U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

# H2@Scale Overview

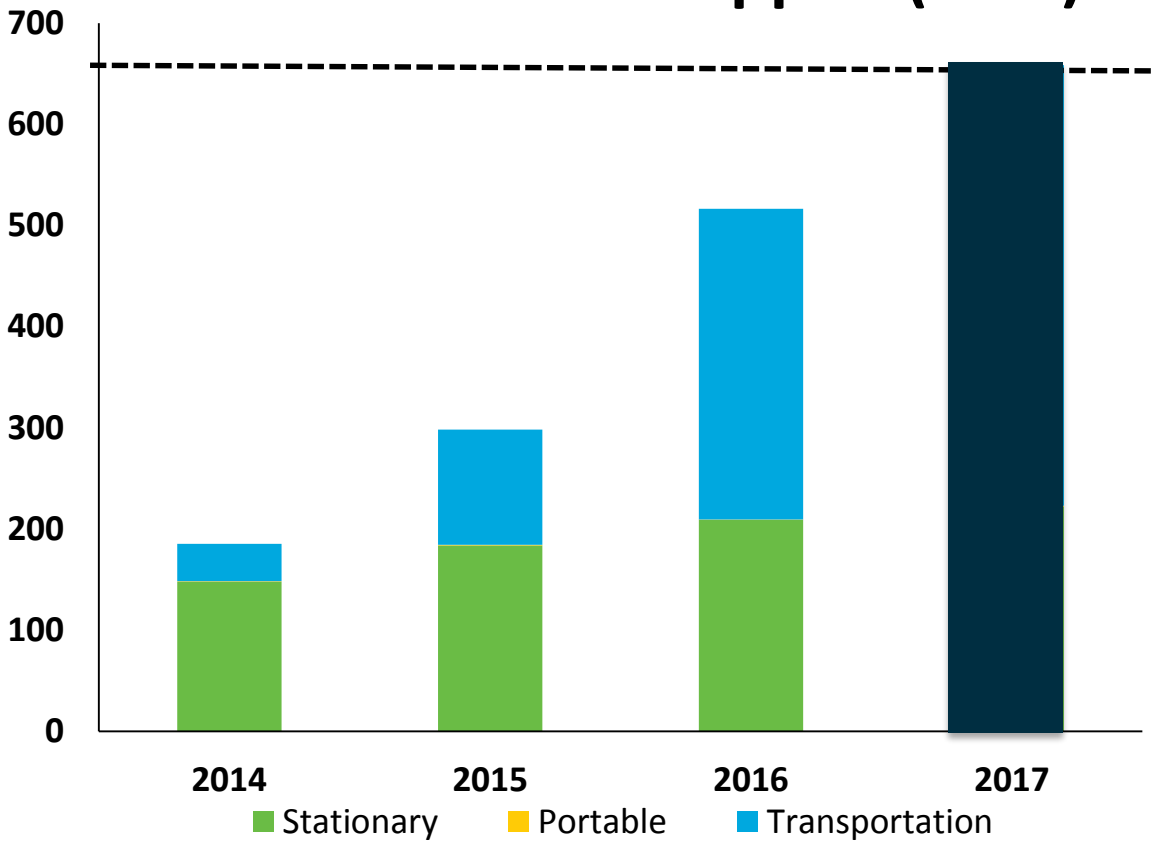

## Dr. Sunita Satyapal, Director - Fuel Cell Technologies Office


H2@Scale R&D Consortium Kickoff Meeting

Chicago, IL – August 1, 2018


# 1. Progress

# Upward trend with global fuel cell shipments




**650 MW**
**fuel cell power**
shipped worldwide

**70,000**
**fuel cell units**
shipped worldwide

Approximately
**$2 Billion**
**fuel cell revenue**

Source: DOE and E4Tech

**Electrolyzers: Over 100MW/year** estimated global sales

*Courtesy of NOW, E4tech and partners: A collaborative effort to assess electrolyzer market potential

# An exciting time for the transportation sector

*Honda Clarity*

Nearly **5,000** | **sold or leased** in the United States

As of Dec 2017


*Hyundai Tucson Fuel Cell SUV*

## Commercial **fuel cell electric cars are here**


*Toyota Mirai*

- No petroleum, no pollution
- Refuels in minutes
- More than 360 mi driving range
- Over 60 mpgge

# Interest in material handling equipment applications


More than **20,000 forklifts**

Over **12 million refuelings**

# Long-Range, Heavy Duty Applications Emerging


Fuel cell delivery and parcel trucks starting deliveries in CA and NY


Fuel cell buses in CA surpass 19M passengers


Industry demonstrates first heavy duty fuel cell truck in CA

# New Applications Emerging- Examples

## China


### Eight Fuel Cell Trams

Capacity: 285 passengers
Maximum speed: 70 km/hr.

## Germany

### Trains to operate in Germany in 2018

Capacity: 300 passengers
Maximum speed: 140 km/hr.

# Stationary Power Applications Expanding

**Fuel cells provided backup power during Hurricane Sandy in the U.S. Northeast**

**Fuel cells used to power new World Trade Center in NYC**

**Fuel cell power for maritime ports demonstrated in Honolulu, Hawaii**


**Over 240 MW of fuel cell stationary power installed across more than 40 US states**


Photo Credit: Fukuoka Pref.

# Multiple $H_2$ and Fuel Cell Applications in the U.S.

## U.S. Snapshot

**>240MW**
Backup Power

**>20,000**
Forklifts

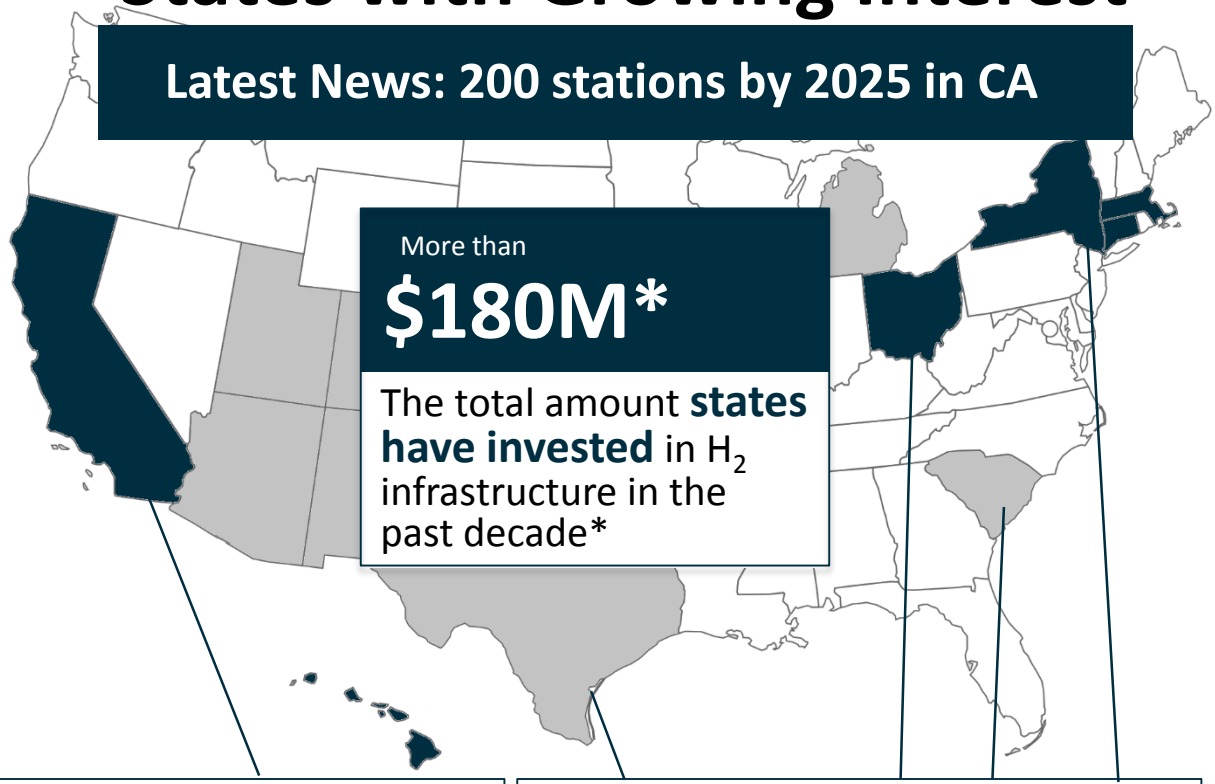
**>30**
Fuel Cell Buses

**35**
$H_2$ retail stations

Nearly
**5,000**
fuel cell cars

## States with Growing Interest

**Latest News: 200 stations by 2025 in CA**



More than
**$180M***
The total amount **states have invested** in $H_2$ infrastructure in the past decade*

