

# U.S. Department of Energy Hydrogen and Fuel Cell Technology Perspectives

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FCVC 2018

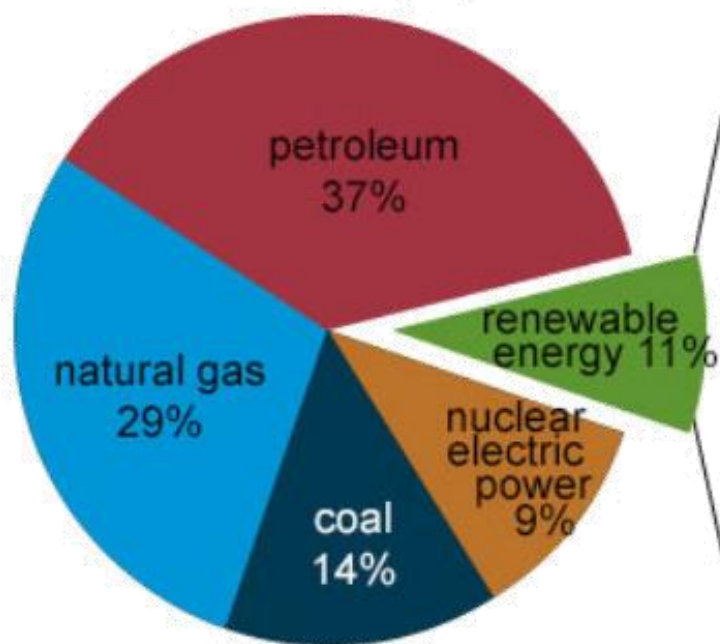
Rugao, China – October 24, 2018



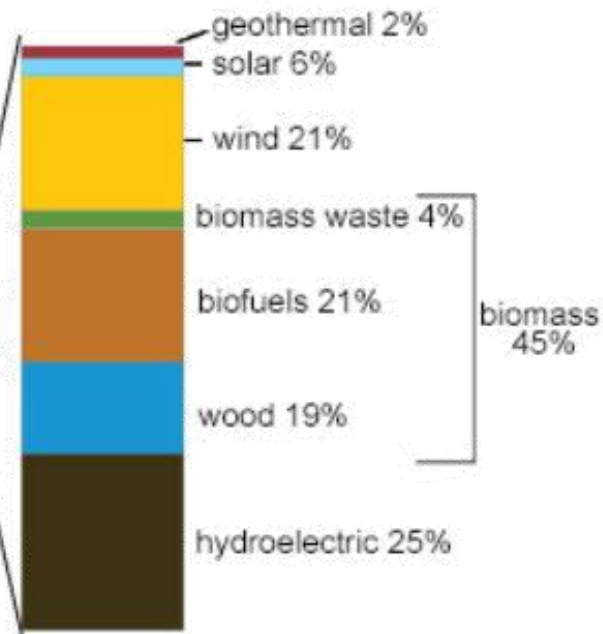
# U.S. energy mix covers wide of energy sources

## U.S. energy consumption by energy source, 2017

Total = 97.7 quadrillion  
British thermal units (Btu)



Total = 11.0 quadrillion Btu



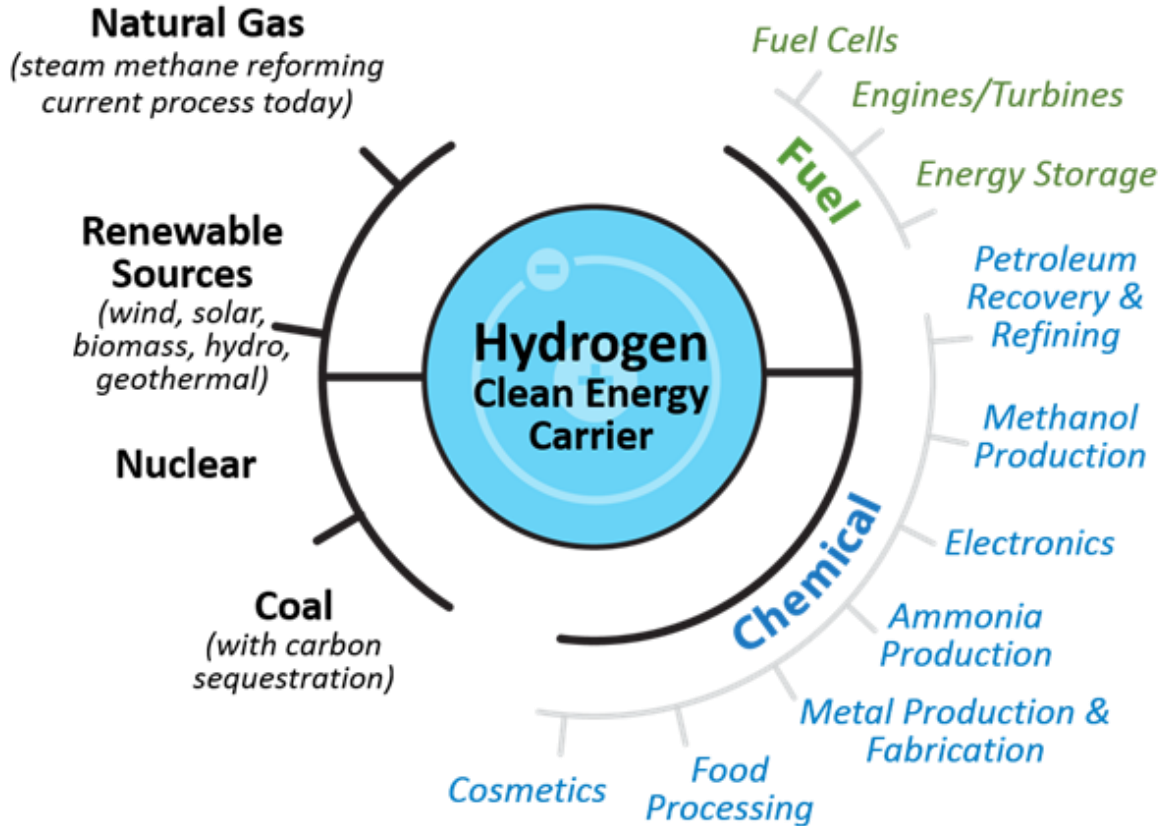
Note: Sum of components may not equal 100% because of independent rounding.  
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2018, preliminary data



