

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

Sunita Satyapal, Director, Fuel Cell Technologies Office

IPHE Industry Forum

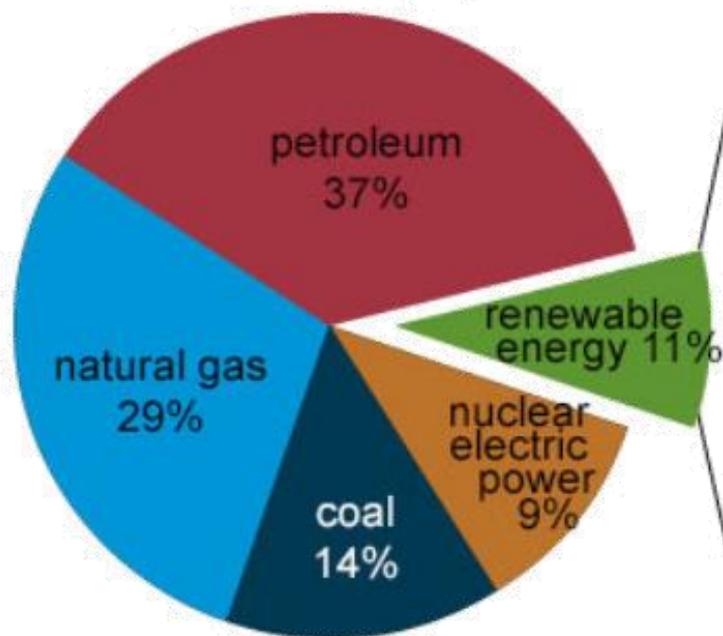
Pretoria, South Africa – December 5, 2018



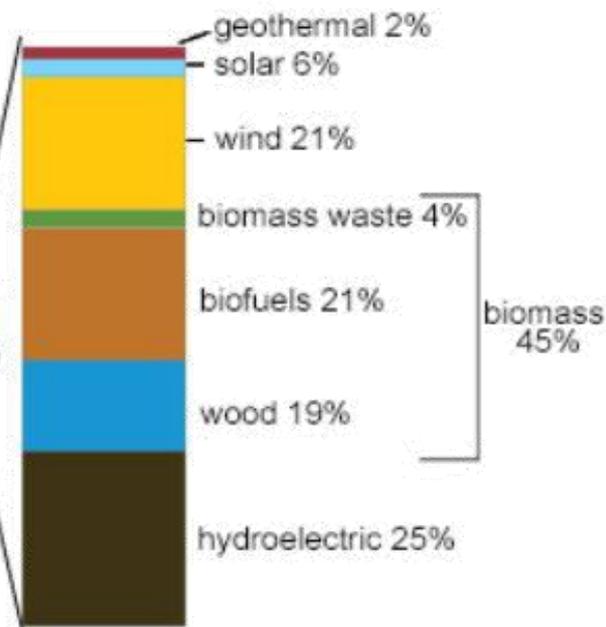
# U.S. energy mix covers wide of energy sources

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

Total = 97.7 quadrillion  
British thermal units (Btu)



