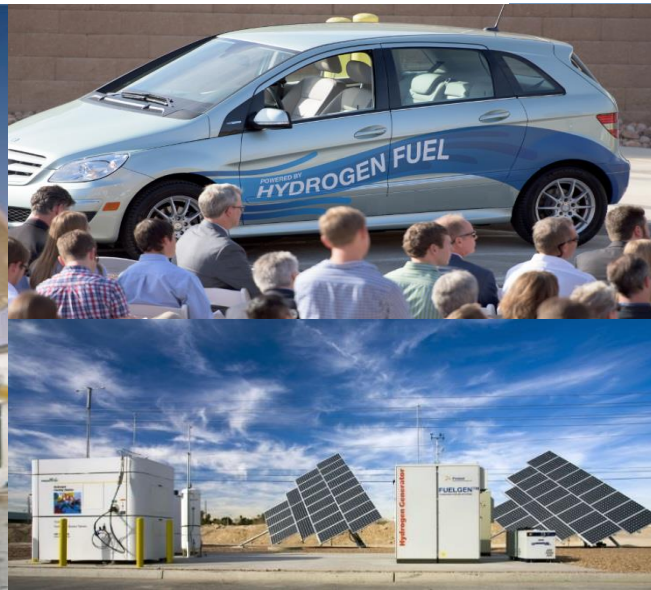


Opportunities for Hydrogen Scale Up through DOE's H2@Scale Initiative

Dr. Sunita Satyapal, Director, U.S. Dept. of Energy Hydrogen and Fuel Cells Program

Hydrogen Shell EBI Virtual Workshop

May 13, 2020



Guiding Legislation and Budget

Energy Policy Act (2005) Title VIII on Hydrogen

- Authorizes U.S. DOE to lead a comprehensive program to enable commercialization of hydrogen and fuel cells with industry.
- Includes broad applications: Transportation, utility, industrial, portable, stationary, etc.

Program To Date

- **\$100M to \$250M per year**
- **100 to 200+ projects per year**
- **>100 organizations & extensive collaborations**
- **Includes H2, fuel cells and cross cutting RD&D:**
 - H2 production, delivery, storage, utilization (including fuel cells)
 - Analysis, systems development/integration, safety, codes and standards, education & outreach
- **Reduced fuel cell cost 60%, quadrupled durability, reduced electrolyzer cost 80% and other advances**

Funding in \$K	FY 2018	FY 2019	FY 2020
Fuel Cell R&D	32,000	30,000	26,000
Hydrogen Fuel R&D	54,000	39,000	45,000
Hydrogen Infrastructure R&D	-	21,000	25,000
Technology Acceleration	19,000	21,000	41,000
Safety, Codes, and Standards	7,000	7,000	10,000
Systems Analysis	3,000	2,000	3,000
Total	\$115,000	\$120,000	\$150,000

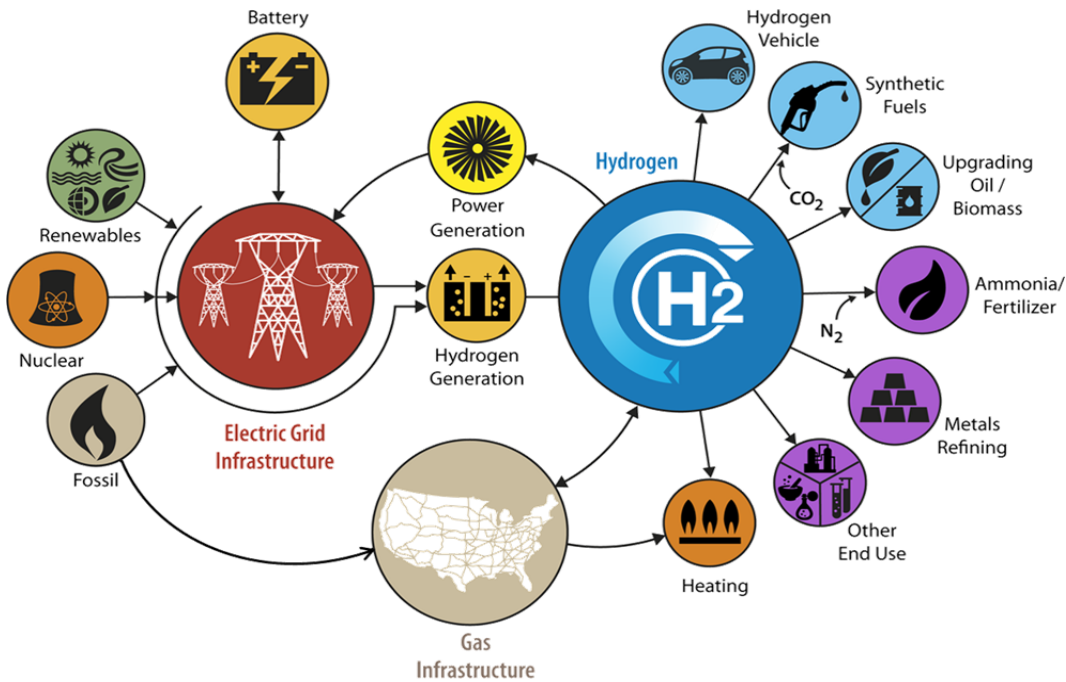
DOE Office	Funding (in \$K)
EERE (FCTO) - Lead	\$150,000
Fossil Energy (SOFC)	\$30,000
Nuclear Energy	\$11,000*

• EERE: Energy Efficiency and Renewable Energy Office
 • FCTO: Fuel Cell Technologies Office
 • SOFC: Solid Oxide Fuel Cell Office

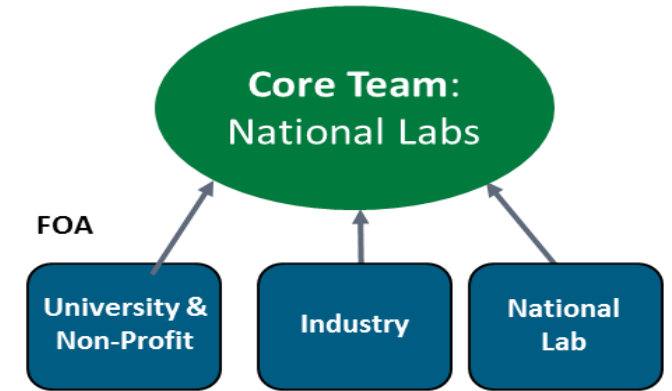
* FY20 Appropriations for nuclear to H2 demonstration project with FCTO (\$10M)

