

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

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IPHE Industry Forum

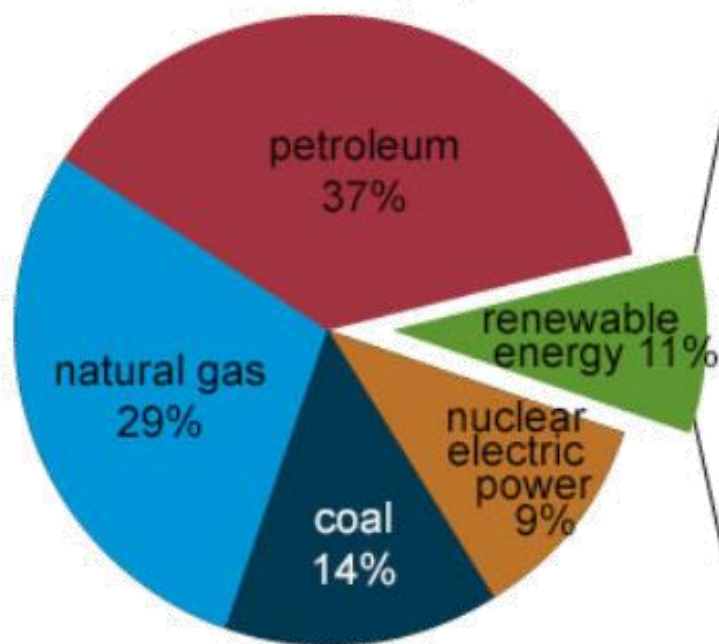
Pretoria, South Africa – December 5, 2018



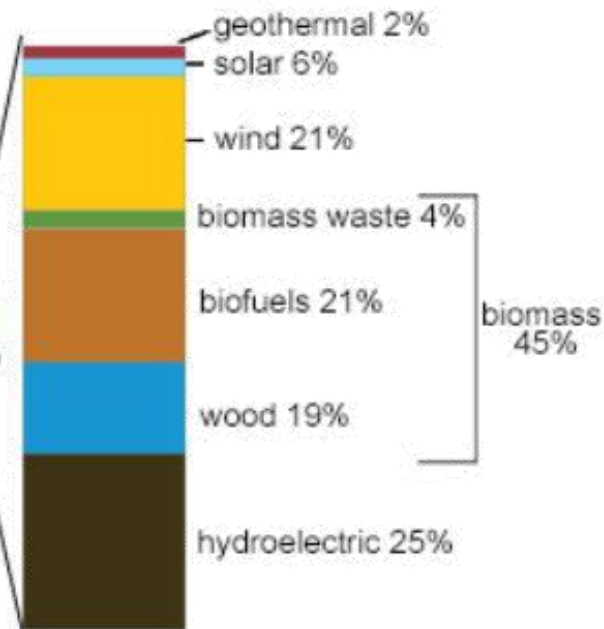
U.S. energy mix covers wide of energy sources

U.S. energy consumption by energy source, 2017

Total = 97.7 quadrillion
British thermal units (Btu)