# Hydrogen is part of an all-of-the-above portfolio

H<sub>2</sub> can be produced from diverse domestic sources

Many applications rely on or could benefit from H<sub>2</sub>



**Clean , sustainable, versatile, and efficient energy carrier**

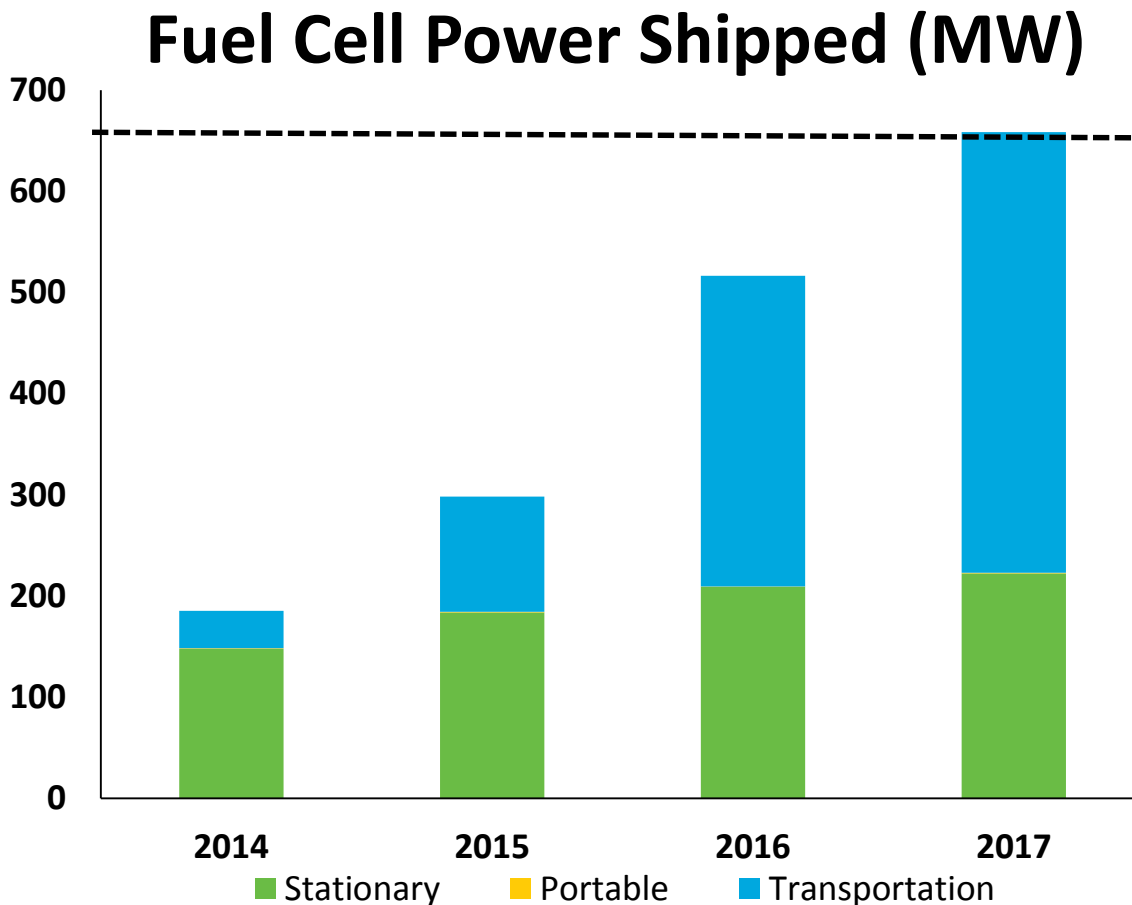
# 4 Key Messages



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 refueling station is a tall, white and blue structure with a "HYDROGEN" sign at the top. The background shows a clear blue sky and a chain-link fence.

# 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*

**5,600** | **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

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Over 13 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

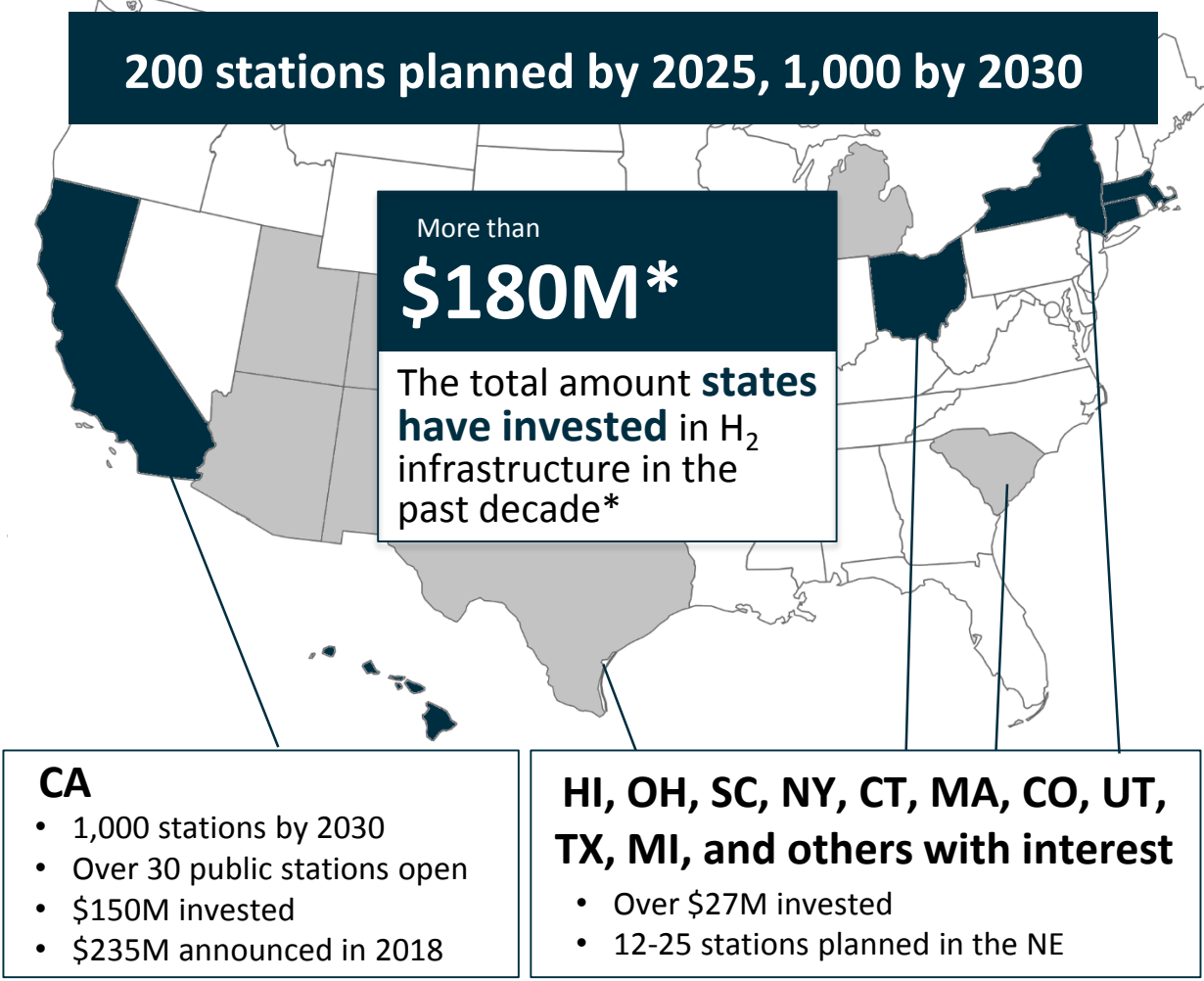


# Multiple H<sub>2</sub> and Fuel Cell Applications in the U.S.

## U.S. Snapshot

	Over <b>&gt;240MW</b> Backup Power
	More than <b>20,000</b> Forklifts
	More than <b>30</b> Fuel Cell Buses
	More than <b>35</b> H <sub>2</sub> Retail Stations
	<b>5,600</b> Fuel Cell Cars

## States with Growing Interest



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



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# 2. Challenges

# Remaining challenges being addressed

**Cost and durability**  
**Infrastructure cost,**  
**availability, reliability**



**What can we learn  
from history?**

# Henry Ford's Quadricycle in 1896 to Model T in 1908



## FORD CARS

1909 MODELS

The enormous demand for the new 4-cylinder Model "T" touring car makes it impossible for us to get these cars on short notice; deliveries will be made strictly in the order given. If you want one of these cars, see us soon.