Key Programmatic Area: H2@Scale

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

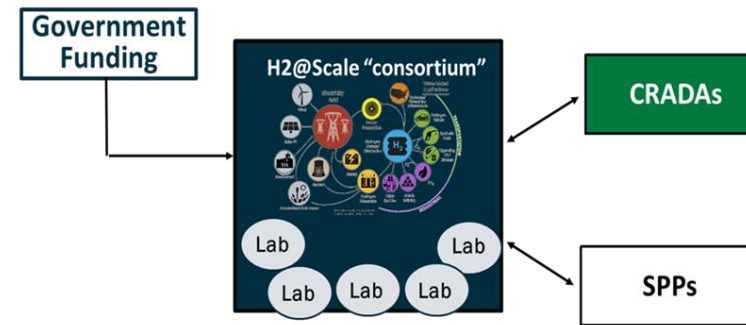


Includes Early stage R&D: Funding Opportunity Announcements (FOAs) for industry, universities and national labs, including consortia



And includes later stage RD&D:

Leverages private sector for large-scale demos
 New H2@Scale demonstration projects announced
 Texas, Florida, Midwest, complements California deployments



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

How DOE is bringing together industry and labs to address RD&D challenges and accelerate progress – Examples

Lab-Based Consortia



Labs - Industry Bridge

- H2@Scale Consortium
- CRADAs
- SPPs (WFOs)
- L’Innovator
- Technology Commercialization Fund

Private Sector

- FOA projects
- SBIRs
- Prizes
- State funding
- Demos & Deployments
- Partnerships
- US National Roadmap



H₂ materials R&D, enable codes & standards, reduce regulatory barriers

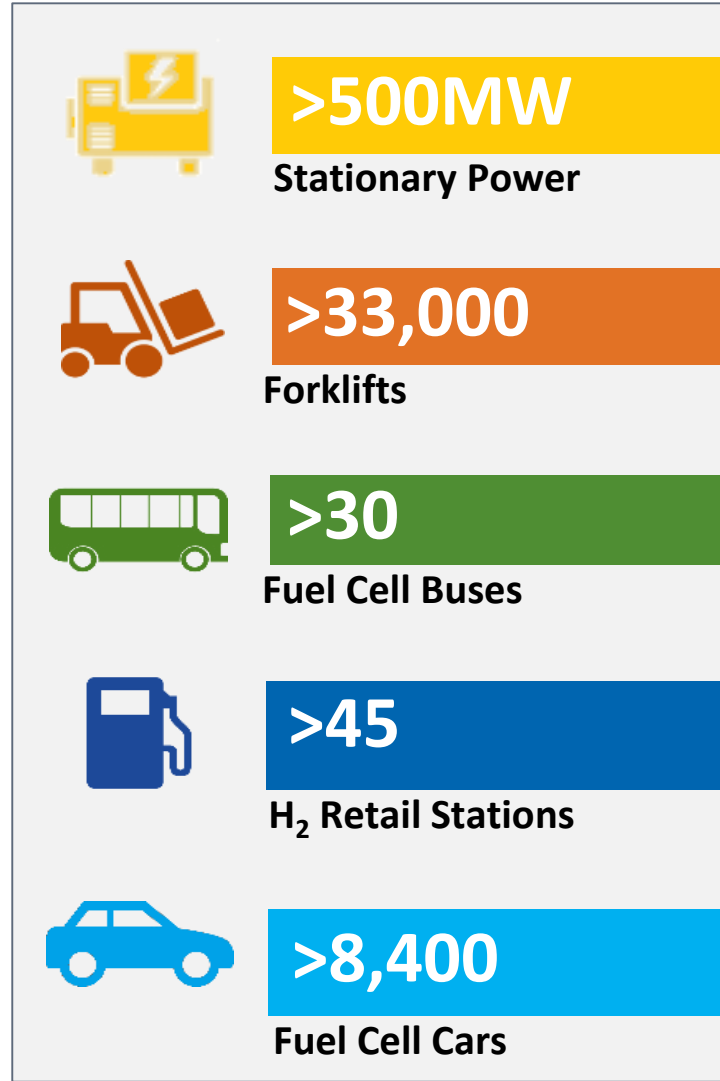
Safety – Lessons learned, best practices, enable safe infrastructure

Examples of Applications



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

Examples of Applications



Hydrogen Production Across the U.S.



- 10 million metric tons produced annually
- More than 1,600 miles of H₂ pipeline
- World's largest H₂ storage cavern

Hydrogen Stations: Examples of Plans Across States

California

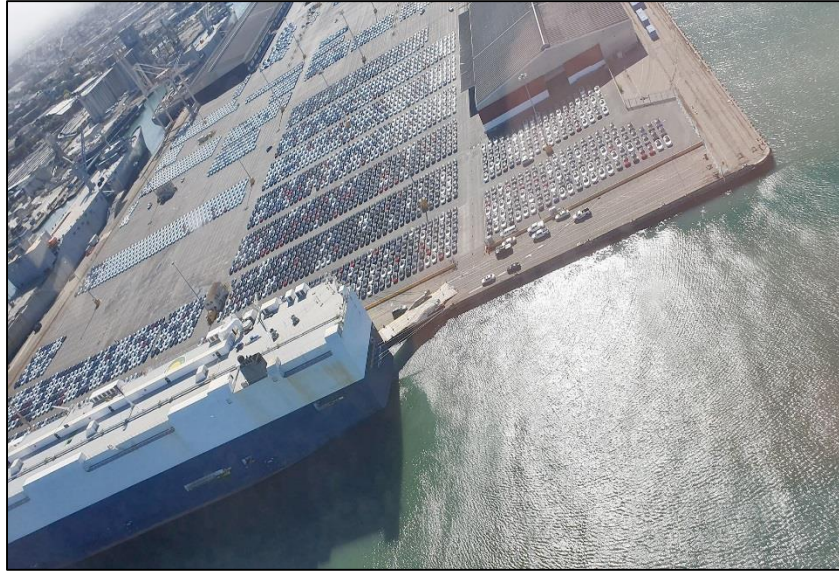
200 stations planned - CAFCP goal

Northeast

12 – 20 stations planned

HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others

Opportunities Identified in H2@Ports, H2@Rail, H2@Datacenters Workshops



H2@Datacenters

- Collaboration between DOE, industry, end users
- RD&D & techno-economic assessment needs
 - Prime or backup power for critical loads of data centers
 - Scenario development to enable cost effective fuel cells and hydrogen storage
 - Potential additional revenue streams



