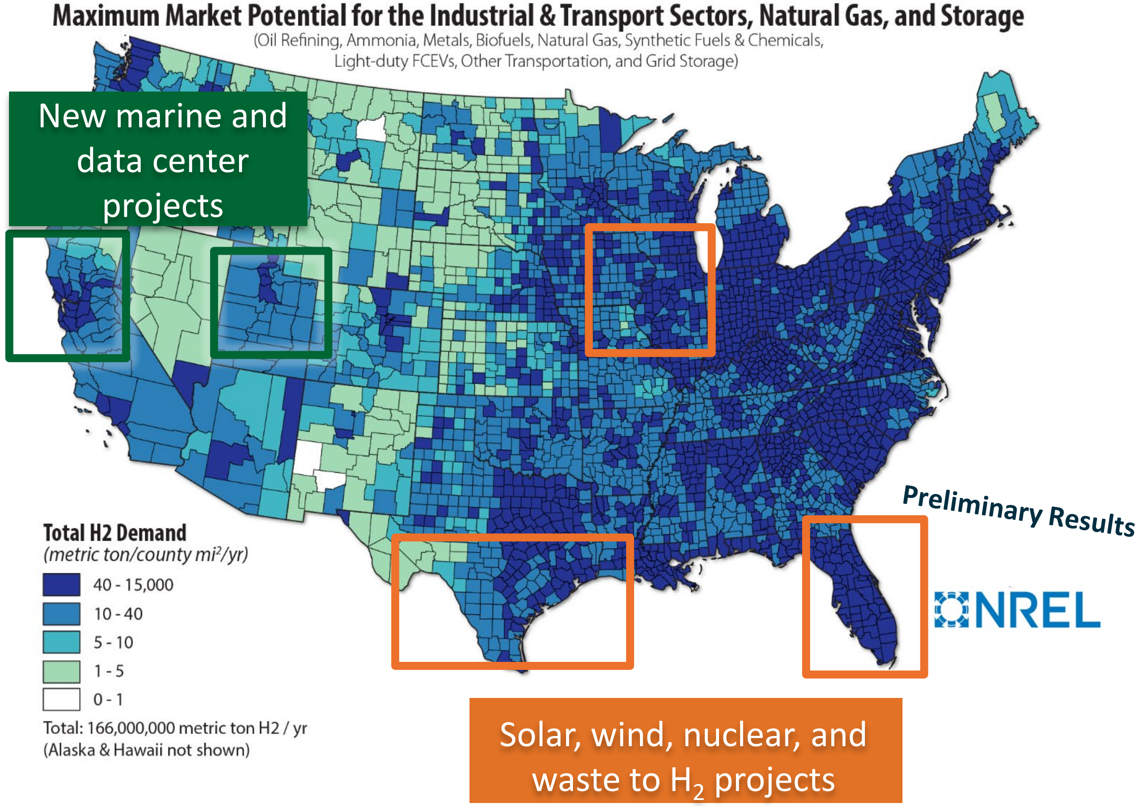
*Includes 1 project by Office of Nuclear Energy

Hydrogen Availability



Red: Only regions where projected industrial & transportation demand exceeds supply.

