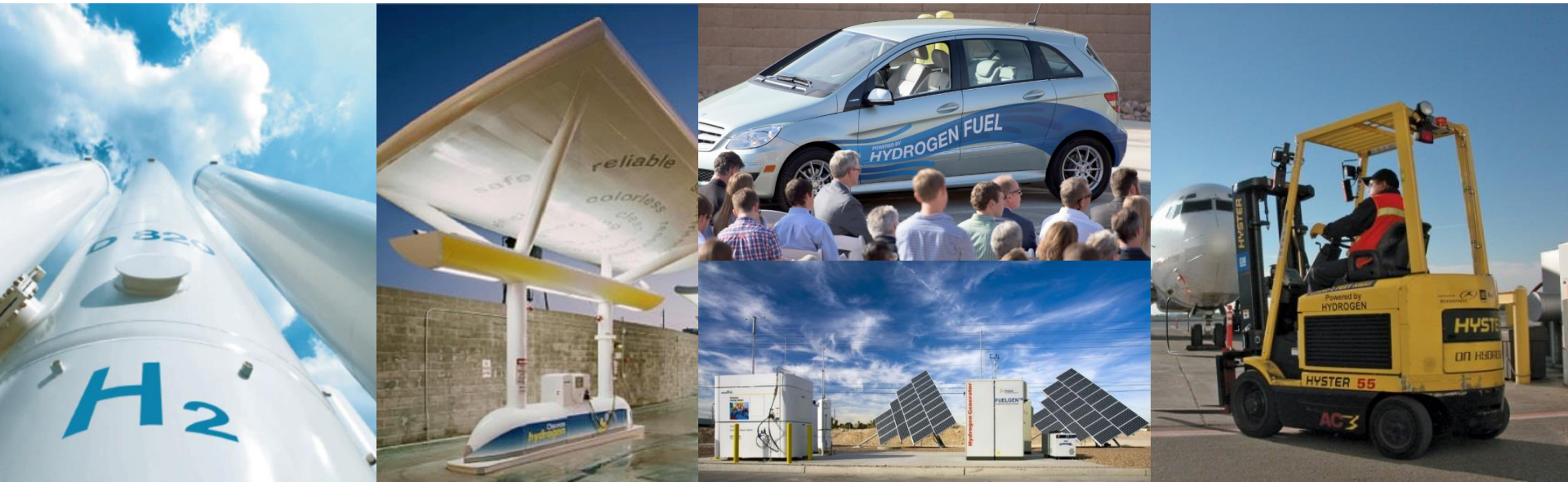


DOE Hydrogen and Fuel Cells Program: H2@Scale Activities

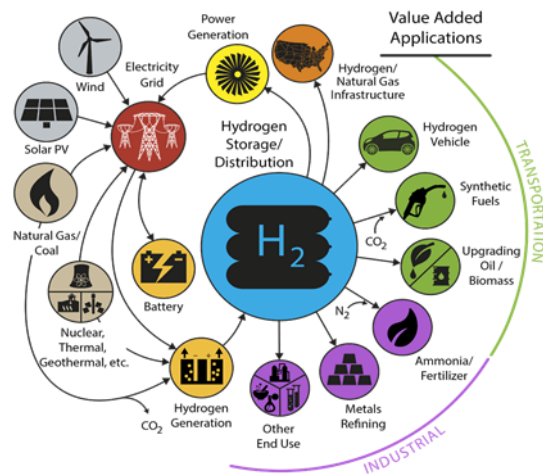
Dr. Sunita Satyapal, Director - Fuel Cell Technologies Office

2018 National Fuel Cell & Hydrogen Forum

Washington, DC – June 12, 2018



H2@Scale



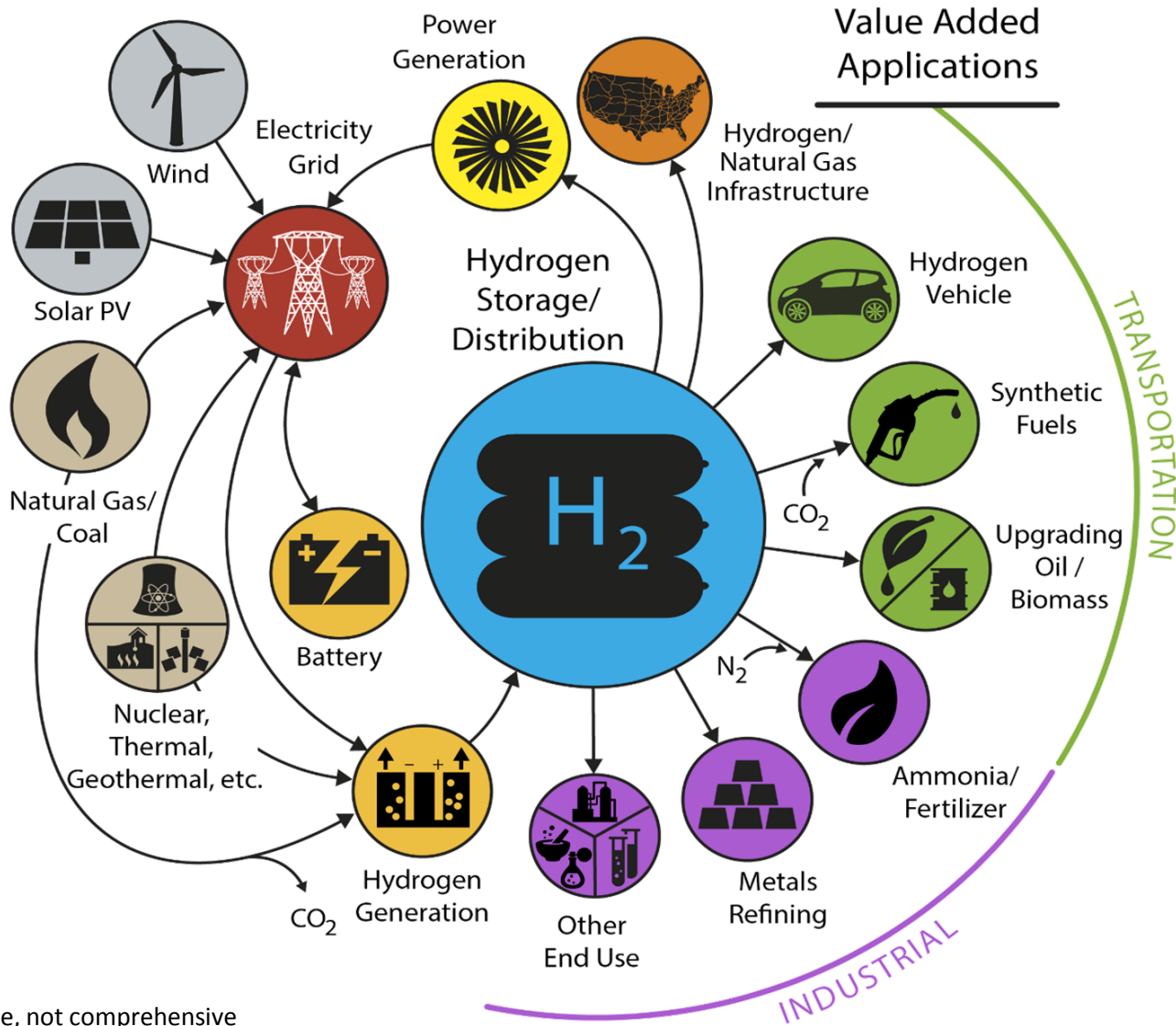
**H2@Scale: Enable
affordable, reliable,
clean and secure
energy across sectors**

