



U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

H2@Scale: Progress, Opportunities and Needs

Dr. Shuk Chan - Fuel Cell Technologies Office

NELHA ESS 2018 Conference

Kailua-Kona, Hawaii – December 6, 2018



EERE Fuel Cell Technologies Office (FCTO)

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

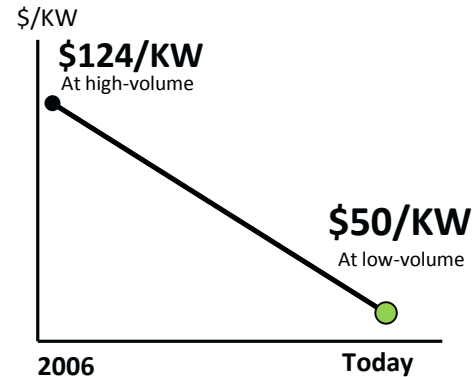
- Safety
- Manufacturing
- Delivery components
- Others

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

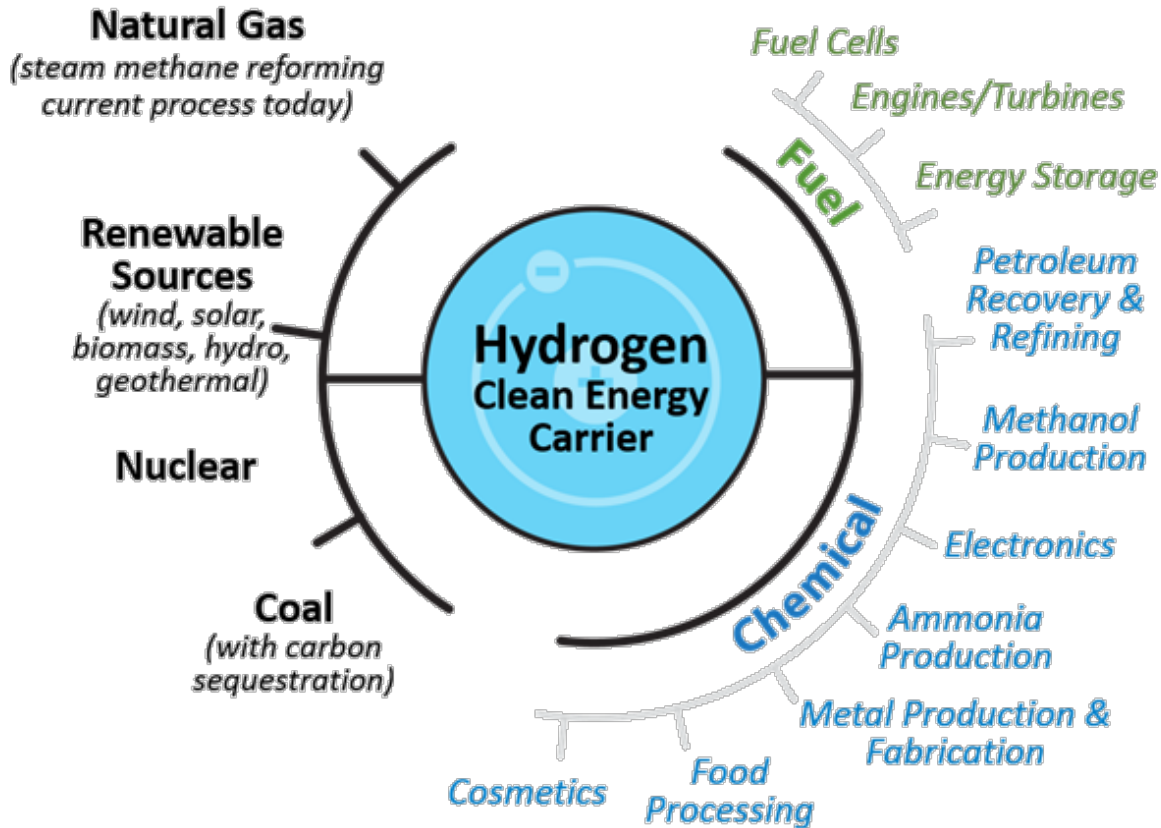
Enabling



Hydrogen is one part of an 'all of the above' portfolio

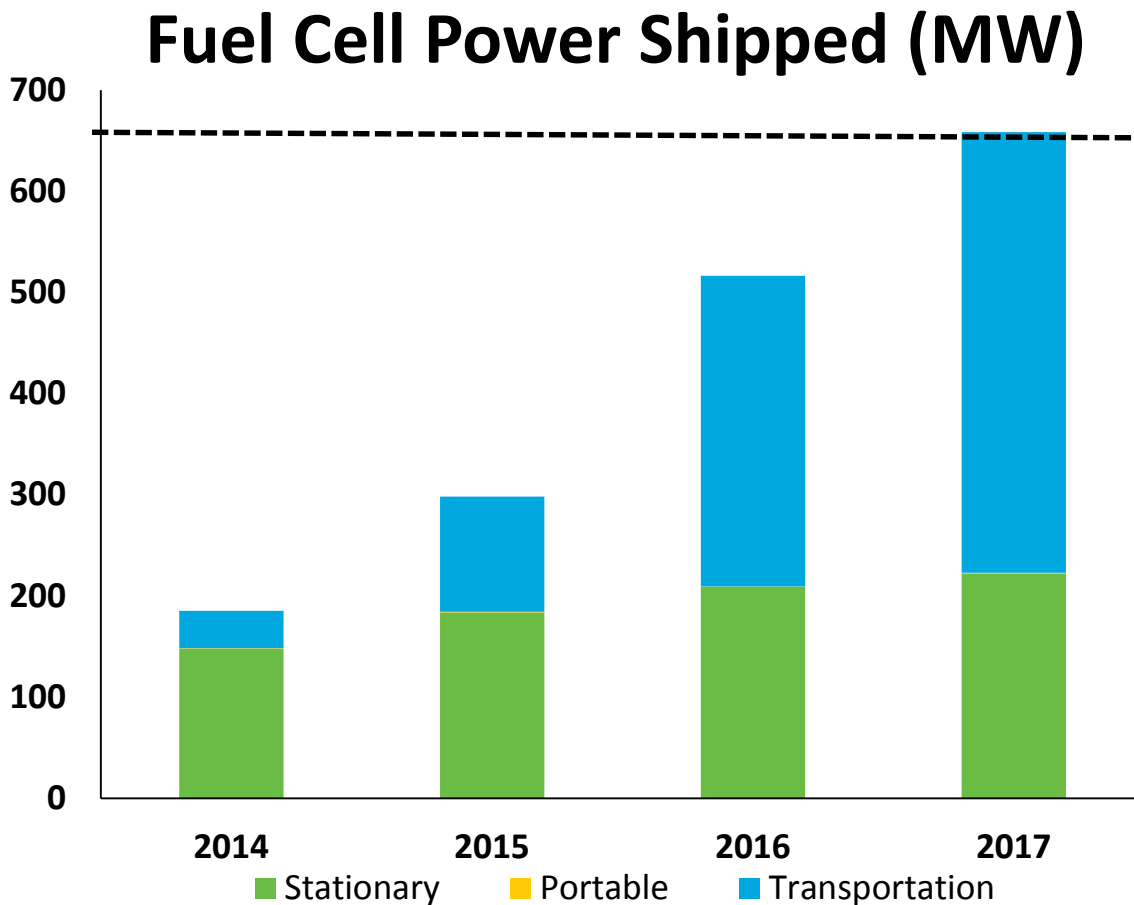
H₂ can be produced from diverse domestic sources

