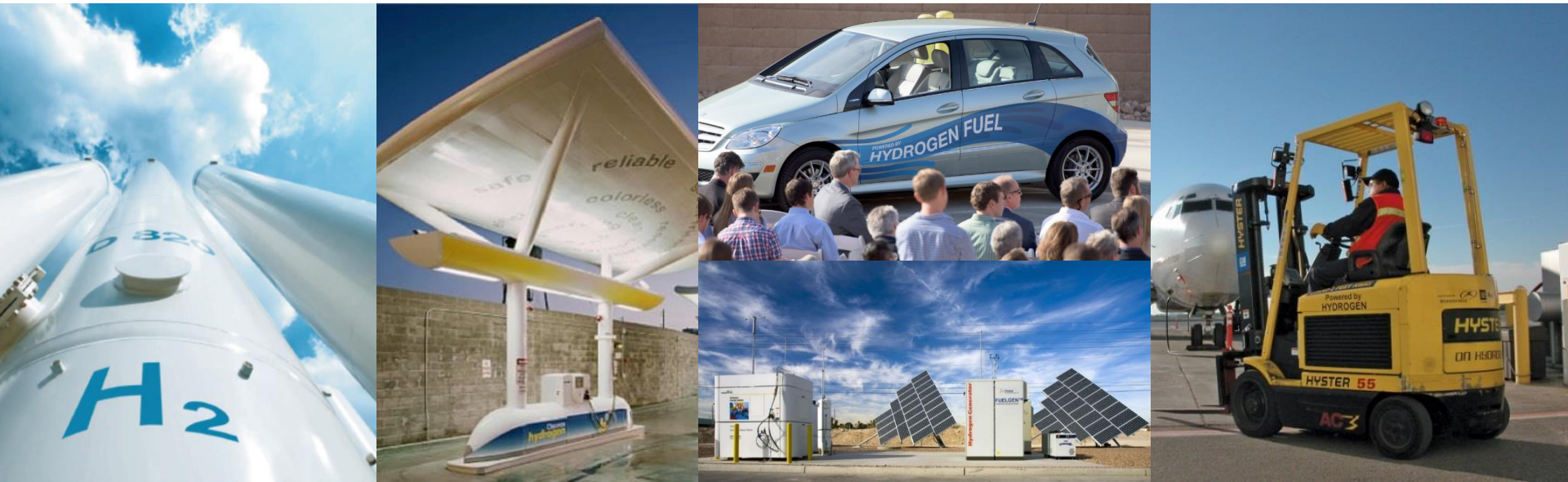


Overview of DOE Hydrogen and Fuel Cell H2@Scale Activities

H2@Scale Session – Fuel Cell Seminar & Energy Exposition

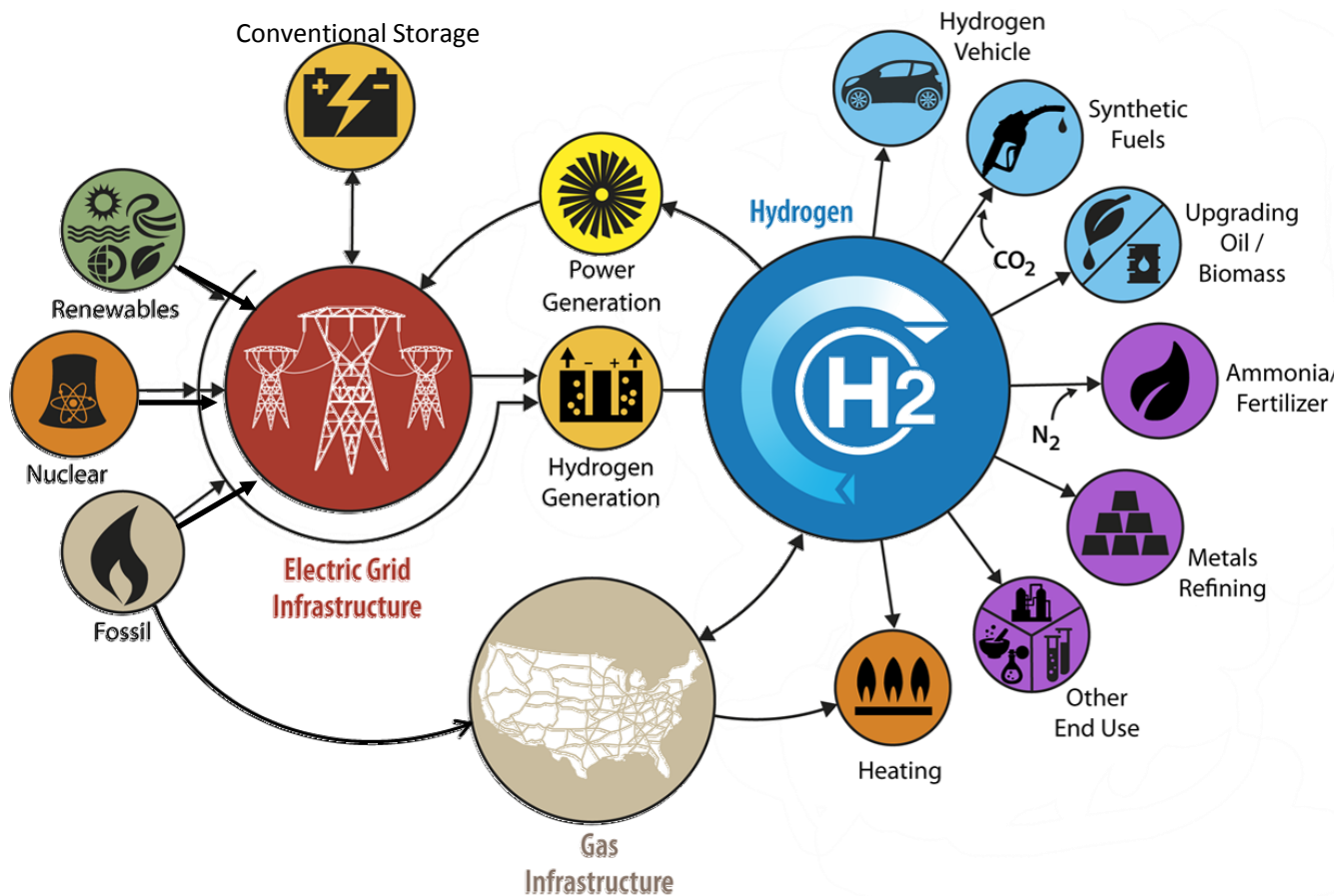
November 5, 2019 – Long Beach, CA



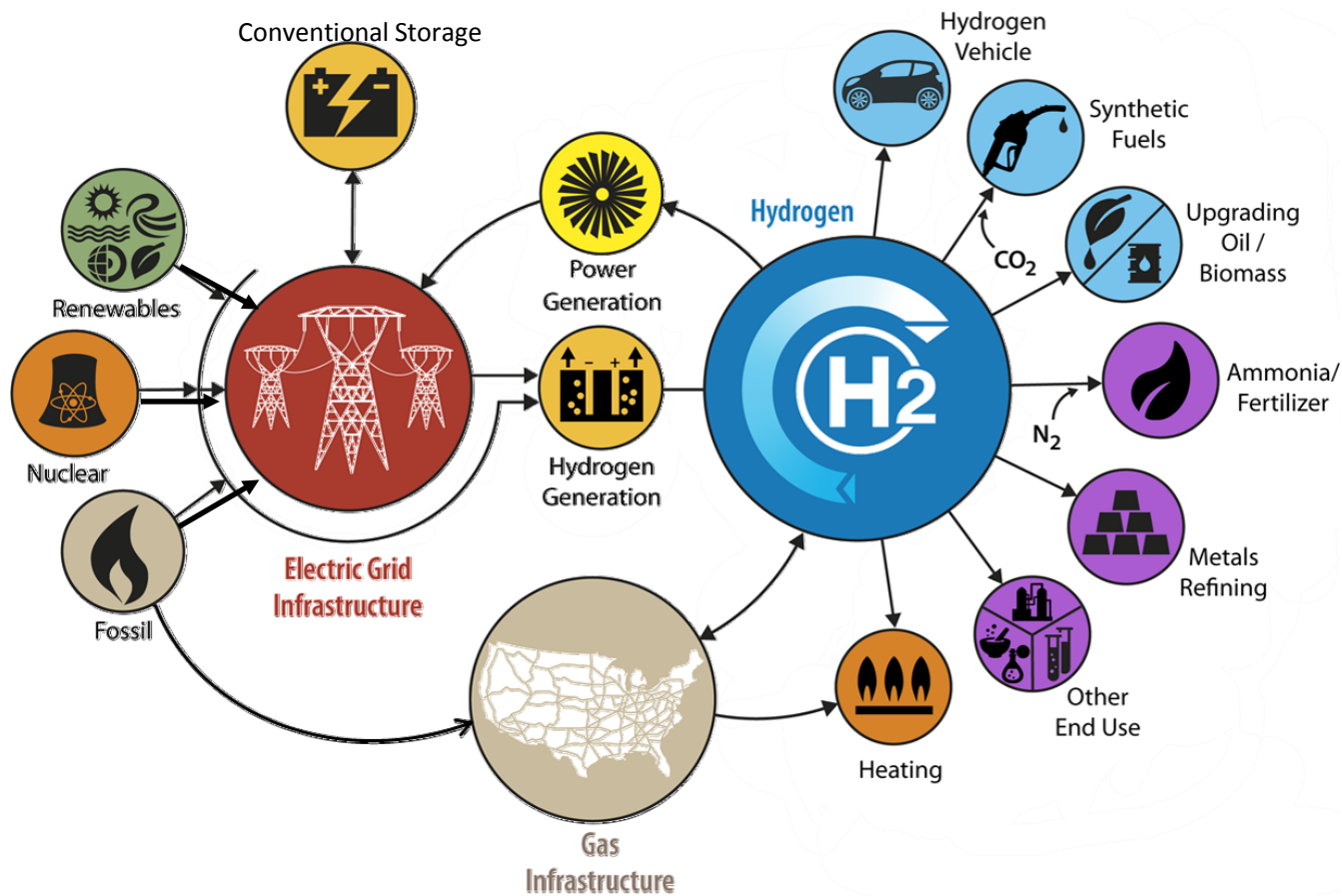
H₂@Scale Initiative

To enable affordable,
reliable, clean and secure
energy across sectors

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



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



A photograph of two white hydrogen fuel cell vehicles (FCVs) parked at a hydrogen refueling station. The vehicles are decorated with blue and white graphics and the text "POWERED BY HYDROGEN FUEL". The station is a tall, white and blue structure with a "HYDROGEN" sign at the top. The background shows a clear blue sky and a fence.