H2@Ports

- Collaboration between DOE, DOT - Maritime Administration, FCH JU, European Commission, global industry, end users and ports, states
- RD&D & techno-economic assessment needs
 - Power system options and TCO
 - Cluster approach to increase scale
 - Regulations and standards

TCO: Total cost of ownership



H2@Rail

- Collaboration between DOE, DOT -Federal Railroad Administration, global industry, end users, states
- RD&D & techno-economic assessment needs
 - Prime power system development
 - Rail system operations and TCO
 - Regulations, safety, codes, standards

Workshop details available at: <https://www.energy.gov/eere/fuelcells/workshop-and-meeting-proceedings>

Examples of Opportunities: H2@Rail, H2@Ports & H2@Datacenter

Main Challenges for Adoption

- Cost of hydrogen and investment required
- Hydrogen supply and storage is a key challenge
- R&D and demos needed to gain knowledge and encourage industry adoption
- Harmonization of codes and standards needed for hydrogen
- Sharing best practices and information on safety, siting, etc. is important
- Public education and outreach

H2@Rail

- Fuel among freight rail's top three operating expenses.
- On-board storage technologies (i.e. LH2 tender car)
- Freight locomotives for long distance hauling is the most technically challenging

H2@Ports

- Hydrogen carriers, e.g. ammonia, for hydrogen storage challenges
- Demos at ports could accelerate hydrogen market development
- Maritime vessel design is a tailored process – hard to standardize

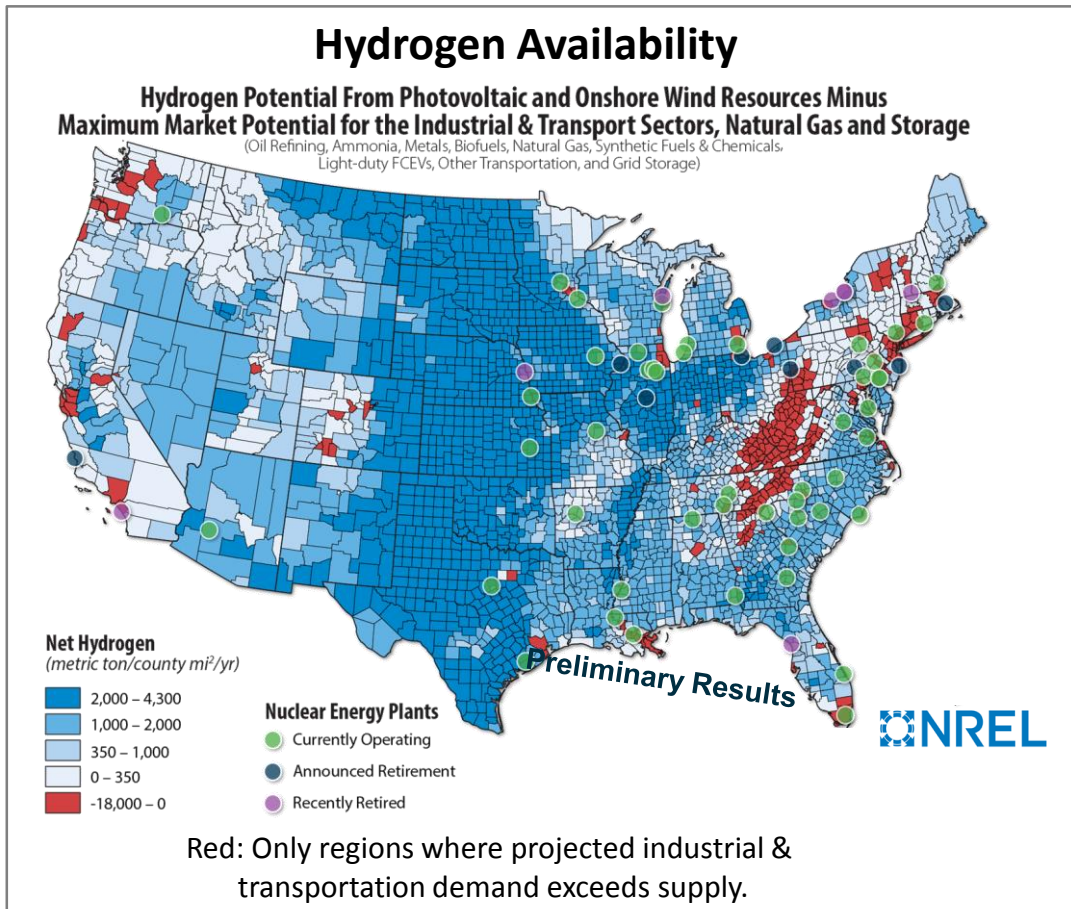
H2@Datacenter

- Unified standards for power requirements
- Low-end modular size requires ~30 tonne/day of hydrogen for a 20 MW data center
- Near term backup power offer solutions to promote adoption