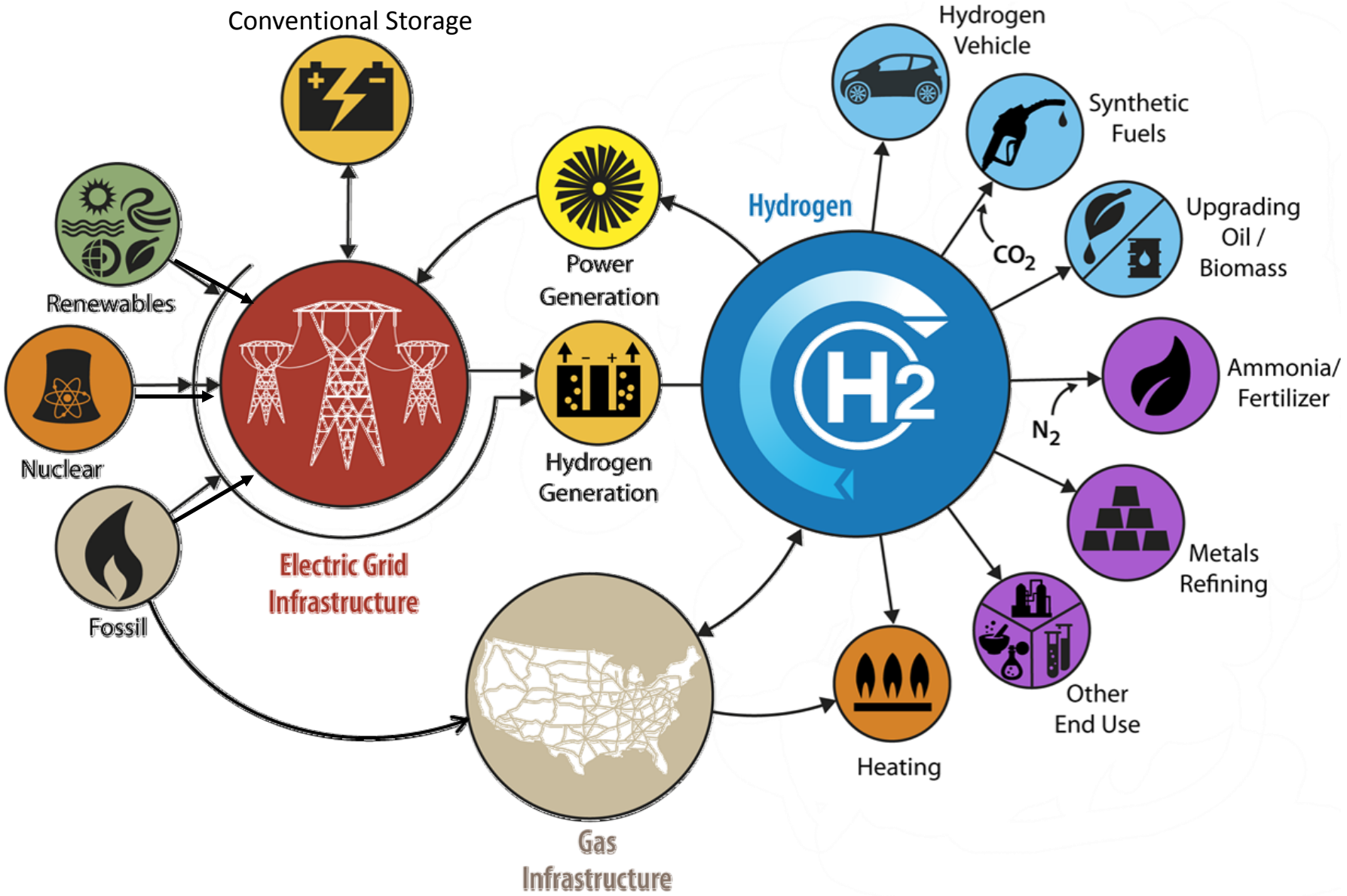
Total = 11.0 quadrillion Btu



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



H₂@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

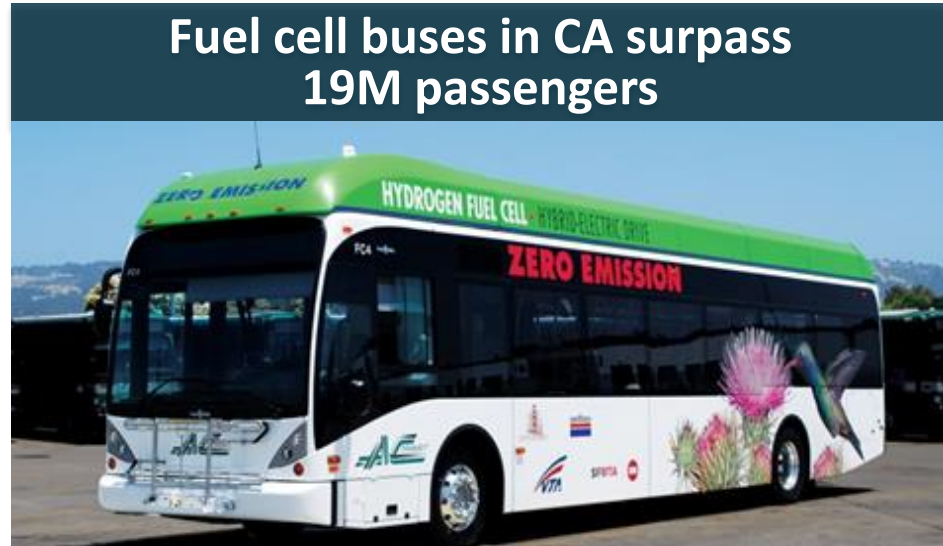
More than **23,000** forklifts

Over **15 million** refuelings