\$850 f. o. b. factory

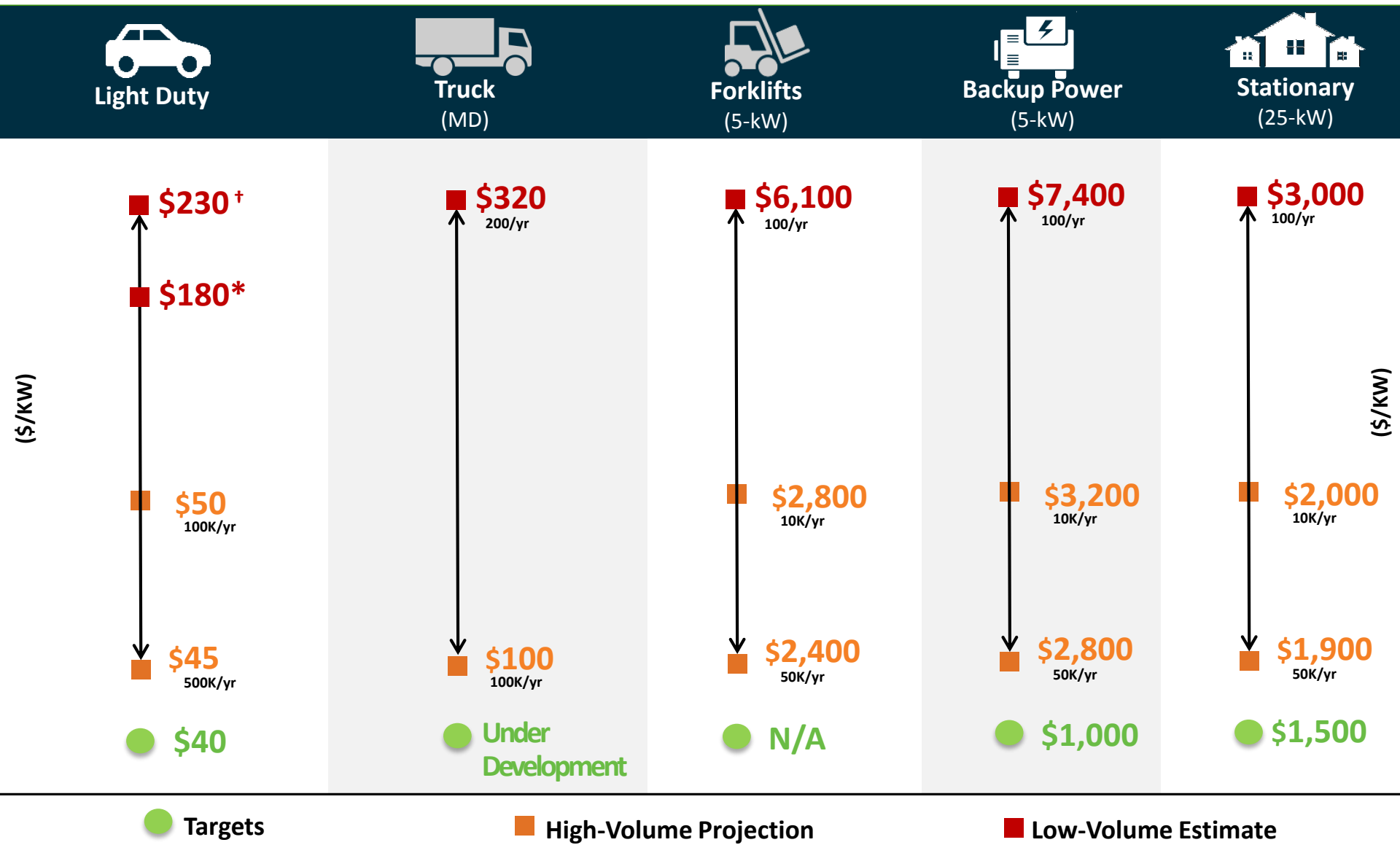
**Colorado Auto Supply Co.**  
Distributors

8-10 E. BIJOU STREET

Three or four splendid second-hand cars for sale cheap.



# Technology targets in various applications guide R&D



\*Based on commercially available FCEVs

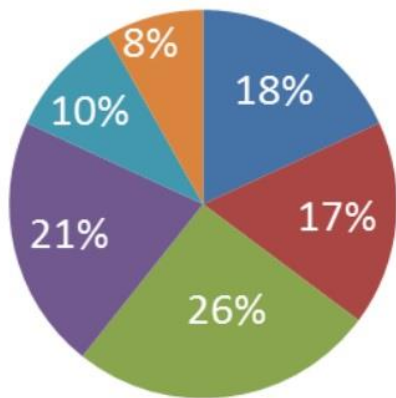
†Based on state of the art technology

Note: Graphs not drawn to scale and are for illustration purposes only.

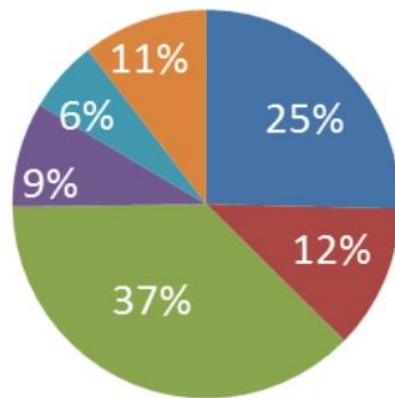
# Fuel Cell Cost Breakdown

Key cost contributors are stack components  
Focus on catalysts, membranes, bipolar plates, etc.

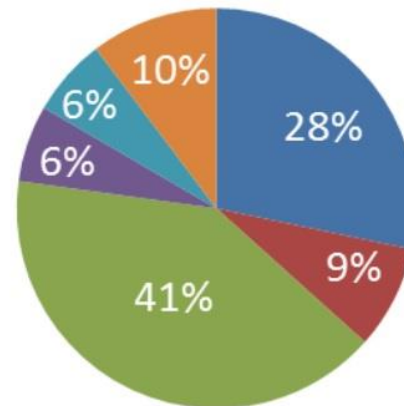
1,000 Systems/Year



100,000 Systems/Year



500,000 Systems/Year

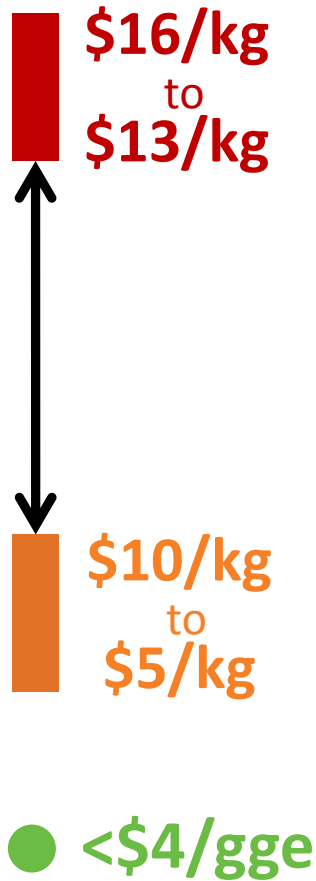


- Bipolar Plates
- Membranes
- Catalyst + Application
- GDLs
- MEA Frame/Gaskets
- Balance of Stack



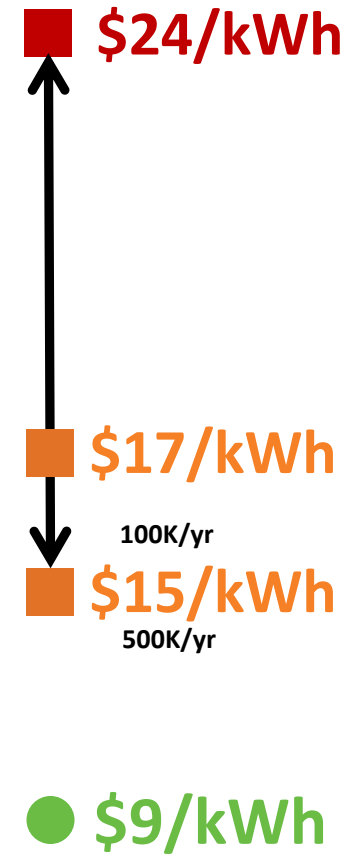
# More R&D needed to meet affordability targets

## Production, Delivery & Dispensing



## On-board Storage

(700-bar compressed system)



● Targets

■ High-Volume Projection

■ Low-Volume Estimate

Note: Graphs not drawn to scale and are for illustration purposes only.