**CA**
- 200 stations planned
- Over 30 public stations open
- $150M invested
- $235M announced in 2018

**HI, OH, SC, NY, CT, MA, CO, UT, TX, MI, and others with interest**
- Over $27M invested
- 12-25 stations planned in the NE

*Excludes recent announcement from CA to invest $235M in electric vehicles


# 2. $H_2$@Scale concept

# Vision

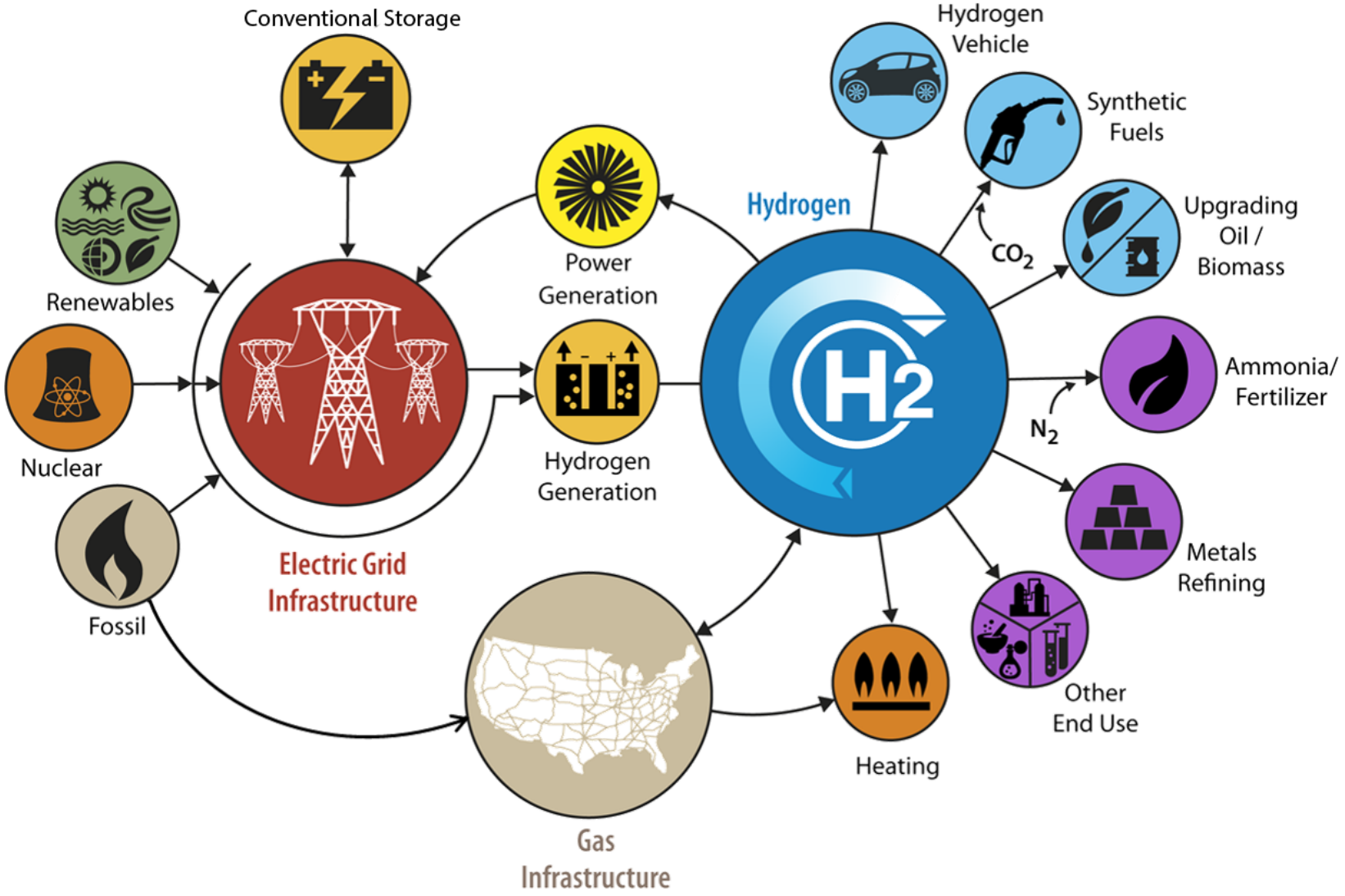
## H2@Scale: Enable affordable, reliable, clean and secure energy across sectors

# Versatility

# Volume

# Value Proposition

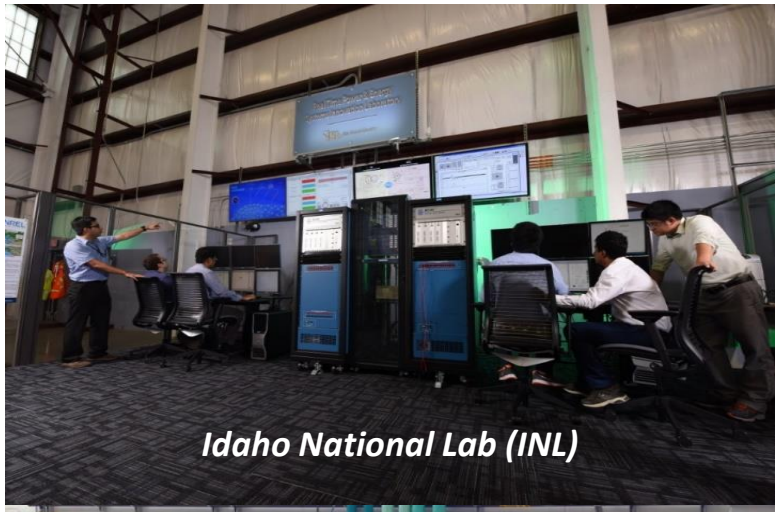
# $H_2$@scale: Enabling affordable, reliable, clean, and secure energy across sectors