Long-Range, Heavy Duty Applications Emerging



Fuel cell delivery and parcel trucks operating in CA and NY



Fuel cell buses in CA surpass 19M passengers

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

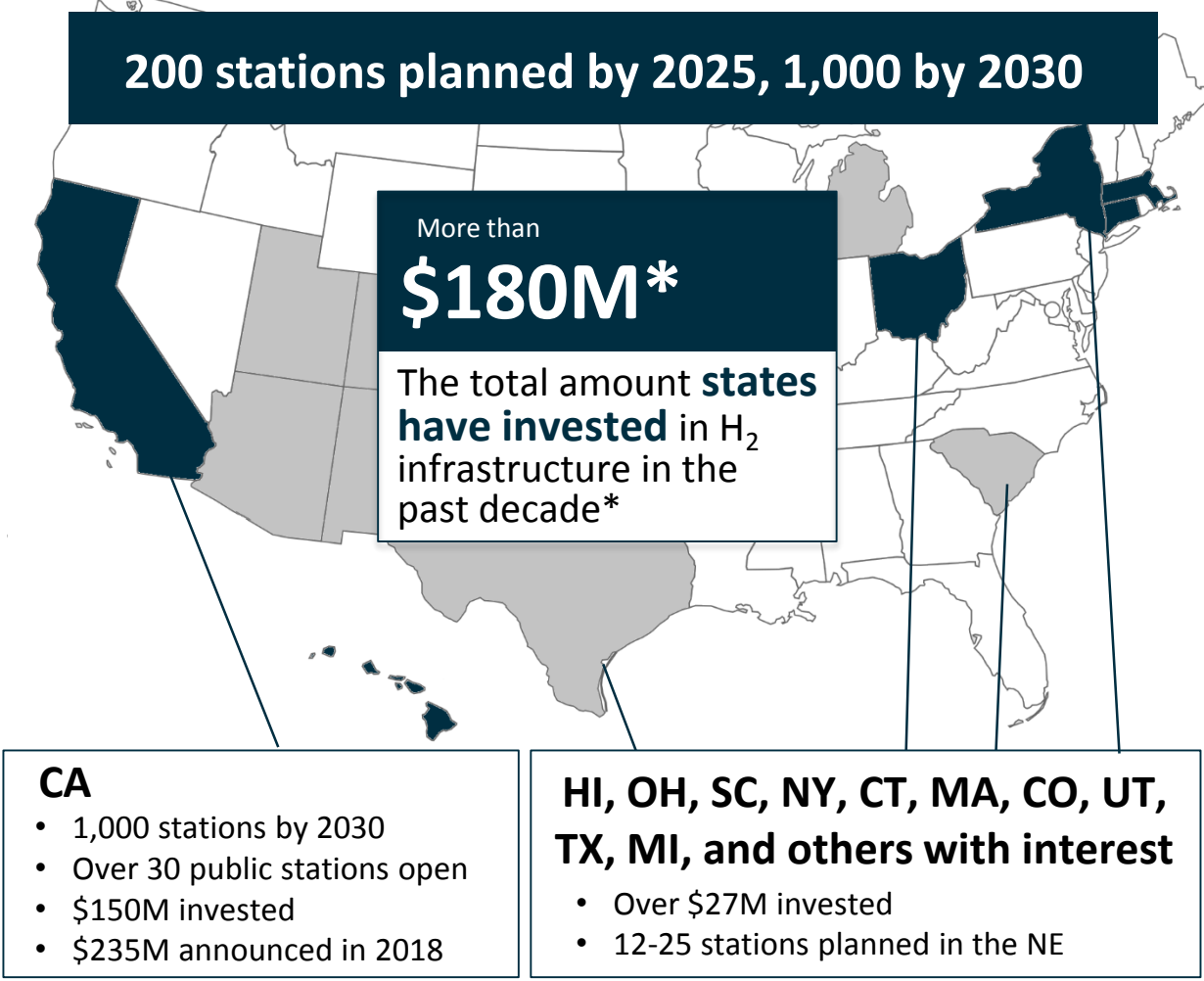


Multiple H₂ and Fuel Cell Applications in the U.S.