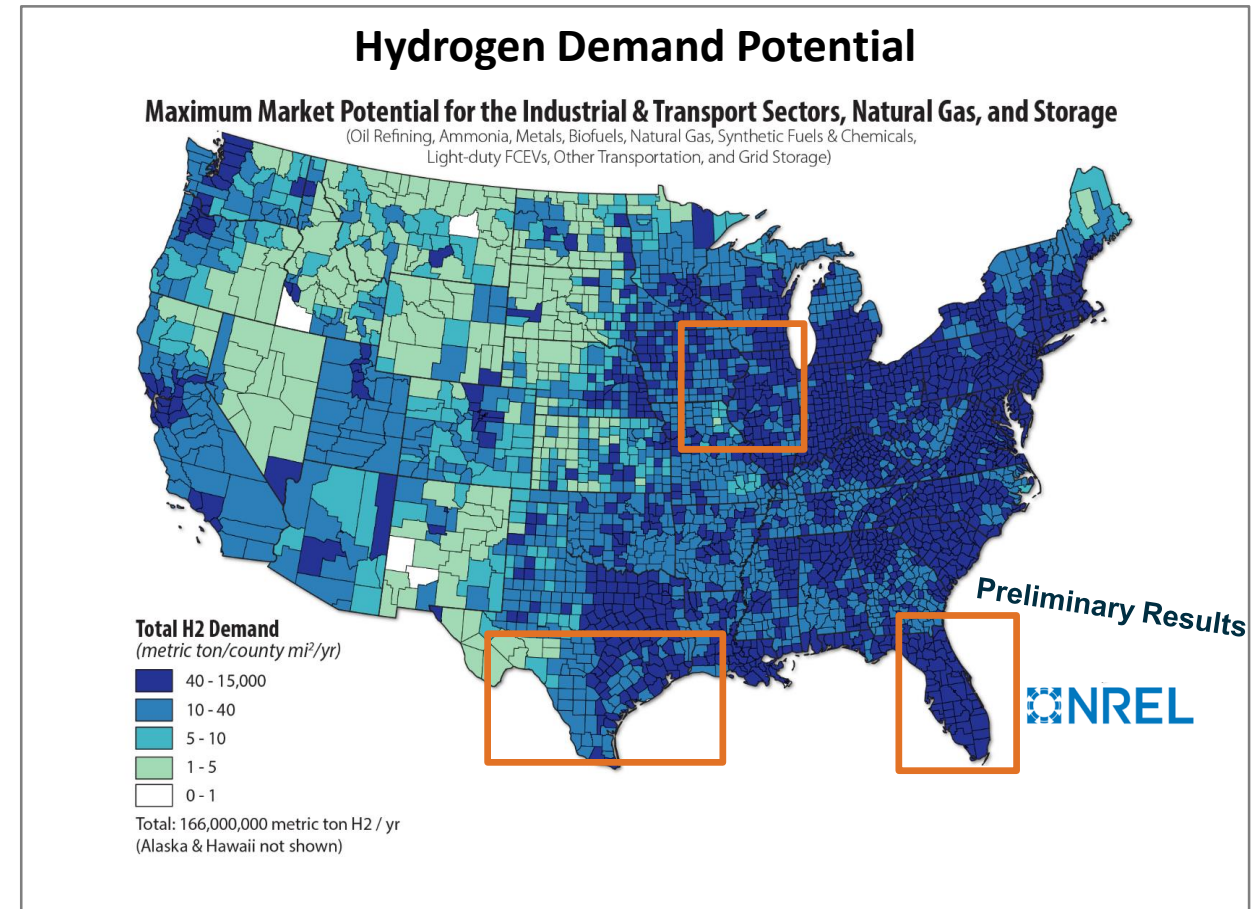
Examples of Activities to Enable H2@Scale

Assessing resource availability.
Most regions have sufficient resources.



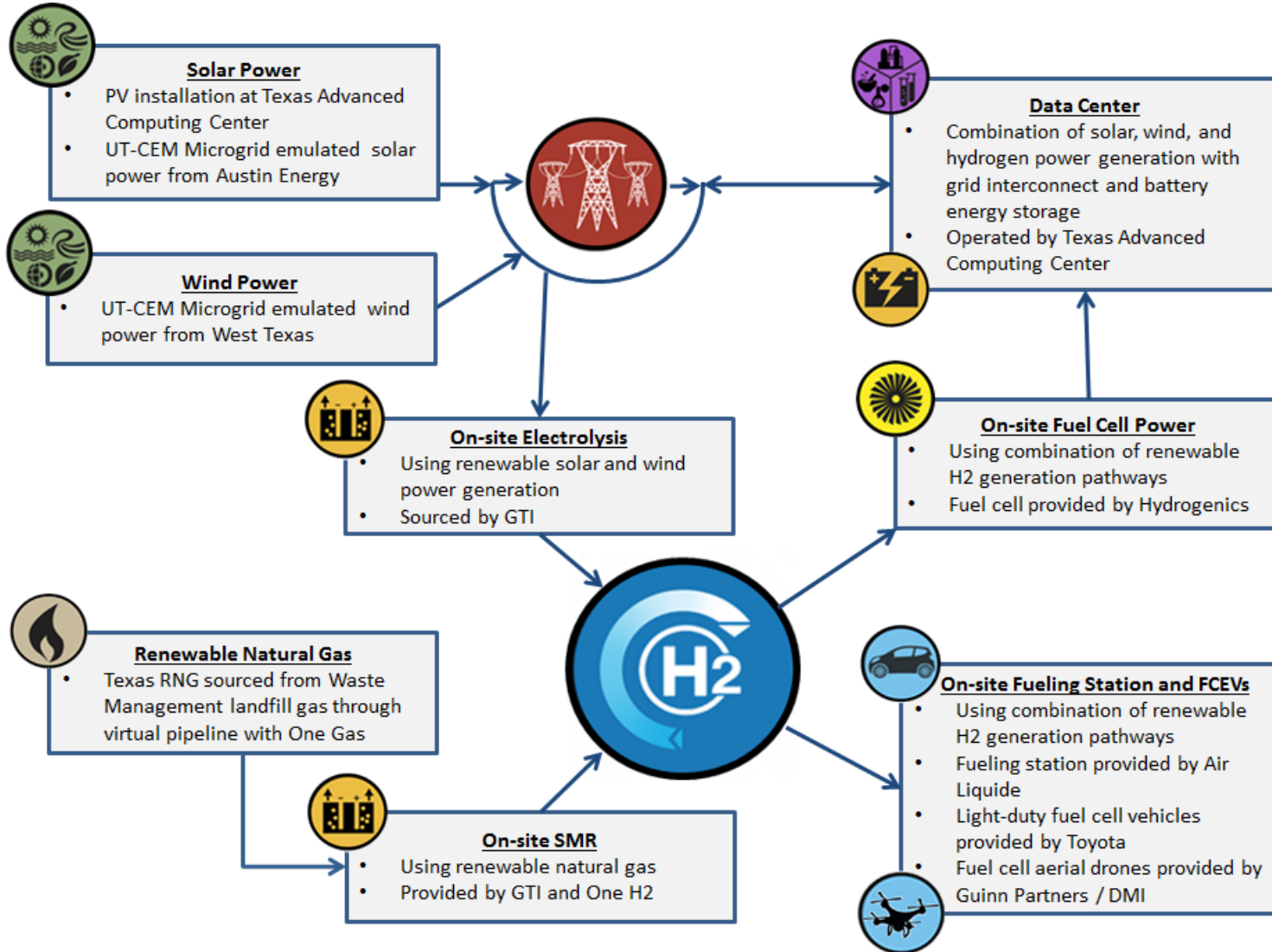
3* new H2@scale demonstration projects in Texas, Florida and Midwest.