Many applications rely on or could benefit from H₂



Clean , sustainable, versatile, and efficient energy carrier

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

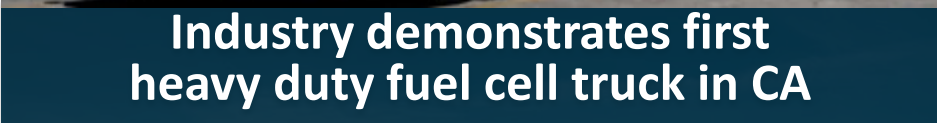
Long-Range, Heavy Duty Applications Emerging



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

Stationary Power Applications Emerging

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

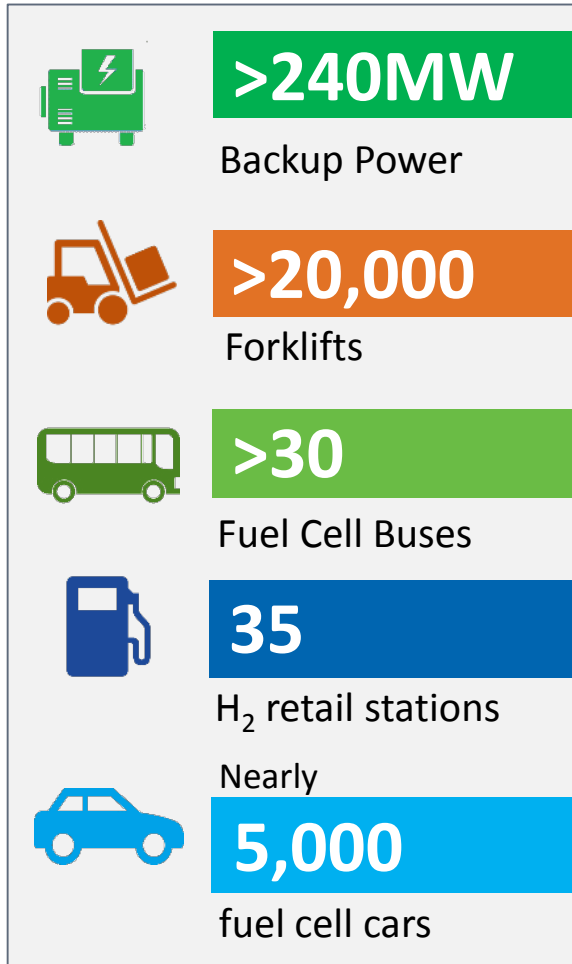


Over 240 MW of fuel cell stationary power installed across more than 40 US states