U.S. Snapshot

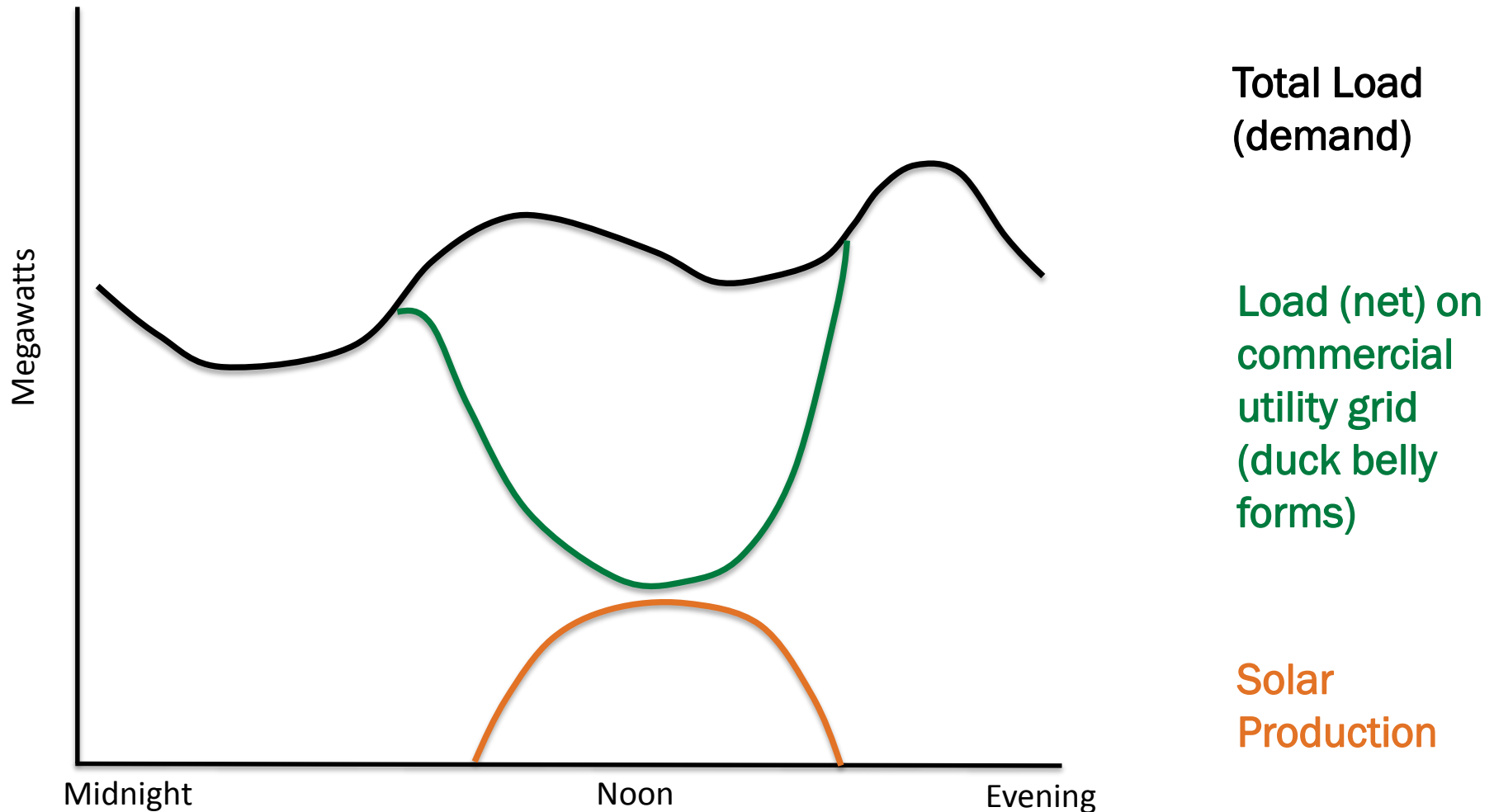
	Over >240MW Backup Power
	More than 23,000 Forklifts
	More than 30 Fuel Cell Buses
	36 H ₂ Retail Stations
	Nearly 5,800 Fuel Cell Cars