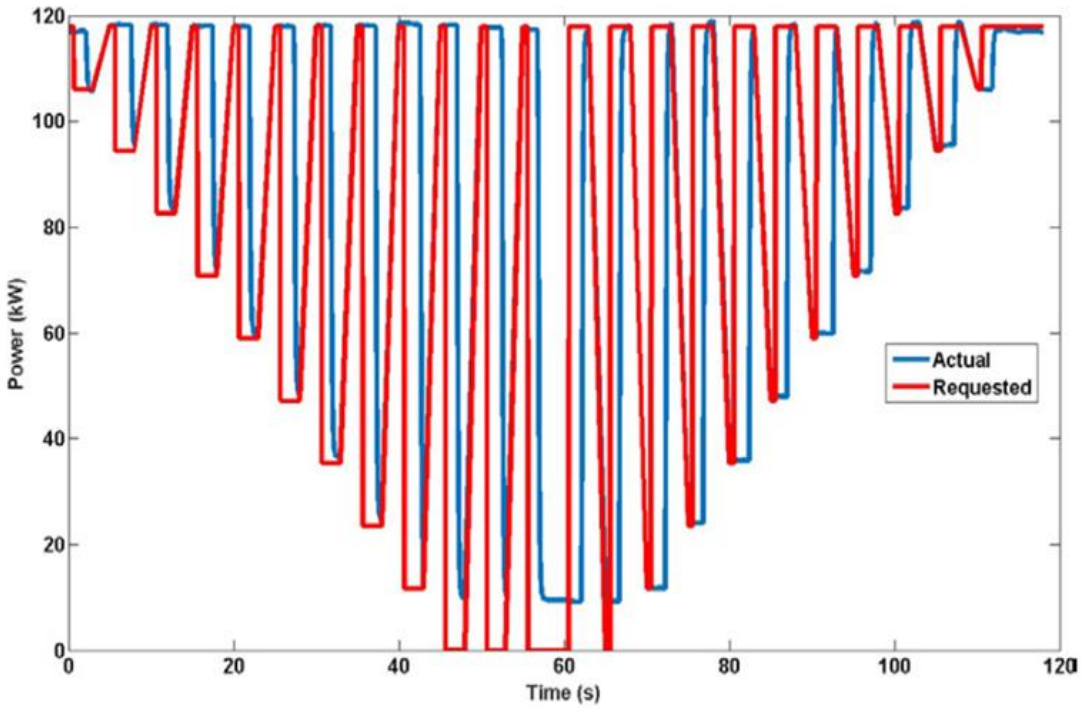

More information at: www.energy.gov/eere/fuelcells/h2-scale

# Lab testing electrolyzers' value for ancillary services

## First Ever Validation of Frequency Regulation with Electrolyzers

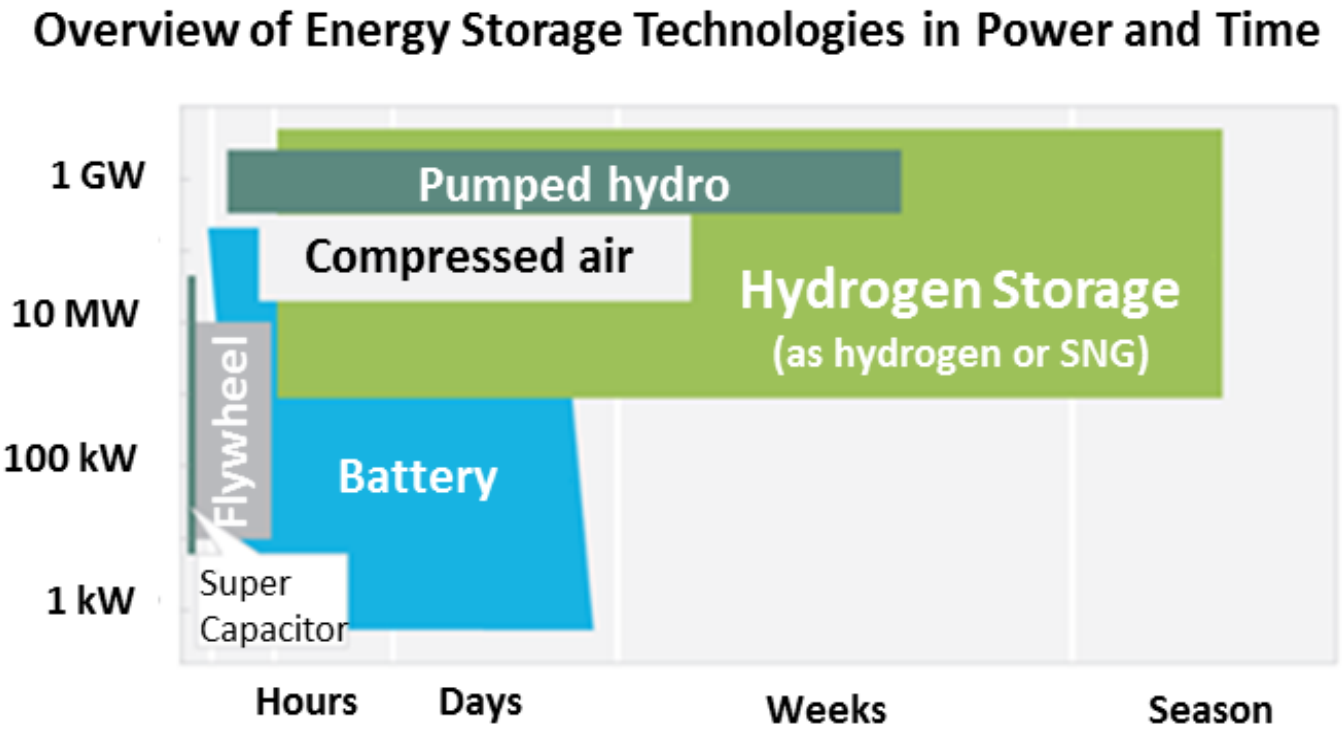

*Idaho National Lab (INL)*


*National Renewable Energy Lab (NREL)*




*Lab testing shows dynamic response within seconds and potential for grid services*

# Hydrogen Energy Storage is Scalable




**One hydrogen cavern** could provide **~ 100 GWh energy storage**

*Image: Hydrogen Council*

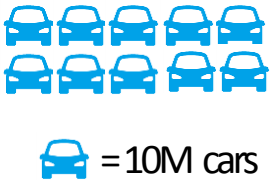
**Hydrogen can be used to monetize surplus electricity from the grid, or remote, off-grid energy feedstock (e.g. solar, wind) for days to months.**

# Scale: Simple Example

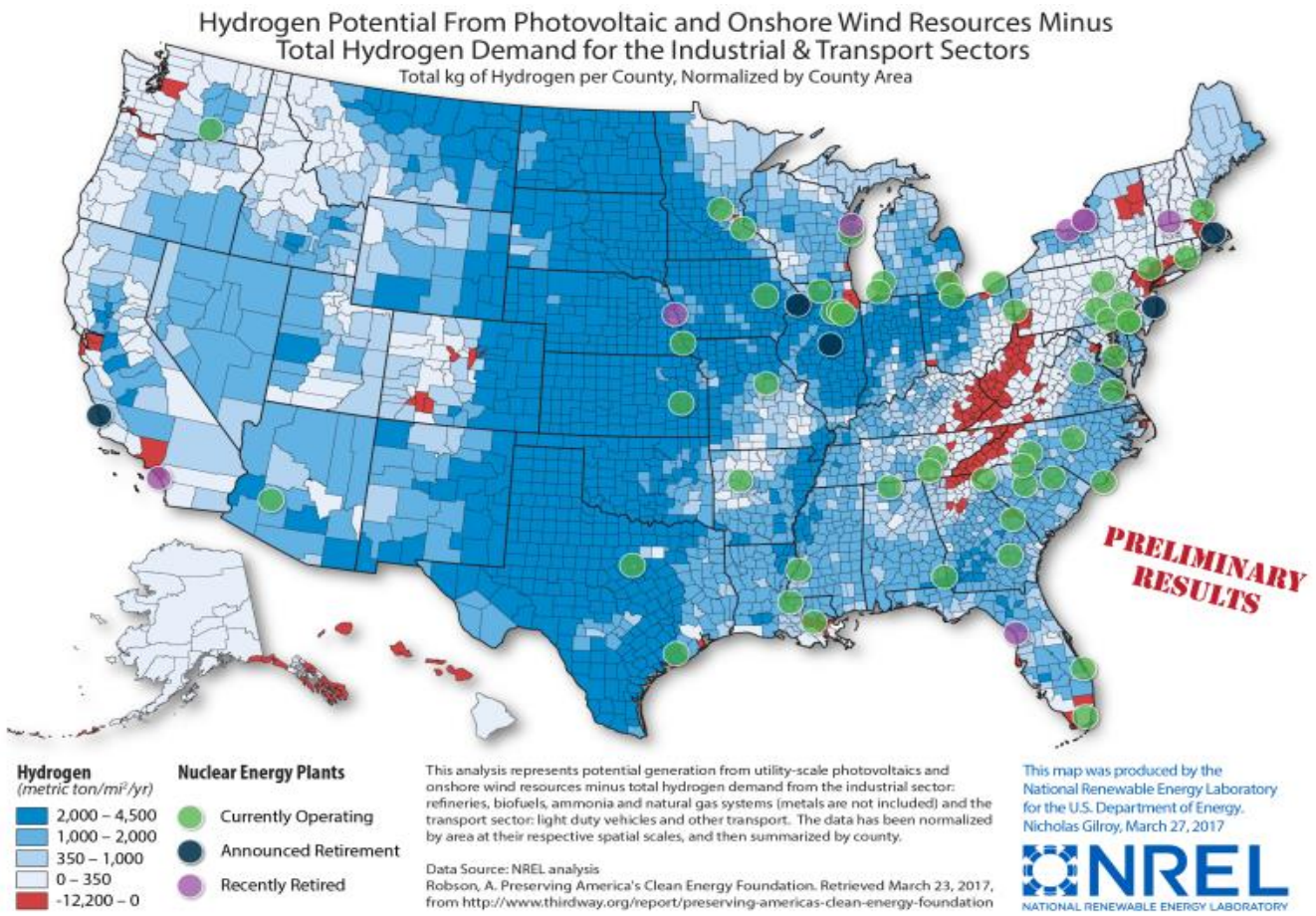
## How much hydrogen for 1 car?