*Includes 1 project by Office of Nuclear Energy



Example of H2@Scale Project: Demonstration and Framework for H2@Scale in Texas and Beyond

Integration Concepts Being Considered



Partners

Frontier Energy
 University of Texas at Austin
 GTI
 Toyota
 Air Liquide
 Waste Management
 OneH2
 Hydrogenics

Duration

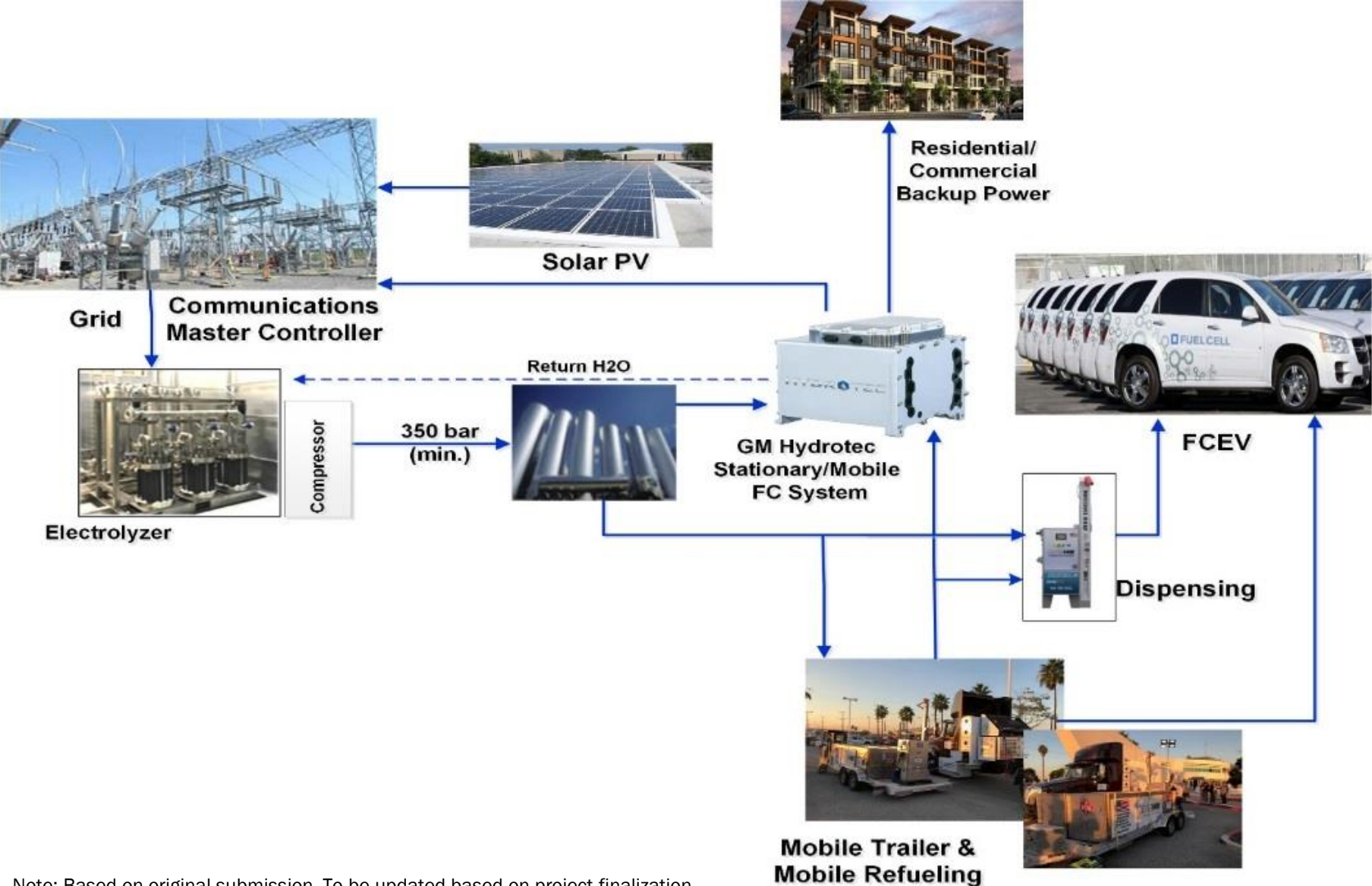
36 Months

Total budget

\$12.7M

Note: Based on original submission. To be updated based on project finalization

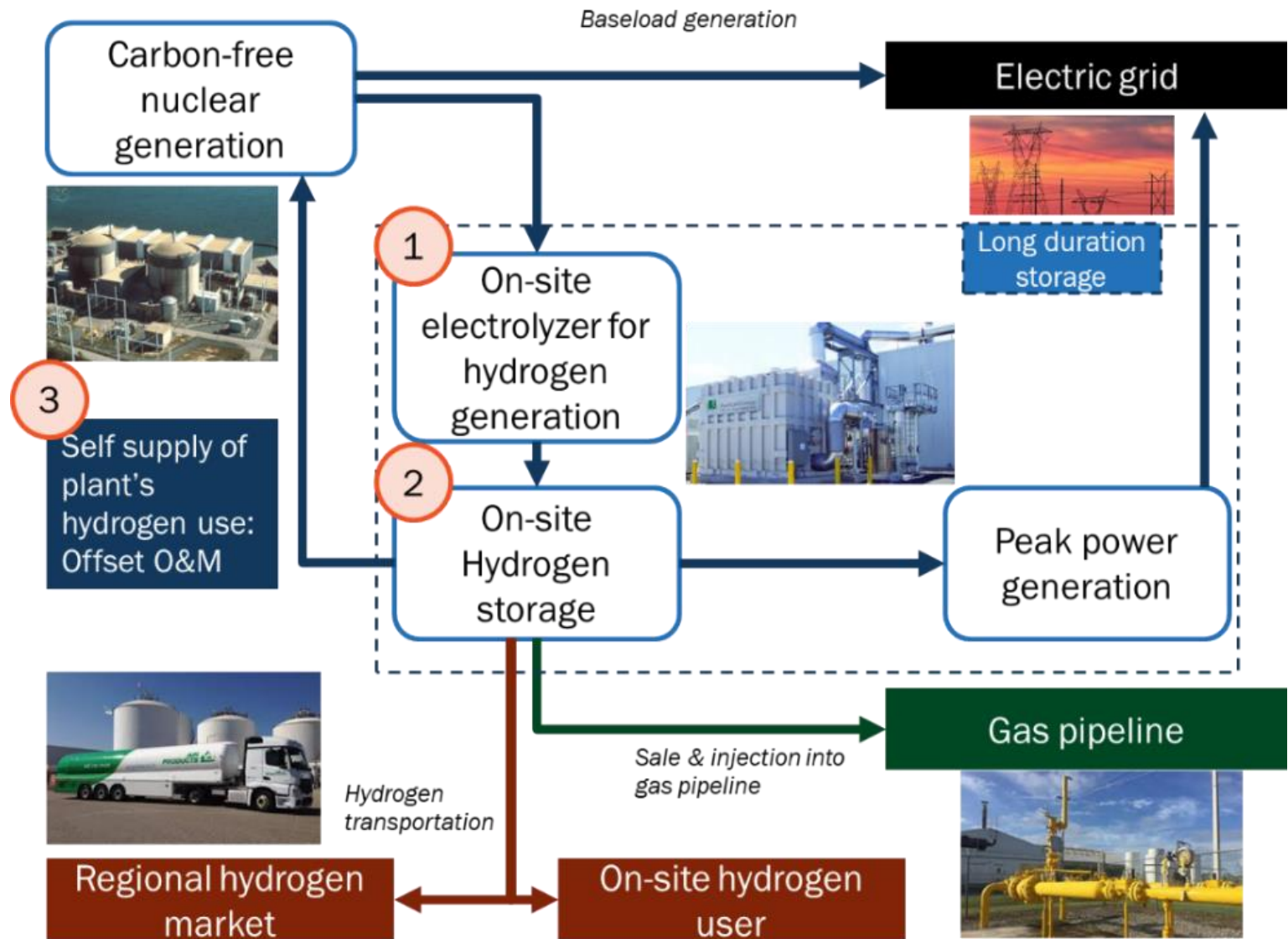
Example of H2@Scale Project: Integrated Hydrogen Production and Consumption for Improved Utility Operations – Orlando, FL