States with Growing Interest



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

New Driver: The Duck Curve Example

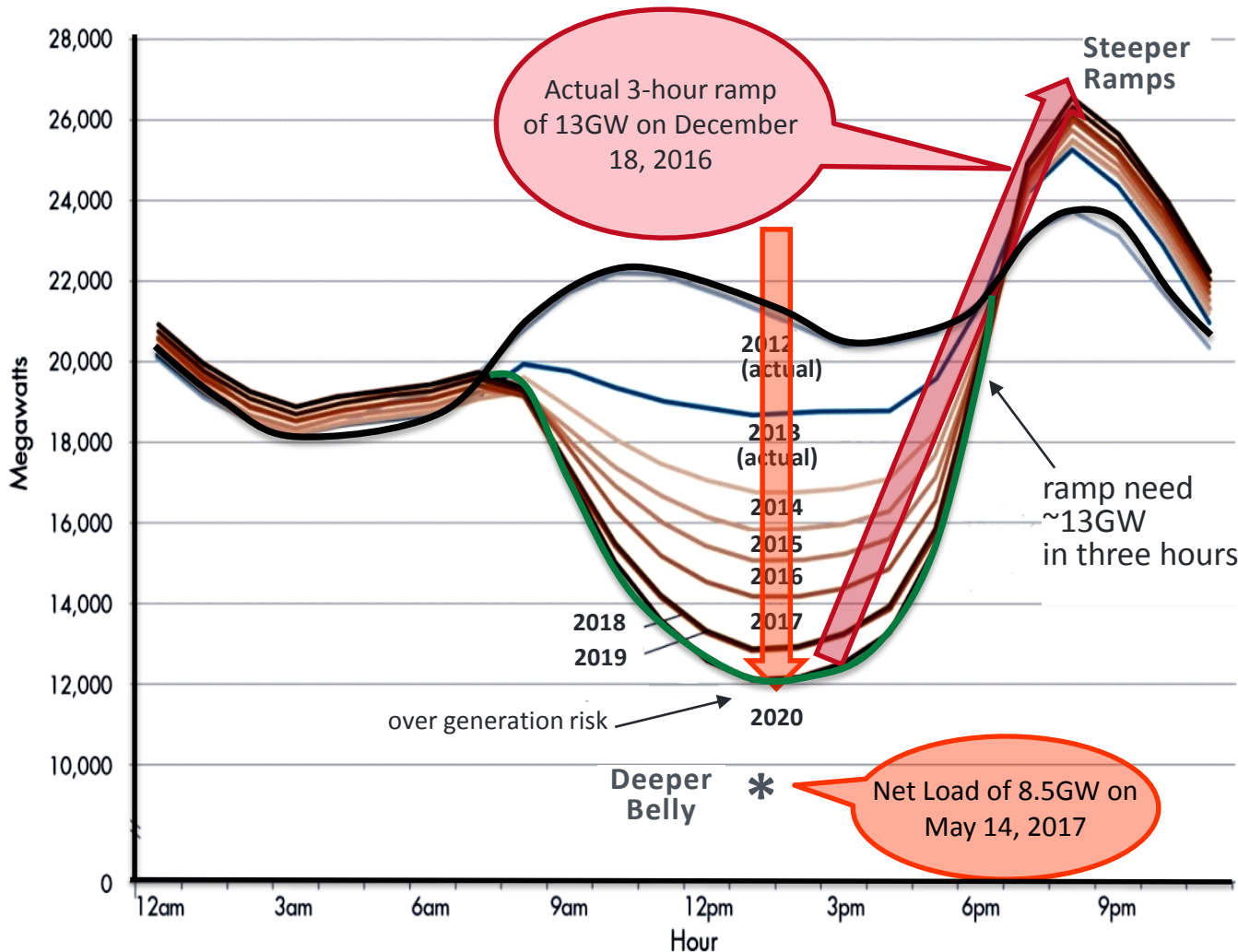


The Duck's belly is getting bigger

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

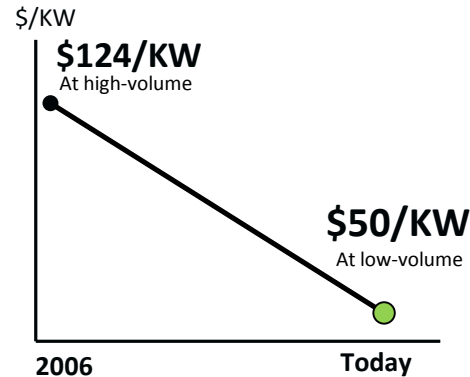
- Safety
- Manufacturing
- Delivery components
- Others

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 H₂ 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



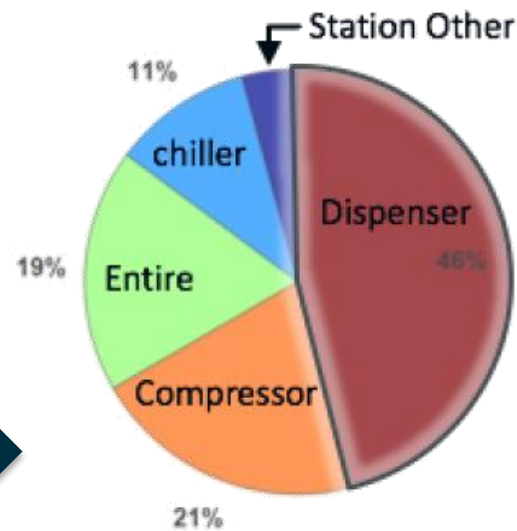
To Participate

techval@nrel.gov

Need to address
infrastructure
component reliability

- Visit: energy.gov/eere/fuelcells/hydrogen-analysis-toolbox

Example: Sources of H₂ Infrastructure Maintenance



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

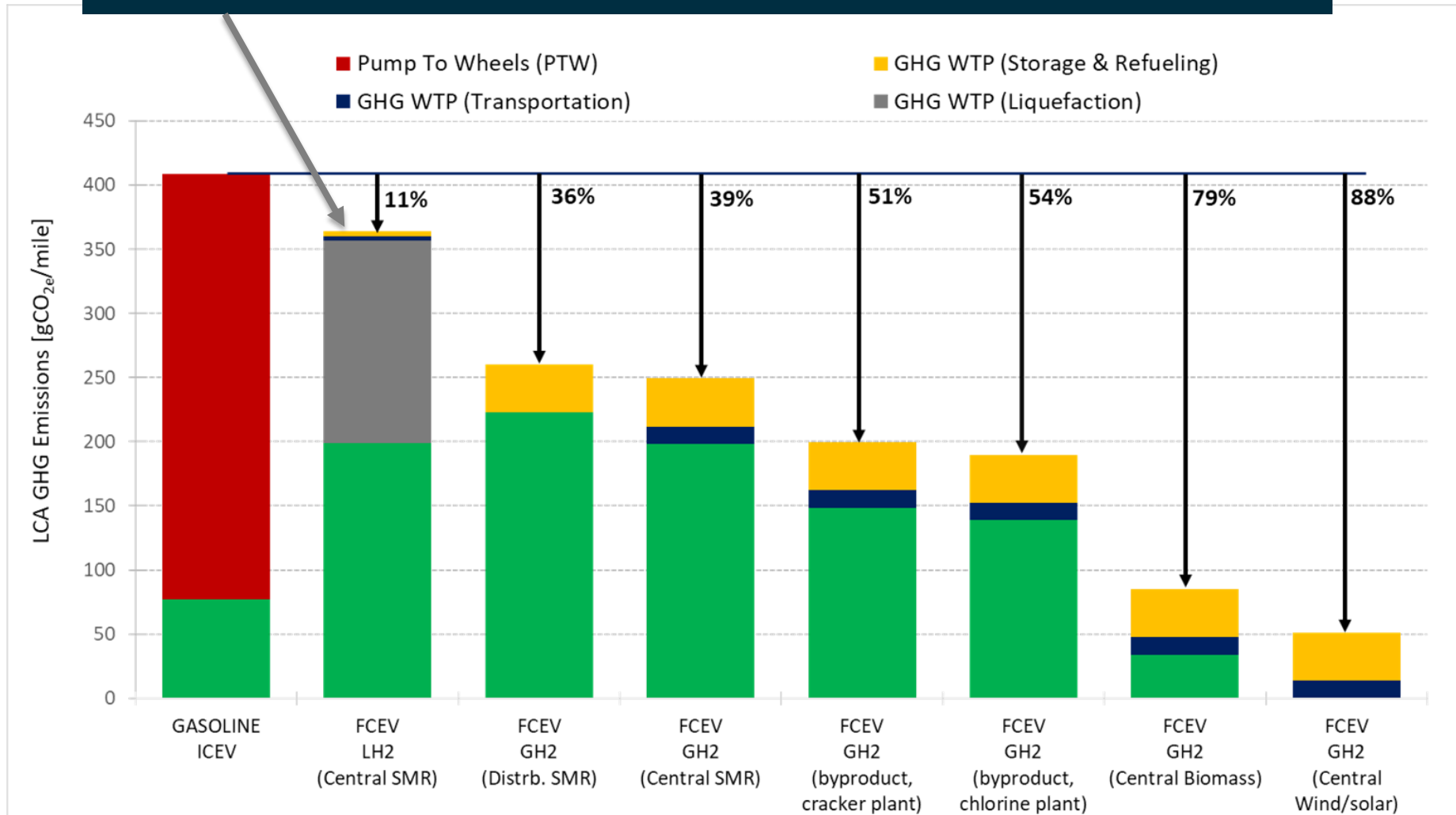
Maintenance by Equipment Type
Retail Stations
Total Events: 4,663
Dispenser: 46% of Events



