U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# U.S. Department of Energy Hydrogen and Fuel Cell Technologies Office Overview


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


Fossil Energy Hydrogen Workshop

July 23 2020

# Background and Guiding Legislation: Hydrogen and Fuel Cell Office

**DOE efforts in $H_2$ and fuel cells began in the mid-1970s, ramped up 1990s, and 2003-2009**

**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.

## Hydrogen and Fuel Cells Office To Date

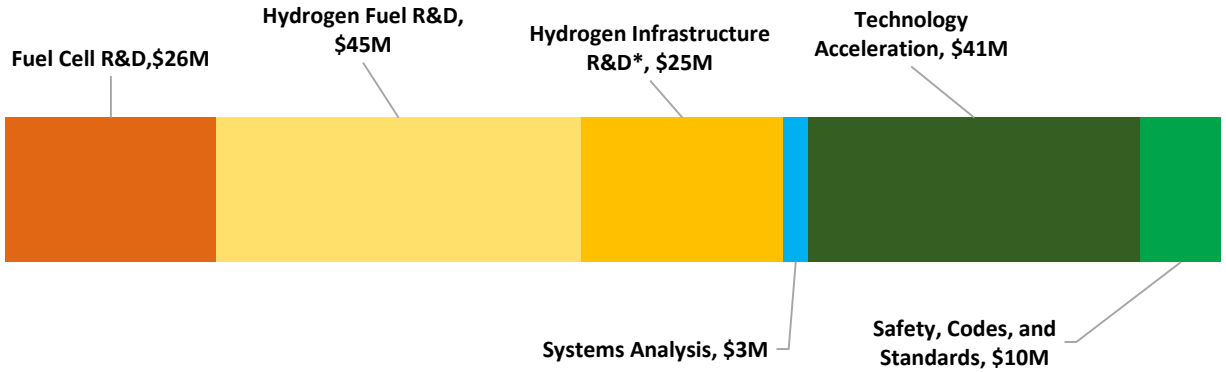
- **>$2.4B since 2003, over 3,000 projects include: $H_2$ production, delivery & infrastructure, storage, fuel cells and cross cutting activities (safety, codes, standards, tech acceleration/validation, manufacturing, market transformation, systems development and integration, energy storage, education, workforce development)**
- **Hundreds of organizations & extensive collaborations including national lab-industry-university consortia**

**Reduced fuel cell cost 60%, quadrupled durability, reduced electrolyzer cost 80%, reduced storage tank cost 30%, and other advances, and *enabled 1,100 patents and* commercial $H_2$ and fuel cell systems across applications**

# Budget and Focus Areas in EERE $H_2$ and Fuel Cell Technologies Office

| EERE HFTO Activities | FY 2020 ($K) |
|---|---|
| **Fuel Cell R&D** | 26,000 |
| **Hydrogen Fuel R&D** | 45,000 |
| Hydrogen Infrastructure R&D (included in Hydrogen Fuel in FY21) | 25,000 |
| **Systems Development & Integration** (formerly Tech Acceleration) | 41,000 |
| Safety, Codes, and Standards (included in Systems Development & Integration in FY21) | 10,000 |
| **Data, Modeling and Analysis** | 3,000 |
| **Total** | **$150,000** |

## HFTO – Hydrogen and Fuel Cells Breakdown FY 2020

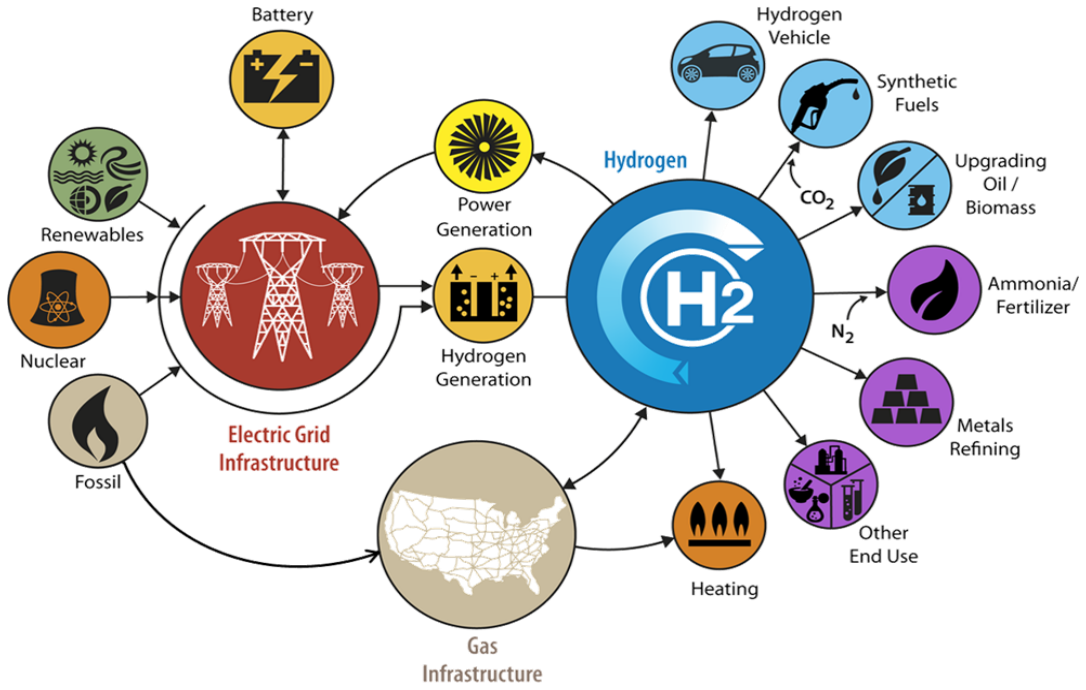



- **Production:** Water splitting – electrolysis (high and low temperature), PEC, STCH, biomass/biological
- **Infrastructure:** Materials, delivery, components & systems
- **Storage**: materials-based, carriers, tanks, liquid
- **Fuel cells**: materials, components, systems, reversible FCs
- **Systems Development & Integration:** Tech Acceleration includes hybrid/grid integration, new markets, heavy duty, energy storage, manufacturing industrial applications (e.g. steel) safety, codes, standard, workforce development