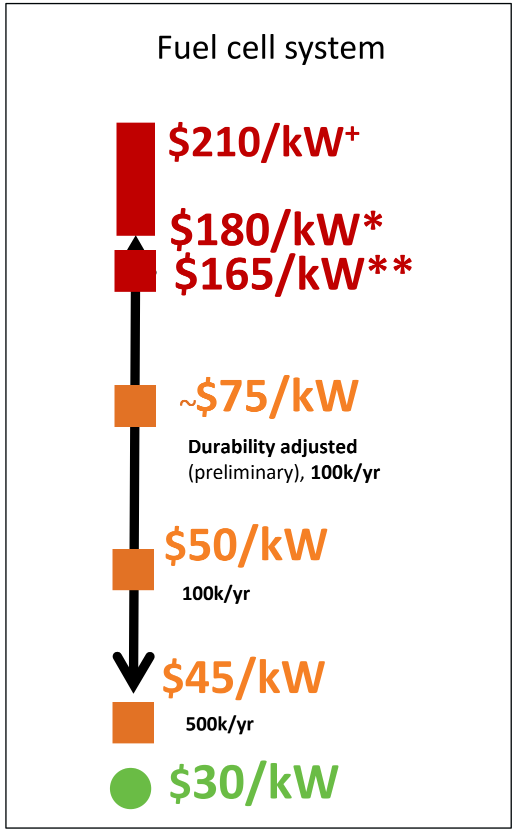
Hydrogen Demand Potential



R&D focus is on Affordability and Performance: DOE Targets Guide R&D

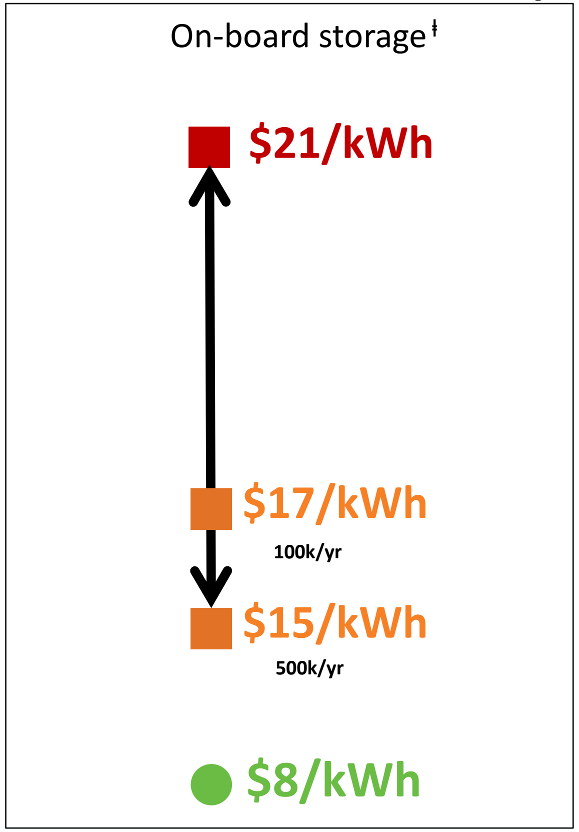
Key Goals: Reduce the cost of fuel cells and hydrogen production, delivery, storage, and meet performance and durability requirements – guided by applications specific targets

Fuel Cell R&D

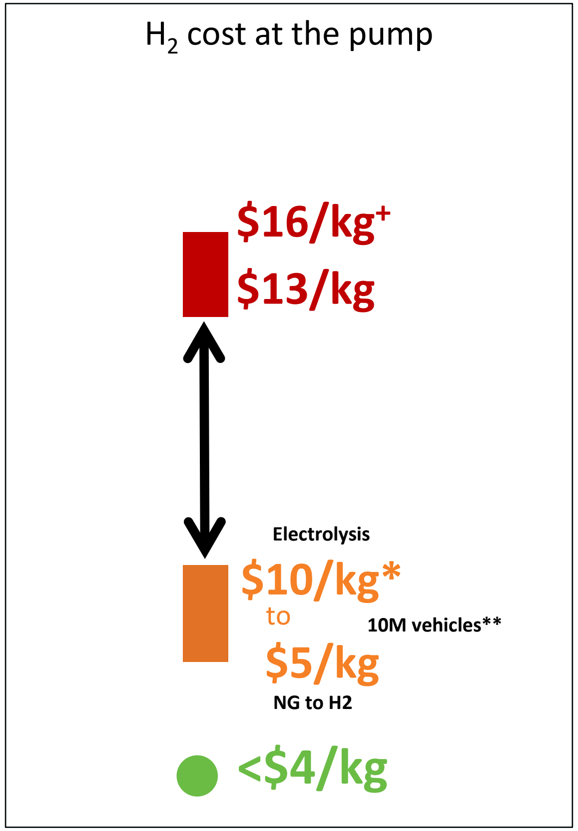


†Based on commercially available FCEVs
*Based on state of the art technology
**Based on commercial FCEV analysis at 3,000/yr