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

## How much hydrogen for many cars?

| 100 M cars | 20M tons $H_2$ per year |
|---|---|
|  = 10M cars | **20 B kg** $H_2$ per year |

# H2@Scale: Nationwide Resource Assessment



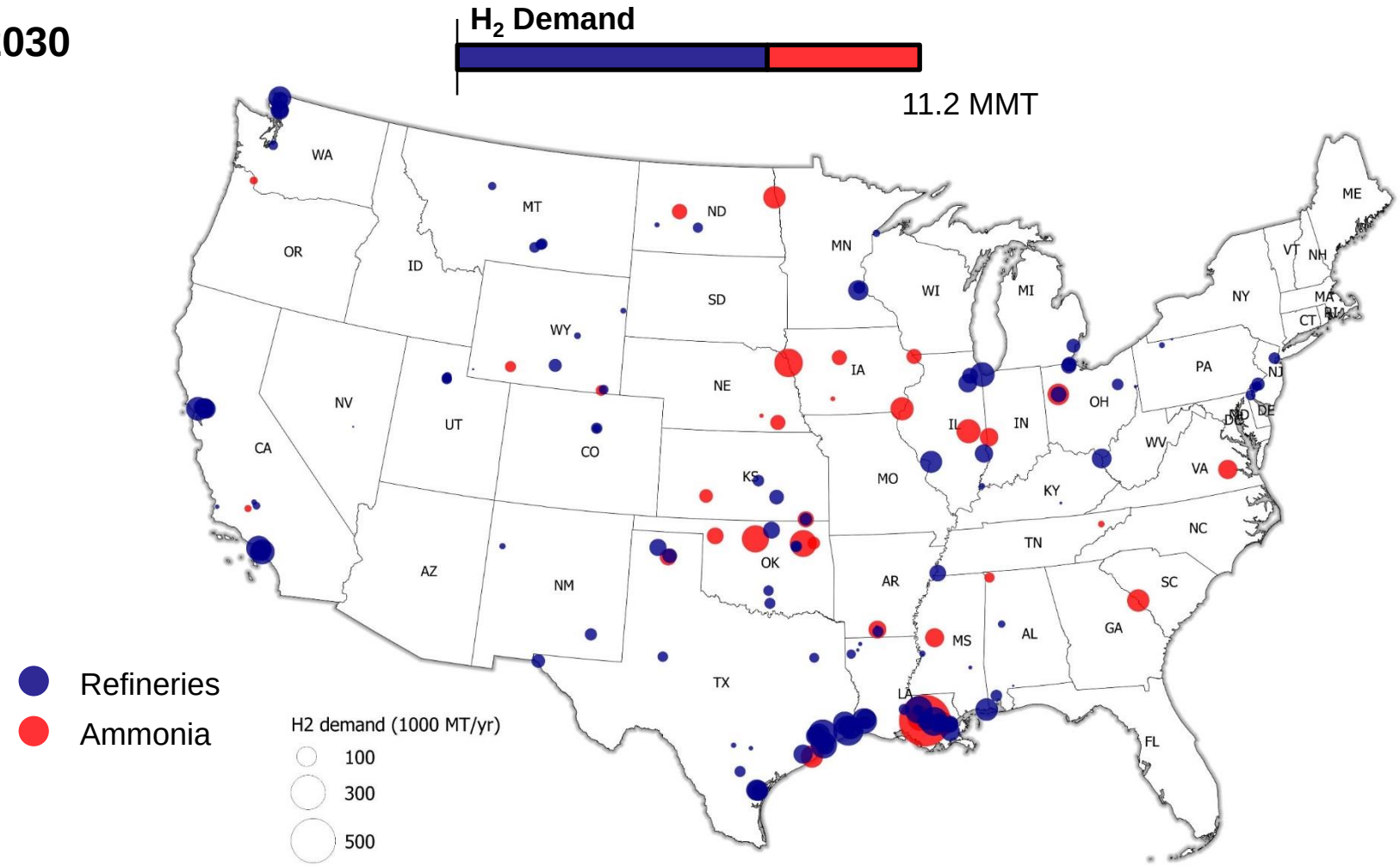

**Labs assess resource availability. Most regions have sufficient resources.**

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

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

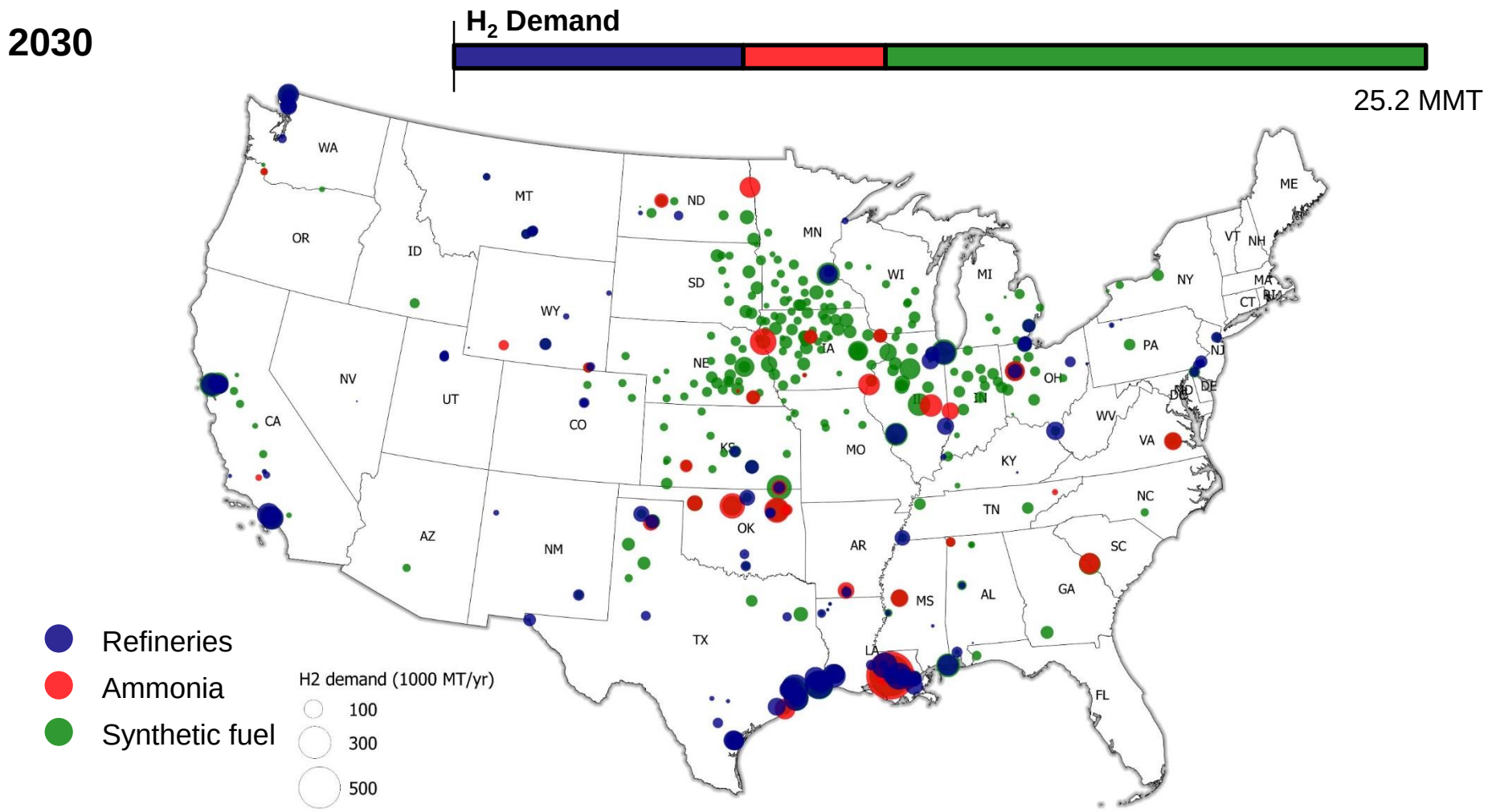
# Ammonia & Refineries - Potential $H_2$ Demand