Status

U.S. Snapshot of Hydrogen and Fuel Cells Applications

Examples of Applications



>500MW

Stationary Power



>30,000

Forklifts



>30

Fuel Cell Buses



>40

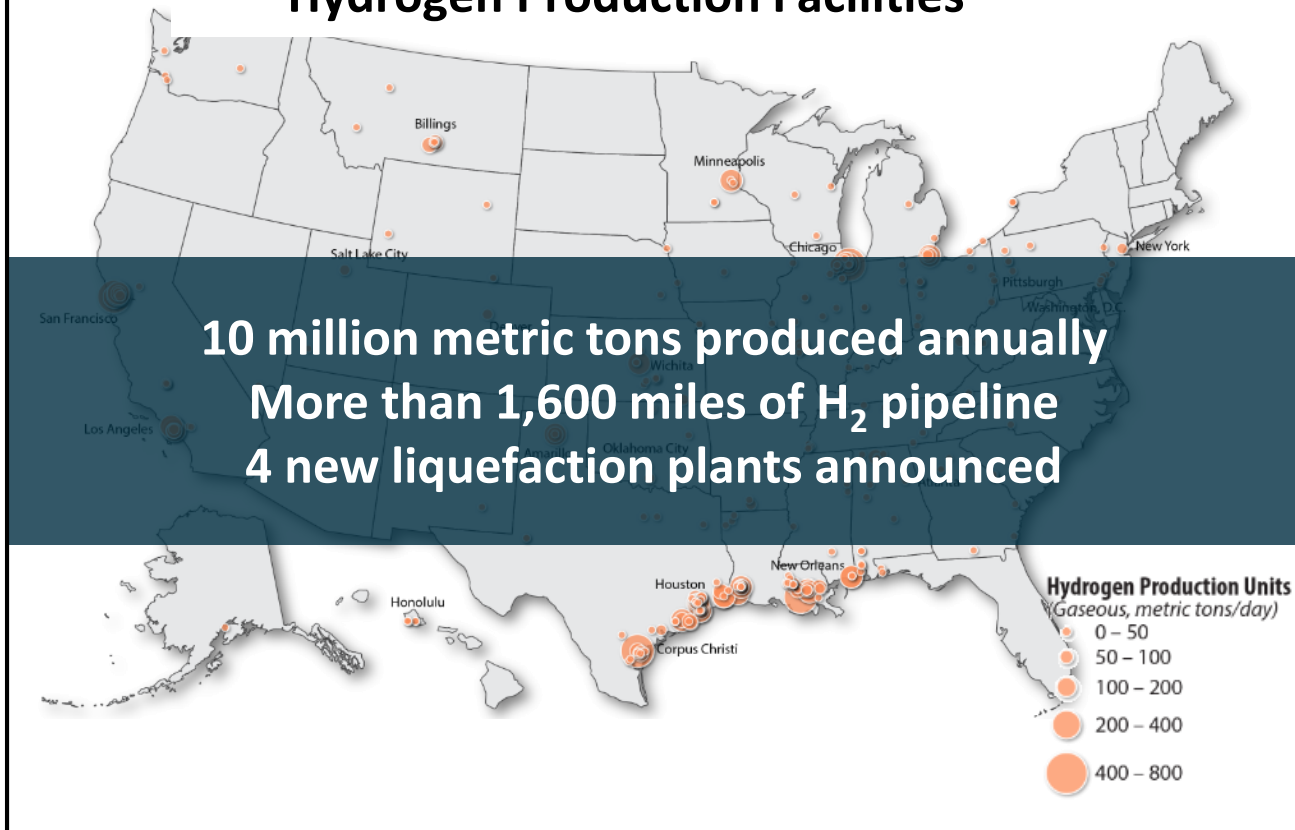
H₂ Retail Stations



>7,800

Fuel Cell Cars

Hydrogen Production Facilities



Hydrogen Stations: Examples of Plans Across States

California

1,000 stations by 2030

Northeast

12 – 20 stations planned

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

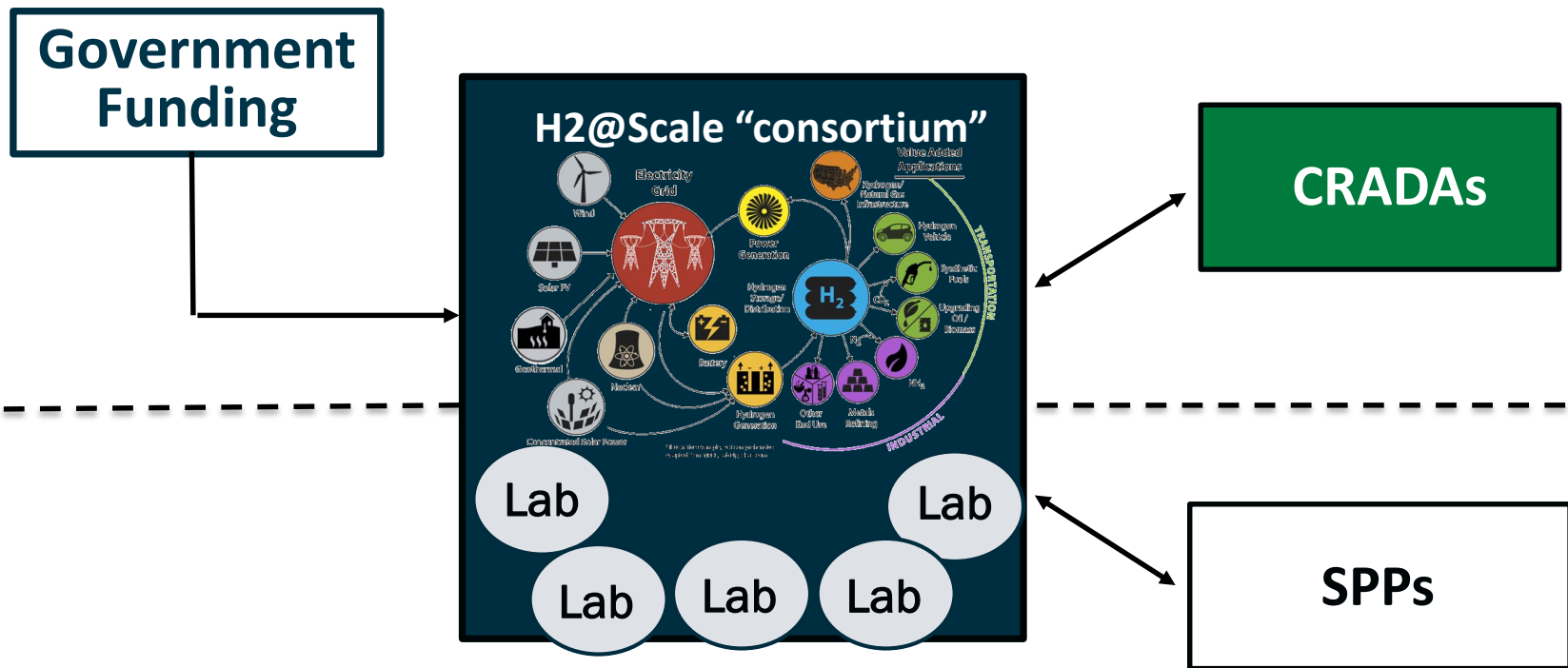
Interest growing in

End use applications across sectors

Heavy duty vehicles, steel
manufacturing, ammonia, energy
storage, liquid fuels, critical loads,
natural gas blending, exports, and more

Recap of H₂@Scale – Lab CRADAs

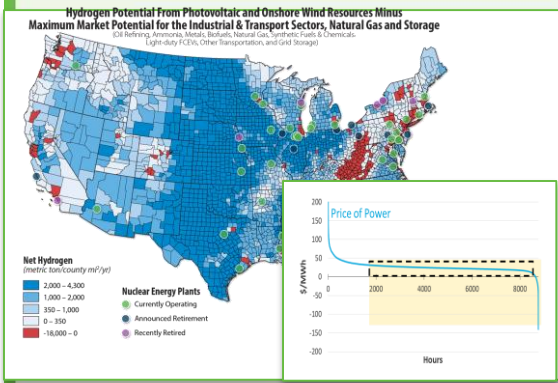
Leverages Lab capabilities and expertise to address challenges—materials R&D, analysis, safety R&D, etc.



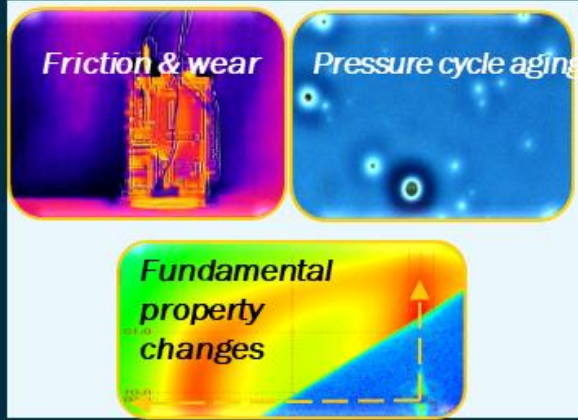
CRADA = Cooperative Research and Development Agreement
SPP- Strategic Partnership Project ('Work for Others')

Requests from Industry: Work with National Labs on...