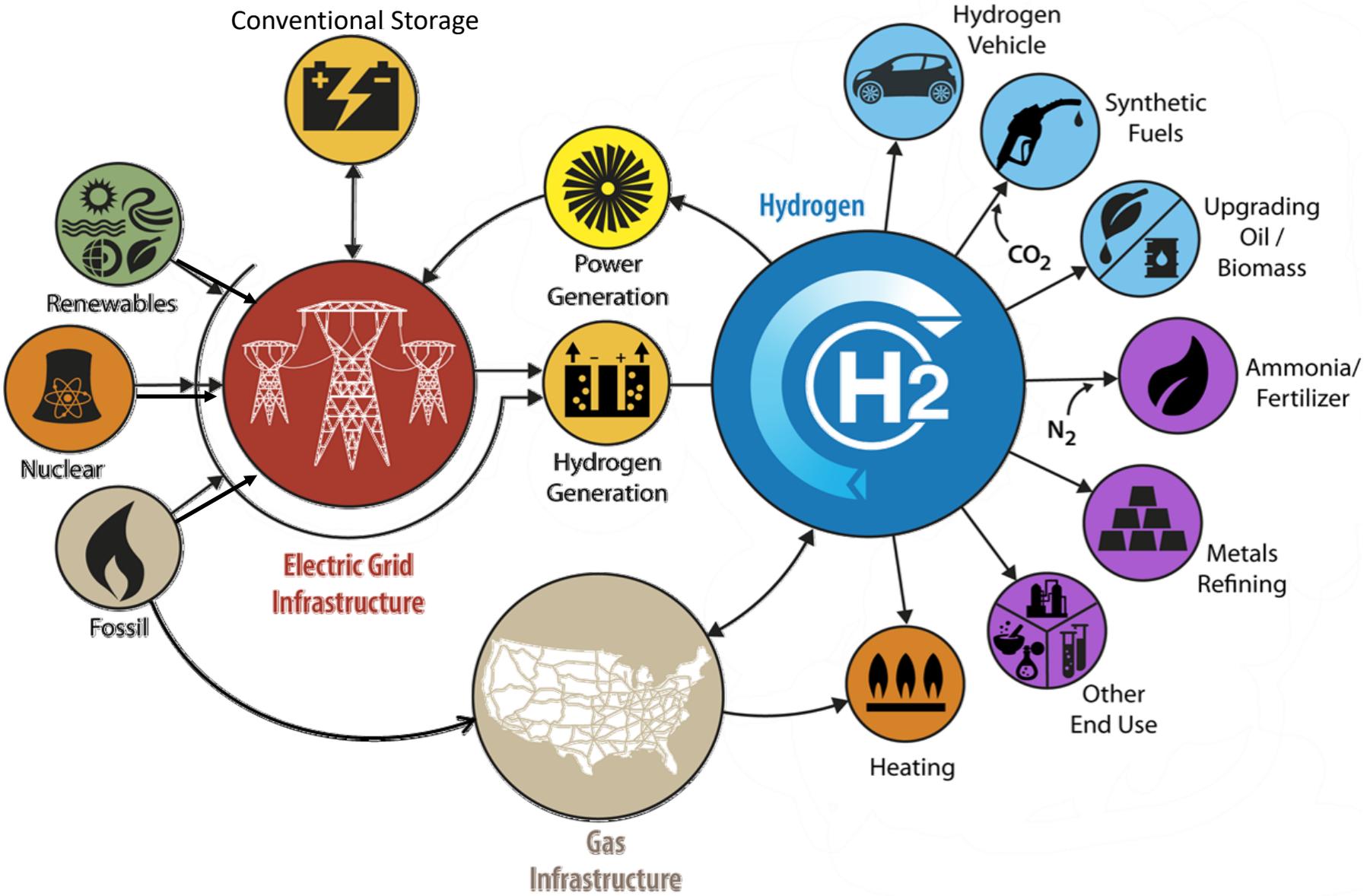
Total = 11.0 quadrillion Btu



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



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



# An exciting time for the transportation sector



*Honda Clarity*

Nearly **5,800** | **sold or leased**  
in the United States



*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

# Fuel cells for material handling equipment

More than **23,000** forklifts

---

Over **15 million** refuelings

# Long-Range, Heavy Duty Applications Emerging



Fuel cell delivery and parcel trucks operating in CA and NY



Industry demonstrates first heavy duty fuel cell truck in CA