Partners
Giner ELX Inc
Orlando Utilities Commission
General Motors
OneH2
UCF-FSEC
Duration
36 Months
Total budget
~\$8.5M

Note: Based on original submission. To be updated based on project finalization

Example of H2@Scale Project: Electrolyzer Operation at Nuclear Plant and In-House Hydrogen Supply

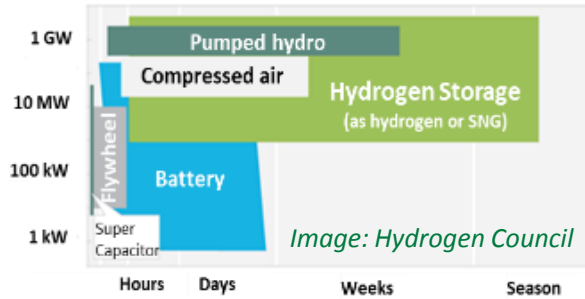


Partners
Exelon & Nel Hydrogen INL NREL ANL
Duration
36 months
Total budget
\$7.2M

Note: Based on original submission. To be updated based on project finalization

Increased Activities on Hydrogen, Energy Storage, Hybrid Systems

Overview of Energy Storage Technologies in Power and Time



H₂ energy storage

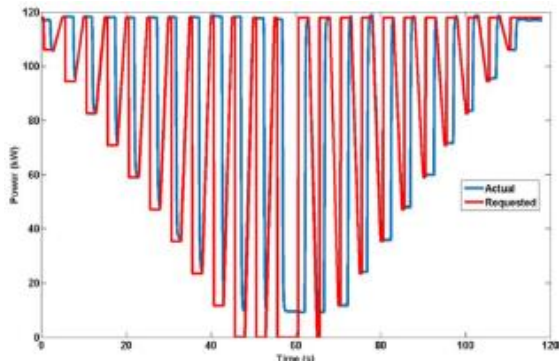
Increased opportunities for nuclear and hydrogen



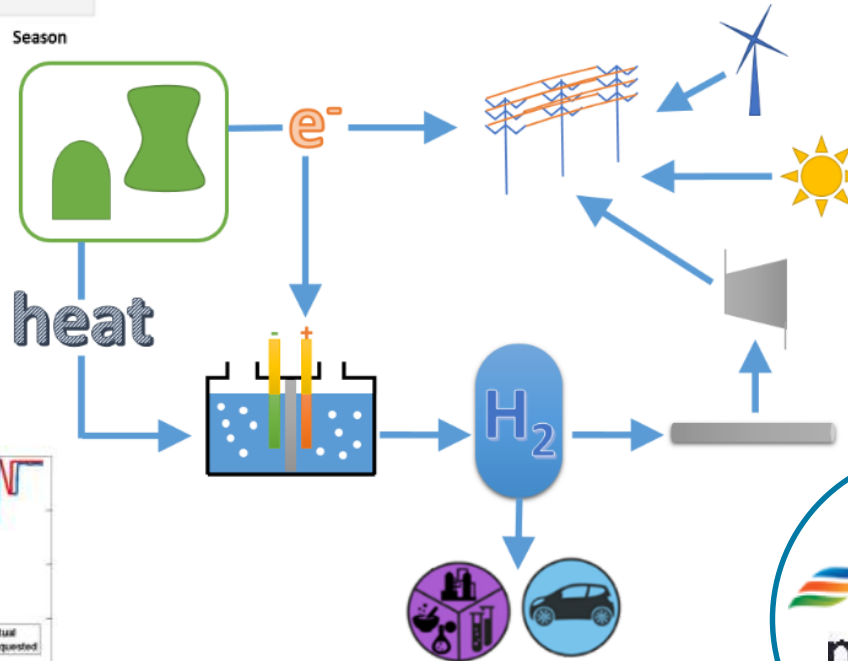
25 kW high-temperature electrolysis @ INL Energy Systems Laboratory

Thermal Integration

Dynamic response



Dynamic electrolyzer response – INL & NREL



Multiple end use applications

DOE Industry demos



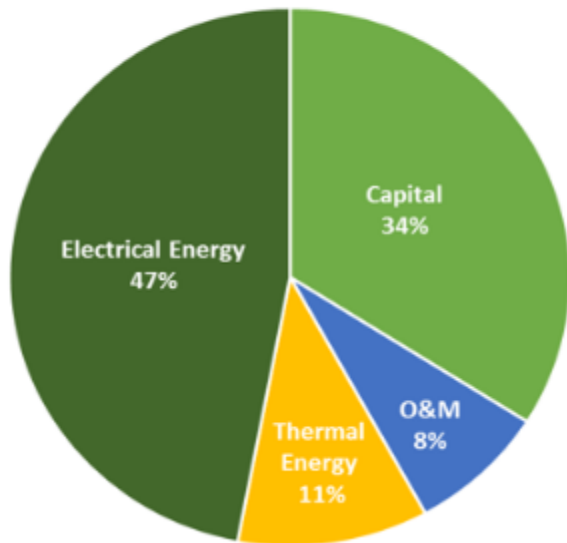
Recently announced demonstrations

Up to \$64M announced under DOE H2@Scale New Markets Funding Opportunity (January, 2020)