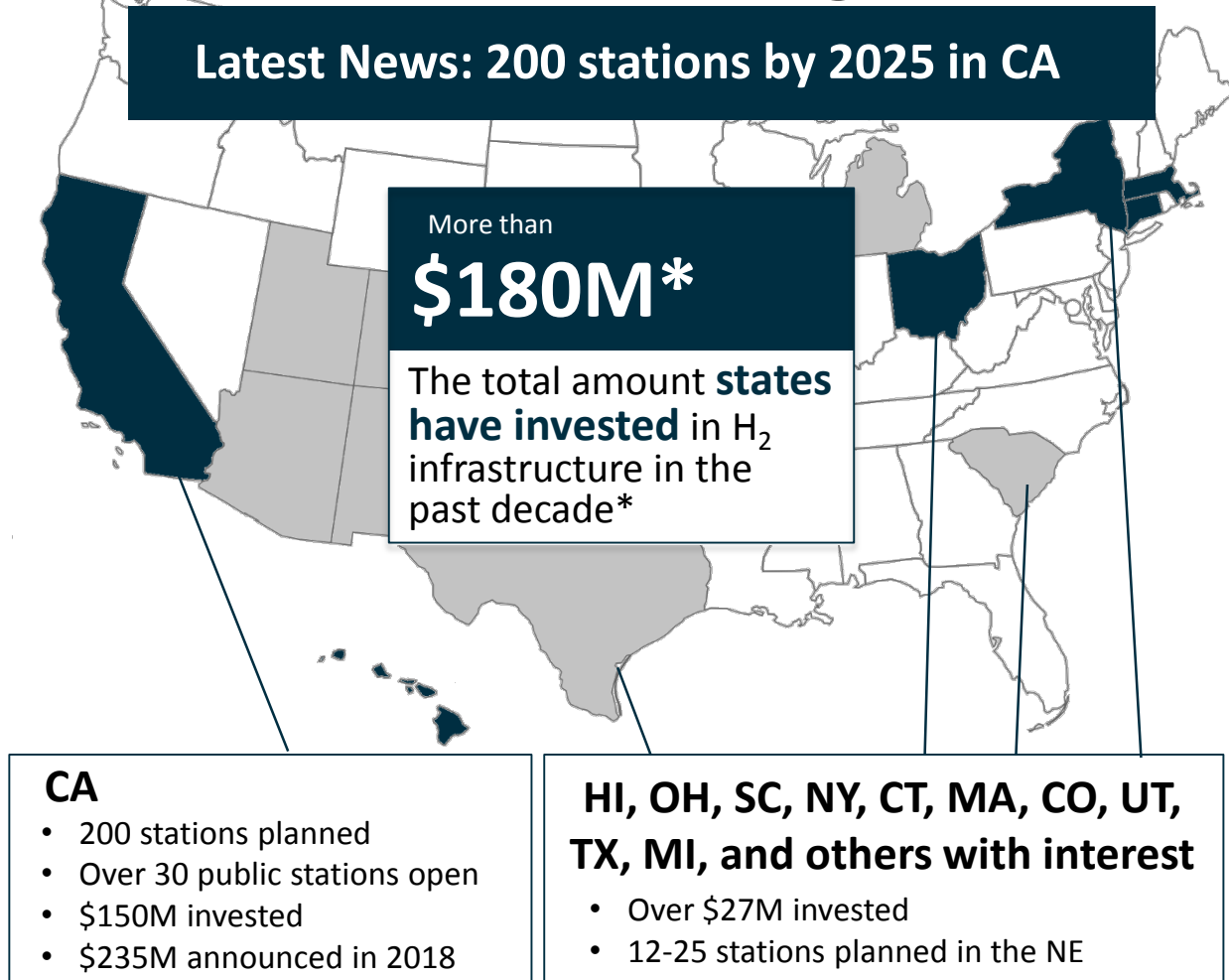


Multiple H₂ and Fuel Cell Applications in the U.S.