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



H₂@Scale: Enabling renewable energy transport?

Where we find abundant solar and wind energy



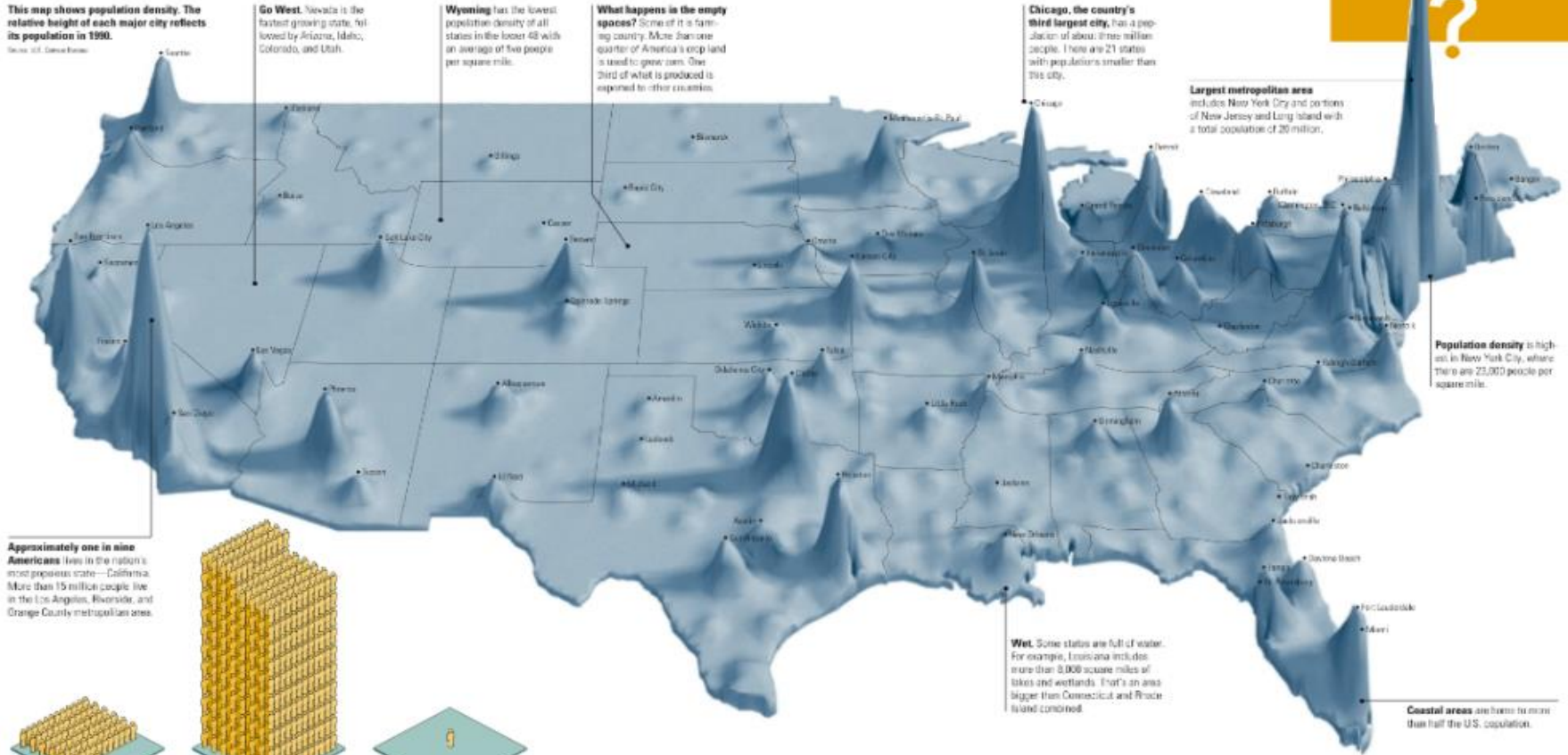
...and deliver it or co-locate distributed generation with demand for certain applications