# U.S. Dept. Of Energy H<sub>2</sub> and Fuel Cells R&D Focus

## Early R&D Focus

Applied research, development and innovation in hydrogen and fuel cell technologies leading to:

- Energy security
- Energy resiliency
- Strong domestic economy

## Early R&D Areas



### Fuel Cells

- PGM- free catalysts
- Durable MEAs
- Electrode performance



### Hydrogen Fuel

- Production Pathways
- Advanced materials for storage



### Infrastructure R&D

- Safety
- Manufacturing
- Delivery components
- Others

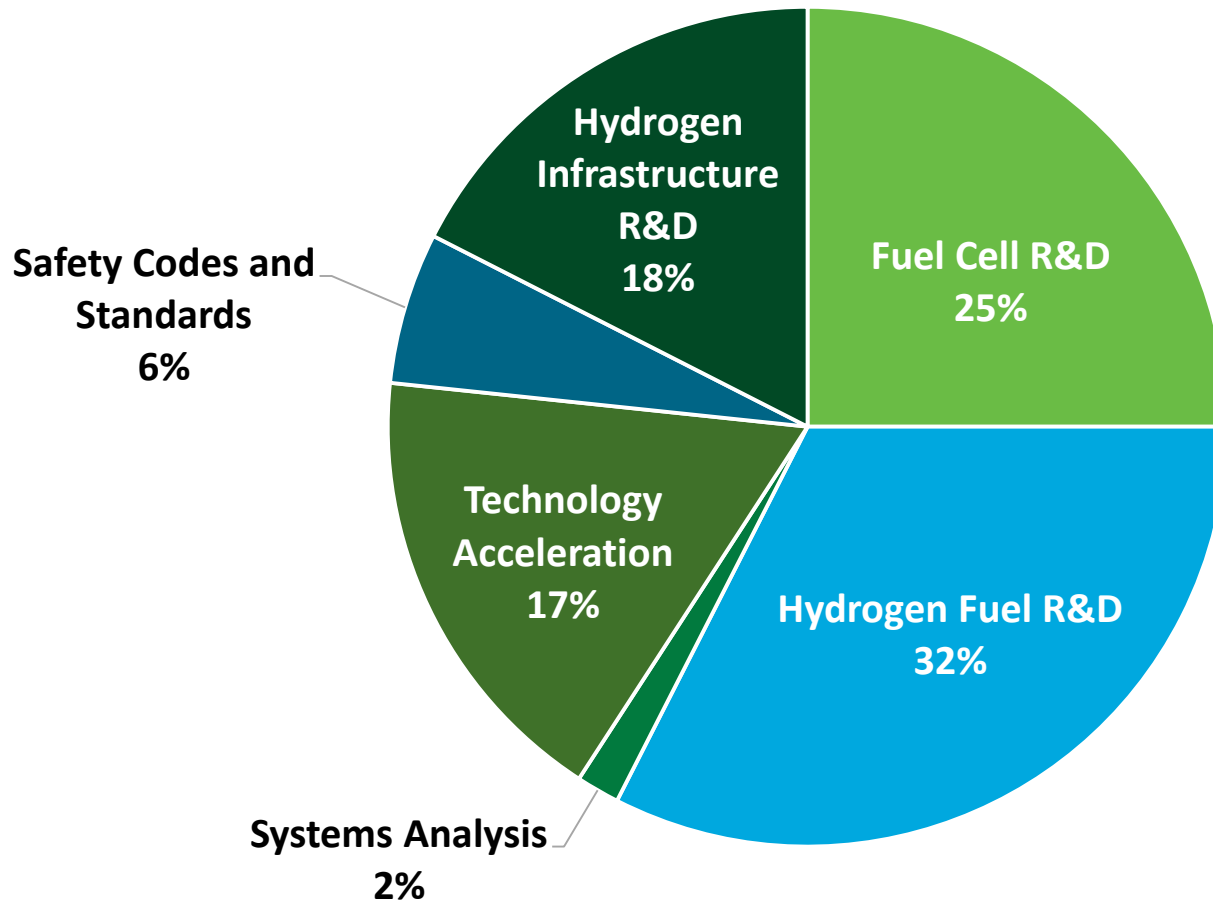
PGM = Platinum group metals  
MEA = Membrane Electrode Assembly