*Will be moved under Hydrogen Fuel R&D in FY 2021

# Key Programmatic Area: H2@Scale

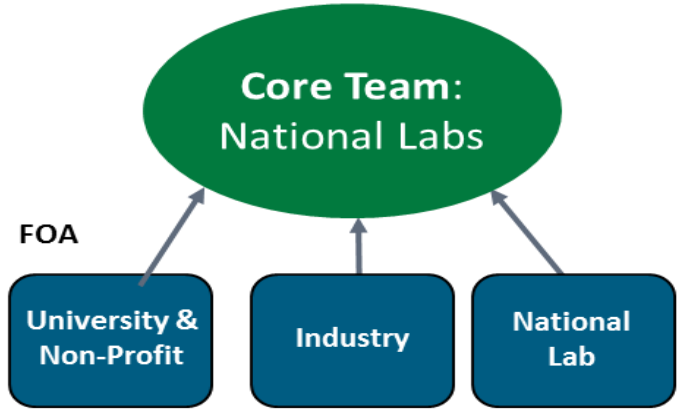
**H2@Scale:** Enabling affordable, reliable, clean, and secure energy across sectors

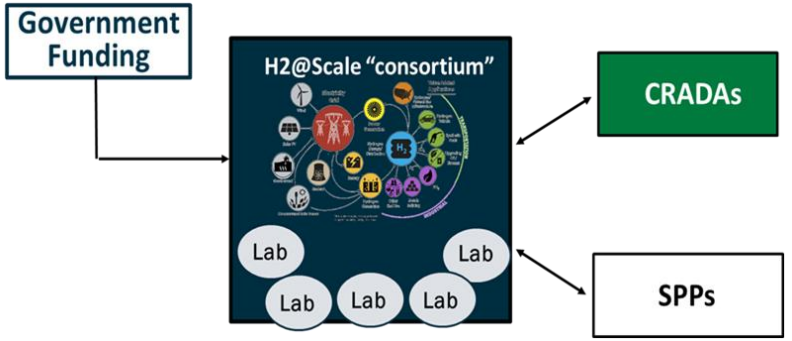



**Includes Early stage R&D:** Funding Opportunity Announcements (FOAs) for industry, universities and national labs, including consortia

**2 New Lab Consortia Planned FY20:**

- **H2NEW**
- **Million Mile Fuel Cell Truck**




**And includes later stage RD&D:**

Leverages private sector for large-scale demos

New H2@Scale demonstration projects announced

Texas, Florida, Midwest (TBD), complements California deployments

**CRADA = Cooperative Research and Development Agreement**

**SPP- Strategic Partnership Project ('Work for Others')**

# Bringing Together Industry and Labs to Accelerate Progress – Examples

## Lab-Based Consortia

HydroGEN
Advanced Water Splitting Materials

HyMARC
Hydrogen Materials Advanced Research Consortium

ElectroCat
Electrocatalysis Consortium

FCPAD
FUEL CELL PERFORMANCE AND DURABILITY

## To Be Formed

New Lab Consortia:

- H2NEW
- Million Mile Fuel Cell Truck Consortium (M2FC)

## Lab - Industry Bridge

- H2@Scale Consortium
- CRADAs
- Strategic Partnership Projects (SPPs)
- L'Innovator
- Technology Commercialization Fund

## Private Sector

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

H-Mat™ Hydrogen Materials Compatibility Consortium

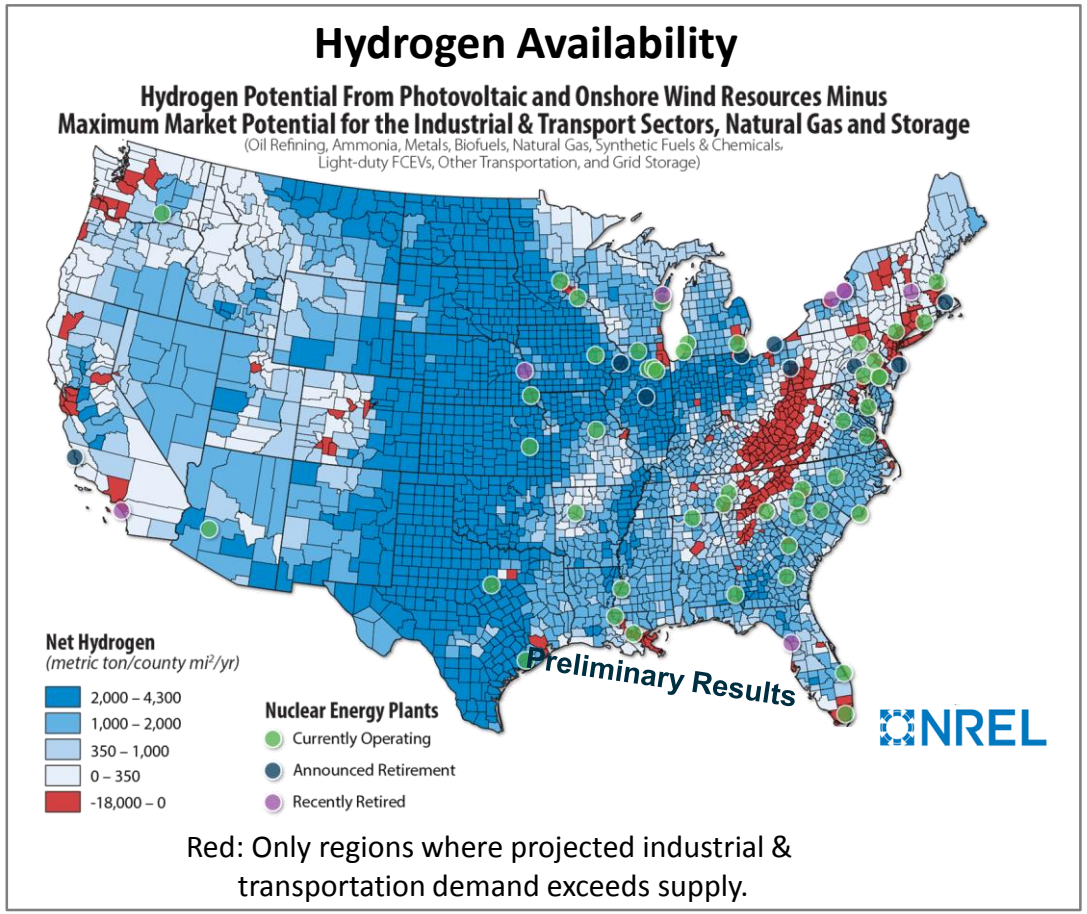
**$H_2$ materials R&D, enable codes & standards, reduce regulatory barriers**