Hydrogen R&D



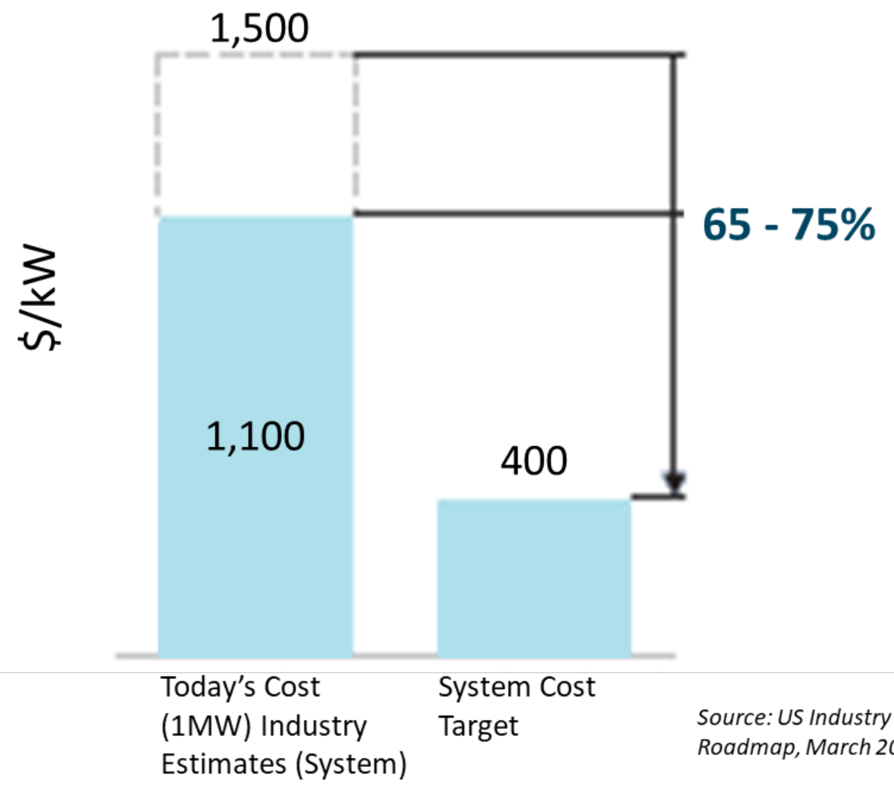
ǂ Storage costs based on preliminary 2019 storage cost record



†For range: H2 production from natural gas (NG), delivered dispensed at today's (2018) stations (~180kg/d)
*For range: Assumes high volume manufacturing in 1) H2 production costs ranging from $2/kg (NG) to $5/kg (electrolysis manufactured at 700 MW/year), and 2) Delivery and dispensing costs ranging from $3/kg (advanced tube trailers) to $5/kg (liquid tanker or advanced pipeline technologies).
** Range assumes >10,000 stations at 1,000 kg/day capacity, to serve 10 million vehicles