# Stationary Power Applications Continue to Grow

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



Fuel cell power for maritime ports demonstrated in Honolulu, Hawaii



Fuel cells used to power new World Trade Center in NYC



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

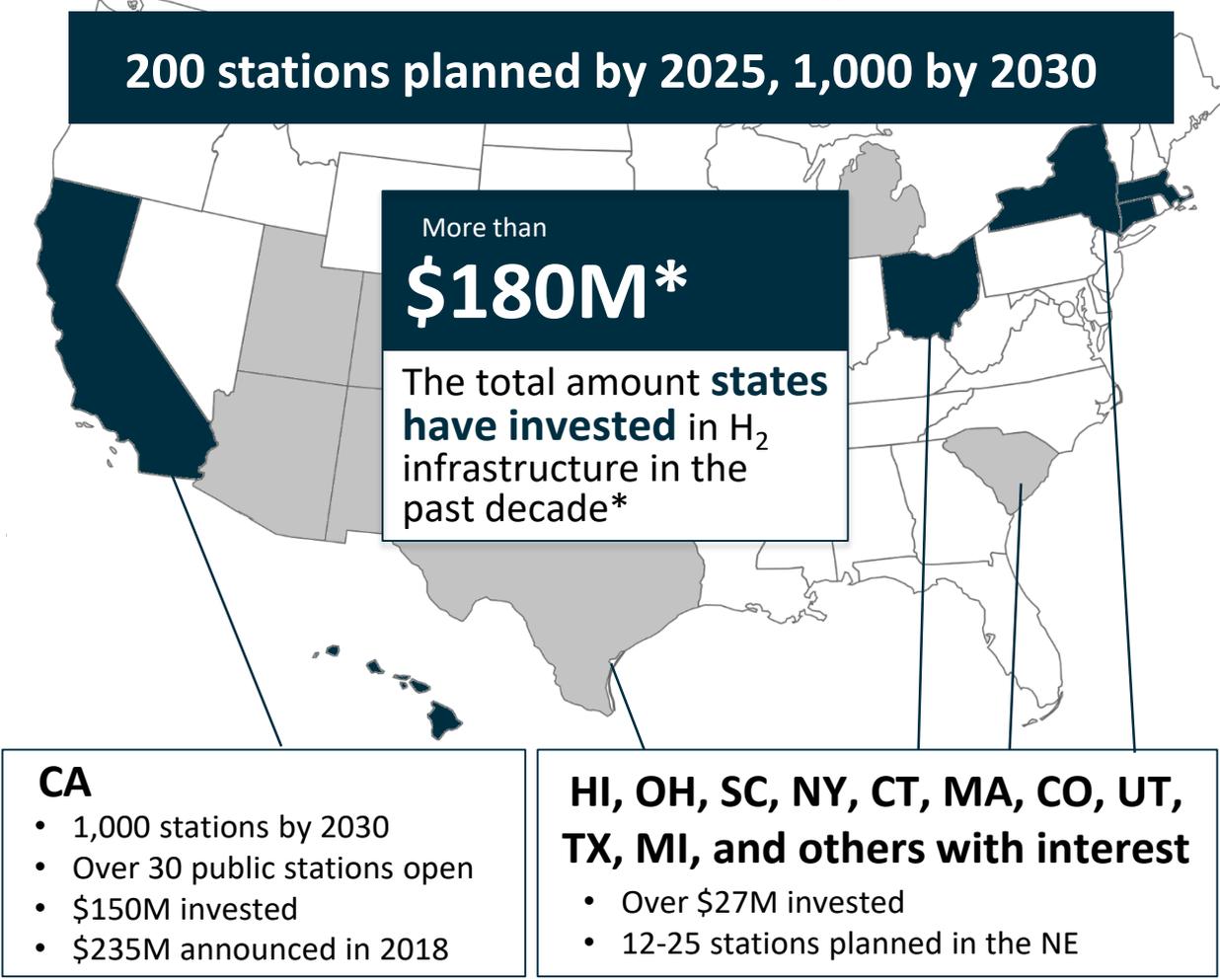


# Multiple H<sub>2</sub> and Fuel Cell Applications in the U.S.

## U.S. Snapshot

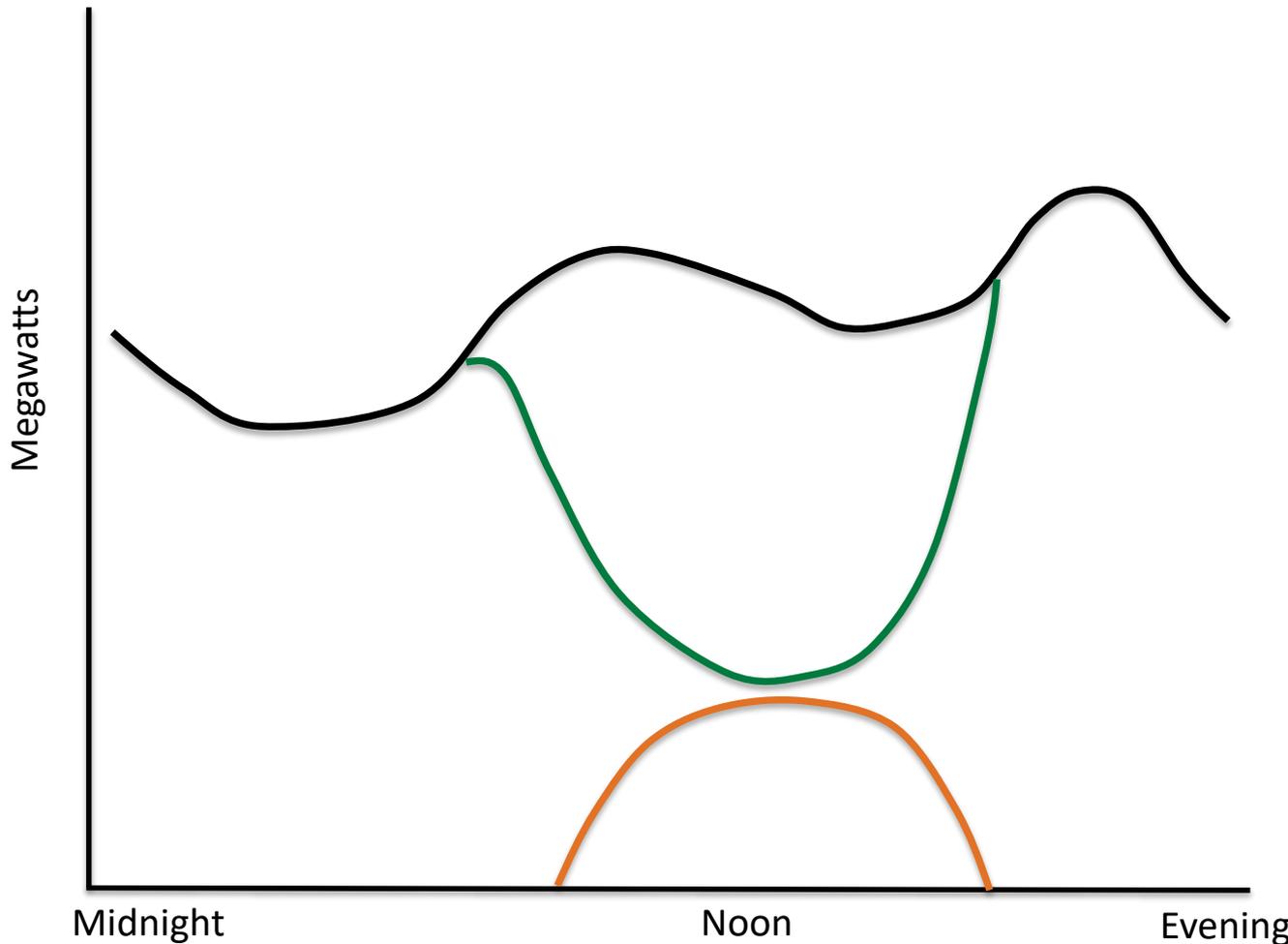
	Over <b>&gt;240MW</b> Backup Power
	More than <b>23,000</b> Forklifts
	More than <b>30</b> Fuel Cell Buses
	<b>36</b> H <sub>2</sub> Retail Stations
	Nearly <b>5,800</b> Fuel Cell Cars