Versatility

Volume

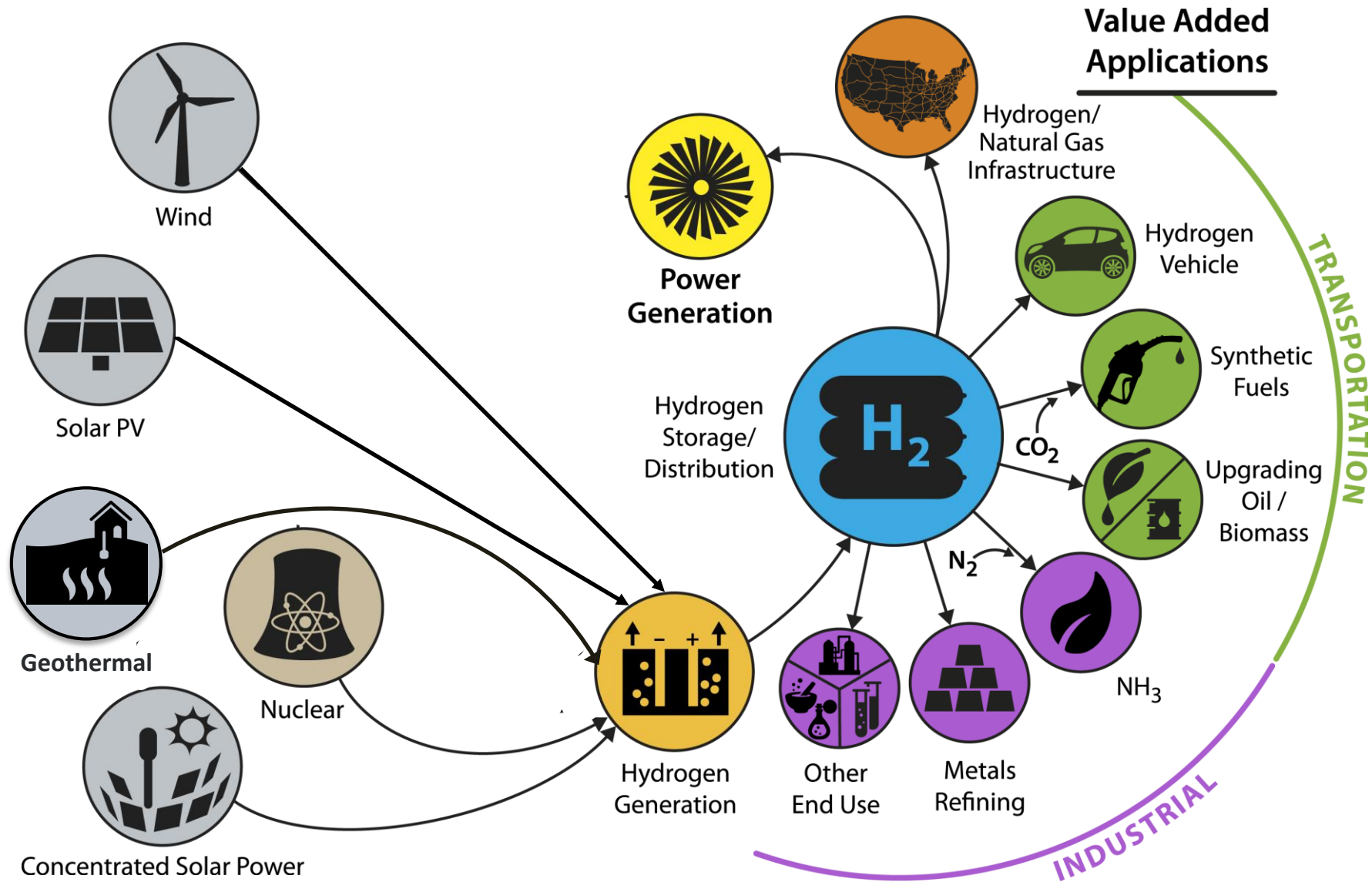
Value Proposition

H2@Scale Energy System



*Illustrative example, not comprehensive
Source: NREL

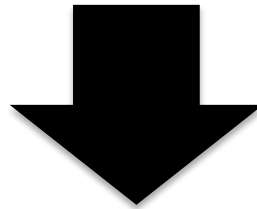
H2@Scale Energy System





Scale: Simple Example

How much hydrogen for 1 car?

$$\frac{12,000 \text{ miles per year}}{60 \text{ miles per kilogram}} = 200 \text{ kg per year} \text{ or } 0.2 \text{ tonnes per year}$$

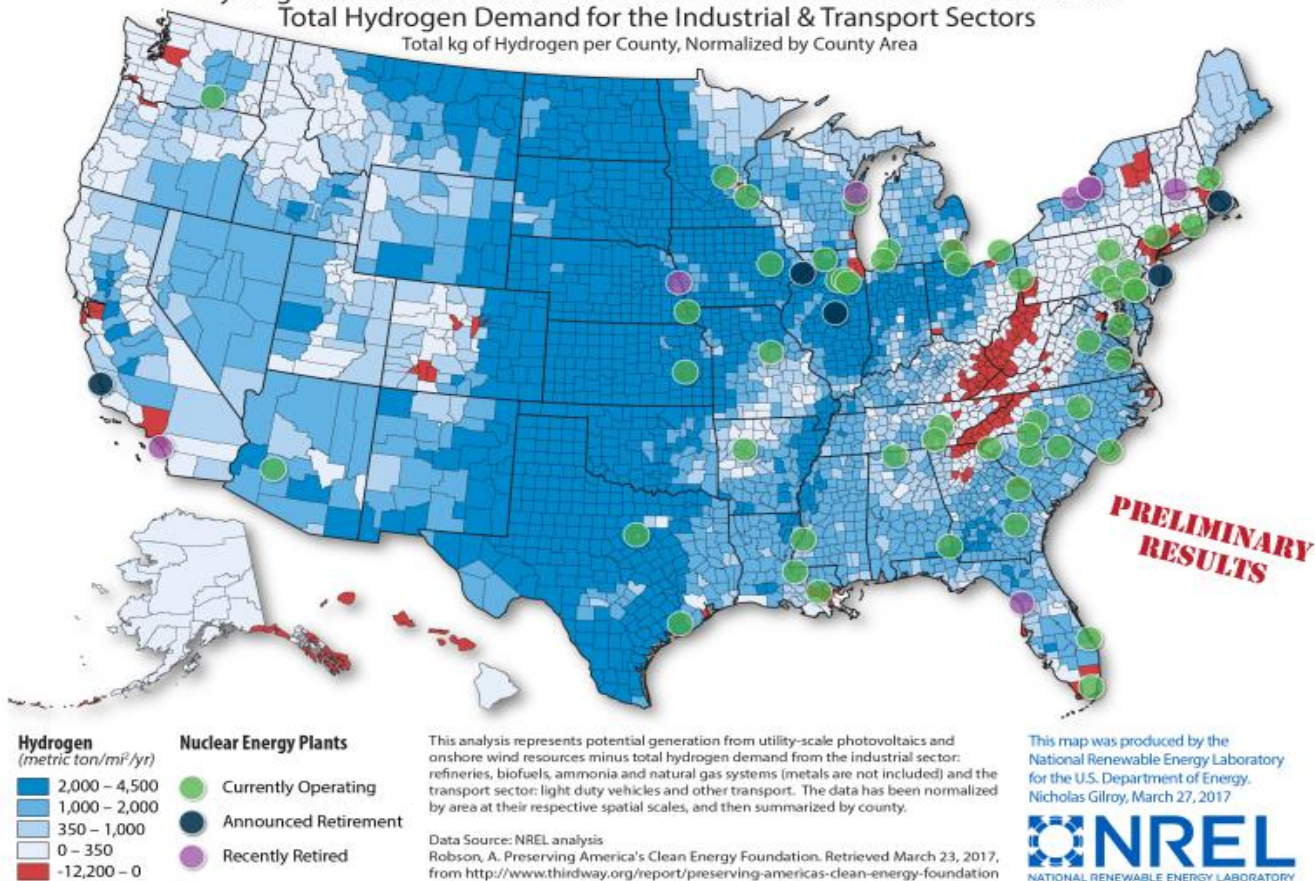


How much hydrogen for many cars?