Techno economic Modeling and Analysis



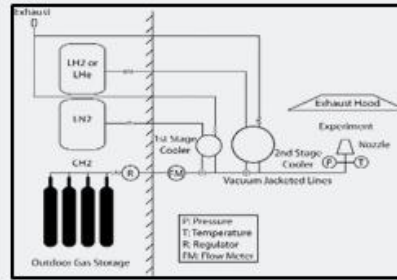
Hydrogen Materials R&D



Grid simulation and Testing R&D



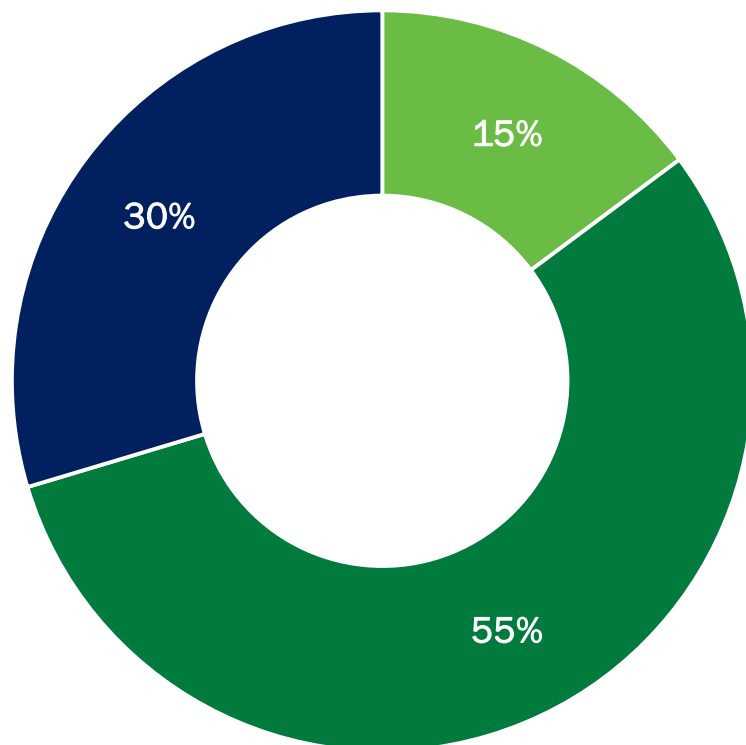
Safety and Infrastructure R&D



Project Status

DOE has contributed ~ \$7M to over 25 projects valued at over \$14M under the original H2@Scale CRADA Call

■ New in 2019 ■ In Progress ■ Completed



New CRADA projects addressing:

1. Heavy-duty refueling
2. Electrolyzer capital cost and water efficiency
3. Hydrogen carriers
4. Electrolytic renewable fuels

Labs still open to H2@Scale CRADAs on a rolling basis

H2Scale@ee.doe.gov

or contact any lab

Recent & Ongoing H2@Scale CRADA Projects

Over 25 Recent CRADA Projects (Recently Completed, Underway, or Upcoming)

HYDROGEN INTEGRATION WITH ENERGY GENERATION R&D

- Electric Power Research Institute
- Exelon
- Southern Company / Terrestrial Energy
- Pacific Gas & Electric
- TerraPower
- Southern / Xcel
- University of California- Irvine

HYDROGEN DISTRIBUTION COMPONENT R&D

- California Go-Biz Office
- Frontier Energy
- HyET
- Honda
- NanoSonic
- RIX
- Tatsuno
- Shell
- Chiyoda

ADVANCED HYDROGEN PRODUCTION CONCEPTS R&D

- Honda
- C4-MCP, Inc.
- GinerELX
- GTA, Inc.
- SoCalGas

HYDROGEN QUANTITATIVE PERFORMANCE ANALYSIS AND OPERATION R&D

- Air-Liquide
- California Energy Commission
- Connecticut Center for Advanced Technology
- PDC Machines
- Quong & Associates, Inc.

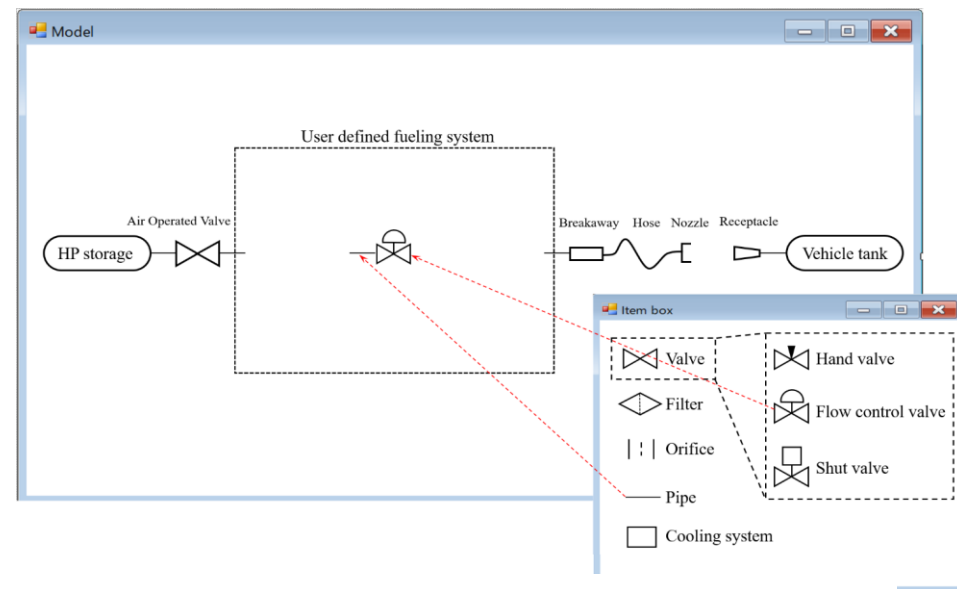
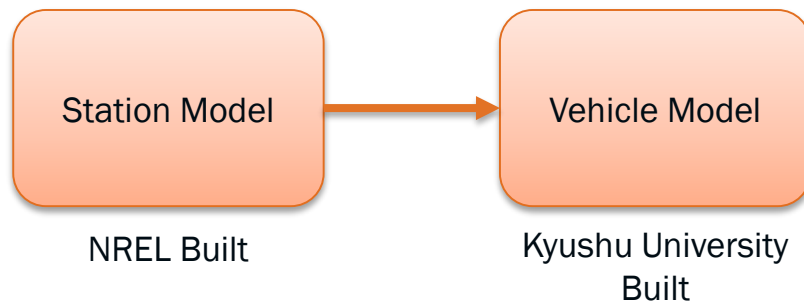


Example CRADA Project: Hydrogen Fueling Model

Validated, free to use hydrogen station and fuel cell electric vehicle fueling model to be released to public in the next few months.