## States with Growing Interest



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

# New Driver: The Duck Curve Example



**Total Load  
(demand)**

**Load (net)  
on  
commercial  
utility grid  
(duck belly  
forms)**

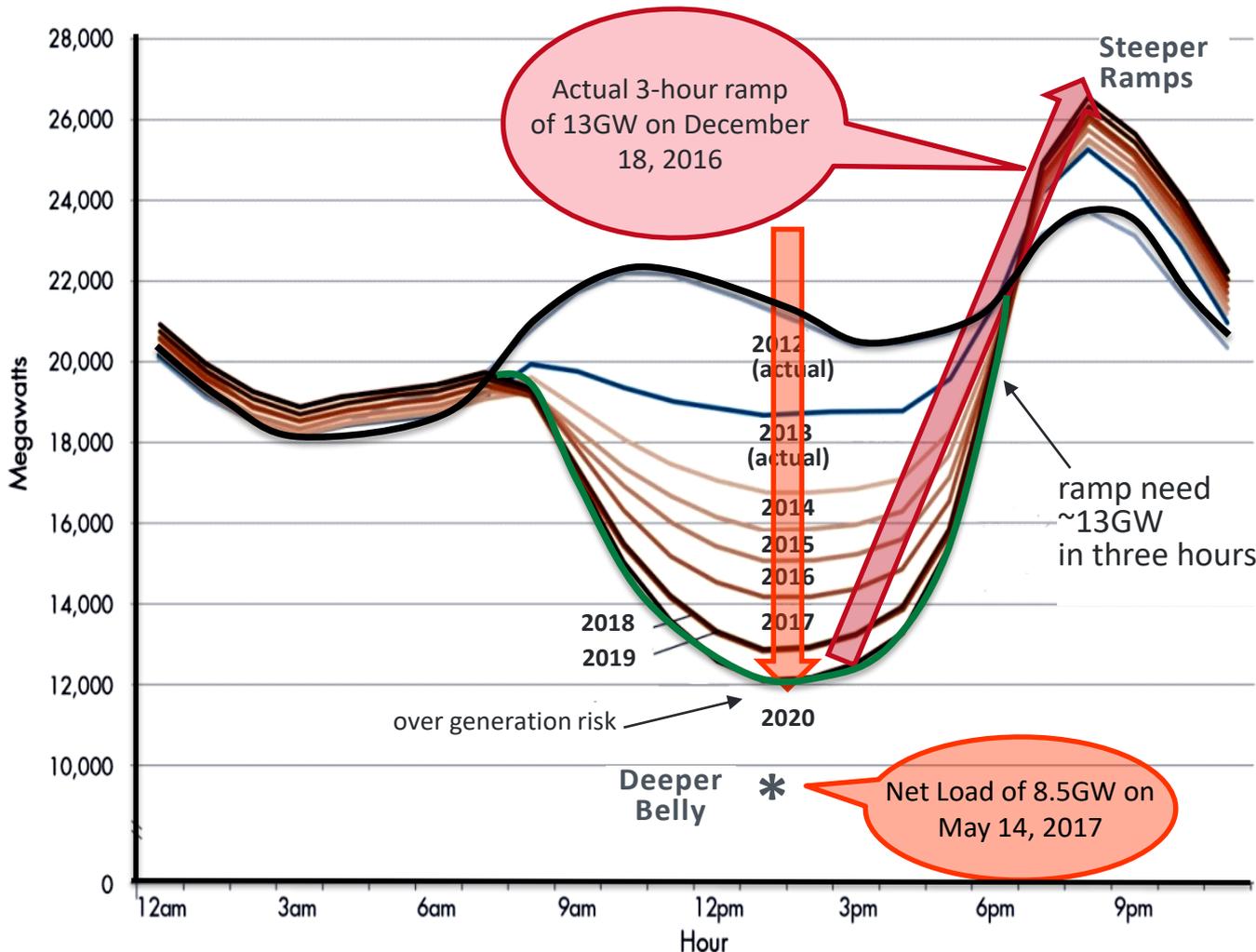
**Solar  
Productio  
n**

# The Duck's belly is getting bigger

## Two Concerns:

- **Low Net Load:**  
flexibility to reduce baseload generation resources is limited
- **High Ramp Rates in Evening:**  
flexibility of other generation to ramp up is limited

Can be addressed by



California Example- Source U.S. DOE Solar Energy Technologies Office

# U.S. DOE Fuel Cell Technologies Office

## Early R&D Focus

Applied research, development and innovation in emerging 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

- Production pathways
- Delivery components
- Advanced materials for storage

### Infrastructure

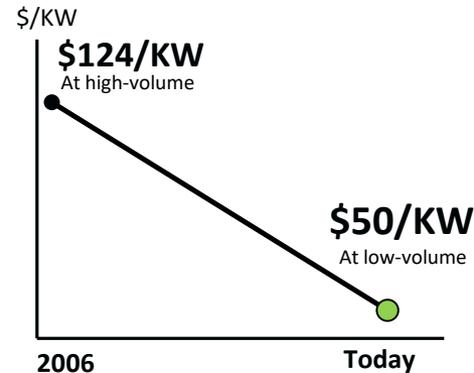
- Safety
- Manufacturing
- Delivery components
- Others

PGM = Platinum group metals

MEA = Membrane Electrode Assembly

## Impact

### 60% Lower Fuel Cell Cost



### Greater Fuel Cell Durability

**4X** more hours of fuel cell lifetime since 2006

### 80% Lower Electrolyzer Cost

for H<sub>2</sub> production since 2002

**Budget: \$120M**  
**Fiscal Year 2019**  
**DOE Fuel Cell Technologies Office**

**Projects with over 100 companies, universities, and national labs**

# Need to Address Challenges: Data Sharing Guides R&D

Through NREL's National Fuel Cell Technology Evaluation Center



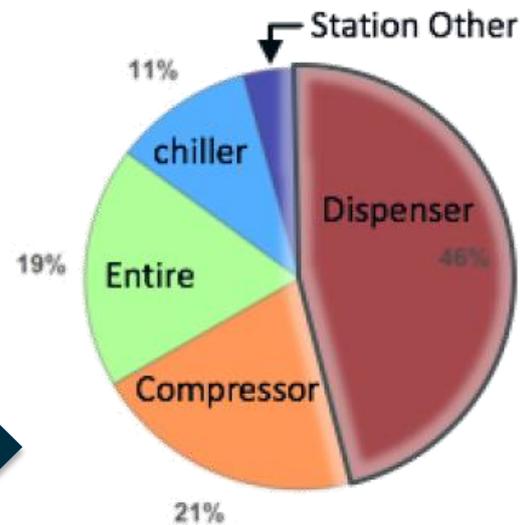
To Participate

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

Need to address  
infrastructure  
component reliability

- Visit: [energy.gov/eere/fuelcells/hydrogen-analysis-toolbox](https://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox)