**Safety – R&D, training, lessons learned, best practices, enable safe infrastructure**




# Examples of Activities to Enable H2@Scale

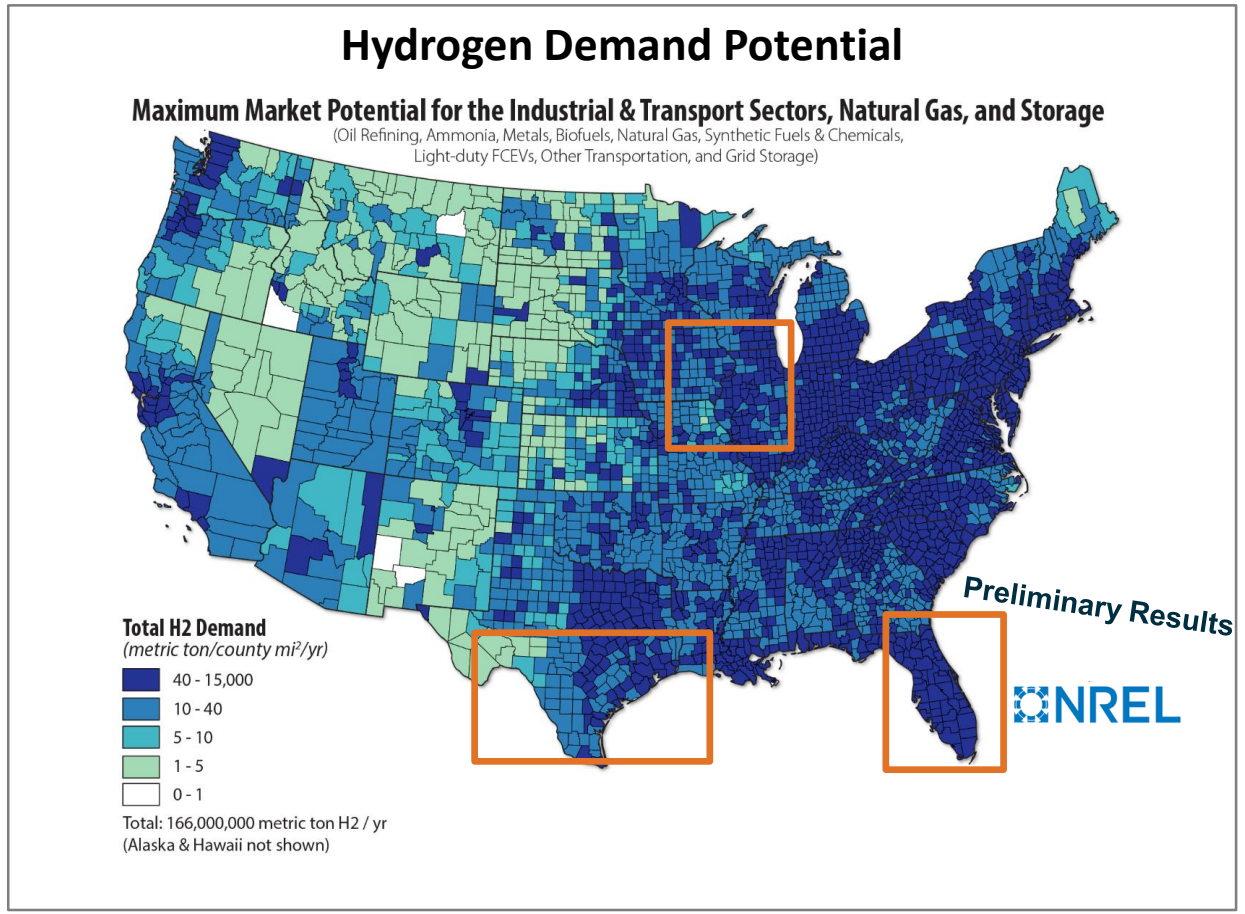
**Assessing resource availability.**
Most regions have sufficient resources.