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

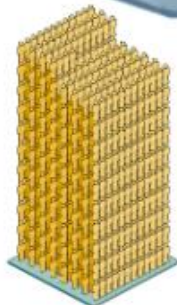
*Where do we live?
Where don't we live?*

?

Approximately one in nine Americans 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.



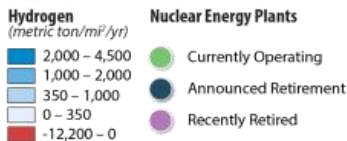
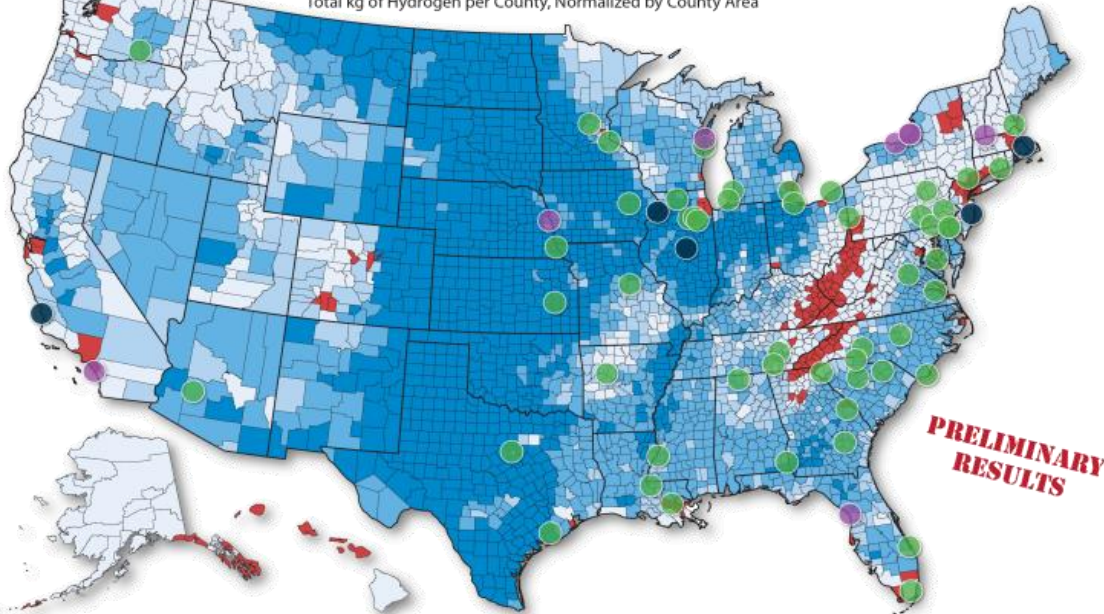
Alaska is a sparsely populated state with an average of one person per square mile.

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.

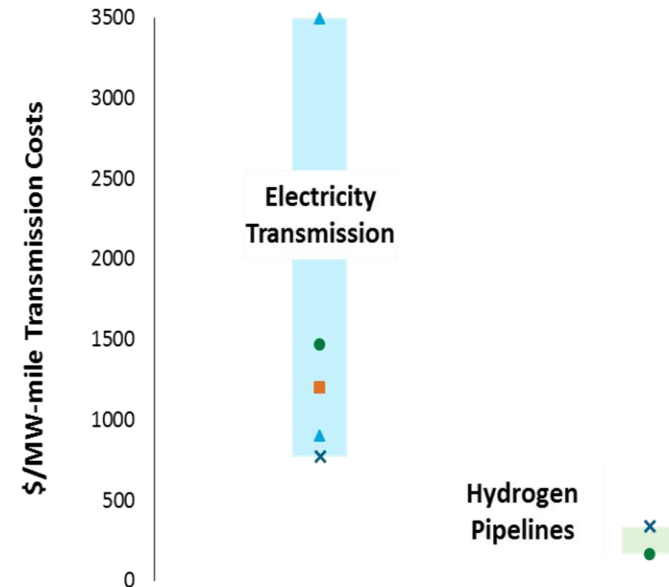
Data Source: NREL analysis
Robson, A. Preserving America's Clean Energy Foundation. Retrieved March 23, 2017, from <http://www.thirdway.org/report/preserving-americas-clean-energy-foundation>