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



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

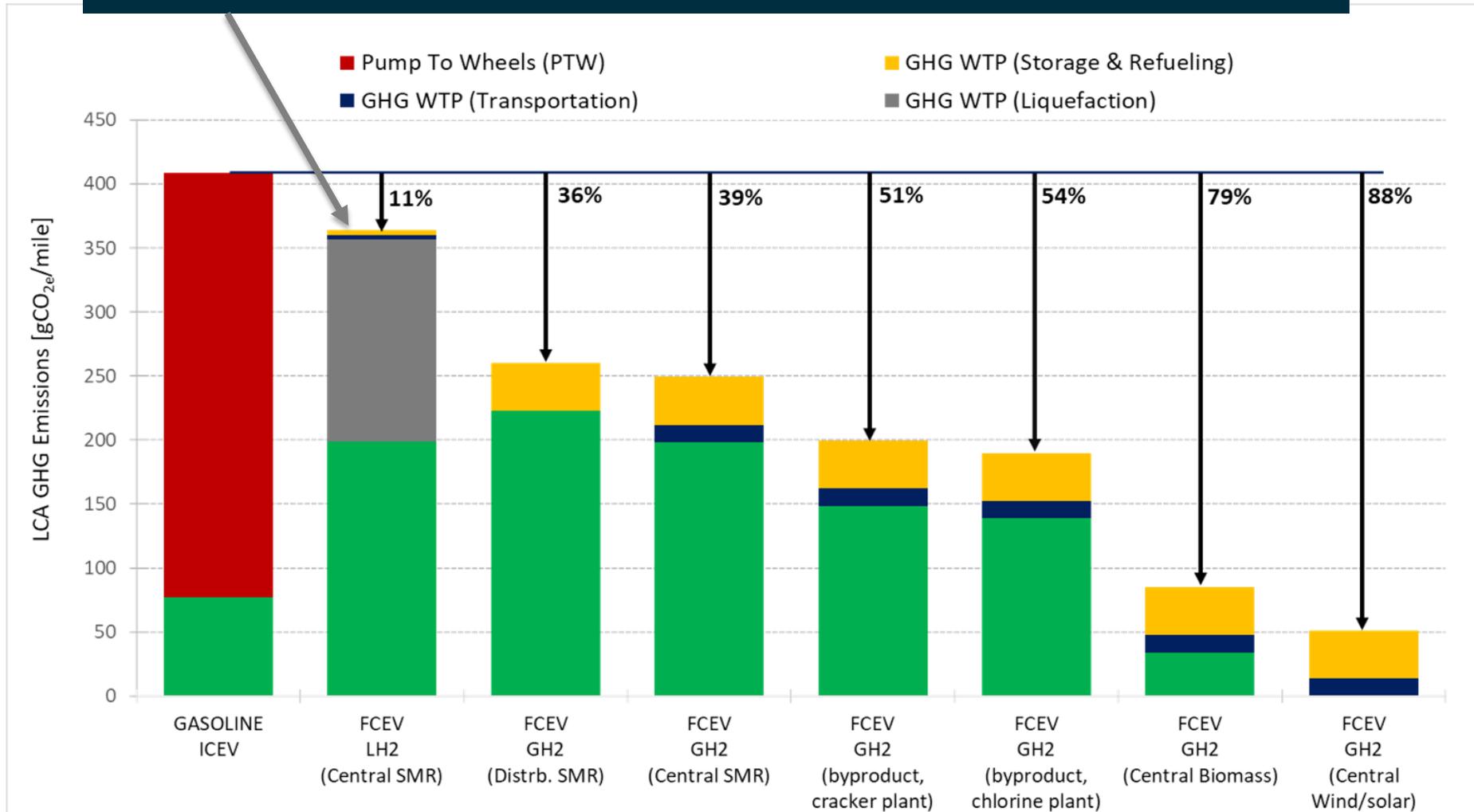
Maintenance by Equipment Type  
Retail Stations  
Total Events: 4,663  
Dispenser: 46% of Events



Source: U.S. DOE Fuel Cell Technologies Office

# Example of R&D Needs: Upstream Hydrogen Delivery & Dispensing Must be Improved

## R&D needed to improve liquefaction efficiency



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

Where we find abundant solar and wind energy



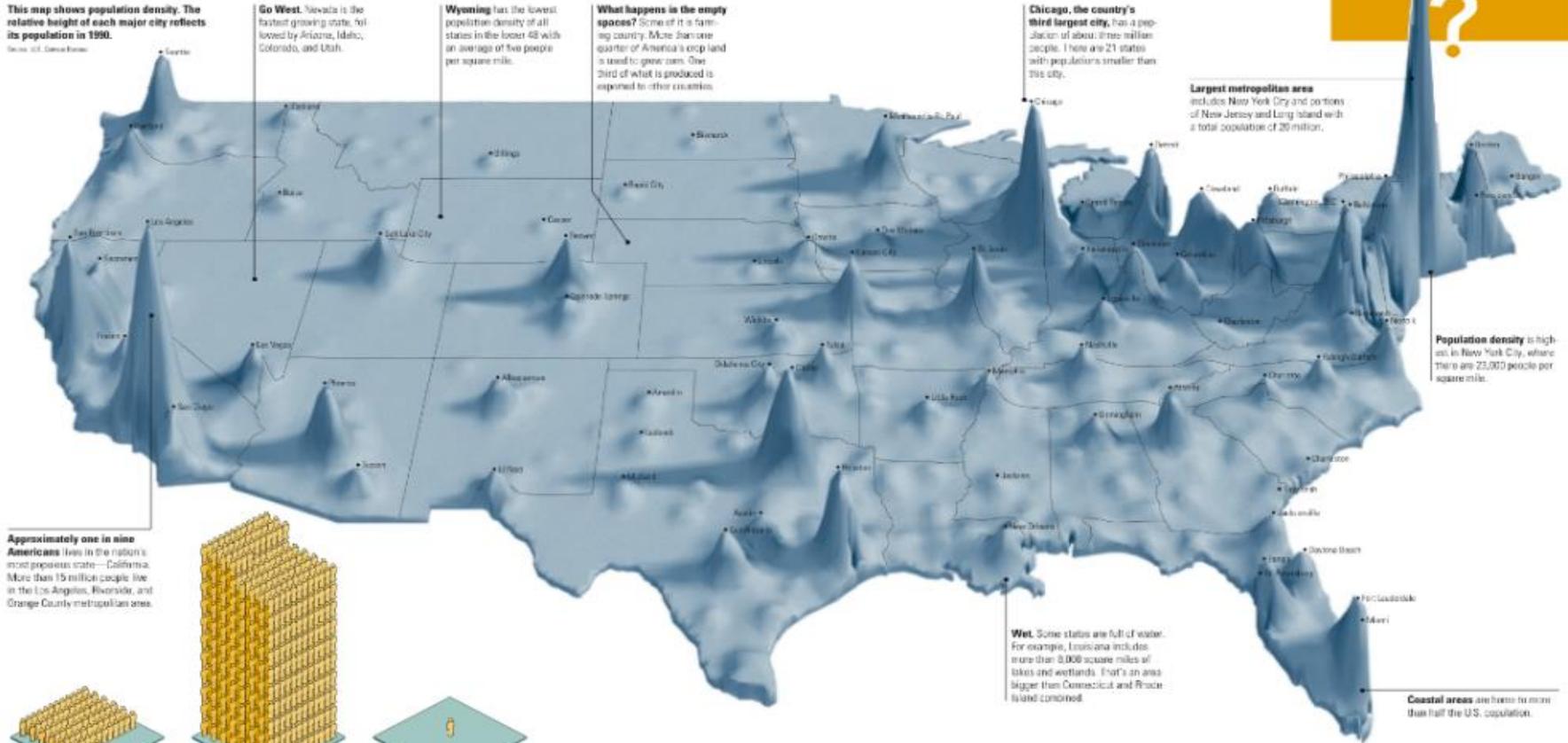
# ...and deliver it or co-locate distributed generation with demand for certain applications