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

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

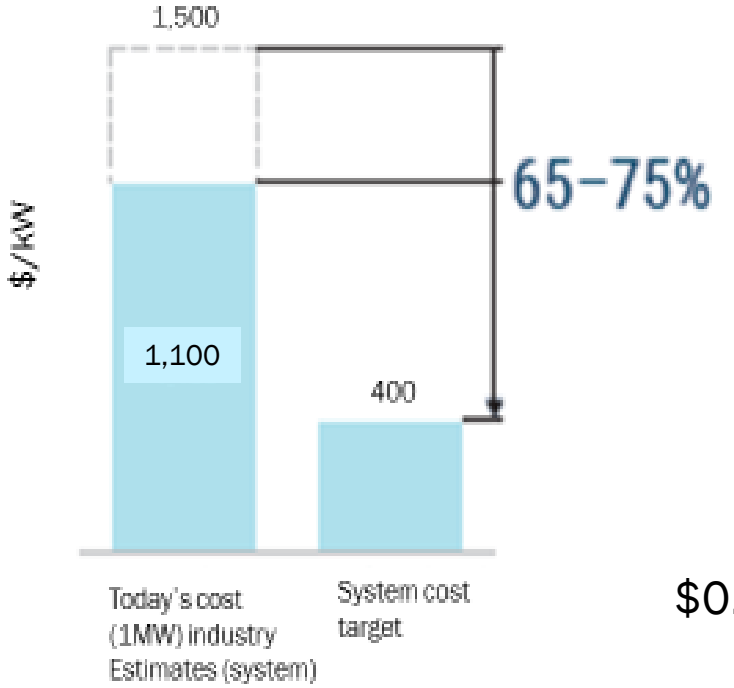
*Includes 1 project by Office of Nuclear Energy



# Hydrogen Production - Electrolysis

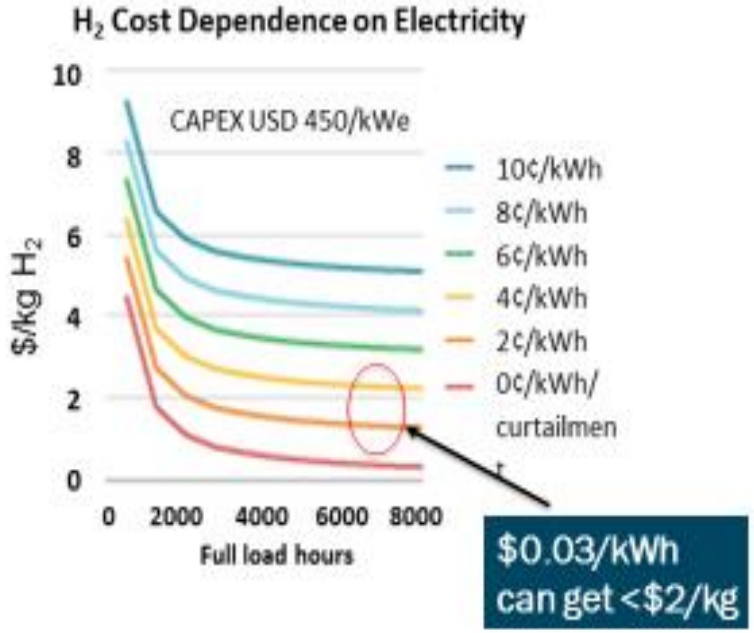
**Today's Polymer Electrolyte Membrane (PEM) electrolyzers require 65-75% cost reduction**

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




Source: US Industry H2 Roadmap, March 2020

Today:
$H_2$ cost from electrolyzers:
$5 to $6/kg at
$0.05 to $0.07/kWh




Source: IEA Hydrogen Future Report, 2019

**Strategy:** **Focus on low and high temp electrolyzer R&D to reduce cost, improve durability, efficiency**
**Diverse methods and innovations for water splitting, bio options (non fossil energy)**