100 M cars   = 10M cars	20M tons H ₂ per year 20 B kg H ₂ per year
--	---

H2@Scale: Nationwide Resource Assessment

Hydrogen Potential From Photovoltaic and Onshore Wind Resources Minus
Total Hydrogen Demand for the Industrial & Transport Sectors
Total kg of Hydrogen per County, Normalized by County Area



Labs assess resource availability. Most regions have sufficient resources.

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

Lab PIs: Mark Ruth, Bryan Pivovar, Richard Boardman, et al

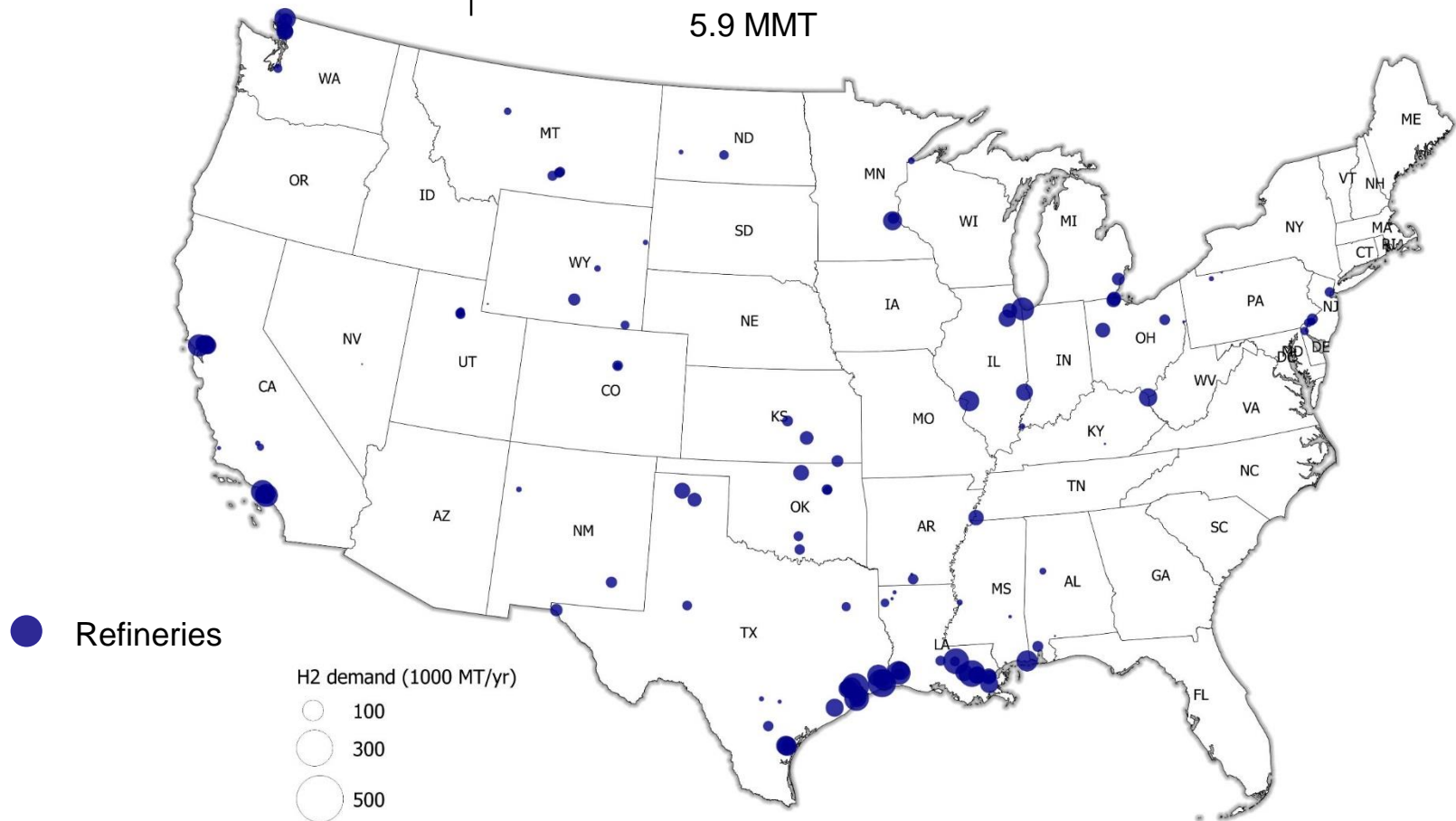
Refineries: Where is the H₂ demand today?