Topic Area	Total Funding Level	Anticipated # of Awards	Max. Federal Funding per Award	Max. Project Duration (yrs)	Min Required Non-Federal Cost Share %
Topic 1: Electrolyzer Manufacturing R&D	\$15M	Up to 4	\$5M	3	20%
Topic 2: Advanced Carbon Fiber for Compressed Gas Storage Tanks	\$15M	Up to 3	\$9M	5	20%
Topic 3A: Fuel Cell R&D for Heavy-Duty Applications - Membranes for Heavy-Duty Applications	\$4M	Up to 4	\$1M	3	20%
Topic 3B: Fuel Cell R&D for Heavy-Duty Applications - Domestically Manufactured Fuel Cells for Heavy-Duty Applications	\$6M	2 to 3	\$3M	3	20%
Topic 4: H2@Scale New Markets R&D-HySteel	\$8M	1 to 2	\$8M	3	20%
Topic 5A: H2@Scale New Markets Demonstrations -Maritime Demonstrations	\$8M	1 to 2	\$8M	3	50%
Topic 5B: H2@Scale New Markets Demonstrations - Data Center Demonstrations	\$6M	1 to 2	\$6M	3	50%
Topic 6: Training and Workforce Development for Emerging Hydrogen Technologies	Up to \$2M	1	\$2M	5	0%
Total:	Up to \$64M	Up to 21			

Identifying key hydrogen cost drivers is key

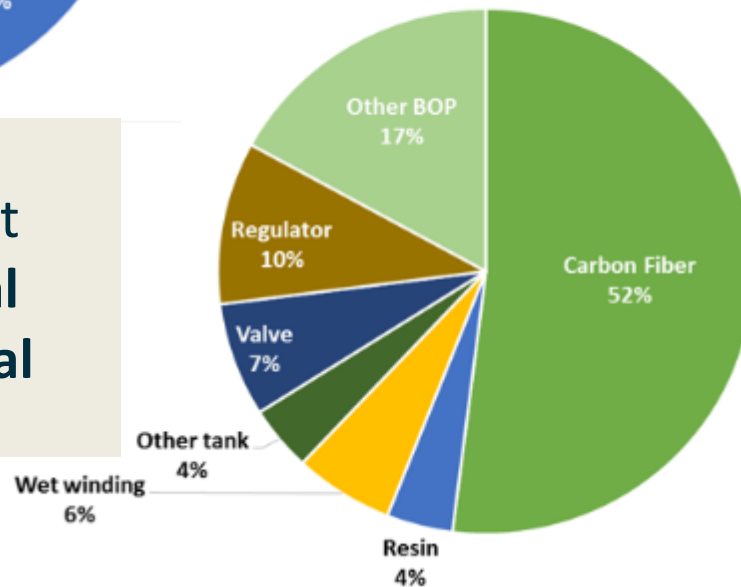
Hydrogen Production Cost
(High Temperature Electrolysis)



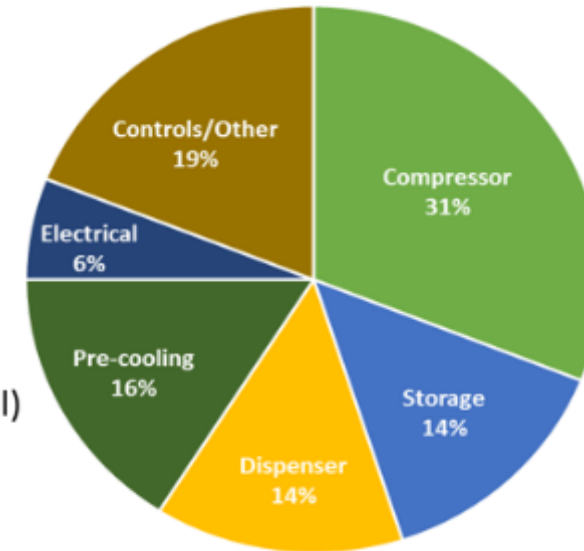
H₂ Production (Electrolysis) Cost Drivers: **Electrical energy and capital costs**

H₂ 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)

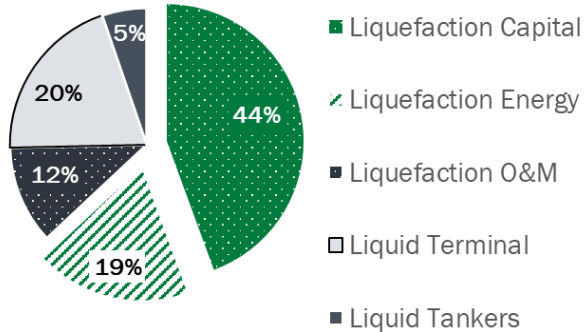


H₂ Infrastructure Cost Drivers: **Compressors and Storage**

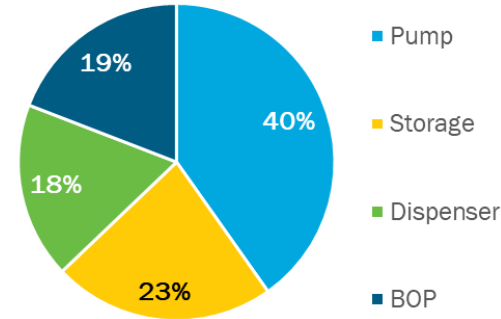
Note: Updates to be published May, 2020

Key Challenges related to Infrastructure

Cost of Liquid H₂



700-bar Liquid-based Station Cost



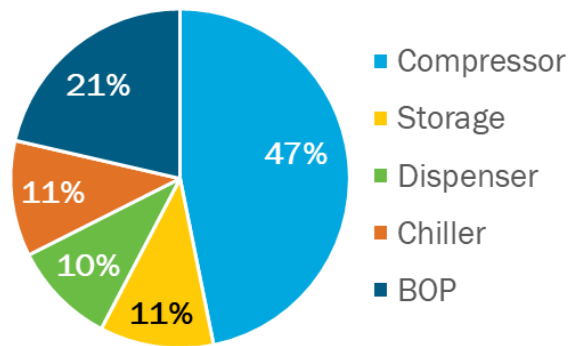
Liquid based H₂ usage is important for large-scale end uses

Heavy duty applications

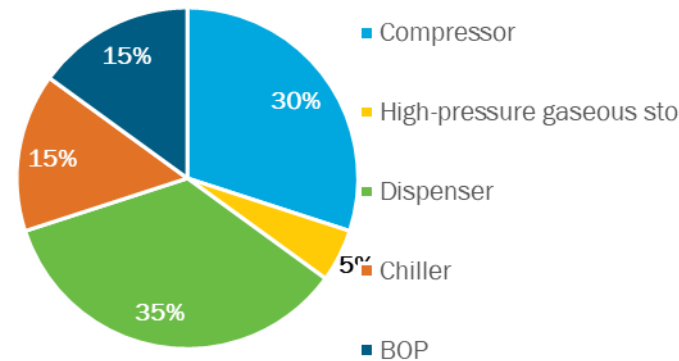


Strategy: R&D on liquefaction, low boil-off pumps, bulk storage, dispensers & components