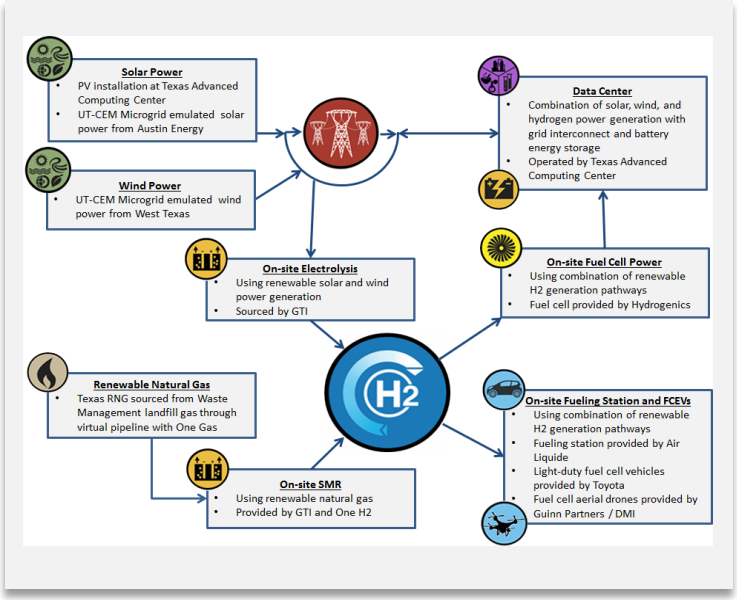
# Example of H2@Scale Projects

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

### Texas

**Total Budget**
**$12.7M**

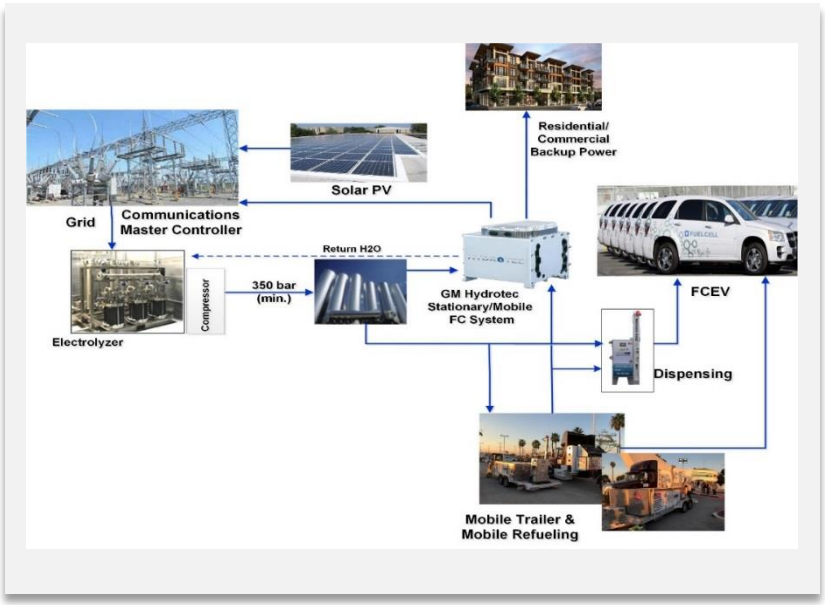
**Wind, Solar, RNG/Waste**




### Florida

**Total budget**
**$8.5M**

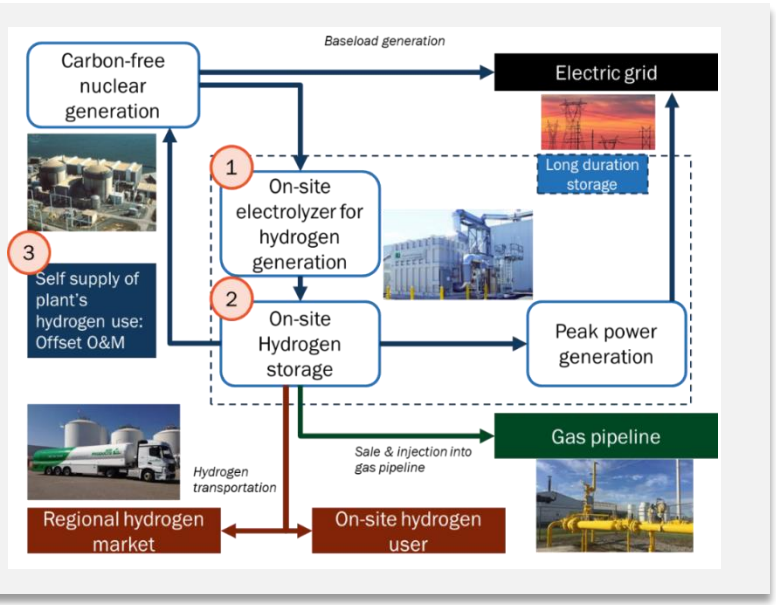
**Solar-to-H2 with End Uses**




### Midwest/TBD

**Total Budget**
**$7.2M**

**Nuclear To H2 For At-Plant Use**




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

# Integrated, Hybrid Systems and Energy Storage

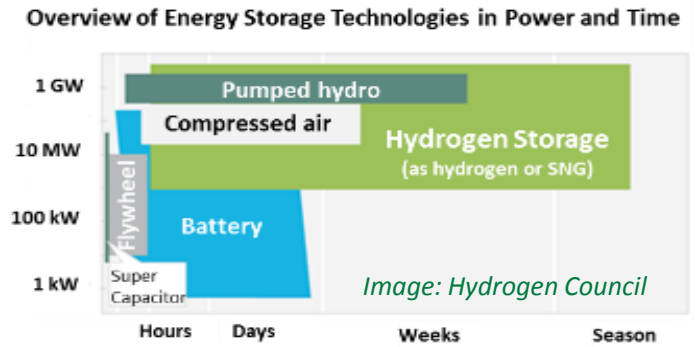
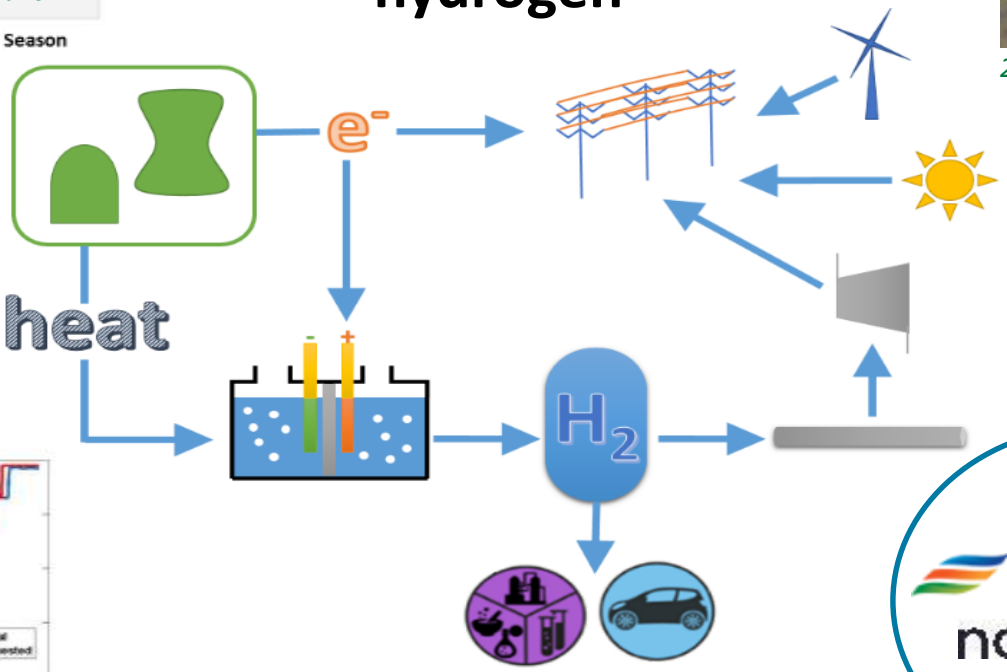