2017

H₂ Demand



5.9 MMT

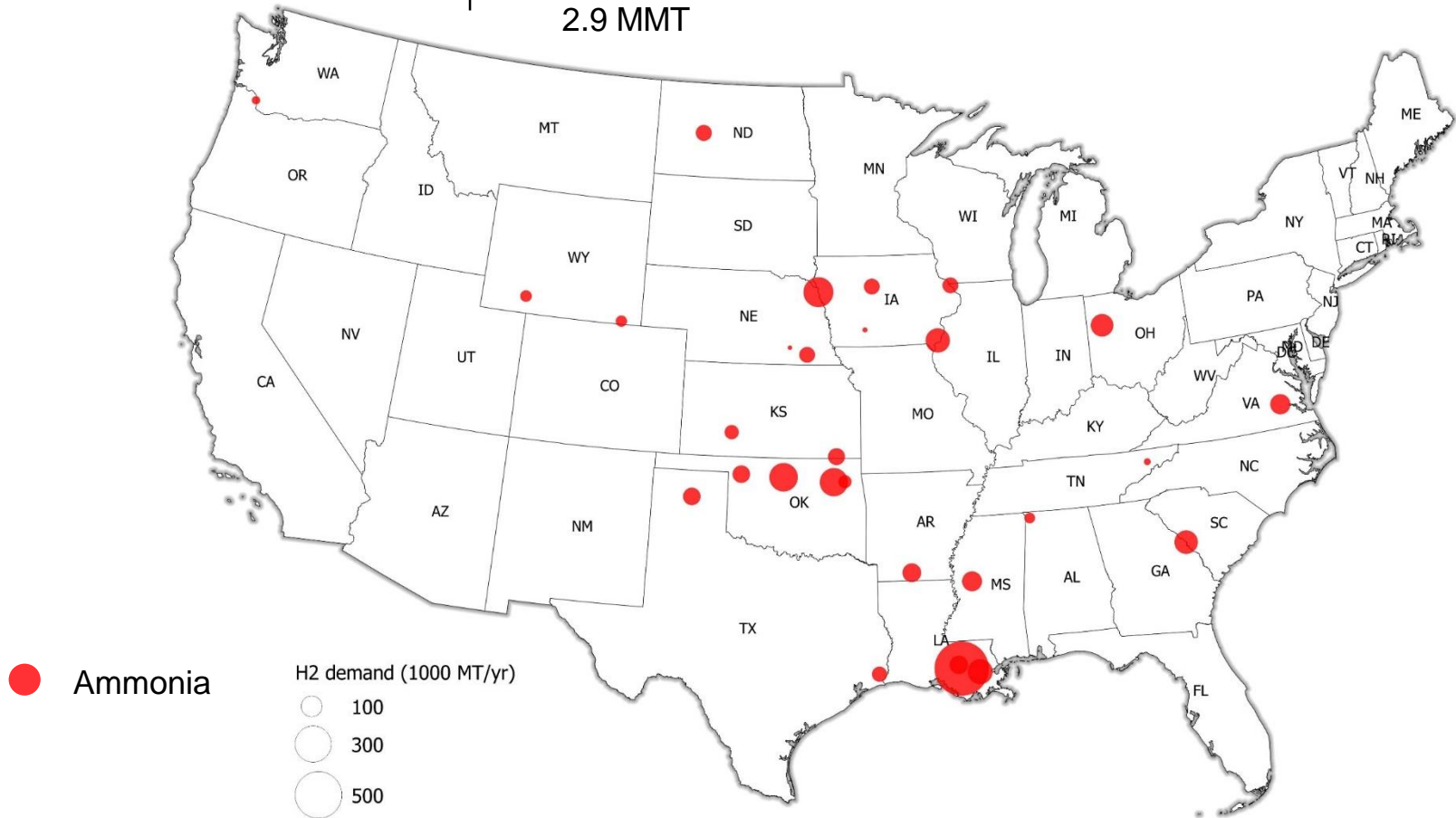


Source: Elgowainy, et al, ANL

Ammonia: Where is the H₂ demand today?

2017

H₂ Demand
2.9 MMT



Source: Elgowainy, et al, ANL

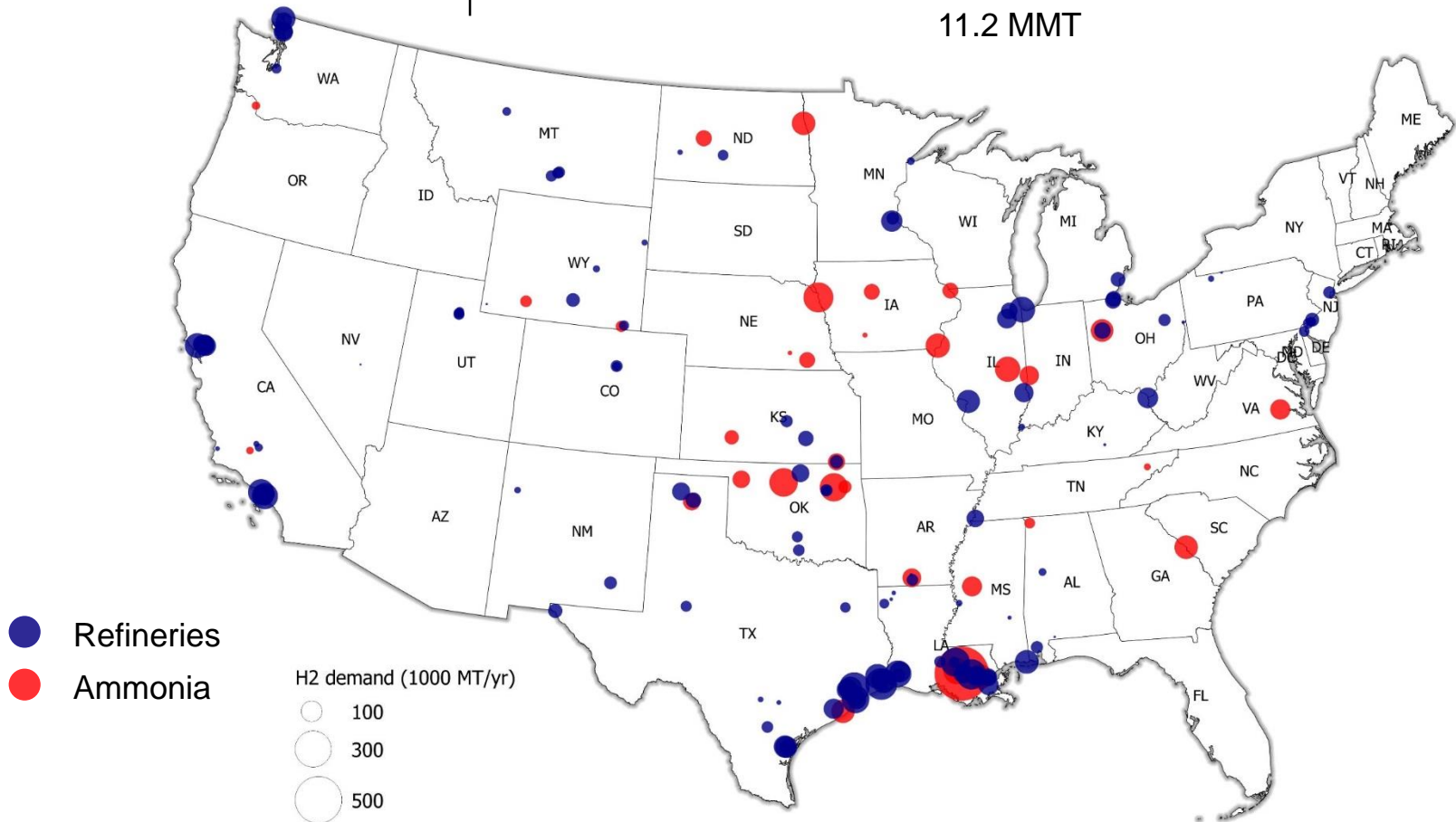
Ammonia & Refineries: Potential H₂ Demand

2030

H₂ Demand



11.2 MMT



Source: Elgowainy, et al, ANL

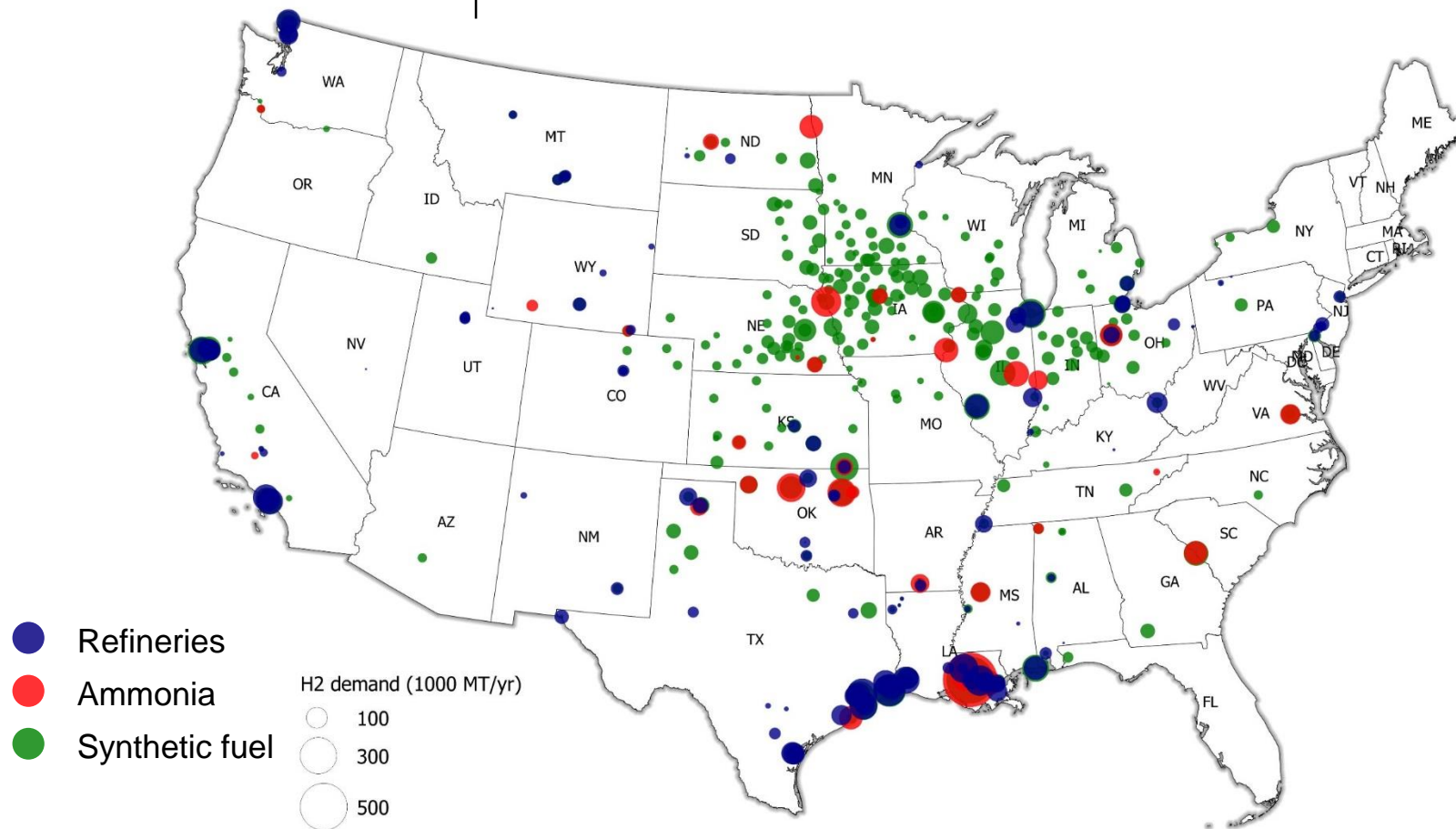
Plus demand from synthetic fuel production...