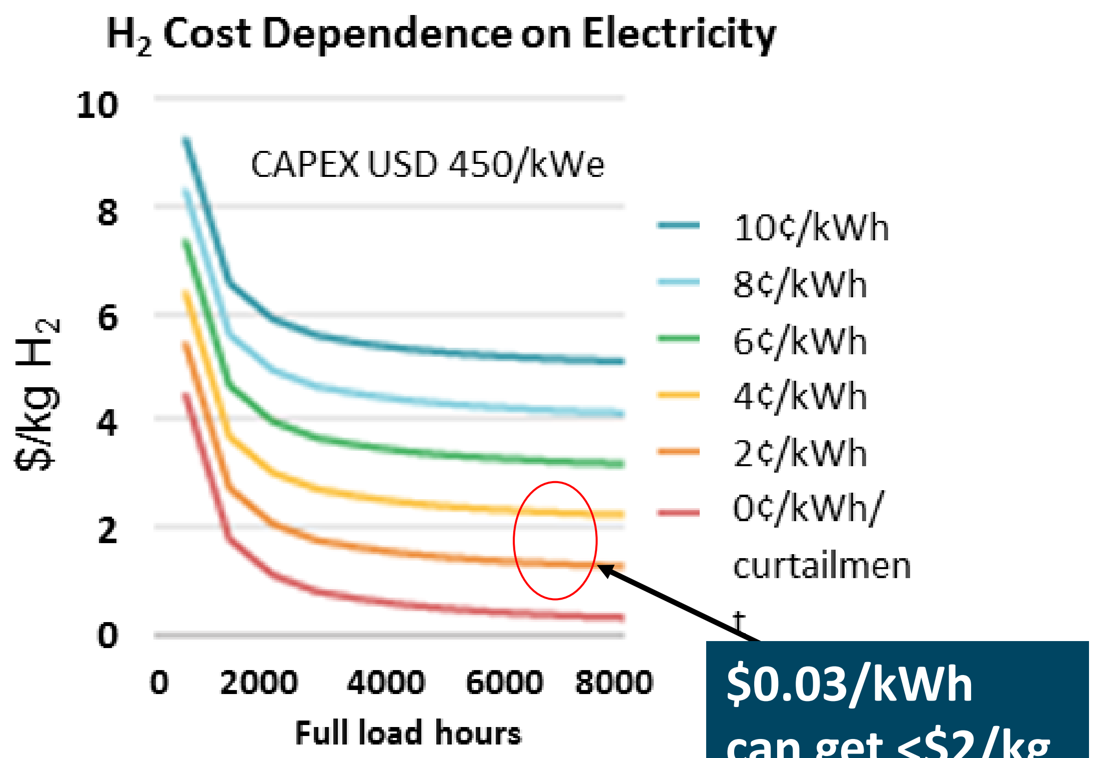
Electrolysis Cost – Recent Independent Analyses