*Image: Hydrogen Council*

**$H_2$ energy storage**

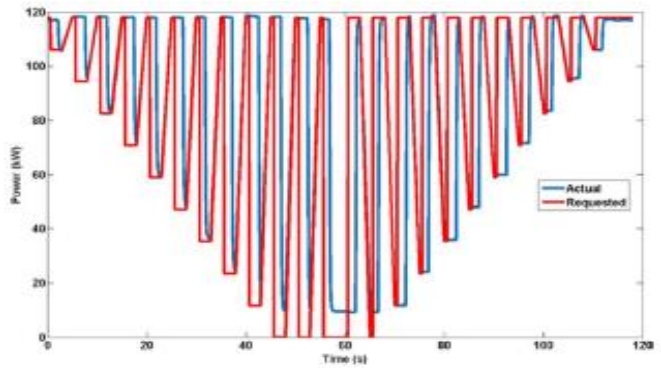
**Increased opportunities for nuclear and hydrogen**




*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*

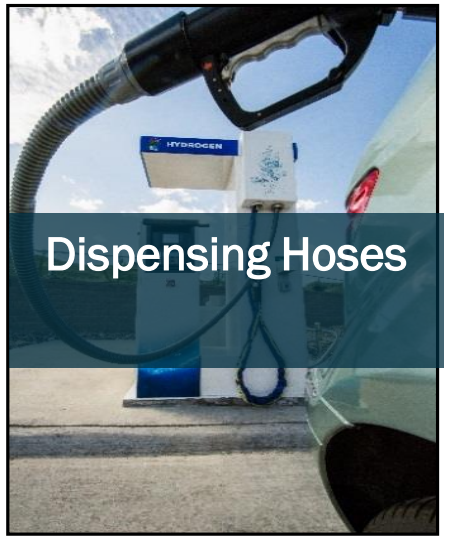
*∗ Energy Harbor formerly known as FirstEnergy Solutions*

Nuclear to $H_2$ funded projects – Offices of NE and EERE

# Cross-cutting Materials Compatibility R&D

H-Mat SM Hydrogen Materials Compatibility Consortium

## H-Mat Consortium conducts R&D on hydrogen effects on polymers and metals







**Focus of current activities include:**

1) **Reduce expansion of seals in hydrogen by 50%**
2) **Enhance life of vessels by 50% through improved understanding of crack nucleation.**
3) **Enhance fracture toughness of high-strength (>950 MPa) steels by 50%.**

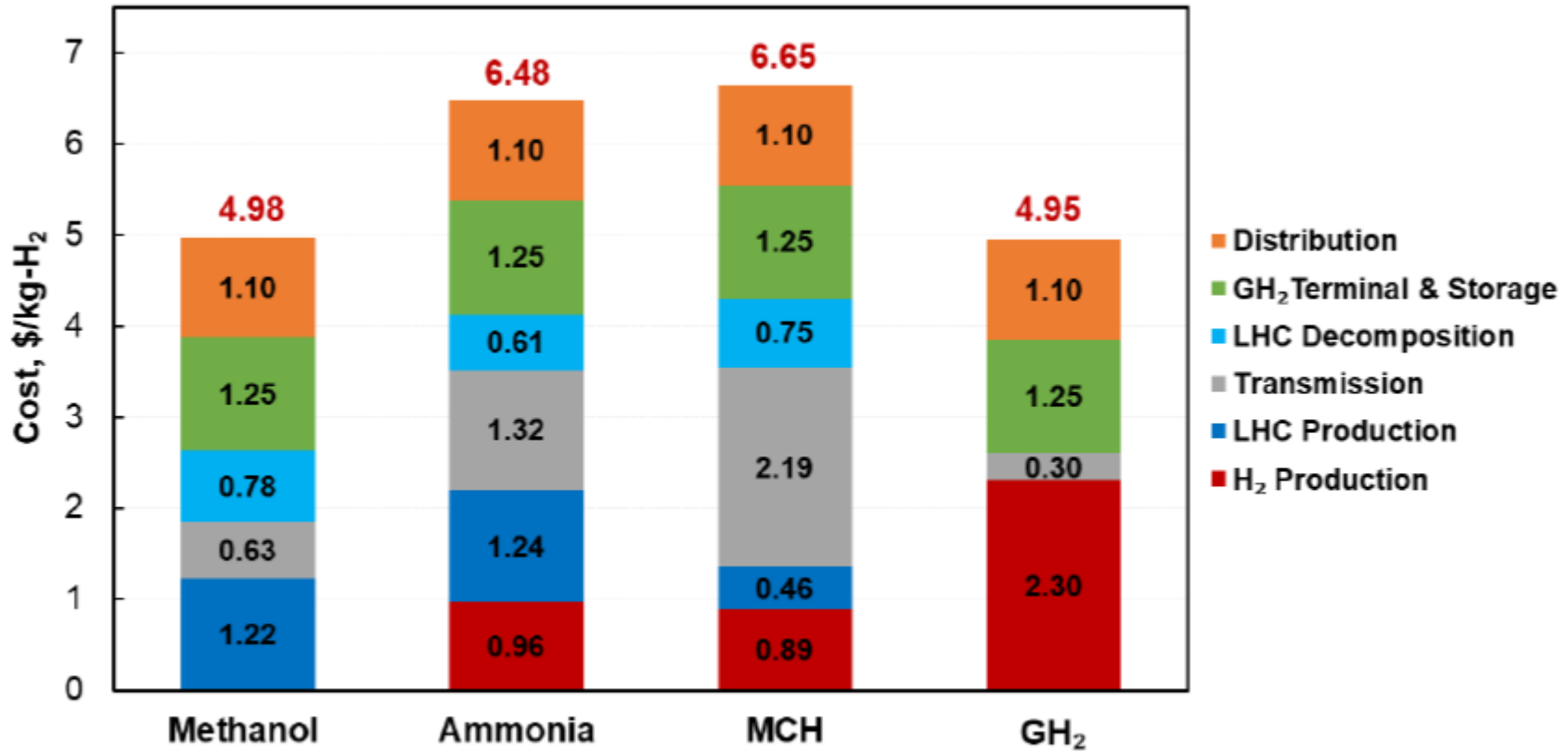
Sandia National Laboratories | Pacific Northwest National Laboratory | Oak Ridge National Laboratory | Savannah River National Laboratory (Operated by Savannah River Nuclear Solutions) | Argonne National Laboratory