2030

H₂ Demand



25.2 MMT



Source: Elgowainy, et al, ANL

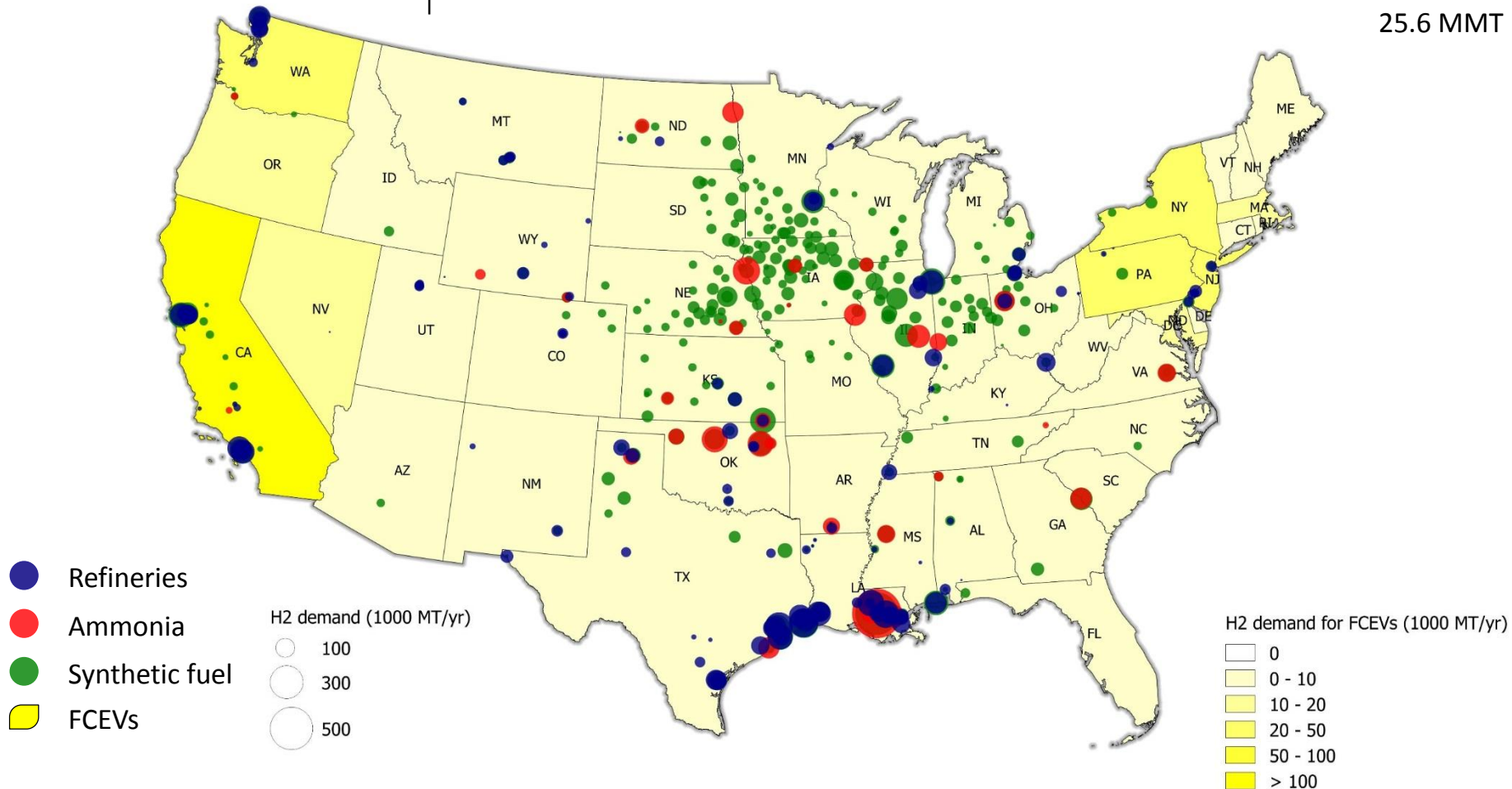
Hydrogen Demand Potential

2030

H₂ Demand



25.6 MMT



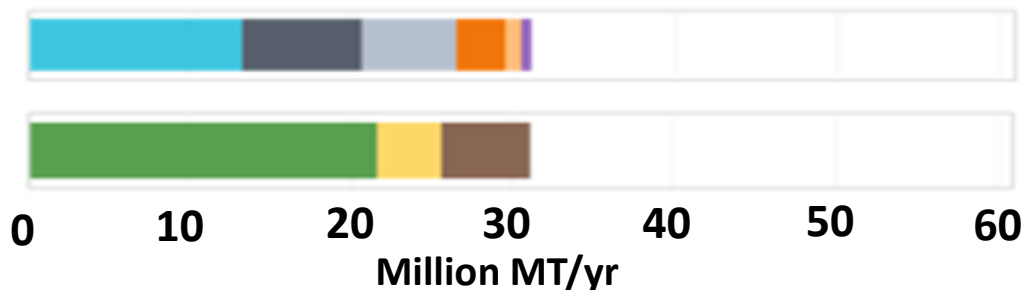
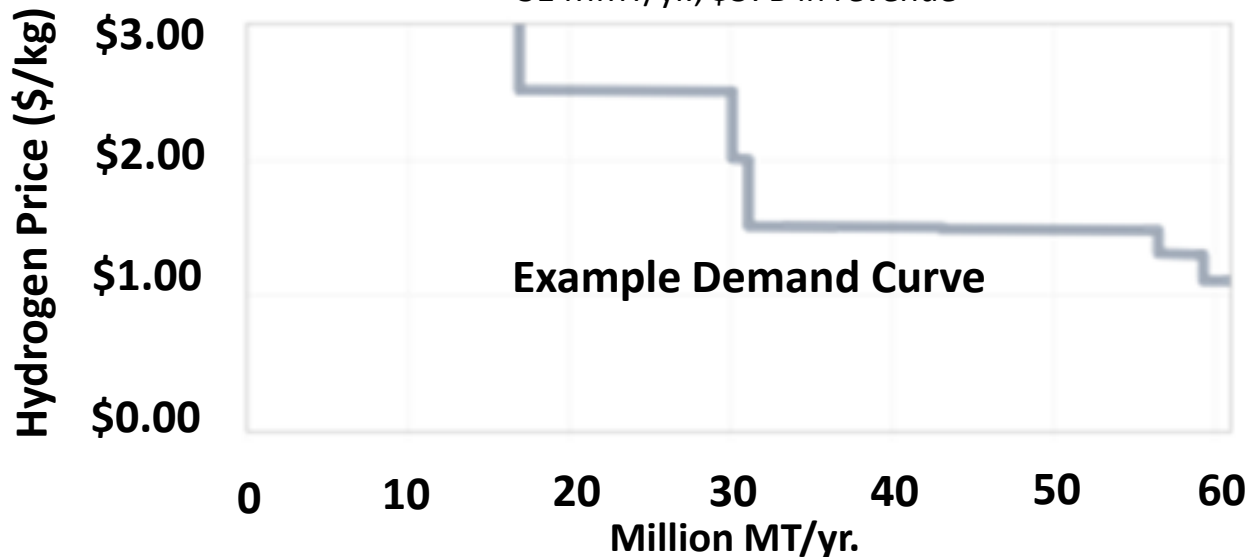
Source: Elgowainy, et al, ANL