U.S. Snapshot



States with Growing Interest



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

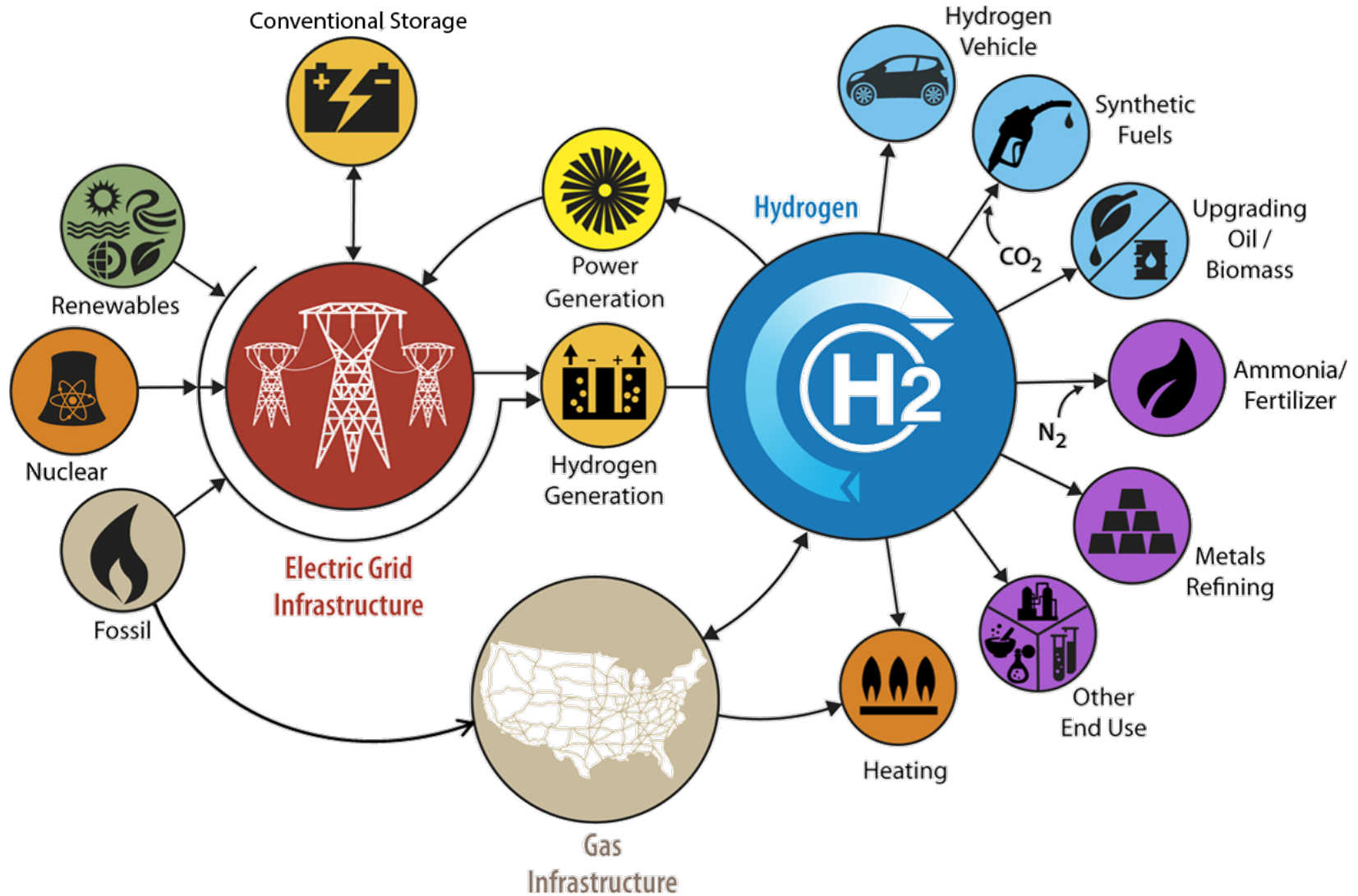


H₂@Scale concept

Vision

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