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



Source: US Industry H2 Roadmap, March 2020

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

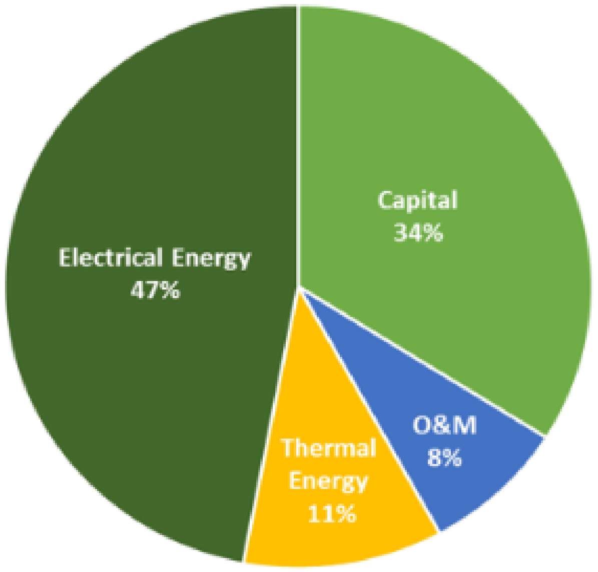


Source: IEA Hydrogen Future Report 2019

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

Identifying Hydrogen Cost Drivers is Key

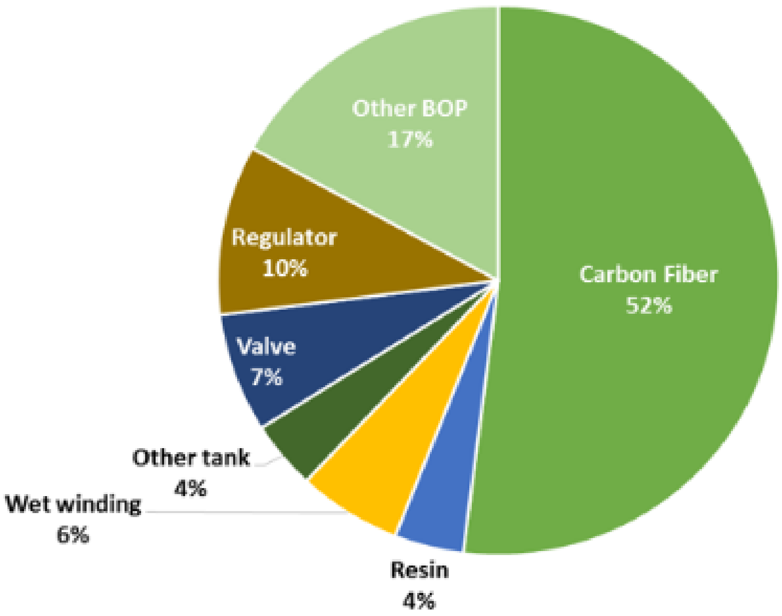
Hydrogen Production Cost
(High Temperature Electrolysis)



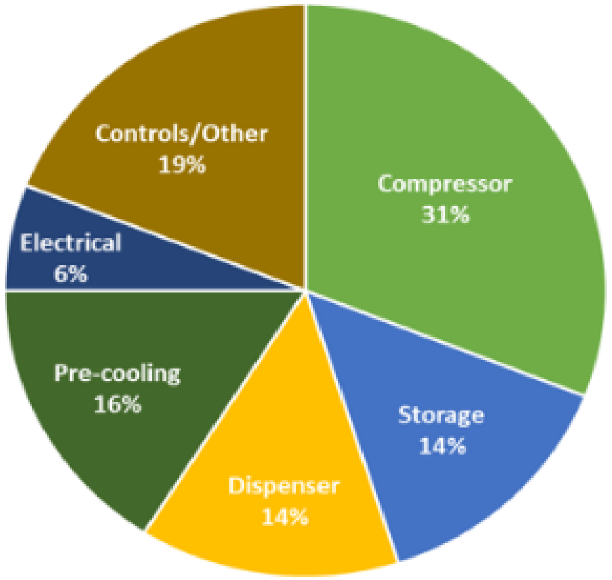
H_2 Production (Electrolysis) Cost Drivers: **Electrical energy and capital costs**

H_2 Onboard Storage Cost Drivers:
Carbon Fiber Precursors and Processing

Hydrogen Storage Cost
(Onboard 700 Bar Hydrogen Storage Vessel)