H2@Scale scenarios, supply and demand curves

Technological advances in H2@scale can enable increased hydrogen demand and revenue

H2@Scale Success Example



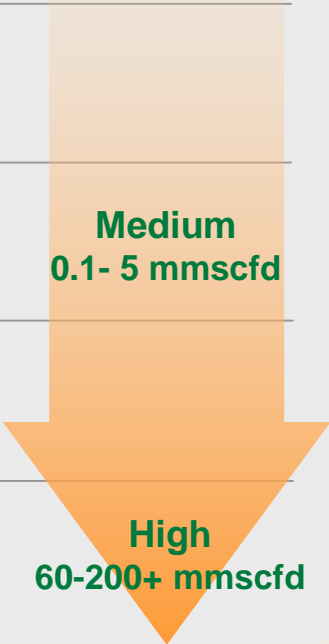
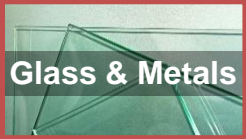


31 MMT/yr., \$57B in revenue



- Light Duty Vehicles
- Refineries
- Metals
- Ammonia
- Methanol
- Non Light-Duty Vehicles
- Electrolytic
- Nuclear
- Steam Methane Reforming

Source: NREL

Hydrogen for different scales and applications

<u>Industry</u>	<u>Key Applications</u>	<u>Supply Systems</u>	<u>Volume</u>	
 <p>Small Scale</p>	<ul style="list-style-type: none"> ■ Laboratories ■ Fuel Cell Applications 	<ul style="list-style-type: none"> ■ Small on-site ■ Cylinders ■ Tube trailers ■ Liquid H₂ 	<p>Low < 0.1 mmscfd</p>	
 <p>Electronics</p>	<ul style="list-style-type: none"> ■ Thin-film solar ■ Semi-Conductors ■ Materials Processing 	<ul style="list-style-type: none"> ■ Tube trailer ■ Liquid H₂ ■ Small On-Site Plant 		
 <p>Glass & Metals</p>	<ul style="list-style-type: none"> ■ Float glass mfg ■ Steel Analing 	<ul style="list-style-type: none"> ■ Liquid H₂ ■ On-Site Plant 		<p>Medium 0.1- 5 mmscfd</p>
 <p>Chemicals</p>	<ul style="list-style-type: none"> ■ Chemicals ■ Food ■ Biofuels 	<ul style="list-style-type: none"> ■ Liquid H₂ ■ On-Site Plant ■ Pipeline 		
 <p>Refining, Ammonia</p>	<ul style="list-style-type: none"> ■ Hydro-processing ■ De-sulfurization ■ Haber-Bosch 	<ul style="list-style-type: none"> ■ Pipeline ■ On-Site Plant 		<p>High 60-200+ mmscfd</p>

Early stage R&D needs include cost reduction for materials, compressors, storage, transportation, etc.

Strategy: Partnerships to enable H2@Scale

Early- Stage R&D

Department of Energy

- Fuel Cells R&D
- H₂ Fuel R&D

Other Federal Agencies



Demonstration, Deployment & Commercialization

Private Sector Industry, Other Agencies, States Partnerships

FCHEA (H2USA), CaFCP, OFCC, CT, HI, CO, NJ, etc.



H2@Scale Consortium

H2@Scale Stakeholder Feedback – Examples

Hundreds of stakeholders engaged
6 DOE Offices engaged
(EERE, FE, NE, OE, SC, ARPA-E)

Planned:
2018 Kickoff
Chicago, IL

2016 Session at
Intermountain Energy
Summit

Idaho Falls, ID

2017 Session at
Fuel Cell Seminar
Long Beach, CA

Examples of additional
presentations:

- Utah (2017)
- Michigan (2017)
- Minnesota (2017)
- Germany (2017, 2018)
- Japan (2018)

2017 Session at
FCTO's Annual
Merit Review
Washington, D.C.

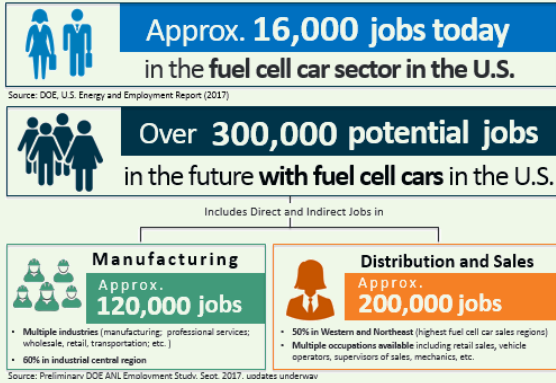
Planned: 2018
AMR
Washington, D.C.