Project Participants

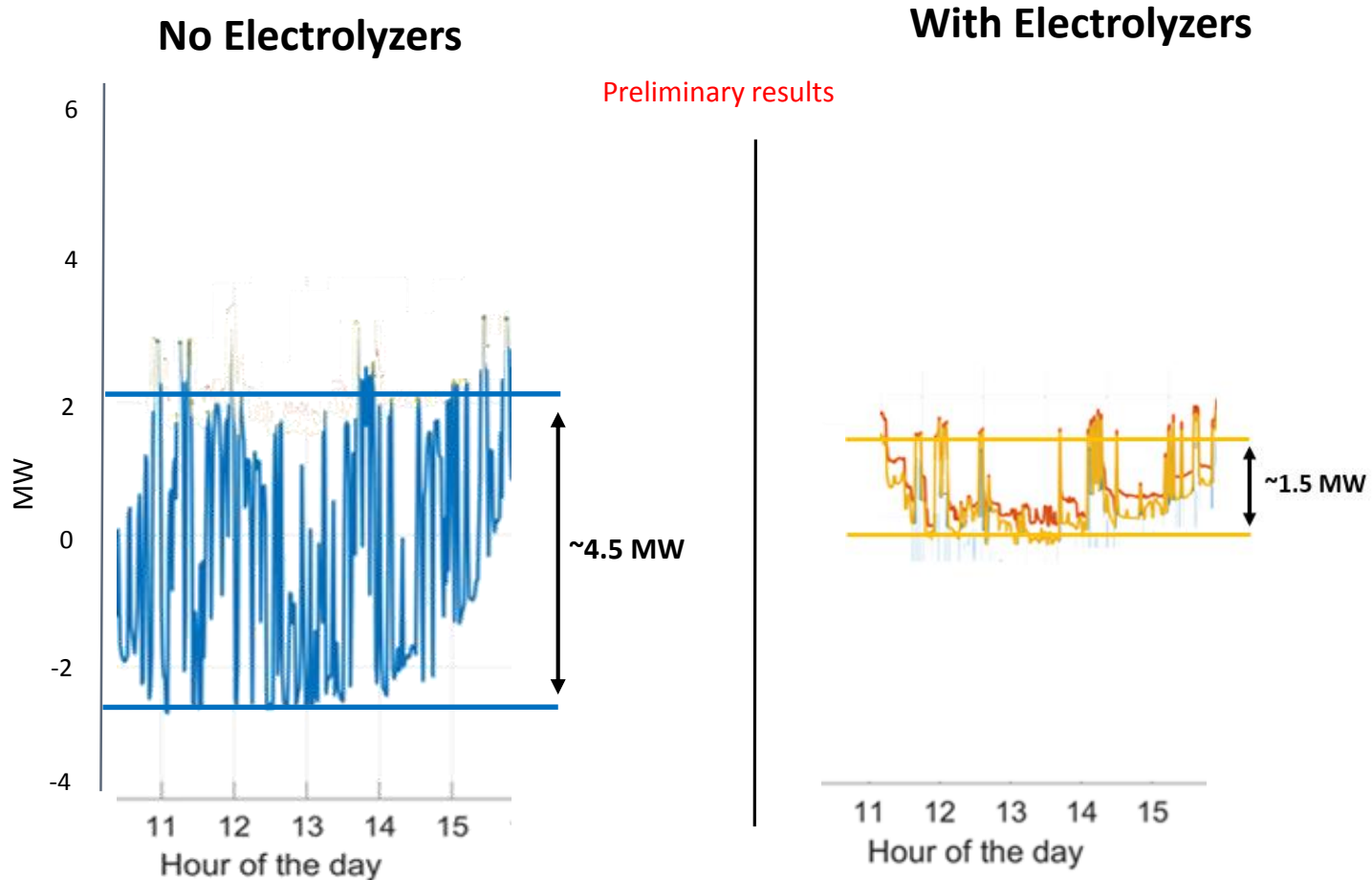
- Leads: DOE, NREL, and Frontier Energy
- Industry: Ford, GM, Honda, Hyundai, IVYS, Shell, Toyota
- National Labs: ANL and SNL
- Academia: Kyushu University



Customize station configurations and fueling conditions to simulate performance of new fueling methods and technologies!

New National Lab Facilities: Systems integration with electrolyzers and the grid

Preliminary study shows electrolyzers can reduce amplitude of power fluctuations in a grid with high renewables



Source: D. Murphy, et al, NREL and INL. Specific case with high solar penetration and electrolyzers used to compensate for power fluctuations

H2@Scale FOA Projects

Current Projects

FY18 FOA (Topic 2 – H2@Scale)

Integrated Energy Production and Hydrogen Fueling R&D

- Autonomous Fueling
- Synthetic Fuel Production
- Electrolysis of Non-Potable Water

Electrolyzer Manufacturing R&D

- Roll-to-Roll Fabrication
- Catalyst Loading Reduction
- 3D Printing

Breakthrough Infrastructure R&D

- Innovations for Hydrogen Cooling: Turboexpander, Vortex Tube, Free-Piston Expander

New Projects

FY19 FOA

Advanced Hydrogen Storage and Infrastructure R&D

- Novel Hydrogen Carrier Development
- Materials Compatibility

Innovative Concepts for Hydrogen Production and Utilization

- Advanced Water Splitting Materials
- Biological Hydrogen Production
- Co-production of H₂ and Value-add Byproducts
- Reversible Fuel Cells

H2@Scale Pilot – Integrated Production, Storage, and Fueling System

Total FOA funding from FCTO: FY18- \$38M and FY19-\$56M (H2@Scale and truck FOA)

Recent Collaborations with the Office of Nuclear Energy

Selected from FY 19 H2@Scale FOA

Demonstration of Electrolyzer Operation at a Nuclear Plant to Allow for Dynamic Participation in an Organized Electricity Market and In-House Hydrogen Supply