## Enabling



# Fuel Cell Technologies Office Funding - FY 2019

Total FY 2019 EERE FCTO Funding: \$120 M





# 3. H<sub>2</sub>@Scale concept

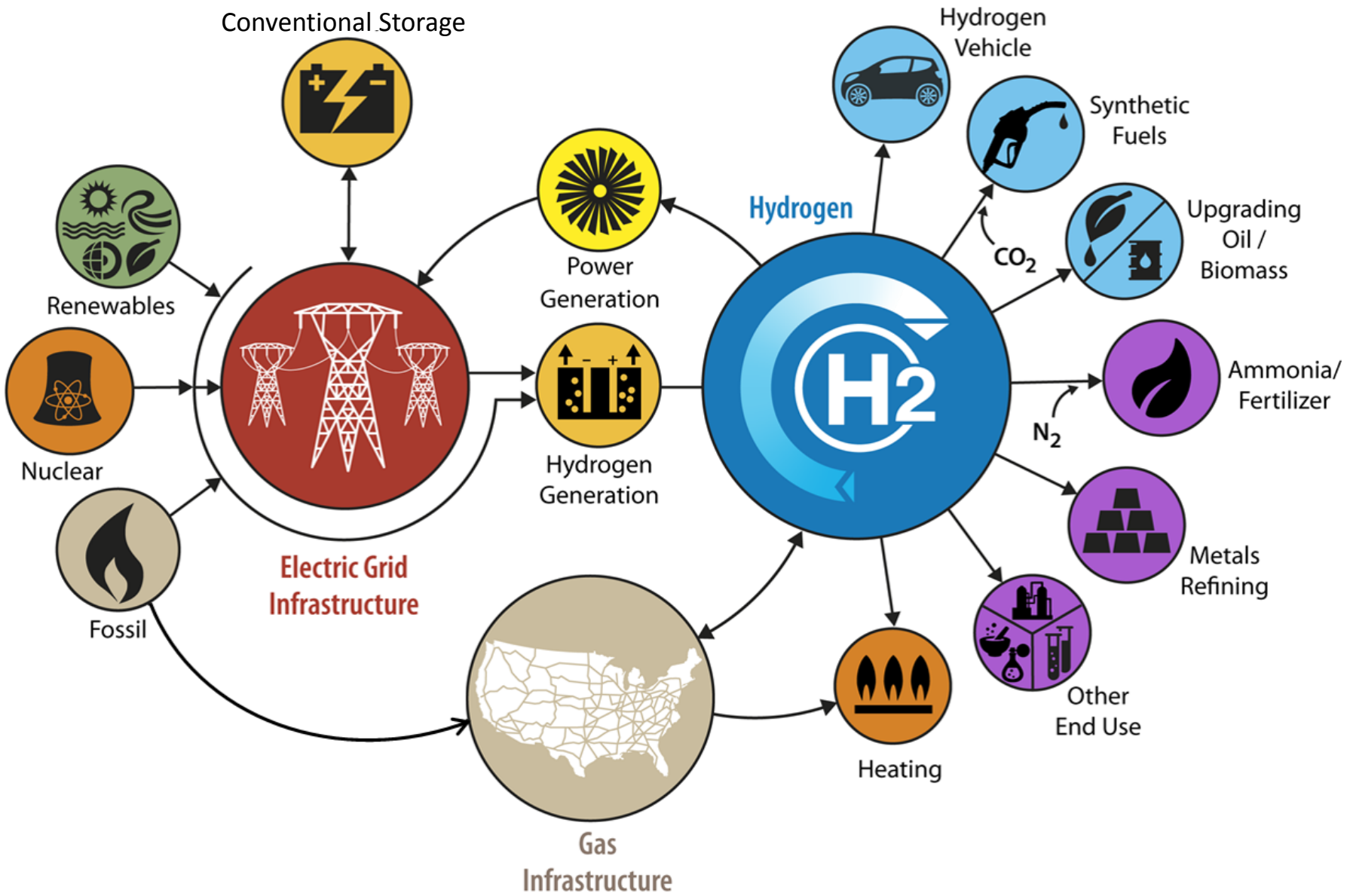




# Vision

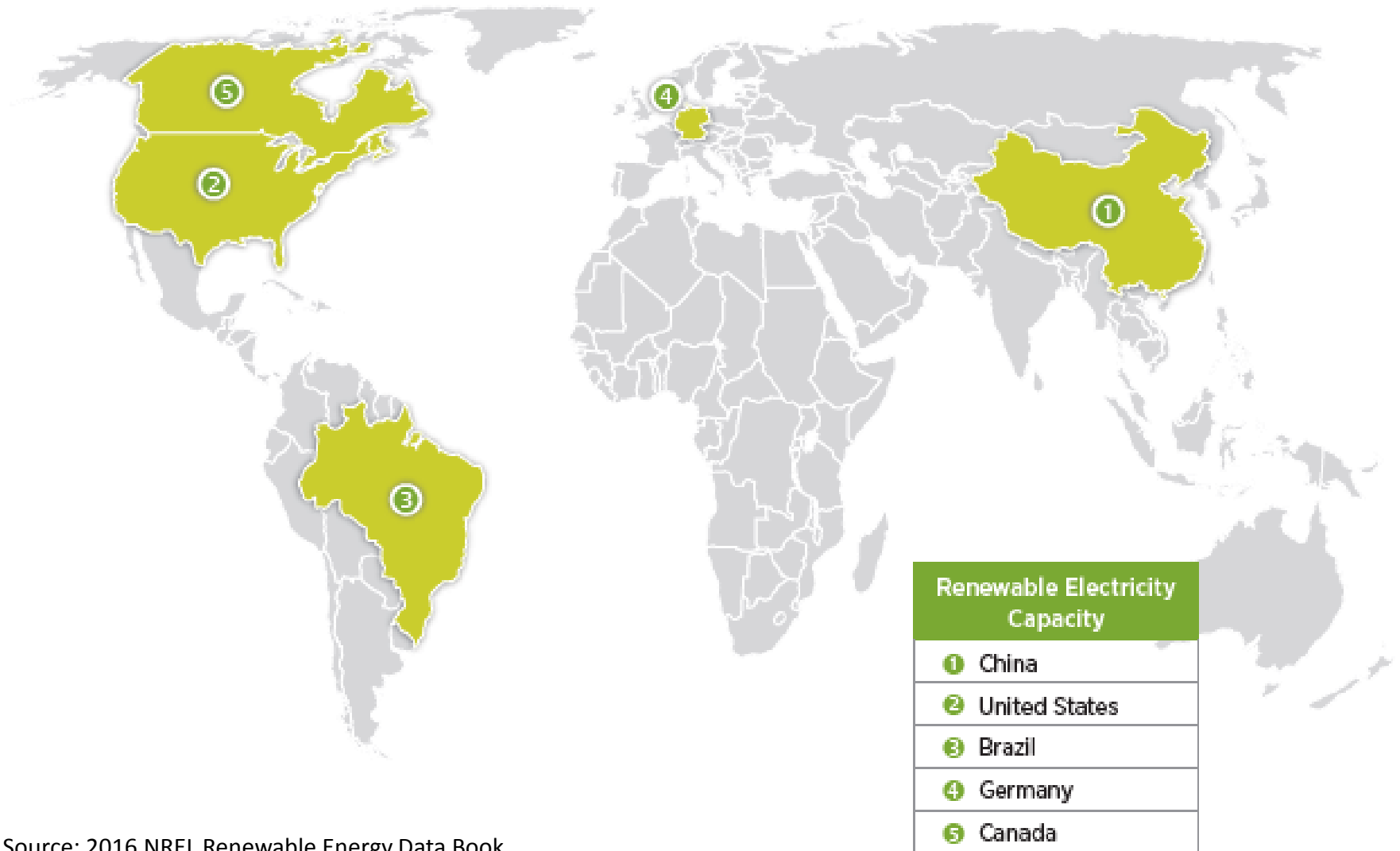
**H2@Scale: Enable  
affordable, reliable,  
clean and secure energy  
across sectors**

# H<sub>2</sub>@scale: Enabling affordable, reliable, clean, and secure energy across sectors



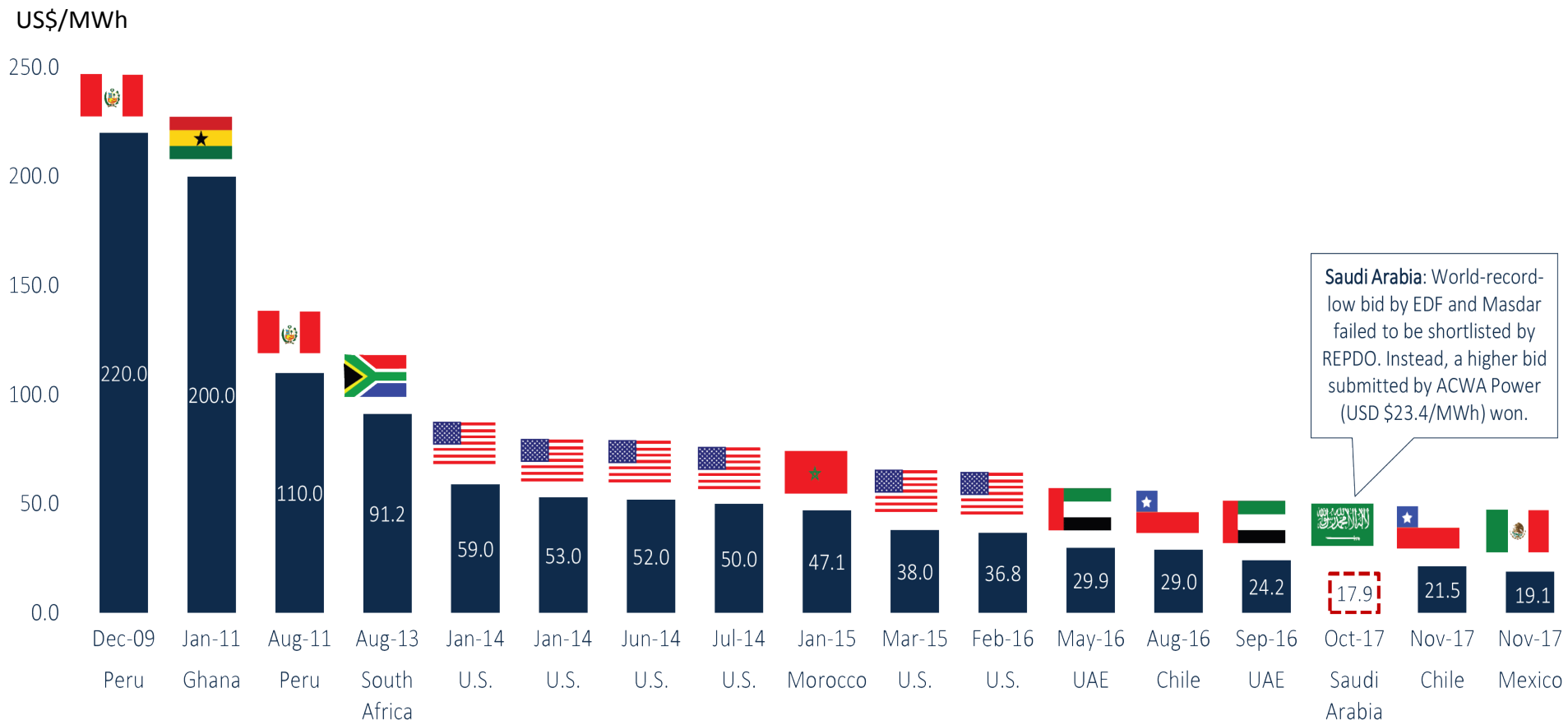
# H<sub>2</sub>@scale can enable increased renewable penetration