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



**Go West.** Nevada is the fastest growing state, followed by Arizona, Idaho, Colorado, and Utah.

**Wyoming** has the lowest population density of all states in the lower 48 with an average of two people per square mile.

**What happens in the empty spaces?** Some of it is farming country. More than one quarter of America's crop land is used to grow corn. One third of what is produced is exported to other countries.

**Chicago, the country's third largest city,** has a population of about three million people. There are 21 states with populations smaller than this city.

**Largest metropolitan area** includes New York City and portions of New Jersey and Long Island with a total population of 20 million.

**Population Distribution**

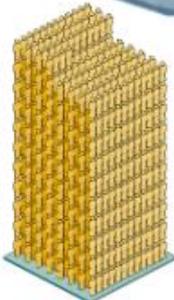
*Where do we live?  
Where don't we live?*

**Population density is highest** in New York City, where there are 23,000 people per square mile.

**Approximately one in nine Americans** live 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.

**Wet.** Some states are full of water. For example, Louisiana includes more than 8,000 square miles of lakes and wetlands. That's an area bigger than Connecticut and Rhode Island combined.

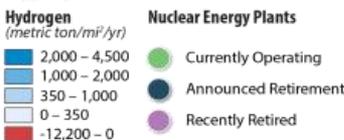
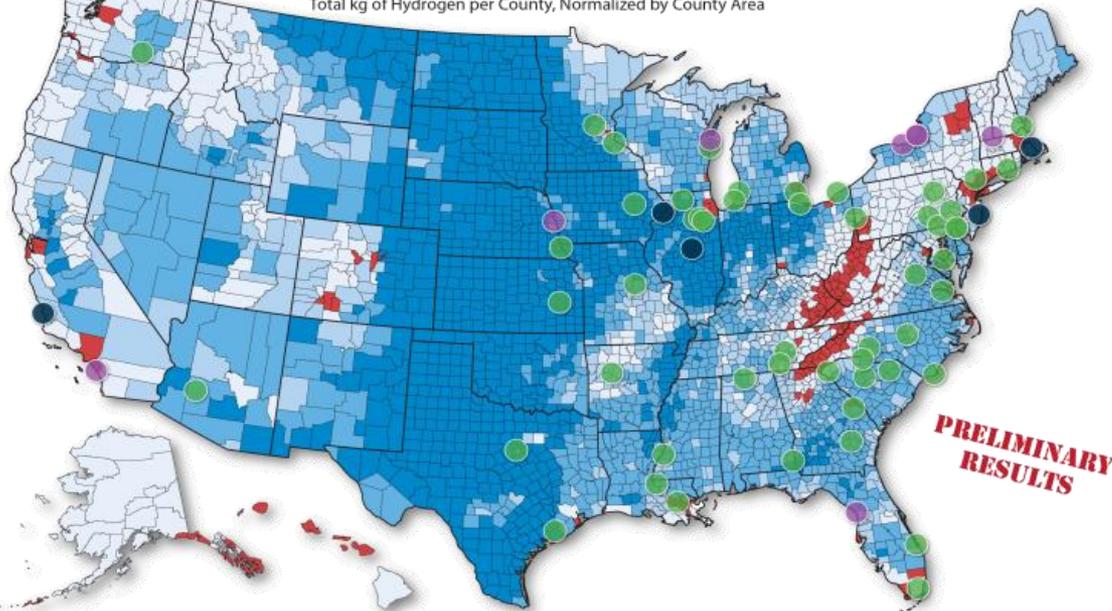
**Coastal areas** are home to more than half the U.S. population.

# 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



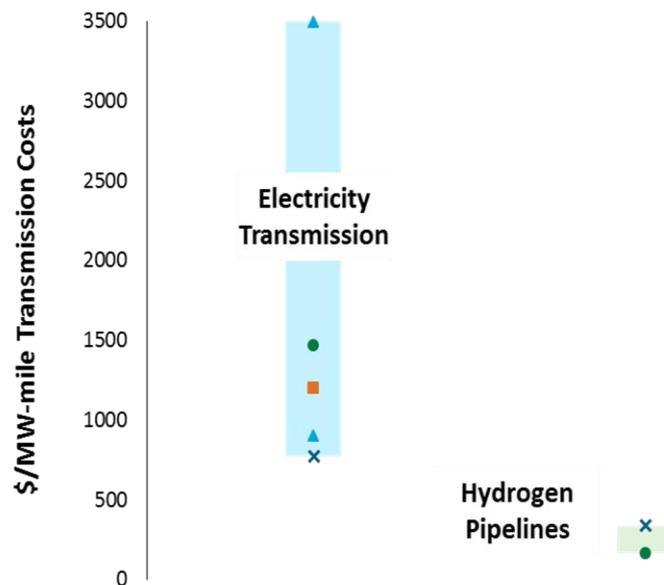
This analysis represents potential generation from utility-scale photovoltaics and onshore wind resources minus total hydrogen demand from the industrial sector: refineries, biofuels, ammonia and natural gas systems (metals are not included) and the transport sector: light duty vehicles and other transport. 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>