2017 Workshop
Houston, TX

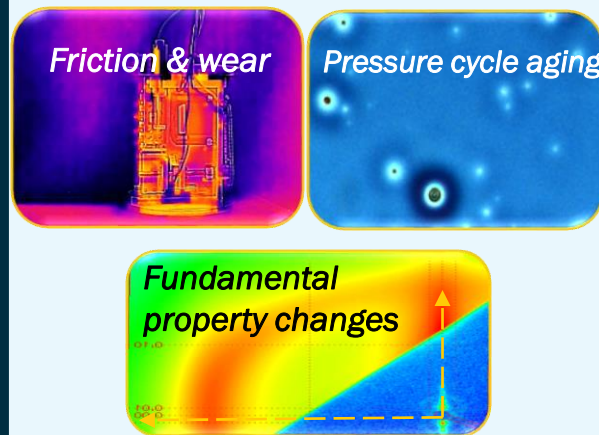
2016 Workshop
Golden, CO

H2@Scale R&D Lab Capabilities— Examples

Techno economic Modeling and Analysis



Hydrogen Materials R&D



Grid simulation and Testing R&D



Safety and Infrastructure R&D



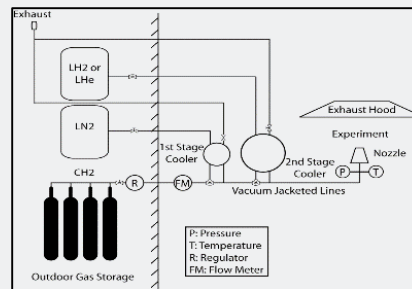
Hydrogen_Delivery_Scenario_Analysis

Refueling Station - Gaseous H2

Update Station Parameters

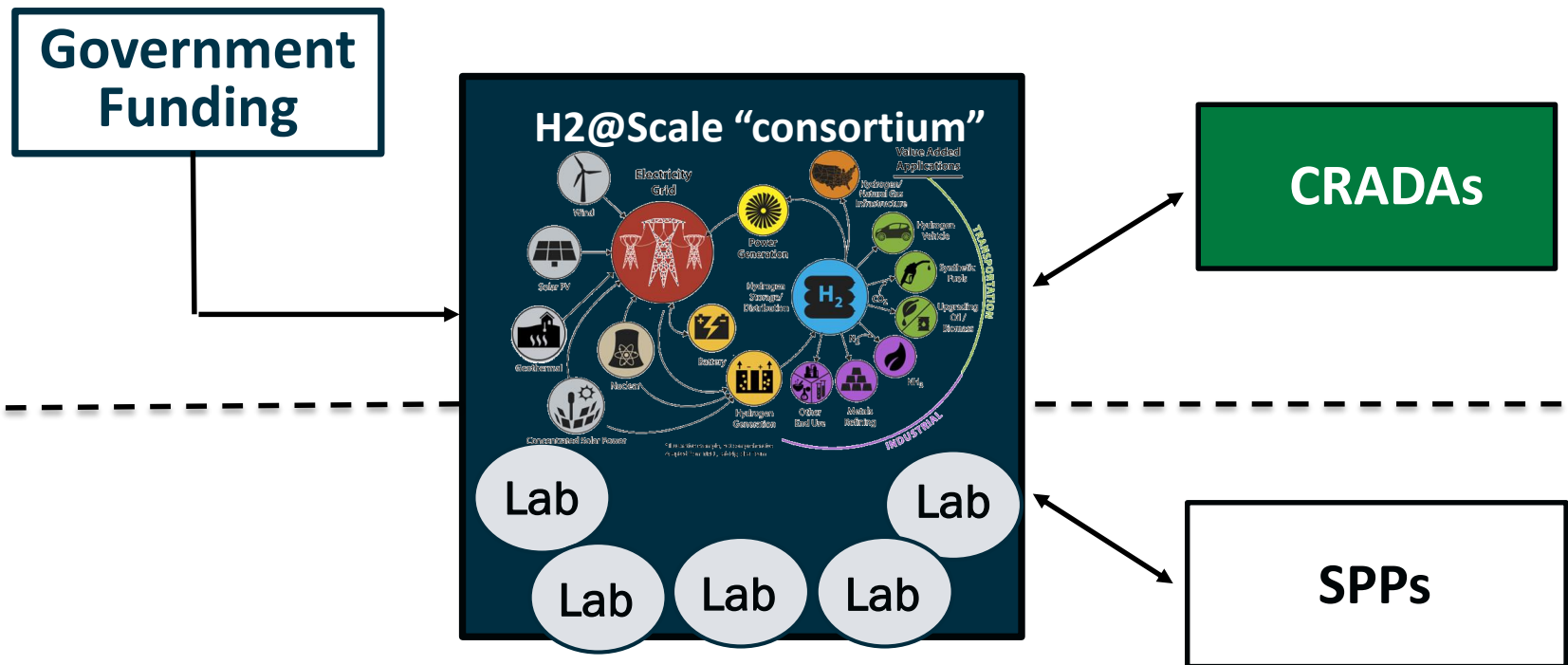
Calculation Outputs (Be sure ALL data is entered before checking)

	Compressor (\$/2116)	Storage (\$/2116)	Dispenser (\$/2116)	Refrigerant
Gaseous Refueling Station (Number of the New Liquefied Delivered Hydrogen Cost (\$/2116kg of Hydrogen))	\$2.44	\$0.69	\$0.52	\$



H2@Scale – Lab CRADAs

- Leverages Lab capabilities and expertise to address challenges- materials R&D, analysis, safety R&D, etc.
- Round 1 in 2017.



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

H2@Scale 2017 CRADA call selections

HYDROGEN QUANTITATIVE PERFORMANCE ANALYSIS AND OPERATION R&D

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



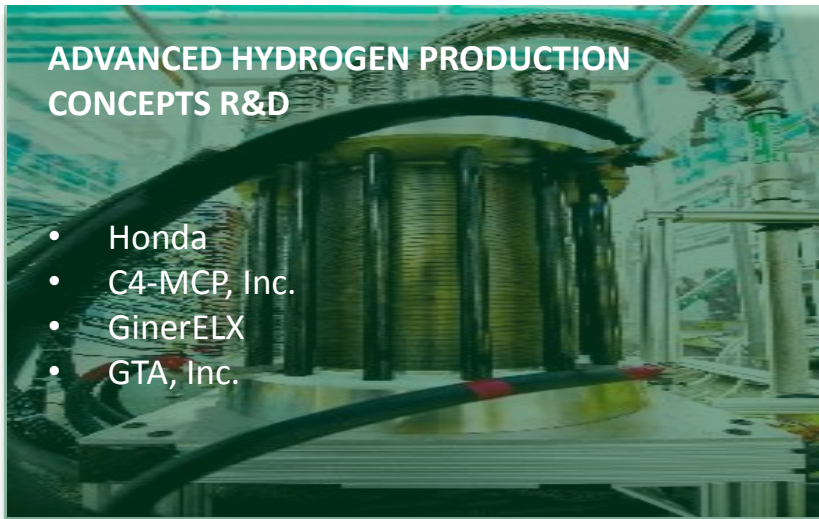
HYDROGEN DISTRIBUTION COMPONENT DEVELOPMENT R&D

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



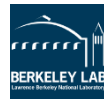
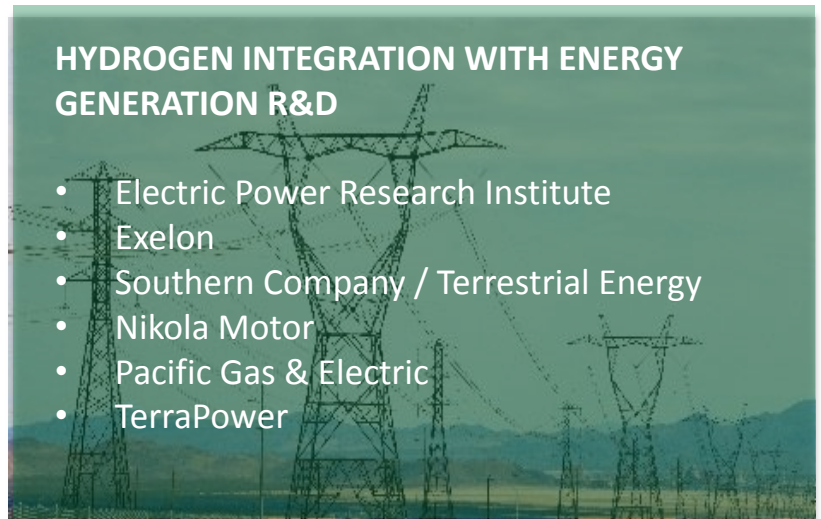
ADVANCED HYDROGEN PRODUCTION CONCEPTS R&D