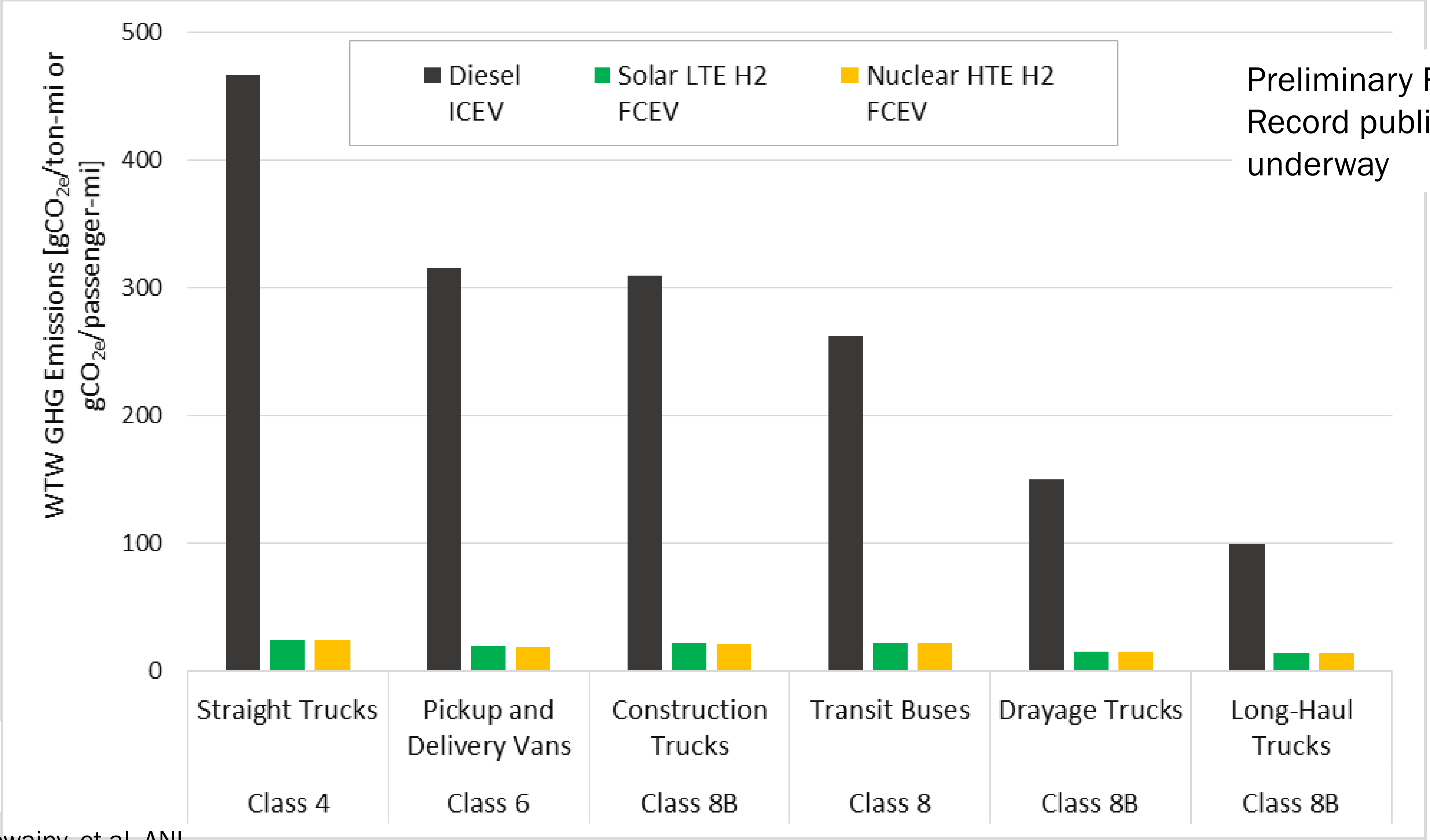
Hydrogen Infrastructure Cost
(700 Bar Hydrogen Station)



H_2 Infrastructure Cost Drivers: **Compressors and Storage**

Note: Updates to be published May, 2020

Life Cycle Analyses Underway – Example



Preliminary Results
Record publication underway

Source: A. Elgowainy, et al, ANL


Collaboration

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

Formed 2003

19 Countries and EC

Activities: Harmonization of codes & standards, Information sharing on safety, policies, regulations, analysis, education.
Task force on developing H_2 production analysis methodology to facilitate international trade, global RD&D monitoring

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

www.iphe.net

CENTER FOR Hydrogen SAFETY 水素安全センター

Connecting a Global Community

IPHE

Hydrogen Council

AIChE

Pacific Northwest NATIONAL LABORATORY

Includes over 40 partners from industry, government and academia

CENTER FOR Hydrogen SAFETY

Connecting a Global Community

HYDROGEN Safety Panel

HYDROGEN Emergency Response Training Resources

Access to >110 countries, 60,000 members

www.aiche.org/CHS

Examples of Activities

U.S. DOE "STEM RISING" activities promote awareness and engagement

https://www.energy.gov/women

IPHE Education & Outreach Working Group fosters engagement in H_2 and fuel cells

#IPHEInfographicChallenge

Submit your entry by Oct 8 to media@iphe.net
Learn more
IPHE.net/challenge

Students (ages 13-18 yrs) from IPHE member countries can design an Infographic on H_2 and fuel cells

Join the IPHE Early Career Group to promote awareness, increase networking and career development

University events at IPHE member country meetings, poster awards and outreach

Follow @the_iphe

IPHE Fellows Program for Students/Postdocs to promote opportunities & foster leadership development

Thank You

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INCREASE YOUR H_2IQ
www.hydrogen.energy.gov

Looking for more info?