## Top Countries for Renewable Electricity Installed



Source: 2016 NREL Renewable Energy Data Book

# Record-Low PPA Prices for Utility-Scale Solar

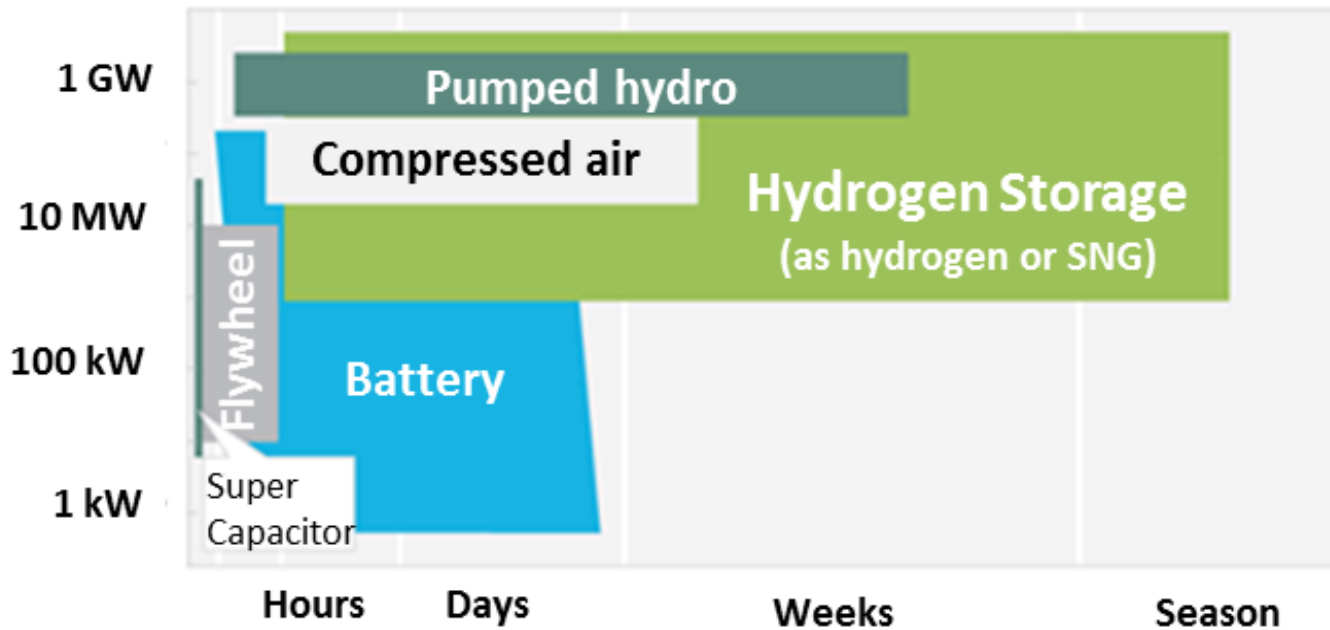


Source: GTM, DOE Solar Technologies Office



# Hydrogen Energy Storage is Scalable

## Overview of Energy Storage Technologies in Power and Time

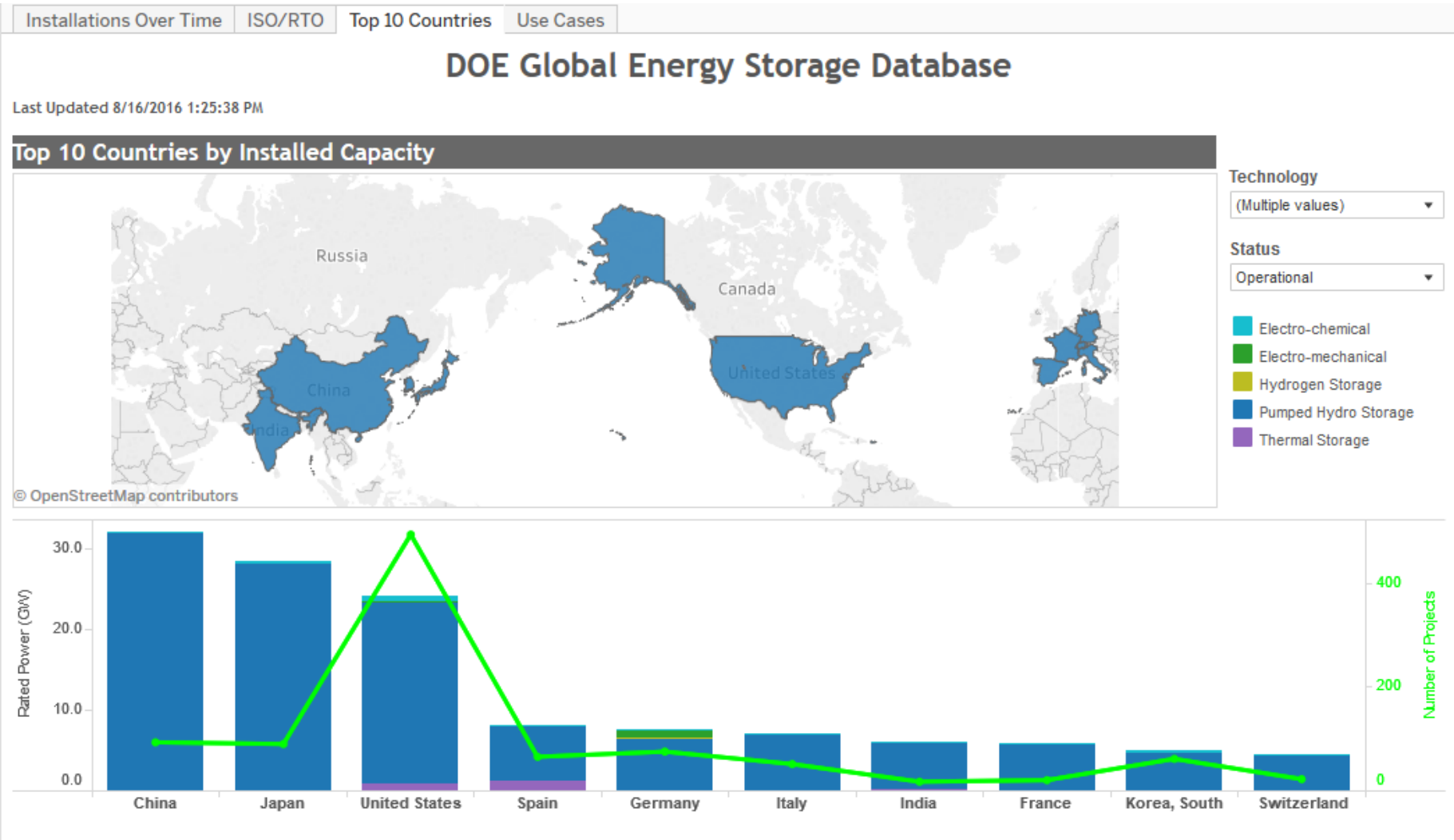


**One hydrogen cavern could provide ~ 100 GWh energy storage**

*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.**

# DOE Global Energy Storage Database



China and the U.S. in the lead: # GW and # of projects

Source: DOE Office of Electricity and Reliability

# H<sub>2</sub>@Scale: Enabling renewable energy transport?

Where we find abundant solar and wind energy



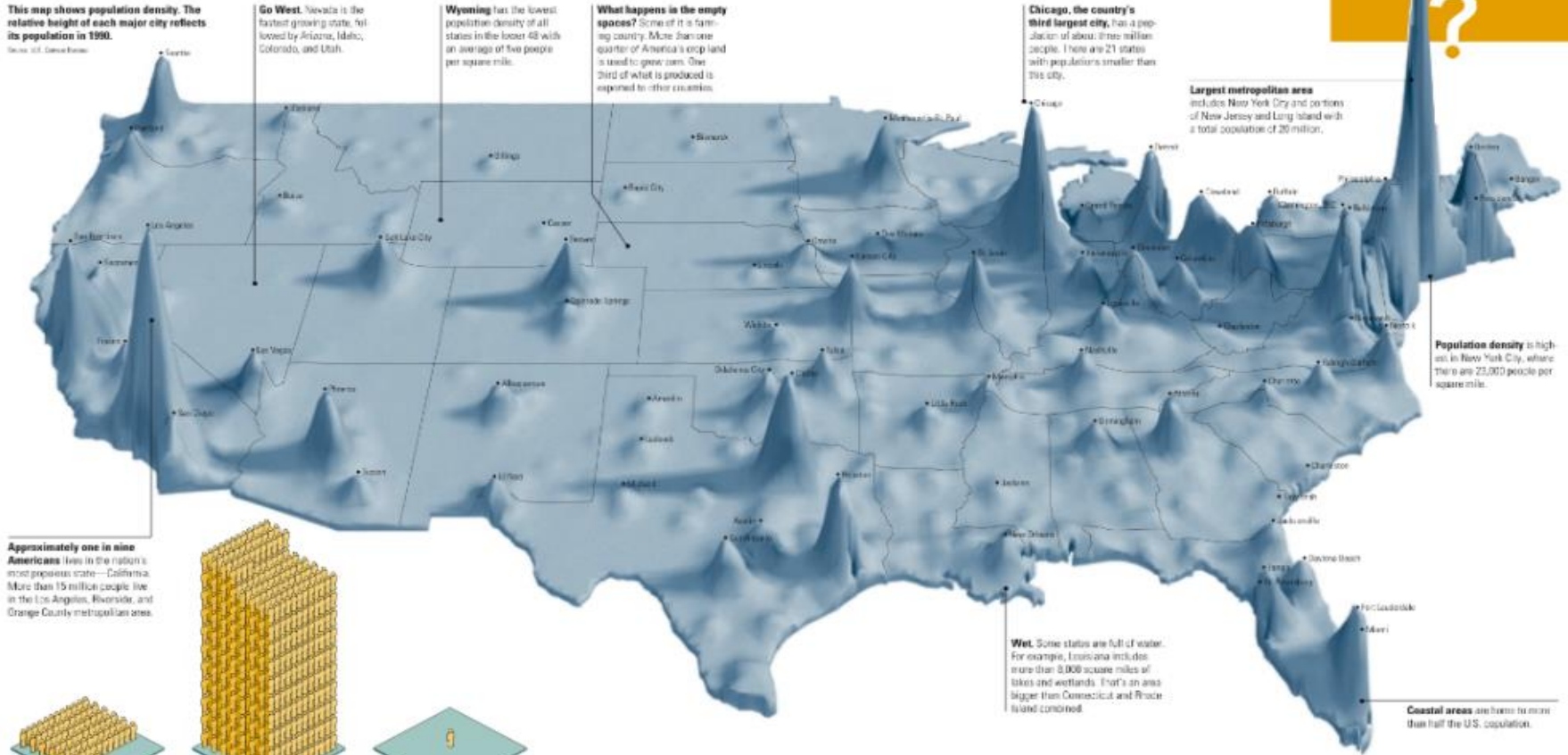
# ...and deliver it or co-locate distributed generation with demand for certain applications

The population of the United States is not distributed evenly. Instead, we tend to bunch up in communities, leaving the spaces in between more sparsely inhabited. Most Americans live in or near cities; today 53 percent live in the 20 largest cities, 75 percent of all Americans live in metropolitan areas.

## Where energy is consumed

This map shows population density. The relative height of each major city reflects its population in 1990.