**2030**



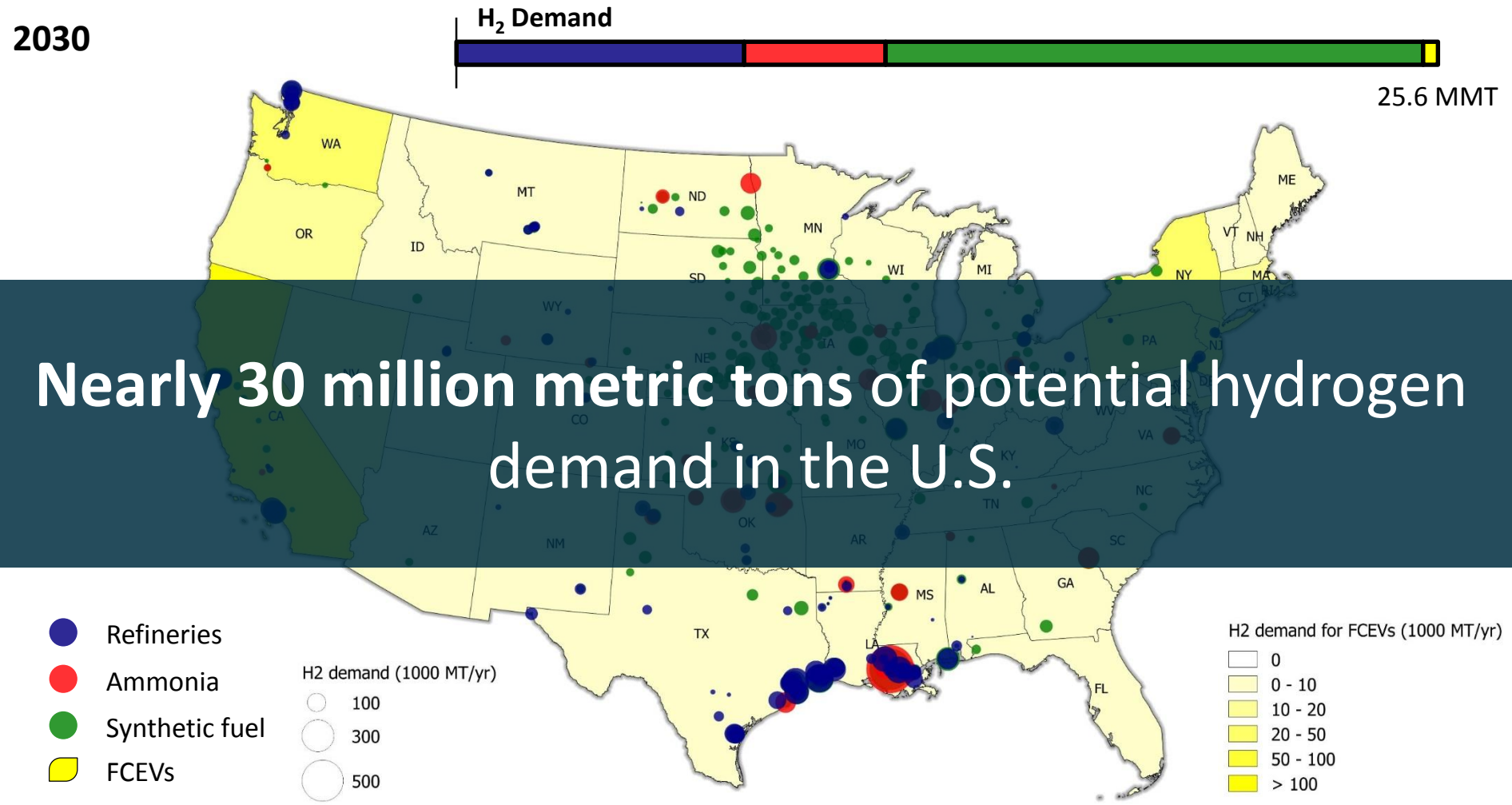

Source: Elgowainy, et al, ANL

# Plus demand from synthetic fuel production…




Source: Elgowainy, et al, ANL

# Plus demand from FCEVs…




**Nearly 30 million metric tons** of potential hydrogen demand in the U.S.

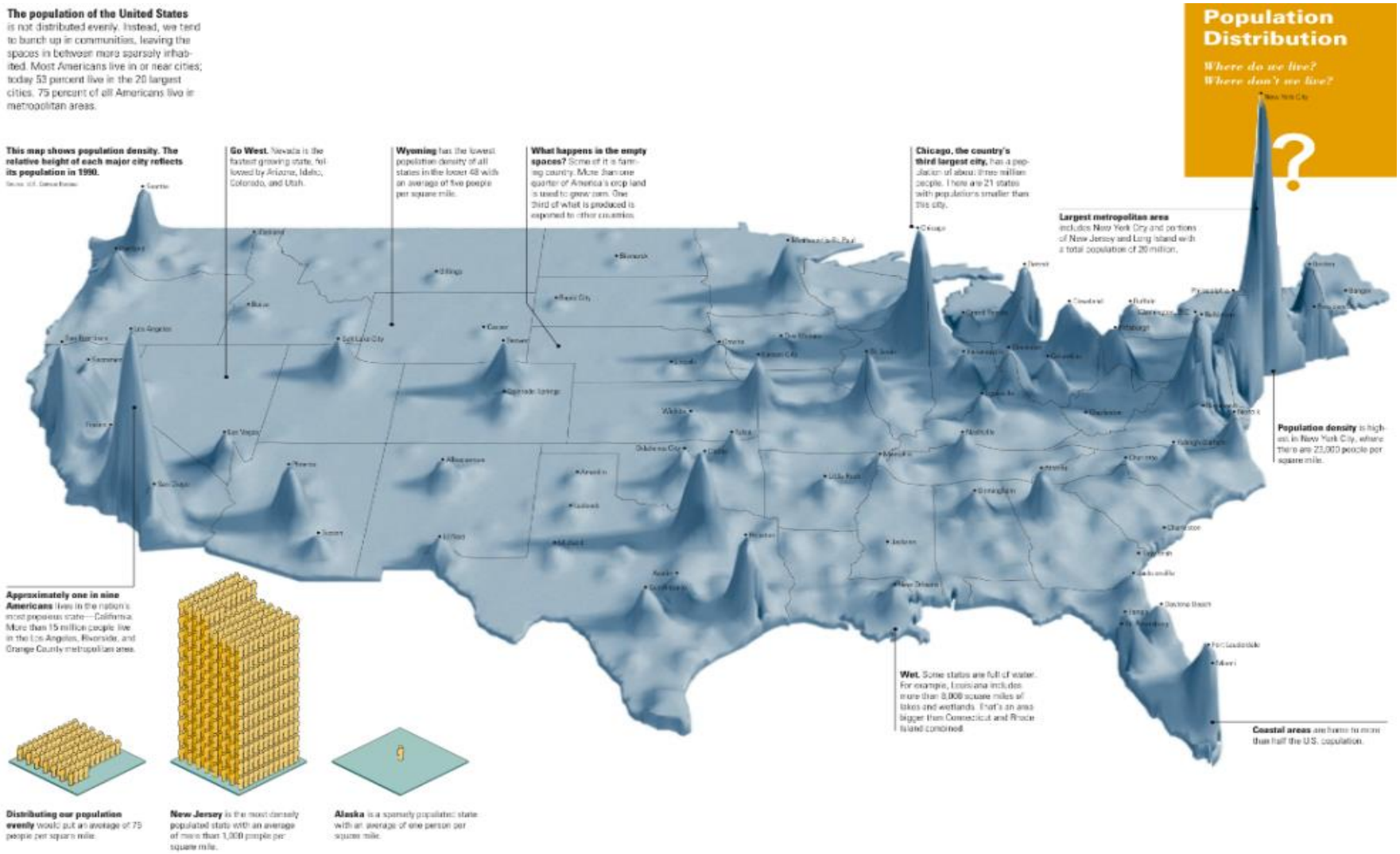
Source: Elgowainy, et al, ANL

# $H_2$@Scale: Enabling renewable energy transport?

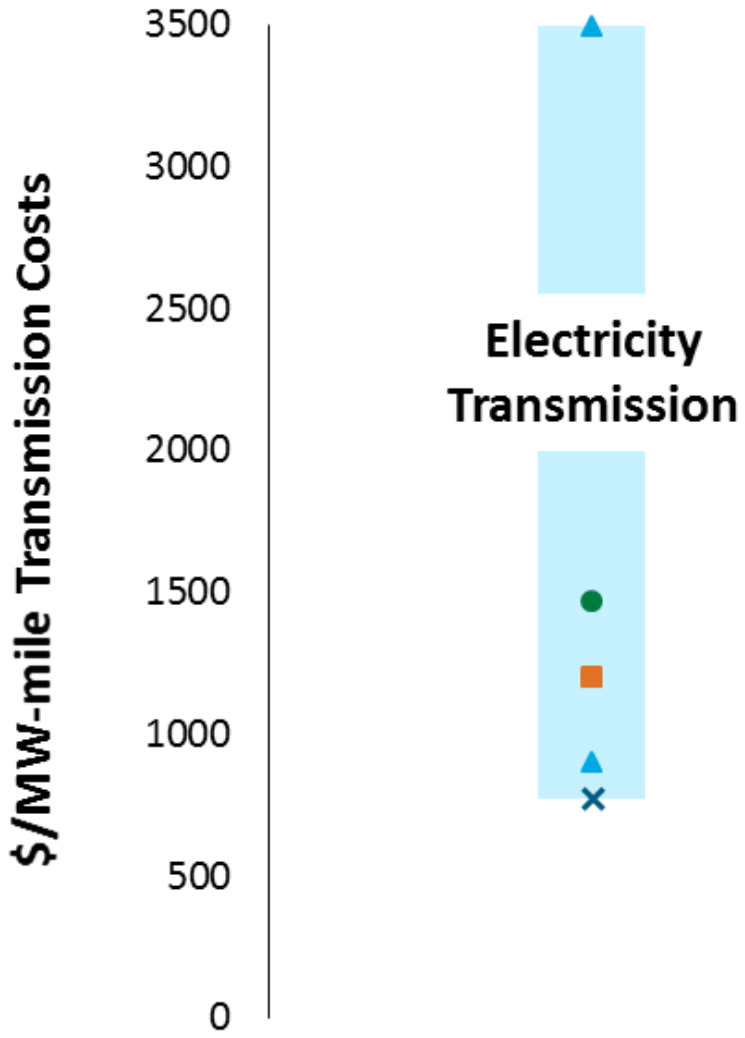
## Where we find abundant solar and wind energy

# $H_2$@Scale: Enabling renewable energy transport?

## Where energy is consumed



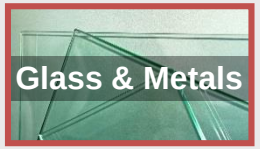
# Analysis underway to guide future plans




**Cost of long distance electricity transmission is high**

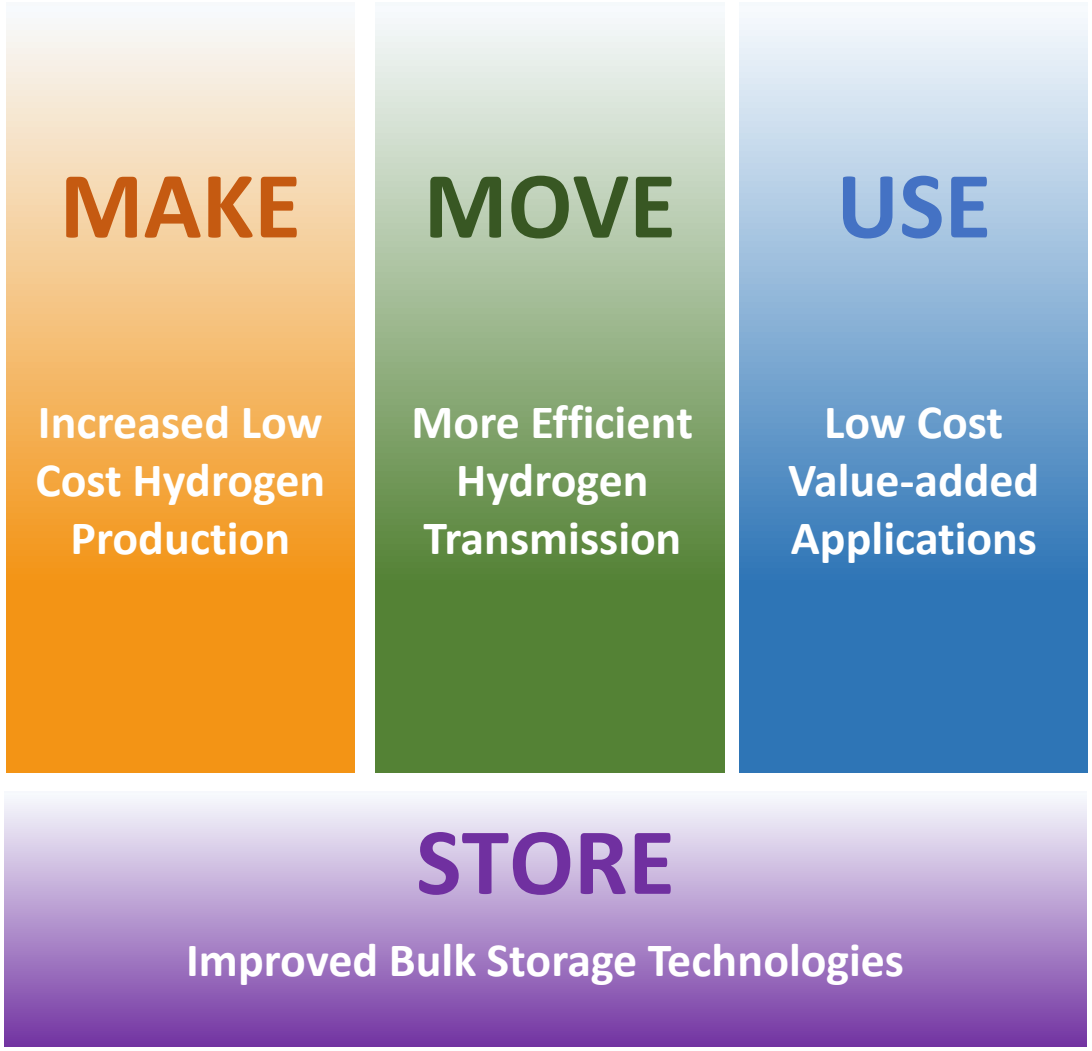
**Can $H_2$ or $H_2$ carriers be an option?**

# Hydrogen for different scales and applications

| Industry | Key Applications | Supply Systems | Volume |