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

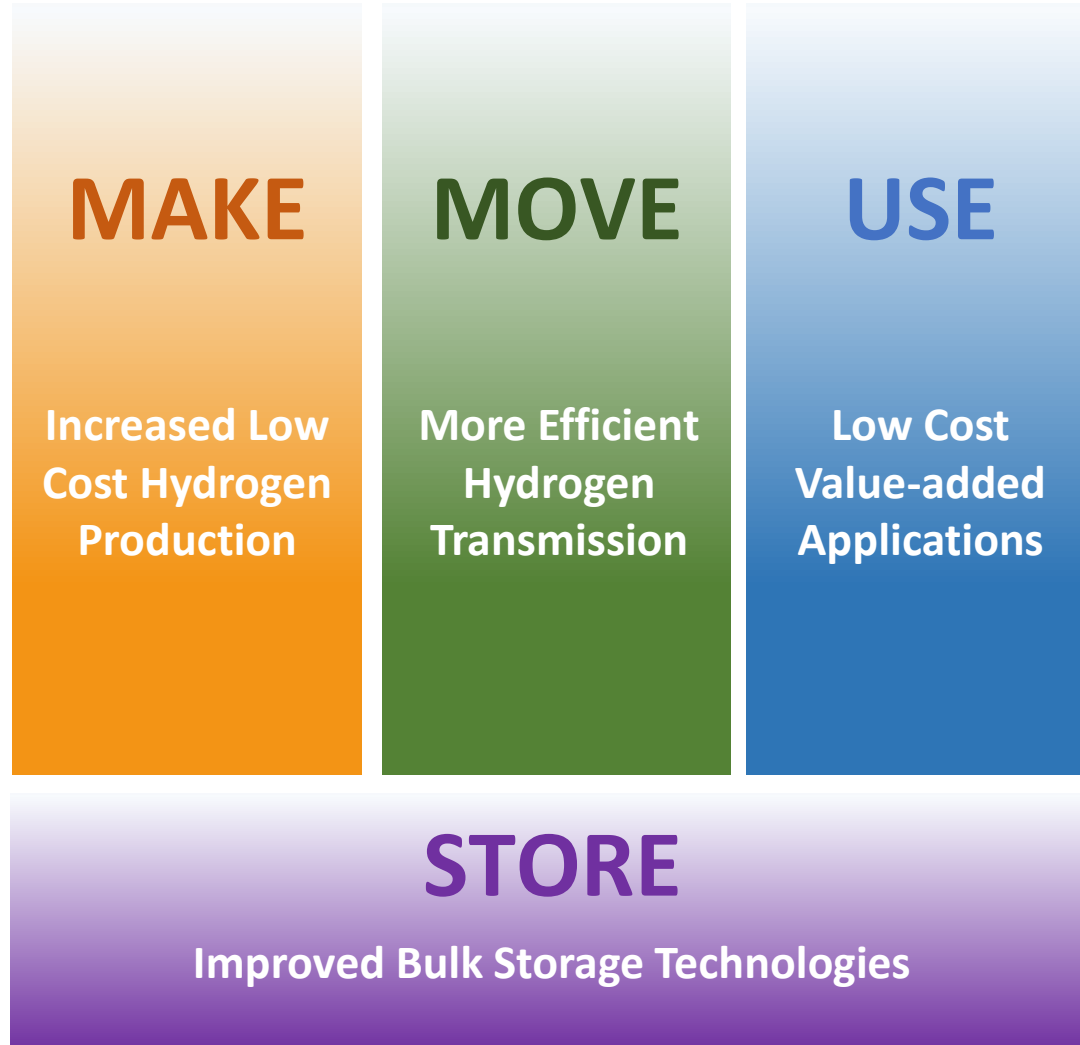


HYDROGEN INTEGRATION WITH ENERGY GENERATION R&D

- Electric Power Research Institute
- Exelon
- Southern Company / Terrestrial Energy
- Nikola Motor
- Pacific Gas & Electric
- TerraPower



H2@Scale Focus: Make, Move, Use and Store Energy



August 1
H2@Scale Kickoff
Meeting Planned
Chicago

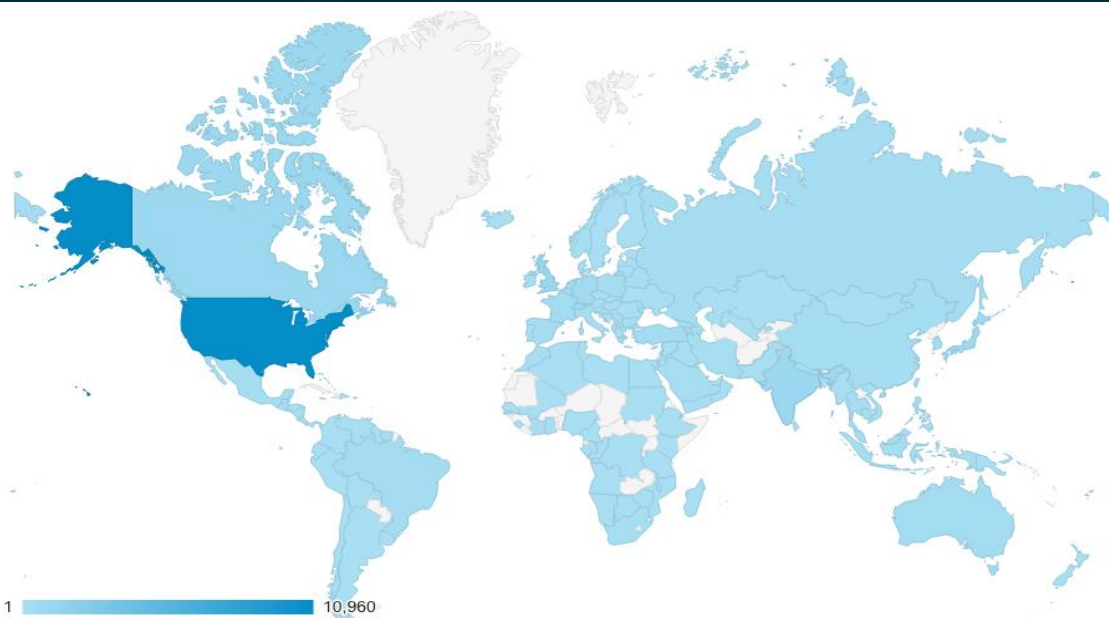
Information Sharing is Critical

Collaboration Tools: H2 Safety Information Sharing

H₂Tools.org : A one stop resource for hydrogen safety



h2tools.org

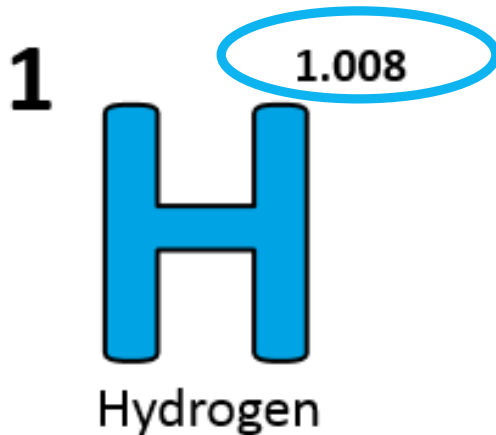


- Site visit tracking shows a **global reach: 50% of visits have been international after launch**
- Over **250,000 site visits**
- Training resource **translated into Japanese. Interest in other languages.**

Collaboration Tools: Increasing Awareness

Celebrate National Hydrogen & Fuel Cell Day October 8 or 10/8

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



DOE Slides and Resources Available for Download

INCREASE YOUR
H₂IQ

Download for free at:

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

Learn more at: energy.gov/eere/fuelcells

U.S. DEPARTMENT OF
ENERGY

June 13-15, 2018
Washington, DC



U.S. Department of Energy Hydrogen and Fuel Cells Program 2018 Annual Merit Review and Peer Evaluation Meeting

Hydrogen and fuel cell projects funded by DOE are presented and reviewed for their merit.

Register at: www.annualmeritreview.energy.gov

First time ever

All Agencies working on hydrogen and fuel cell technologies at AMR

Thank you

Dr. Sunita Satyapal

Director

Fuel Cell Technologies Office

Sunita.Satyapal@ee.doe.gov

energy.gov/eere/fuelcells