H₂@scale: Enabling affordable, reliable, clean, and secure energy across sectors



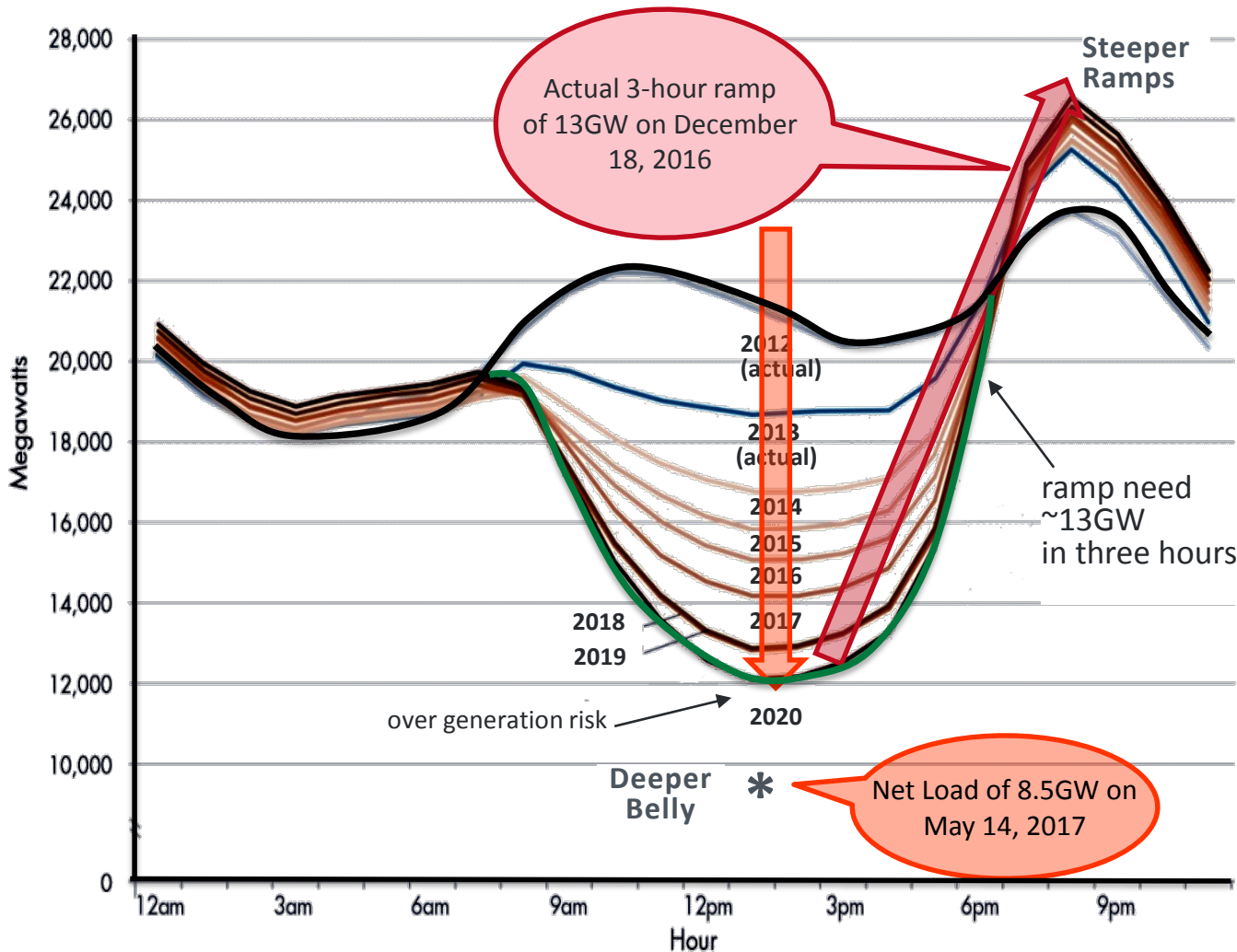
More information at: www.energy.gov/eere/fuelcells/h2-scale