|---|---|---|---|
|  Small Scale | ■ Laboratories<br>■ Fuel Cell Applications | ■ Small on-site<br>■ Cylinders<br>■ Tube trailers<br>■ Liquid $H_2$ | Low<br>< 0.1 mmscfd |
|  Electronics | ■ Thin-film solar<br>■ Semi-Conductors<br>■ Materials Processing | ■ Tube trailer<br>■ Liquid $H_2$<br>■ Small On-Site Plant | |
|  Glass & Metals | ■ Float glass mfg<br>■ Steel Anealing | ■ Liquid $H_2$<br>■ On-Site Plant | Medium<br>0.1- 5 mmscfd |
|  Chemicals | ■ Chemicals<br>■ Food<br>■ Biofuels | ■ Liquid H2<br>■ On-Site Plant<br>■ Pipeline | |
|  Refining, Ammonia | ■ Hydro-processing<br>■ De-sulfurization<br>■ Haber-Bosch | ■ Pipeline<br>■ On-Site Plant | High<br>60-200+ mmscfd |

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

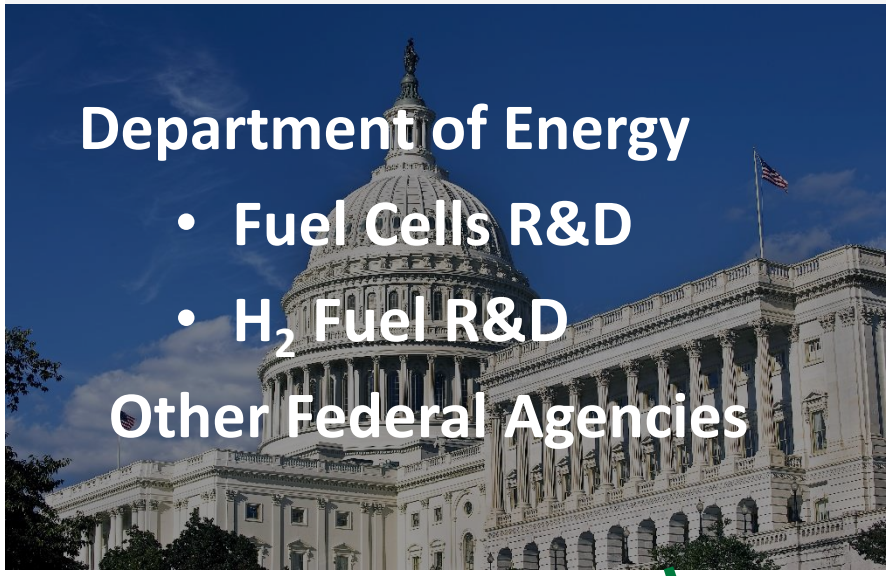
# Key focus areas to realize the $H_2$@scale vision