#H2IQ

hydrogen.energy.gov

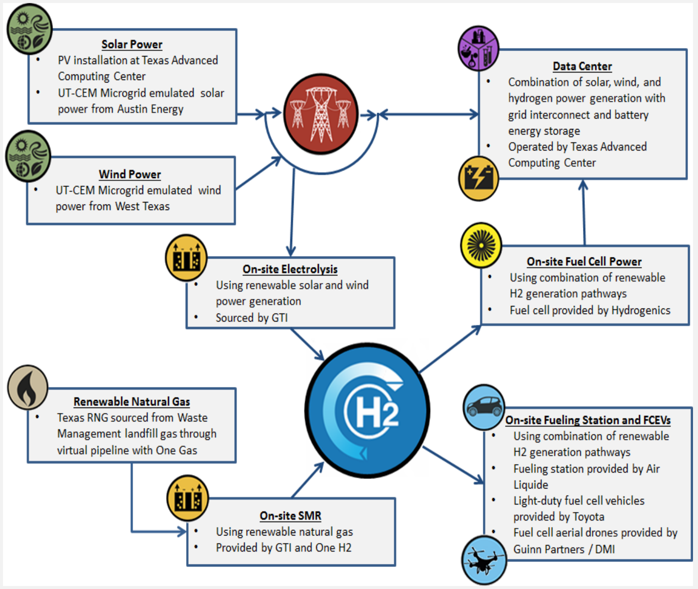
Examples of H2@Scale Demonstration Projects - 2019