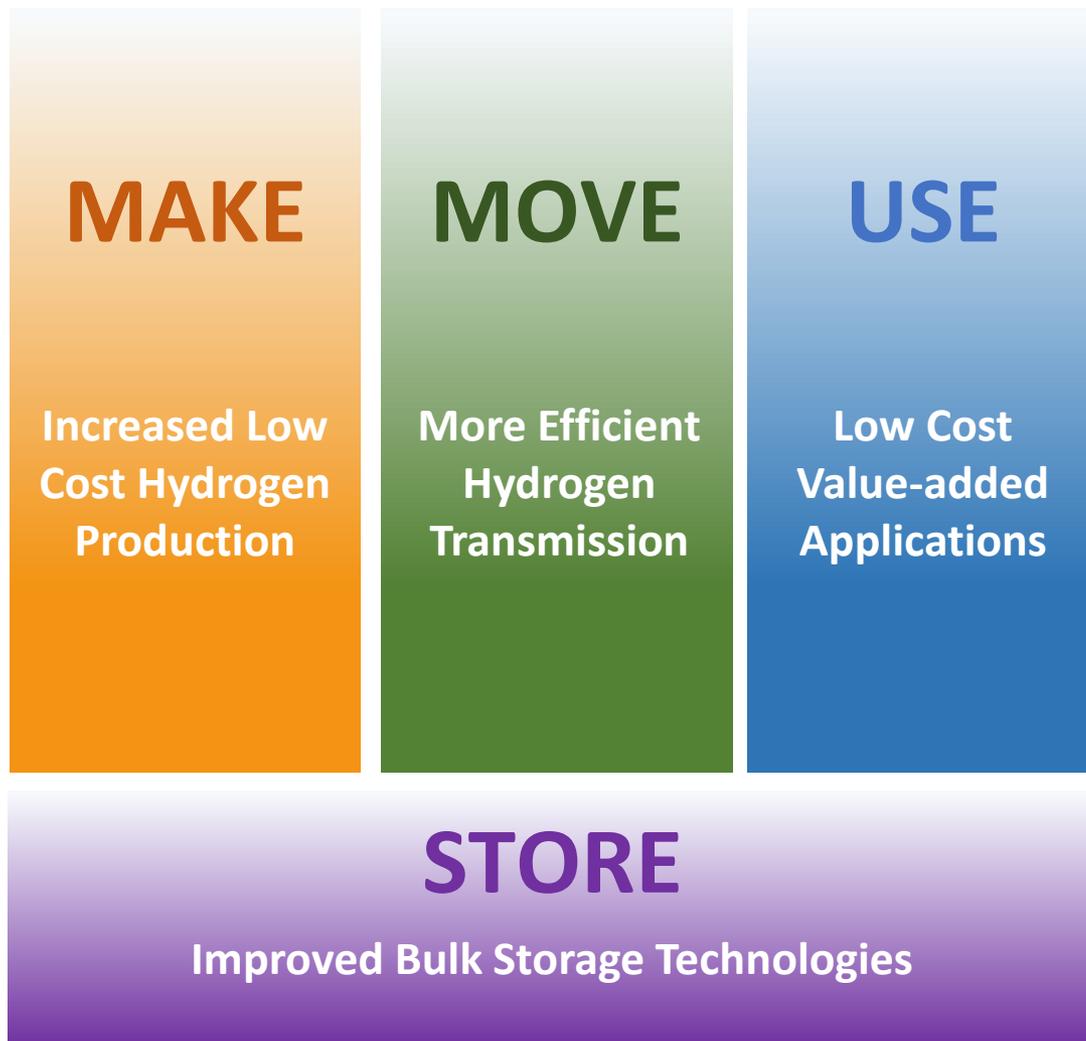
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy.  
Nicholas Gilroy, March 27, 2017

**NREL**  
NATIONAL RENEWABLE ENERGY LABORATORY

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



# Key focus areas to realize the H<sub>2</sub>@scale vision



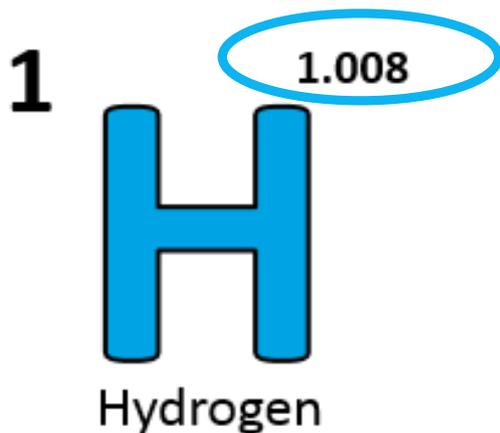
# Opportunities for outreach and to increase awareness

## 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  
 $\text{H}_2\text{IQ}$

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)