Recipient: Exelon Corporation

Selected from FY 19 Nuclear Energy FOA

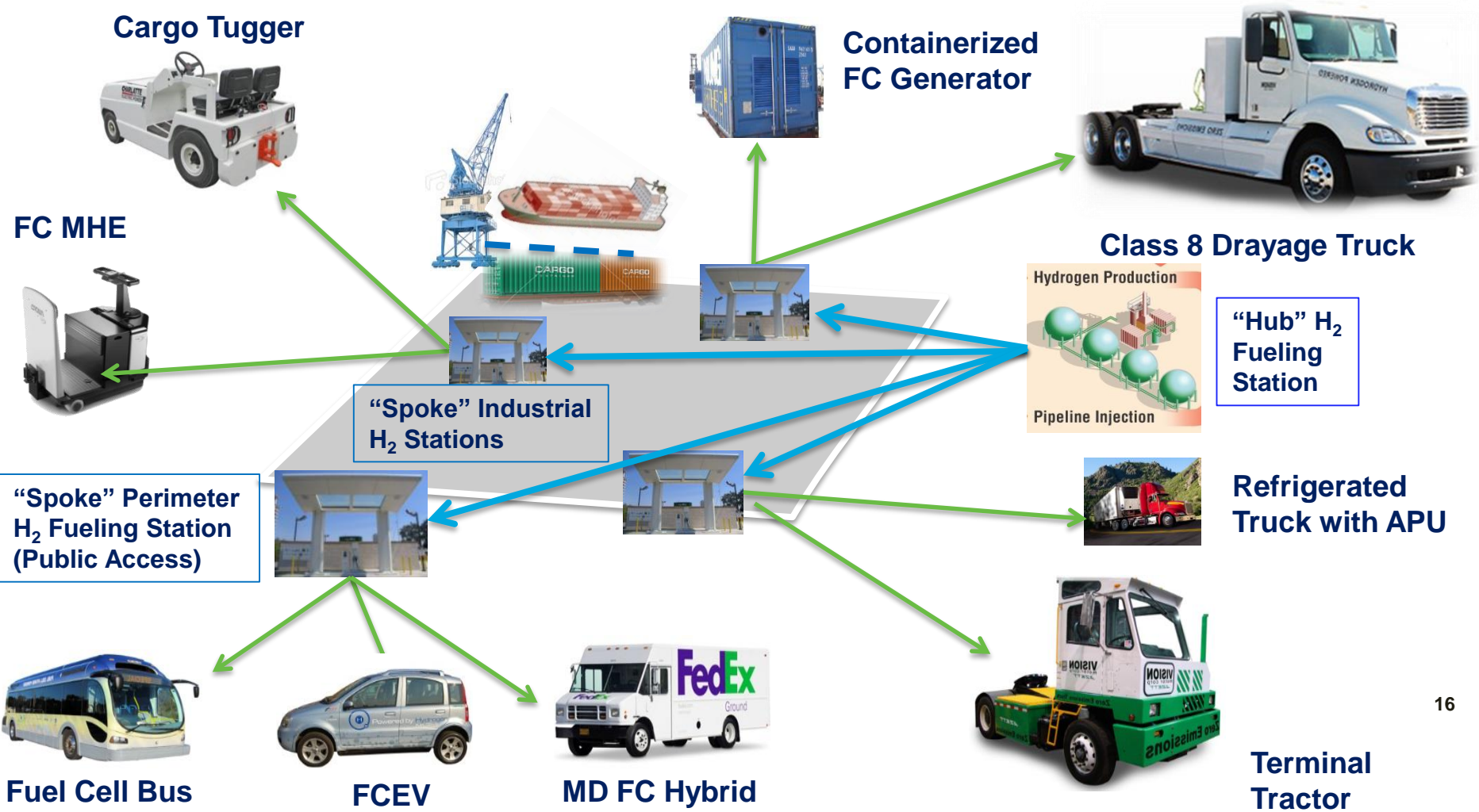
Installation of electrolysis unit at Davis-Besse Nuclear Power Station, and assessment of business case opportunities

Recipient: FirstEnergy Solutions Corporation

Blog at: www.energy.gov/ne/articles/could-hydrogen-help-save-nuclear

“Clustering” Can Drive H₂ Demand

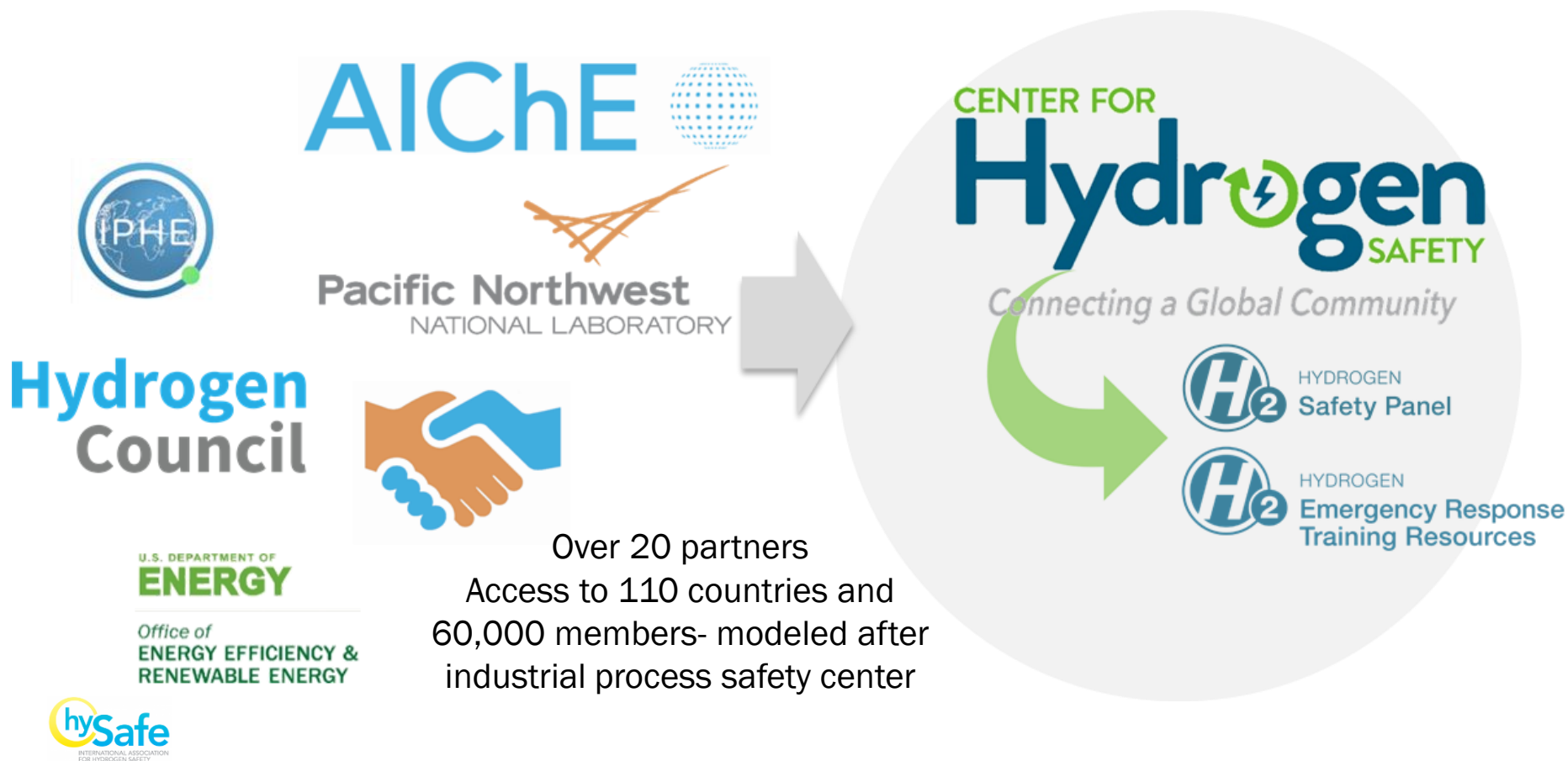
**Representative Port-Based Industrial Complex with Hydrogen Cost < \$6/kg
“Hub and Spoke” H₂ Fueling Stations Connected by Pipelines**