# 3. Collaboration

# Strategy: Partnerships to enable $H_2$@Scale

## Early- Stage R&D



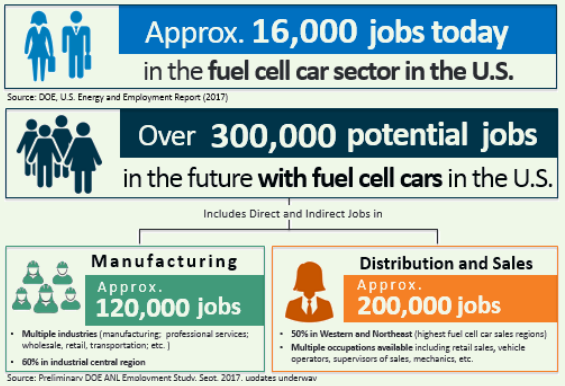

## Demonstration, Deployment & Commercialization


H2@Scale U.S. Department of Energy

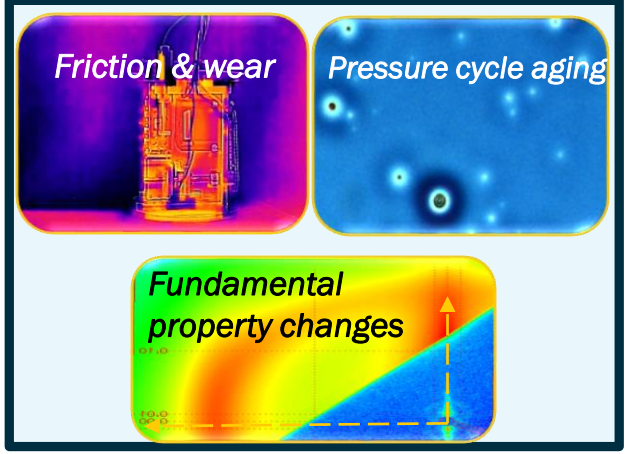
**$H_2$@Scale Consortium**

# $H_2$@Scale R&D Lab Capabilities– Examples

## Techno economic Modeling and Analysis



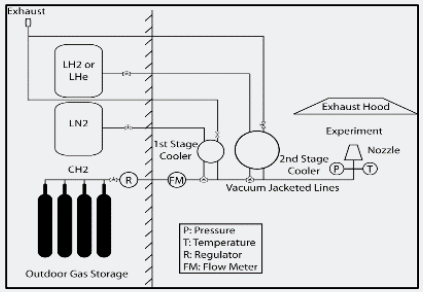

## Hydrogen Materials R&D




## Grid simulation and Testing R&D

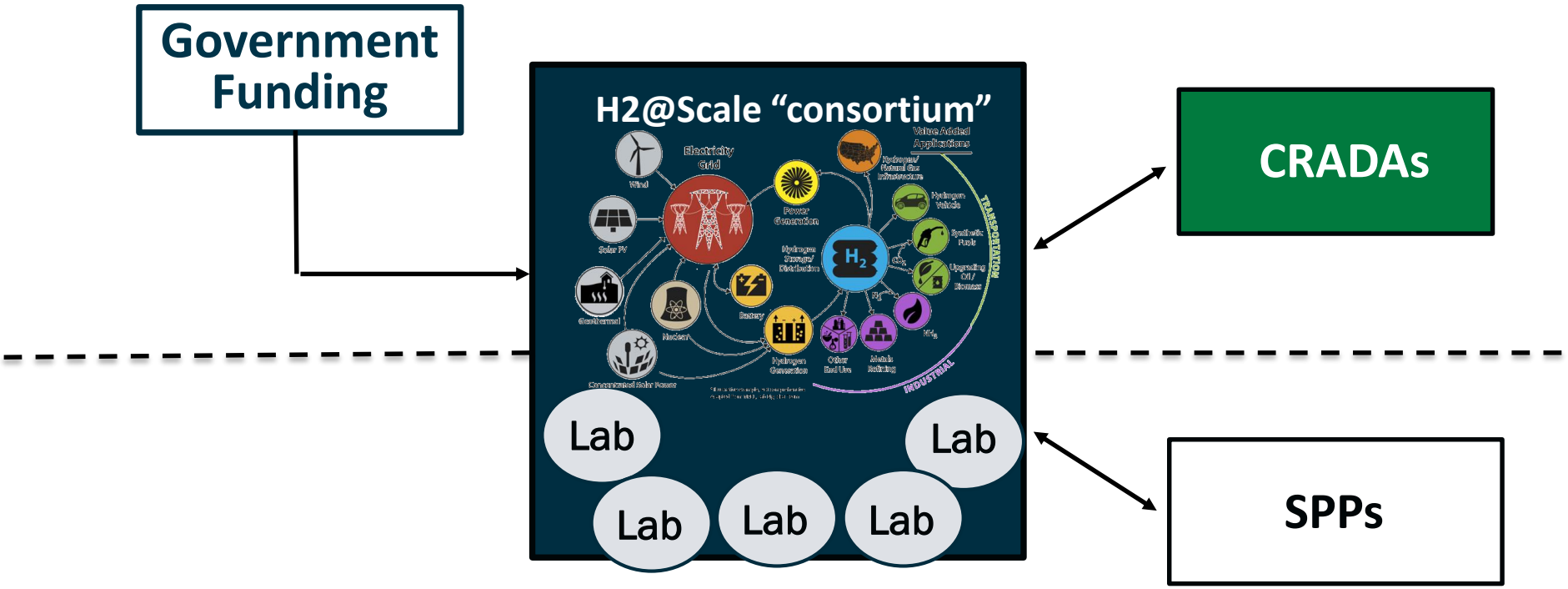
## Safety and Infrastructure R&D

HyRAM
HYDROGEN RISK ASSESSMENT MODELS


# $H_2$@Scale – Lab CRADAs

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

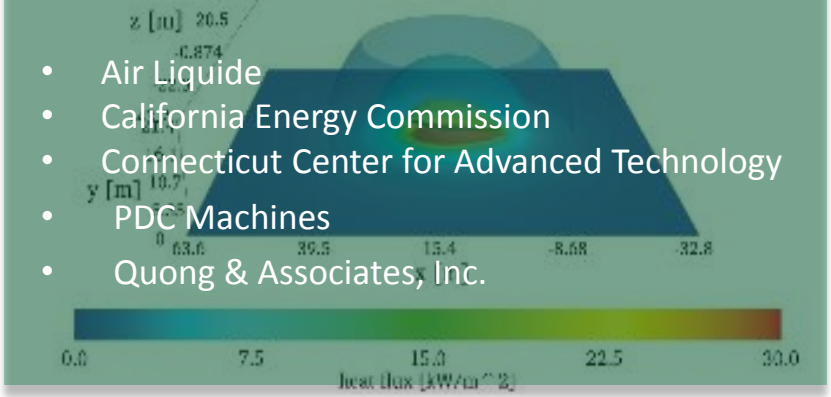



CRADA = Cooperative Research and Development Agreement
SPP- Strategic Partnership Project ('Work for Others')