Source: U.S. Census Bureau



**Population Distribution**

*Where do we live?  
Where don't we live?*

Approximately one in nine Americans lives in the nation's most populous state—California. More than 15 million people live in the Los Angeles, Riverside, and Orange County metropolitan areas.



**Distributing our population evenly** would put an average of 75 people per square mile.



**New Jersey** is the most densely populated state with an average of more than 1,000 people per square mile.



**Alaska** is a sparsely populated state with an average of one person per square mile.

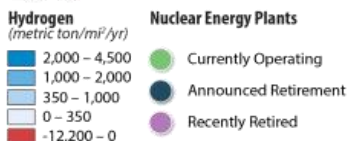
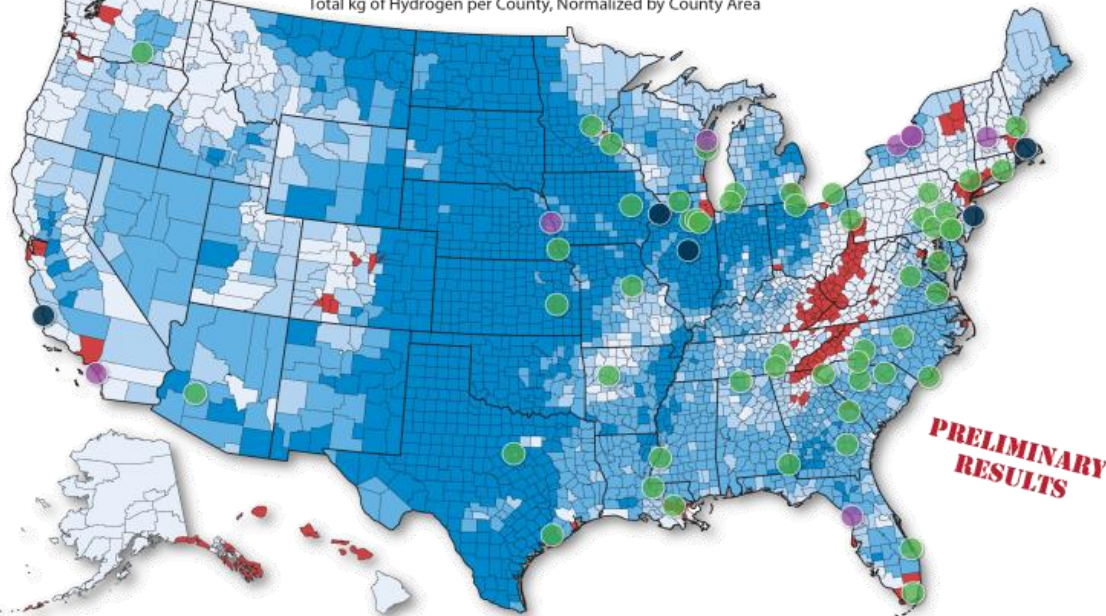


# H2@Scale: Nationwide Resource Assessment

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

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

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



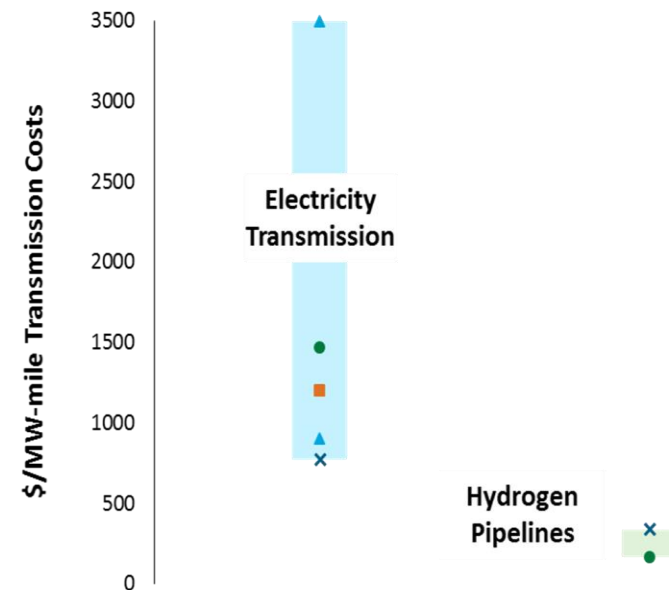
This analysis represents potential generation from utility-scale photovoltaics and onshore wind resources minus total hydrogen demand from the industrial sector: refineries, biofuels, ammonia and natural gas systems (metals are not included) and the transport sector: light duty vehicles and other transport. The data has been normalized by area at their respective spatial scales, and then summarized by county.