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

Texas

Total Budget $10.8M

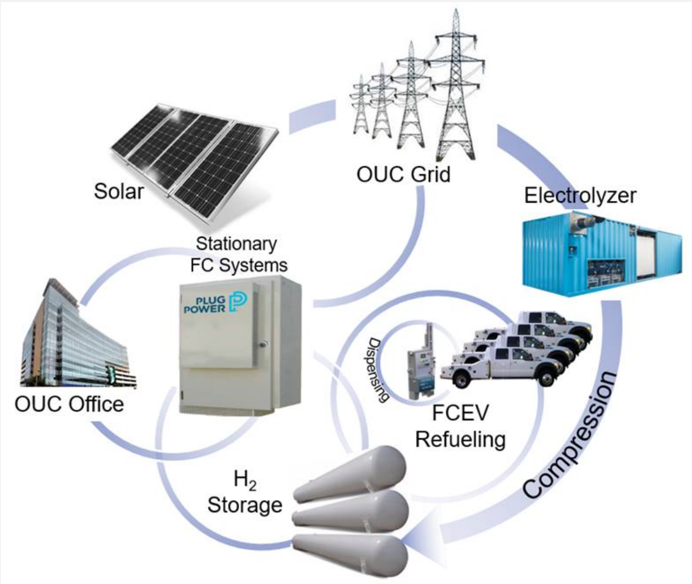
Wind, Solar, RNG/Waste



Florida

Total budget $9.1M

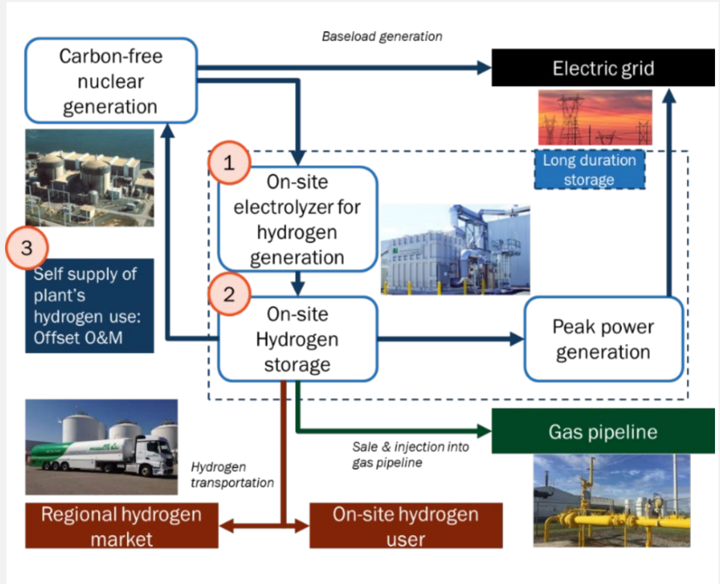
Solar-to-H_2 with End Uses



Site selection in process

Total Budget $7.2M

Nuclear-to-H_2 for at-Plant Use



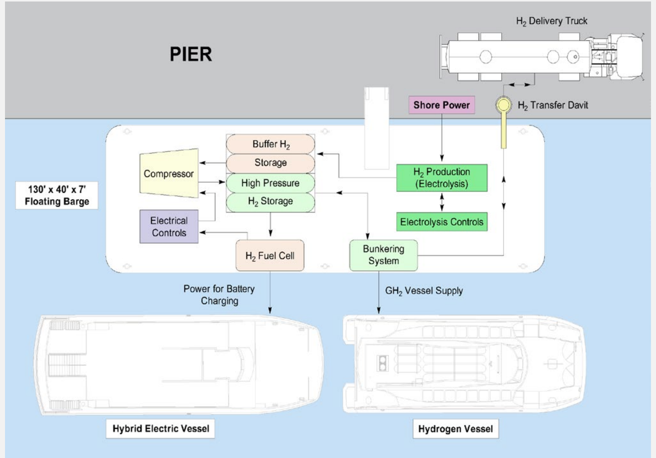
Examples of H2@Scale Demonstration Projects -2020

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

Marine Application

Total Budget $16M

Electrolyzer and fuel cell for marine application

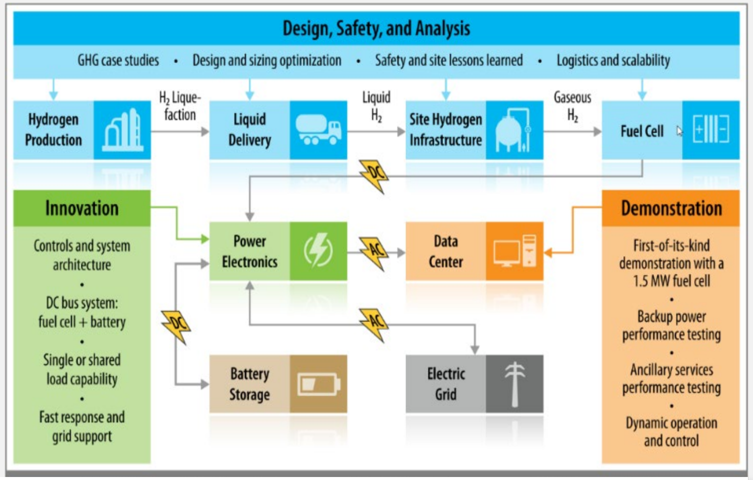


1st-of-its-kind maritime H_2 refueling on floating barge - up to 530 kg H_2 /day

H_2 for Data Center

Total Budget $13.7M

PEM fuel cell for data center power

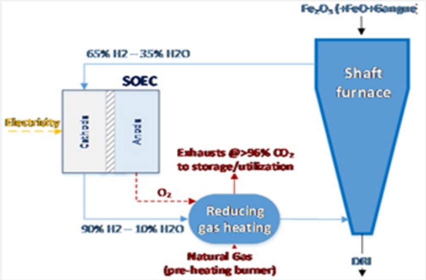


1.5MW fuel cell to meet data center requirements and future scale up

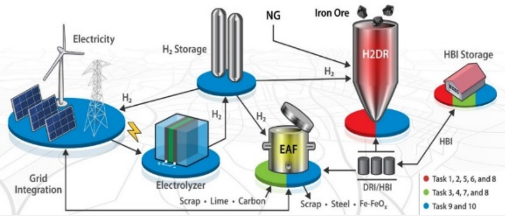
H_2 for Steel Production

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