# $H_2$@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.

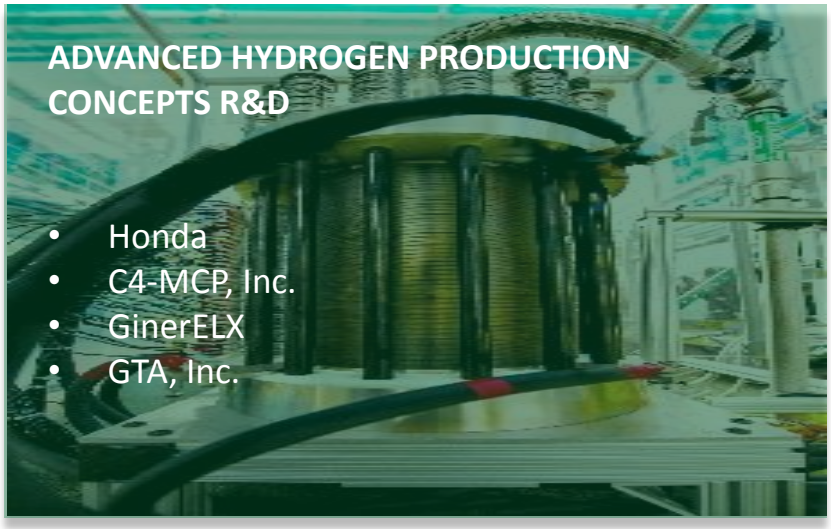



## HYDROGEN DISTRIBUTION COMPONENT DEVELOPMENT R&D

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

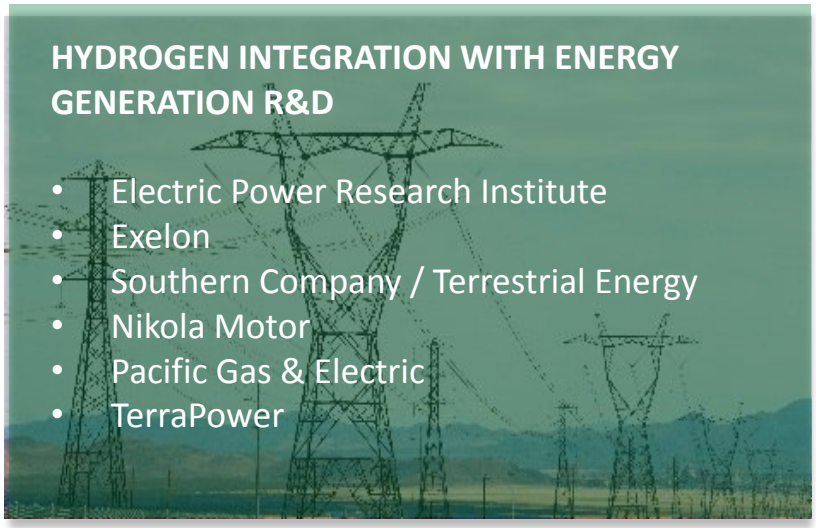
## ADVANCED HYDROGEN PRODUCTION CONCEPTS R&D

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



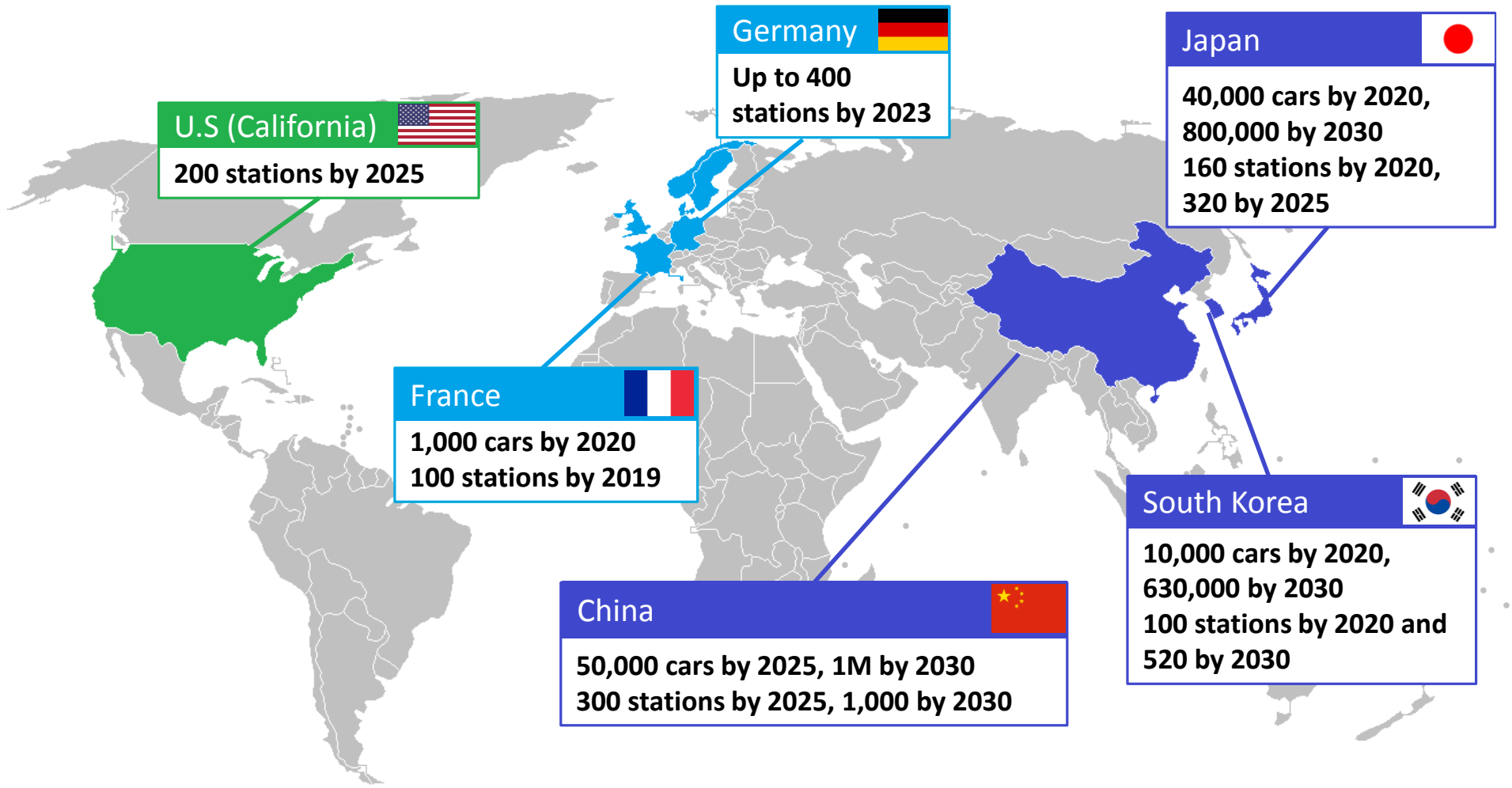
## HYDROGEN INTEGRATION WITH ENERGY GENERATION R&D

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



Argonne NATIONAL LABORATORY · INL Idaho National Laboratory · BERKELEY LAB · NREL NATIONAL RENEWABLE ENERGY LABORATORY · Pacific Northwest NATIONAL LABORATORY · Sandia National Laboratories · SRNL SAVANNAH RIVER NATIONAL LABORATORY OPERATED BY SAVANNAH RIVER NUCLEAR SOLUTIONS

# Global Hydrogen Infrastructure Activity Underway



# IPHE: International Partnership for $H_2$ and Fuel Cells in the Economy

- **Share** information on $H_2$ and fuel cells, lessons learned, best practices
- **Increase** international **collaboration to accelerate progress**

**U.S. elected as Chair**

**May 2018**


Australia


Austria


Brazil


Canada


China


European Commission


France


Germany


Iceland


India


Italy


Japan


Republic of Korea


Norway


Russian Federation


South Africa


United Kingdom


United States

**Launched 2003 and includes 18 countries and the European Commission**

# Two Requests for Information to Enable H2@scale


**Opportunities to multi-sector use of hydrogen**

*Just announced!*

**Reducing barriers to hydrogen infrastructure**

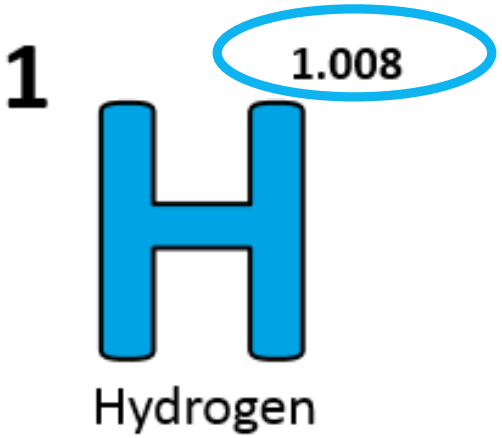
*Closes Aug. 10*

# Opportunities for outreach and to increase awareness

## Celebrate National Hydrogen & Fuel Cell Day

October 8 or 10/8

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




## Information and Training Resources to Increase Awareness

**H2tools.org**

INCREASE YOUR H2IQ

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

**Learn more at: energy.gov/eere/fuelcells**

# Thank You

**Dr. Sunita Satyapal**
Director
Fuel Cell Technologies Office
Sunita.Satyapal@ee.doe.gov

**www.hydrogen.energy.gov**