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

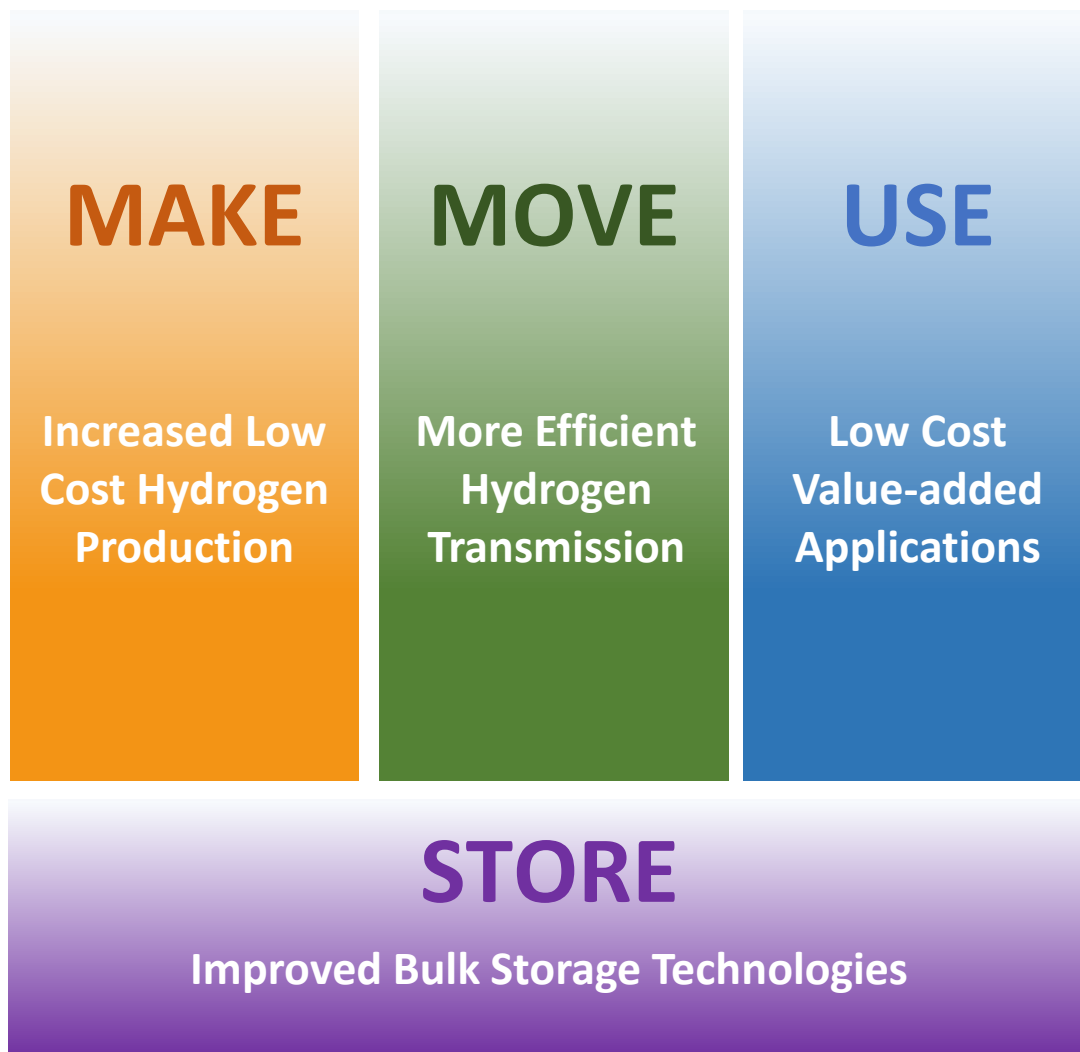
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Assessing cost of H₂ vs electricity transmission

(in process)



Key focus areas to realize the H₂@scale vision



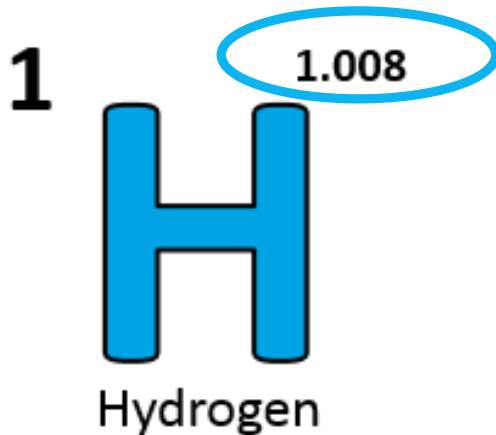
Opportunities for outreach and to increase awareness

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
H₂IQ

Download for free at:

energy.gov/eere/fuelcells/downloads/increase-your-h2iq-training-resource

Learn more at: energy.gov/eere/fuelcells

Thank You

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energy.gov/eere/fuelcells