Collaboration & Resources

New Global Safety Partnership: Center for H₂ Safety launched 2019



Over 20 partners
Access to 110 countries and
60,000 members- modeled after
industrial process safety center

See www.aiche.org/CHS to join

International Collaborations



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

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



Mission Innovation Hydrogen Challenge 2017

Clean Energy Ministerial New Hydrogen Initiative Launched 2019

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www.iphe.net

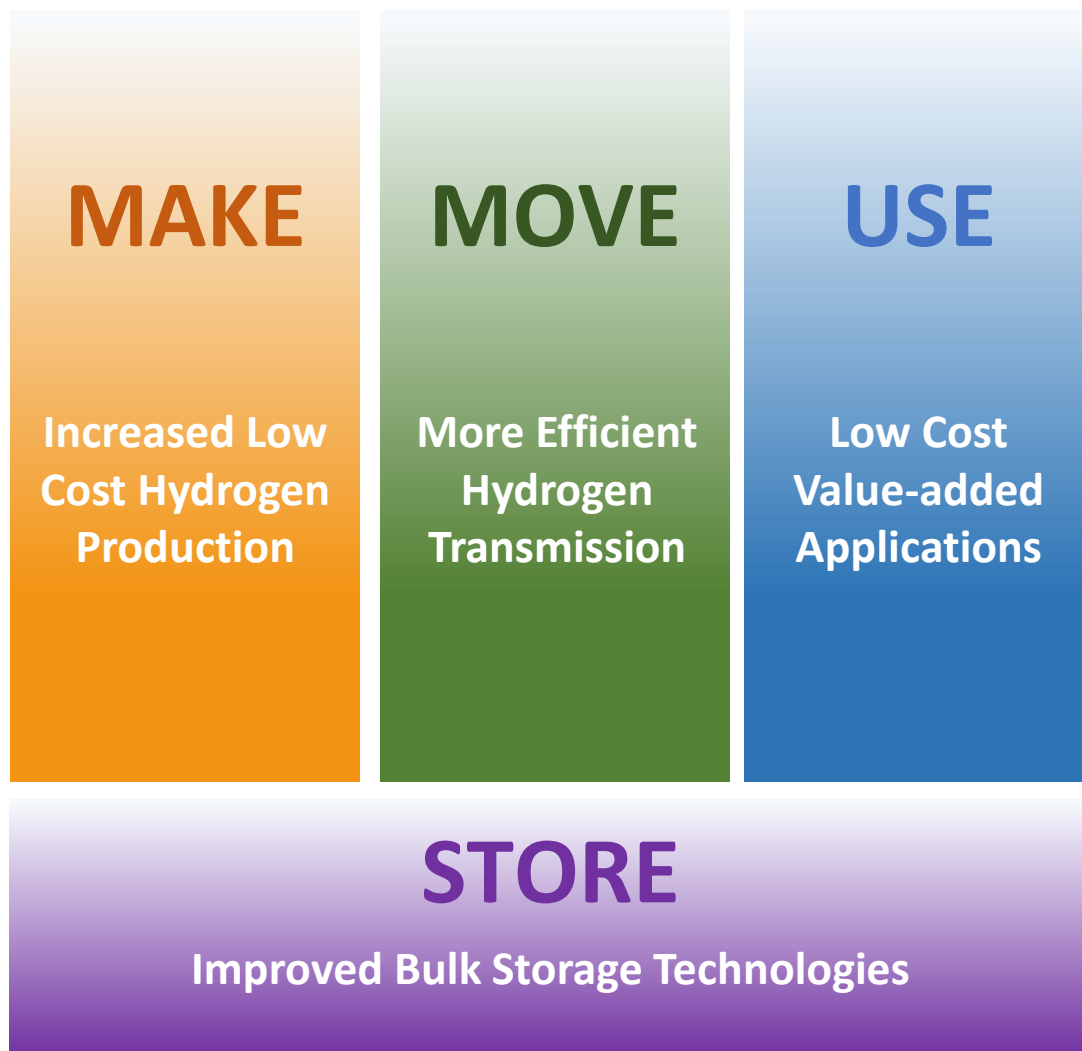


Formed 2003
19 Countries and EC

Hydrogen Energy Ministerial (HEM)

International Energy Agency (IEA)

Key Focus Areas to Realize the H₂@Scale Vision



- **New in FY19:**
H2@Scale Working Group meetings for CRADA partners
- **Coming Soon:**
Hydrogen and Fuel Cells Program Plan to reflect H2@Scale vision and organized around MAKE, MOVE, USE, STORE

Join our Team!