Data Source: NREL analysis  
Robson, A. Preserving America's Clean Energy Foundation. Retrieved March 23, 2017, from <http://www.thirdway.org/report/preserving-americas-clean-energy-foundation>

This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.  
Nicholas Gilroy, March 27, 2017

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

## Assessing cost of H<sub>2</sub> vs electricity transmission (in process)







# 4. Collaboration

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

- Increase international collaboration to accelerate progress
- Working Groups:
  - Regulations, Codes and Standards, Safety
  - Education & Outreach

**U.S. elected  
Chair May  
2018**

**Japan Vice Chair**  
EC, Germany, France,  
Canada support



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

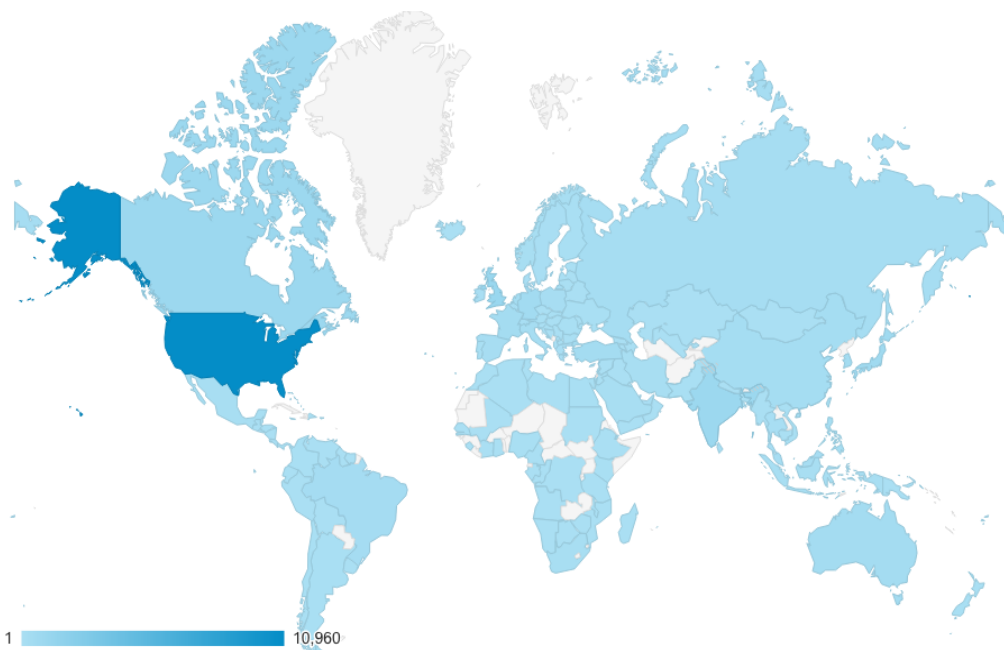
Launched 2003 and includes 18 countries and the European Commission  
Coordination with IEA, Mission Innovation, and Energy Ministerials

# Safety Resources and Models Available

**H2Tools.org** disseminates information on hydrogen safety

## A Global Resource

More than 250,000 visits since 2015 - 50% are international  
Portions translated to Japanese, other languages underway



**Hydrogen Risk Assessment Models (HyRAM)** for risk analysis under various scenarios. Can be applied to develop:

- Conduct **Quantitative Risk Assessment (QRA)** to guide code requirements
- Assess **Liquid Hydrogen Separation Distances**





# Data Sharing Opportunities

## Data Validation of Real World Applications through the NREL's NFCTEC

- Data products provide insights on technology improvements, issues and gaps



NFCTEC: The National Fuel Cell Technology Evaluation Center

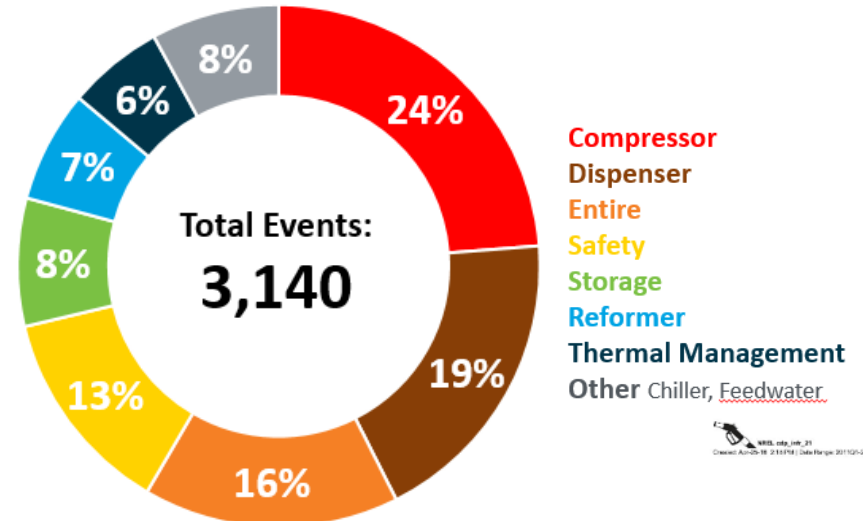
To Participate

[techval@nrel.gov](mailto:techval@nrel.gov)

### Models “Toolbox” Online

- Financial, technical and economic models covering H<sub>2</sub> infrastructure, jobs, and more.
- Visit: [energy.gov/eere/fuelcells/hydrogen-analysis-toolbox](http://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox)

### Example: Sources of H<sub>2</sub> Infrastructure Maintenance



Most maintenance related to **compressors** and **dispensers**



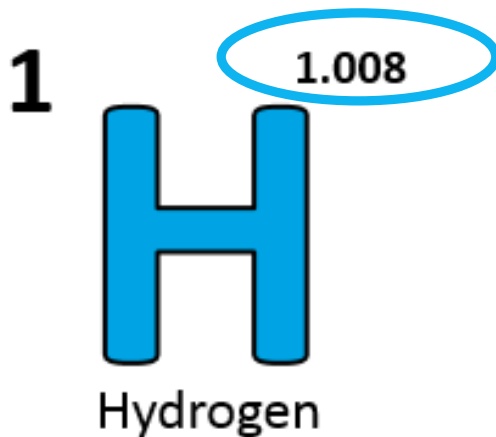
# Opportunities for outreach and to increase awareness

## 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



INCREASE YOUR  
**H<sub>2</sub>IQ**

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](https://energy.gov/eere/fuelcells)

**It is literally true that you  
can succeed best and  
quickest by helping others  
to succeed**

*- Napoleon Hill*

# Thank You

**Dr. Sunita Satyapal**

Director

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[energy.gov/eere/fuelcells](https://energy.gov/eere/fuelcells)