700-bar Gaseous Station Cost



Station Maintenance Issues



Strategy: R&D on compressors, high throughput fueling components, dispenser & component reliability



Collaboration

IPHE: A Government Partnership on Hydrogen & Fuel Cells, working along with other global initiatives



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

Mission Innovation Hydrogen Challenge 2017

Clean Energy Ministerial New Hydrogen Initiative Launched 2019

Working Groups: Education & Outreach
Regulations, Codes, Standards & Safety



Find IPHE on Facebook, Twitter and LinkedIn
Follow IPHE @The_IPHE



www.iphe.net



Formed 2003
19 Countries and EC

Hydrogen Energy Ministerial (HEM)

International Energy Agency (IEA)

Example of Collaboration: Global Center for H₂ Safety (CHS)

IPHE Steering Committee action: Increase awareness of safety partnership.
Promotes safe operation, handling and use of hydrogen across all applications.



**Hydrogen
Council**

Includes over 40 partners from
industry, government and
academia

AICHE



**Pacific Northwest
NATIONAL LABORATORY**



**CENTER FOR
Hydrogen
SAFETY**

Connecting a Global Community



HYDROGEN
Safety Panel



HYDROGEN
Emergency Response
Training Resources

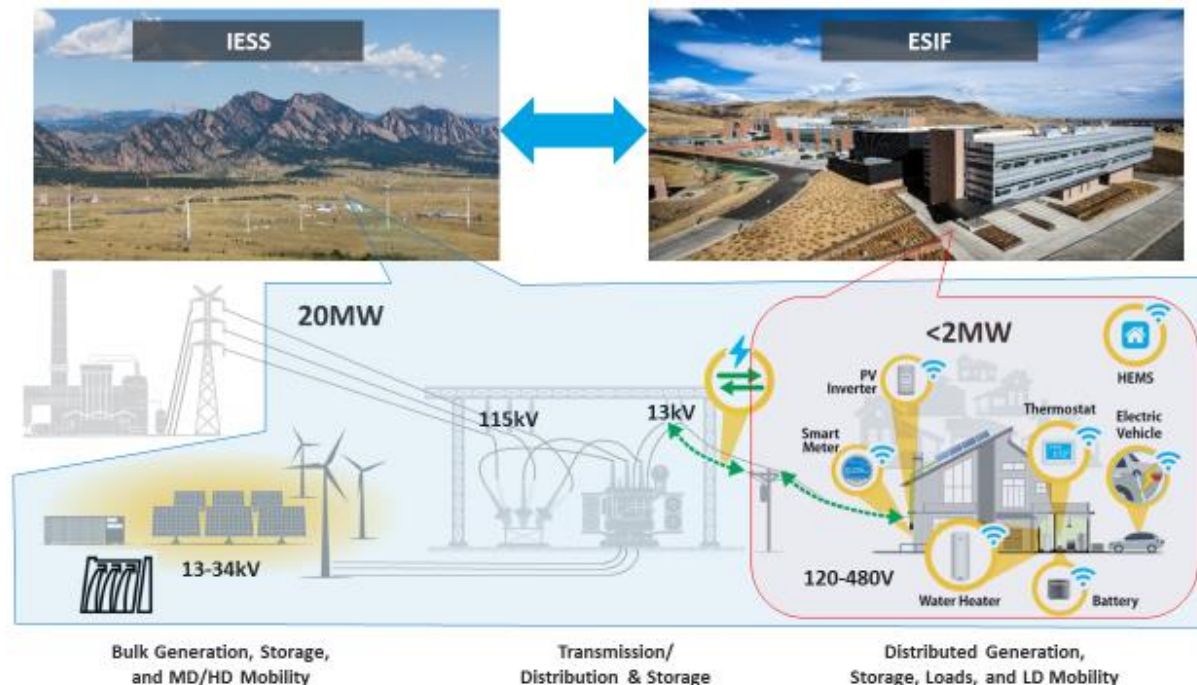
Access to >110 countries,
60,000 members

www.aiche.org/CHS

Advanced Research on Integrated Energy Systems (ARIES) Initiative

ARIES Vision (NREL, in collaboration with other labs and industry)

- Address the fundamental challenges of how to scale up the physical size of new energy technologies and the number of interconnected devices into larger systems.
- Determine how the integration of multiple diverse technologies into future energy systems can provide a range of benefits including improved efficiency, security, and resiliency, lower costs, and greater customer choice.



Key Questions:

- 1) What key benefits will this new capability provide to you and/or your organization?
- 2) What other R&D challenges should be addressed that will ensure success and impact for industry?
- 3) Are the capabilities described above relevant to stakeholders?
- 4) Is there an interest on the part of owners and operators of commercial or large-scale energy generation in partnering?
- 5) What other facilities, equipment, and capabilities may be required?
- 6) What technology innovations and advances can be envisioned with the availability of ARIES?

Use resources available to share knowledge

INCREASE YOUR
H₂IQ

Download the H2IQ resource for free:

energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

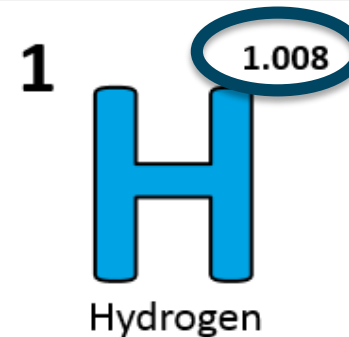
Join monthly H2IQ hours to learn more about hydrogen and fuel cell topics

energy.gov/eere/fuelcells/fuel-cell-technologies-office-webinars



Visit H2tools.org for hydrogen safety and lessons learned

h2tools.org/



Oct 8 - Hydrogen and Fuel Cells Day

(Held on its very own atomic-weight-day)



Sign up to receive hydrogen and fuel cell updates

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

Learn more at:

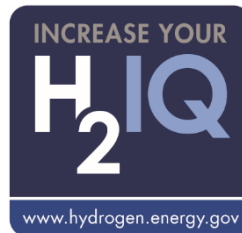
energy.gov/eere/fuelcells
hydrogen.energy.gov

Thank You

Dr. Sunita Satyapal

Director, DOE Hydrogen and Fuel Cells Program

Sunita.Satyapal@ee.doe.gov



Looking for more info?

#H2IQ

hydrogen.energy.gov