Roles Available:

- Fellows
- Contractors
- Interns

Areas:

- Engineering
- Chemistry, Materials
- Project Management
- Communications
- Operations
- Safety, codes, standards

For more info: fuelcells@ee.doe.gov



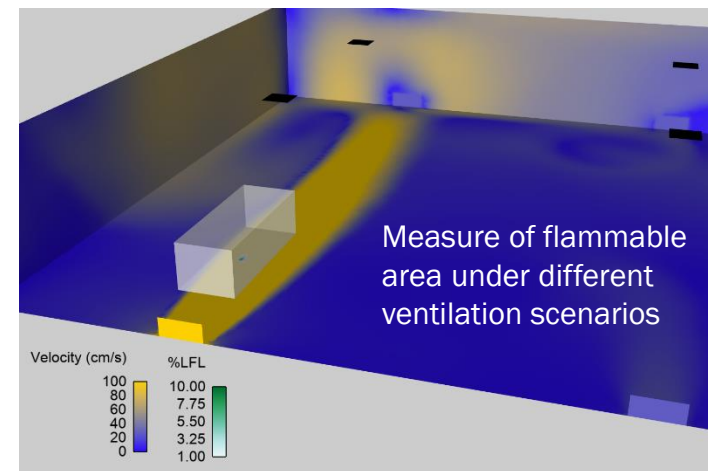
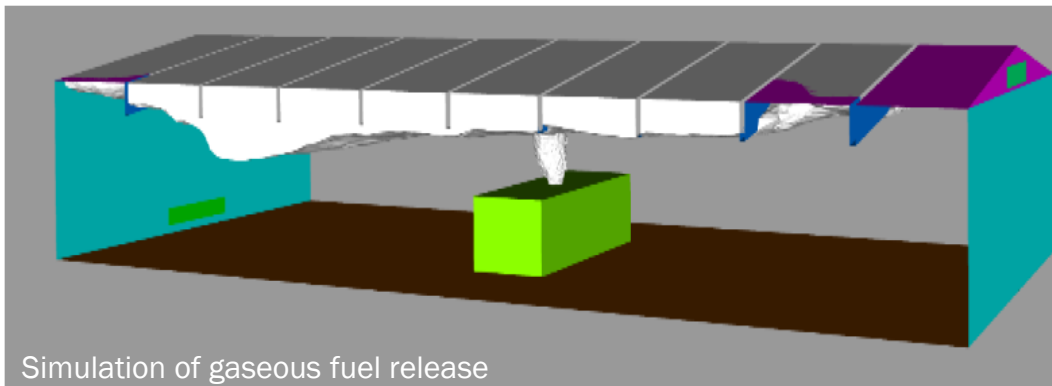
Save the Date
May 19-22, 2020
DOE AMR (Annual Merit Review)

www.hydrogen.energy.gov

Additional Slides

CRADA Project Outcomes

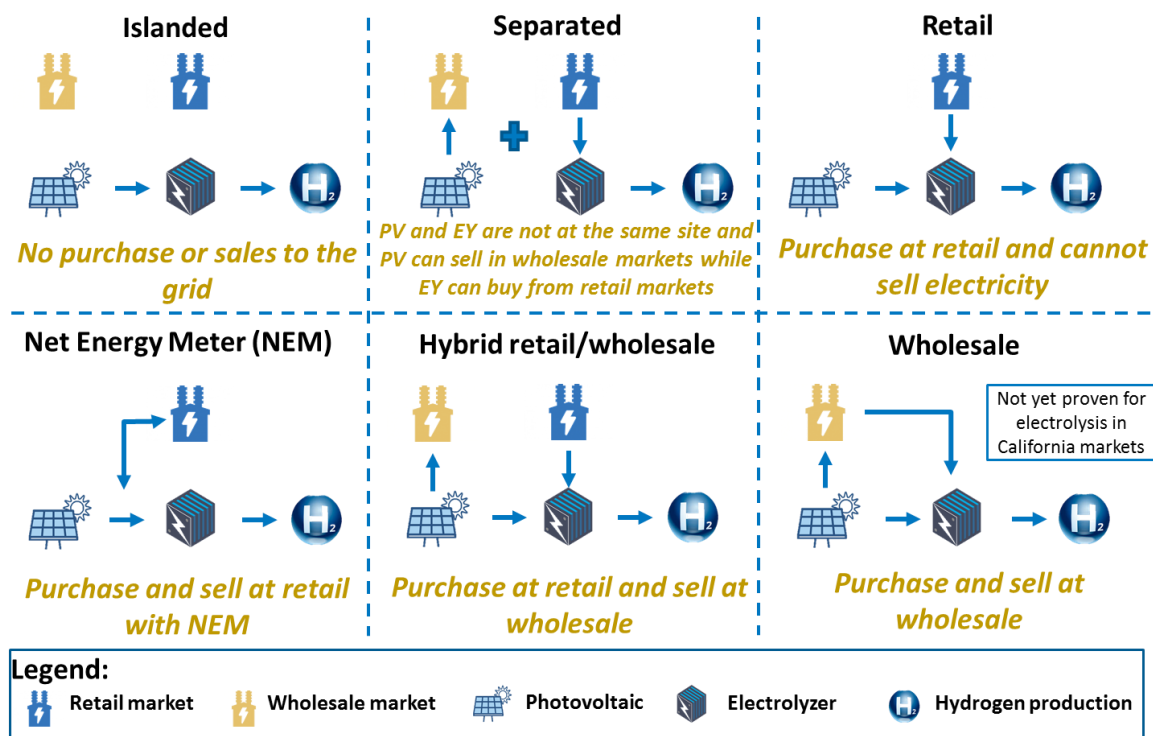
- Validation of Coriolis **flow meter accuracy** using NREL benchmarking test apparatus
- Development of non-Nafion **membranes** with high proton conductivity and mechanical strength for **electrochemical compression** of hydrogen
- Detailed modeling to characterize hazardous **hydrogen release scenarios** in repair garages and inform code requirements



CRADA Project Outcomes (cont.)

- Analysis of electric system benefits (in WI) of long duration storage in a 85% renewable scenario; power systems can benefit from long duration storage (e.g., up to one month of storage); Systems can be cost competitive at storage durations as short as one day.

- Analysis of solar-electrolysis system market configurations indicating wholesale and hybrid/wholesale configurations are the most promising



CRADA Project Outcomes (cont.)

- TEA of existing and advanced nuclear reactor integration showing potential to produce hydrogen for **less than \$2/kg** with energy provided by existing LWRs and improvements in **SOEC durability, manufacturing, and buildup of the supply chain**
- Validated prototype electrolytic cell performance (quantity and quality of hydrogen produced) for design of a **hydrogen production** system powered by **from offshore wind energy**; operated electrolyzer fully-submerged in seawater



Series connection
of electrolytic cells
– biopolar stack
configuration

*Images provided by
GTA*