**For more information:**
**Website: energy.gov/eere/fuelcells/h-mat-hydrogen-materials-consortium**
**Email: h-matinfo@pnnl.gov**

# Example of Recent Activities: Comparison of Hydrogen Carriers

## Baseline levelized cost of $H_2$ at 50,000 kg per day

Argonne NATIONAL LABORATORY




- At 50,000 kg $H_2$ per day, methanol produced at high volume in the gulf coast area, and transport to California can be cost competitive with "locally" produced gaseous hydrogen.
- Ammonia and methylcyclohexane have a cost premium over "locally" produced gaseous hydrogen

# 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

Formed 2003

19 Countries and EC

**Key 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**

## CENTER FOR 水素安全センター Hydrogen SAFETY

Connecting a Global Community

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**

# Hydrogen Production Analysis Task Force (H2PA TF)

## Addressing Priority from Industry and Governments

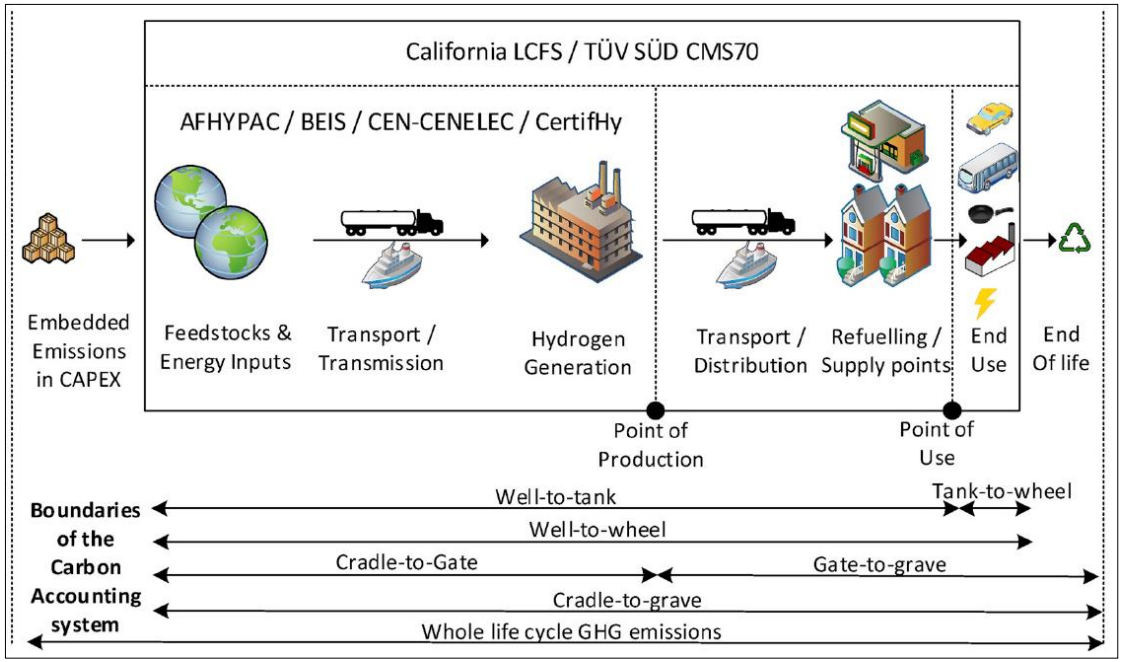
- Harmonize approach and develop framework to facilitate global trade of hydrogen

## Scope

- Develop a mutually agreed upon analytical methodology for determining greenhouse gas (GHG) and other emissions associated with H2 production.

## Next Steps and Engagement

- Continue to engage stakeholders, industry and experts to develop framework for methodology




*(Source: Abad et al., Energy policy 138 (2020) 111300)*

**Application of methodology will help facilitate market valuation and global trade in 'clean' hydrogen by recommending a common approach with adoption not mandatory and subject to each member's discretion and circumstance.**

# $64M Just Announced: H2@Scale New Markets

## Project Selections of the $64M H2@Scale FOA Issued in January 2020

- **18 projects chose**n to advance H2@Scale's next round of RD&D for affordable hydrogen production, storage, distribution, and use
- Includes collaborations with EERE's Advanced Manufacturing Office (AMO) and Vehicle Technologies Office (VTO)
- **Focus areas:** Manufacture of reliable and affordable **electrolyzers**; development of low-cost, hi-strength carbon fiber for H2 storage tanks; IDing durable and cost-effective fuel cell systems and components for **medium- and heavy-duty trucks**


**Press Release**
https://www.energy.gov/articles/energy-department-announces-approximately-64m-funding-18-projects-advance-h2scale