# Thank You

**Dr. Sunita Satyapal**

Director

Fuel Cell Technologies Office

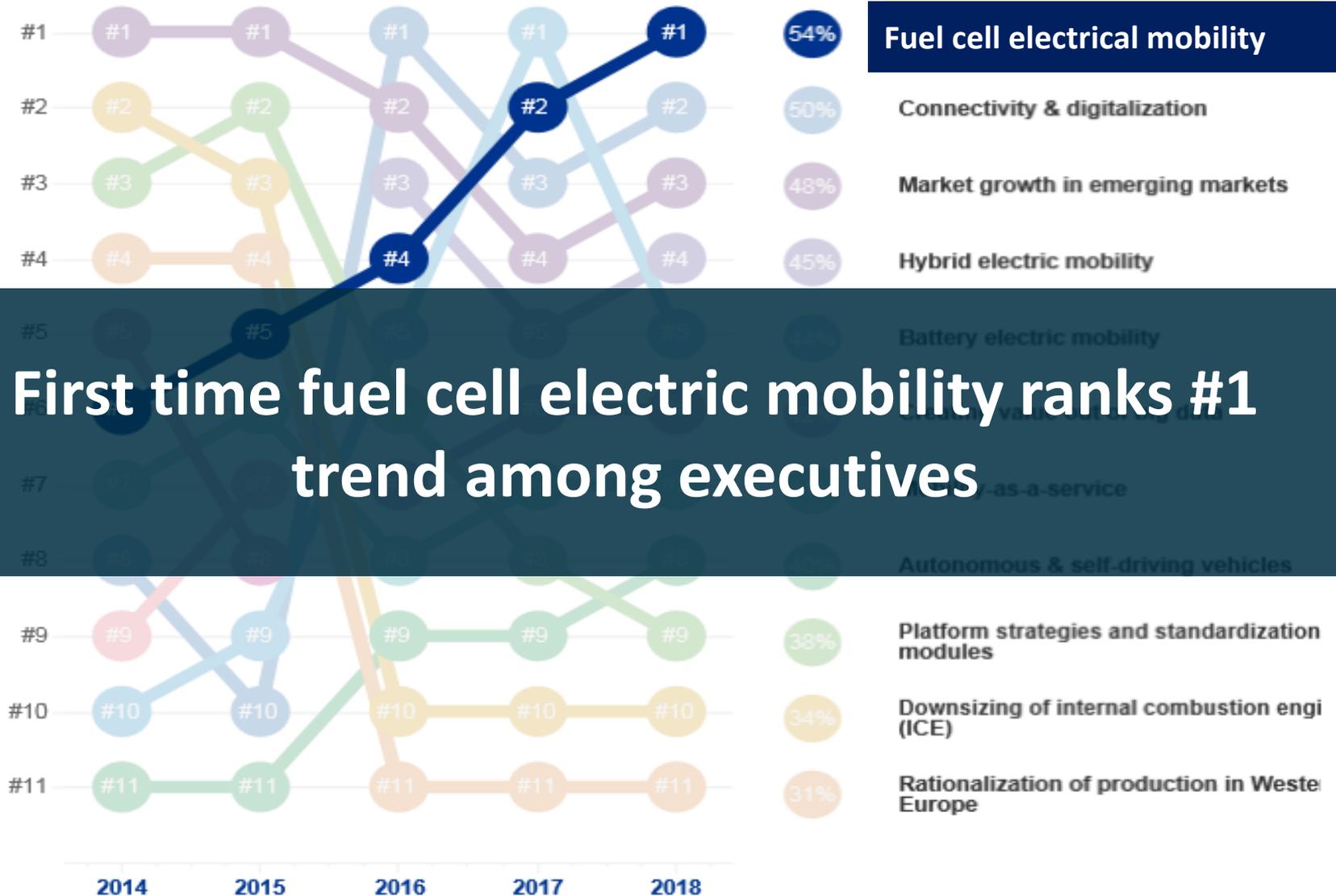
[Sunita.Satyapal@ee.doe.gov](mailto:Sunita.Satyapal@ee.doe.gov)

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

# IPHE: A Global Partnership Advancing Hydrogen and Fuel Cells Technology



# Automotive Executives Survey Results



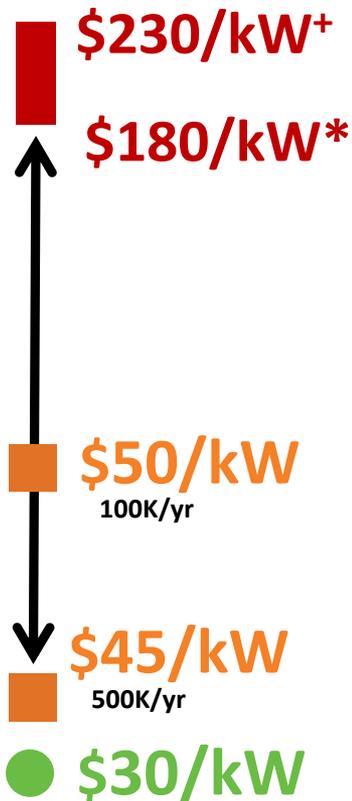
First time fuel cell electric mobility ranks #1 trend among executives

Source: KPMG Global Automotive Executive Survey 2018

# DOE Cost Status and Targets for R&D

## Fuel Cell R&D

### System

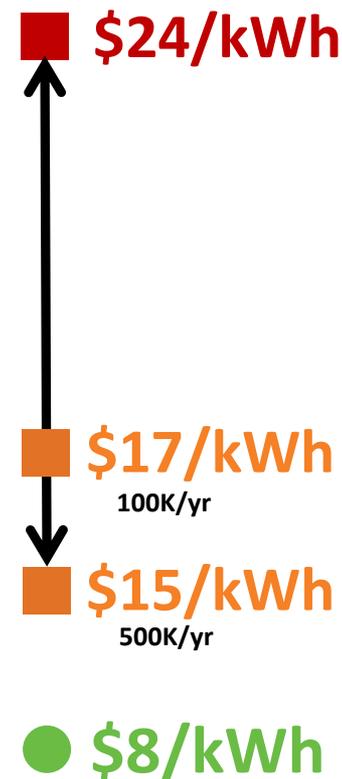


## Hydrogen R&D

### Production, Delivery & Dispensing



### Onboard Storage (700-bar compressed system)



\*Based on commercially available FCEVs

\*\*Based on state of the art technology

<sup>+</sup>Range assumes current production from NG and delivery and dispensing.

<sup>\*</sup>Highest possible cost at high vol., assumes H2 from electrolysis at \$5/gge and delivery via pipelines and liquid tankers at \$5/gge

<sup>\*\*</sup>Lowest possible cost at high vol., assumes H2 from SMR at \$2/gge and delivery via tube trailer at \$3/gge

● Ultimate Targets

■ High-Volume Projection

■ Low-Volume Estimate

Notes: Graphs not drawn to scale and are for illustration purposes only. gge: gallon of gasoline equivalent