| Selectee Name | Location (city, state) | Project Title | Federal Share |
|---|---|---|---|
| **TOPIC 1: ELECTROLYZER MANUFACTURING R&D** | | | |
| 3M Company | Saint Paul, MN | Advanced Manufacturing Processes for Gigawatt-Scale Proton Exchange Membrane Water Electrolyzer Oxygen Evolution Reaction Catalysts and Electrodes | $4,854,808 |
| Giner ELX, Inc. | Newton, MA | Integrated Membrane Anode Assembly & Scale-up | $4,592,664 |
| Proton Energy Systems, Inc. | Wallingford, CT | Enabling Low Cost PEM Electrolysis at Scale Through Optimization of Transport Components and Electrode Interfaces | $4,400,000 |
| **TOPIC 2: ADVANCED CARBON FIBER FOR COMPRESSED HYDROGEN AND NATURAL GAS STORAGE TANKS** | | | |
| Collaborative Composite Solutions Corporation | Oak Ridge, TN | Melt Spun PAN Precursor for Cost-Effective Carbon Fiber in High Pressure Compressed Gas Tankage | $2,700,540 |
| Hexagon R & D LLC | Lincoln, NE | Carbon Composite Optimization Reducing Tank Cost | $2,599,945 |
| University of Kentucky | Lexington, KY | Low-Cost, High-Strength Hollow Carbon Fiber for Compressed Gas Storage Tanks | $2,415,576 |
| University of Virginia | Charlottesville, VA | Low-Cost, High-Performance Carbon Fiber for Compressed Natural Gas Storage Tanks | $2,701,552 |
| **TOPIC 3: FUEL CELL R&D FOR HEAVY-DUTY APPLICATIONS; SUBTOPIC 3A: MEMBRANES FOR HEAVY-DUTY APPLICATIONS** | | | |
| 3M Company | Saint Paul, MN | Extending PFSA Membrane Durability Through Enhanced Ionomer Backbone Stability | $999,889 |
| The Lubrizol Corporation | Wickliffe, OH | Antioxidant Functionalized Polymers for Extended HD Polymer Electrolyte Membrane Lifetimes | $1,000,000 |
| Nikola Corporation | Phoenix, AZ | Advanced Membrane and MEA for HD Fuel Cell Trucks | $998,376 |
| University of Tennessee: Knoxville | Knoxville, TN | A Systematic Approach to Developing Durable, Conductive Membranes for Operation above 120°C | $1,000,000 |
| **TOPIC 3: FUEL CELL R&D FOR HEAVY-DUTY APPLICATIONS; SUBTOPIC 3B: DOMESTICALLY MANUFACTURED FUEL CELLS FOR HEAVY-DUTY APPLICATIONS** | | | |
| Cummins | Columbus, IN | Cummins PEM Fuel Cell System for Heavy Duty Applications | $3,000,000 |
| Plug Power | Latham, NY | Domestically Manufactured Fuel Cells for Heavy-Duty Applications | $2,987,181 |
| **TOPIC 4: H2@SCALE NEW MARKETS R&D—HYSTEEL** | | | |
| Missouri University of Science & Technology | Rolla, MO | Grid-Interactive Steelmaking with Hydrogen (GISH) | $4,000,000 |
| University of California: Irvine | Irvine, CA | Solid Oxide Electrolysis Cells (SOEC) integrated with Direct Reduced Iron plants (DRI) for the production of green steel | $4,043,993 |
| **TOPIC 5: H2@SCALE NEW MARKETS DEMONSTRATIONS; SUBTOPIC 5A: MARITIME DEMONSTRATIONS** | | | |
| Hornblower Yachts | San Francisco, CA | Marine Hydrogen Demonstration | $7,994,208 |
| **TOPIC 5: H2@SCALE NEW MARKETS DEMONSTRATIONS; SUBTOPIC 5B: DATA CENTER DEMONSTRATIONS** | | | |
| Caterpillar Inc. | Mossville, IL | System Demonstration for Supplying Clean, Reliable and Affordable Electric Power to Data Centers using Hydrogen Fuel | $6,000,000 |
| **TOPIC 6: TRAINING AND WORKFORCE DEVELOPMENT FOR EMERGING HYDROGEN TECHNOLOGIES** | | | |
| Electric Power Research Institute, Inc. | Palo Alto, CA | Developing a Workforce for a Hydrogen Technology Economy | $2,000,000 |

# Thank You

Sunita.Satyapal@ee.doe.gov

*Looking for more info?*

**#H2IQ**


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

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

***– H. Luccock***

# Additional Information

# DOE-Funded Innovation Driving Impact

## Innovation

**1,110** $H_2$ and fuel cell patents **enabled by HFTO funds**

**Approx. 35%** of $H_2$ and fuel cell patents **come from National Labs**

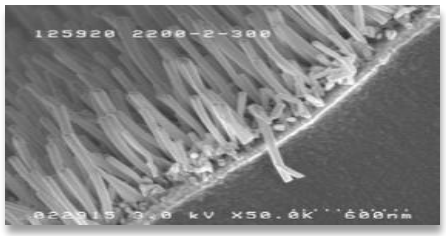
## Market Impact

**More Than 30** Technologies Commercialized by private industry

**And Over 65** with potential to be commercial in the next 3 – 5 years

**Can be traced back to HFTO R&D**

### Fuel Cell Catalysts



Catalyst and Supports for PEM Fuel Cells
3M

### Hydrogen Tube Trailers

Hydrogen Tube Trailers
Hexagon Lincoln

### Electrolyzers

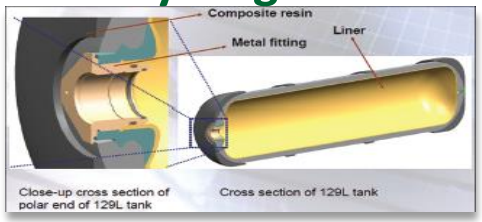
Electrolyzer System
Proton Series

### Forklifts

Class-1, -2, and -3 Forklifts
Plug Power (GenDrive FCs)


PEM Electrolyzer System
Giner

### Hydrogen Tanks




Optimized 129L Tank
Quantum Technologies

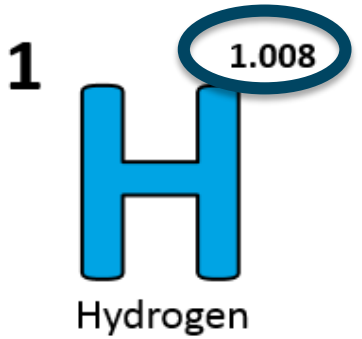
# More Information and Resources

**Download the H2IQ resource for free:**
energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

**Join monthly H2IQ hour 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**