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

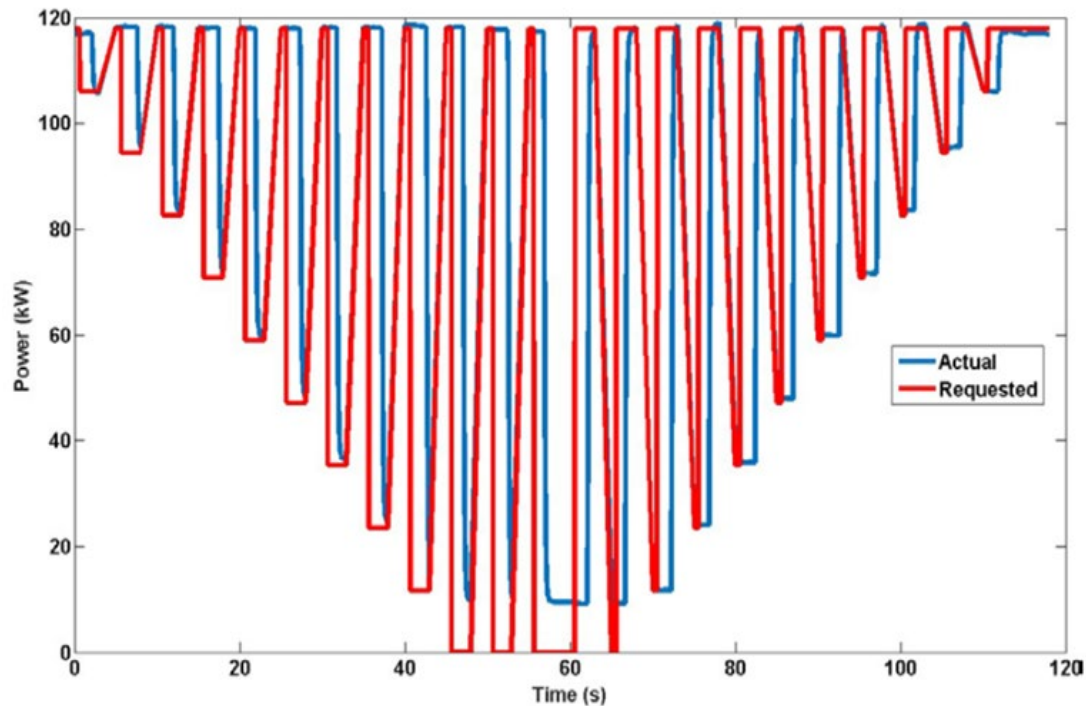
Can be addressed by



Source U.S. DOE Solar Energy Technologies Office

Lab testing electrolyzers' value for ancillary services

First Ever Validation of Frequency Regulation with Electrolyzers

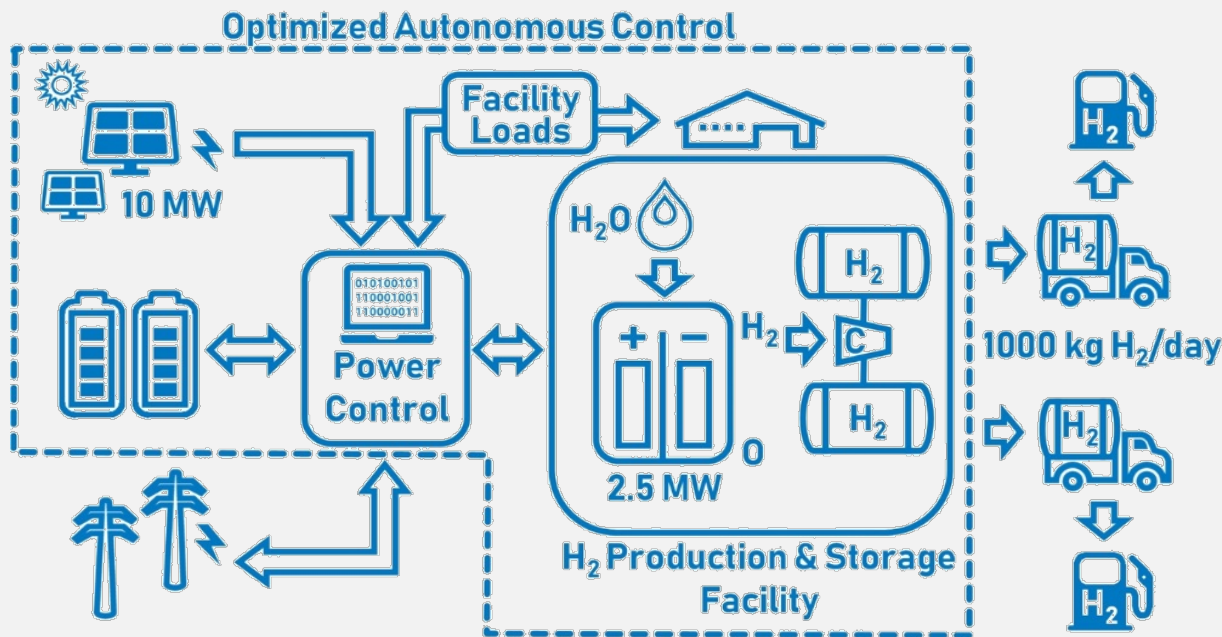


Lab testing shows dynamic response within seconds and potential for grid services



Integrated control & dispatch of renewable hydrogen

Goal: Demonstrate a 100% renewable hydrogen end-to-end supply chain

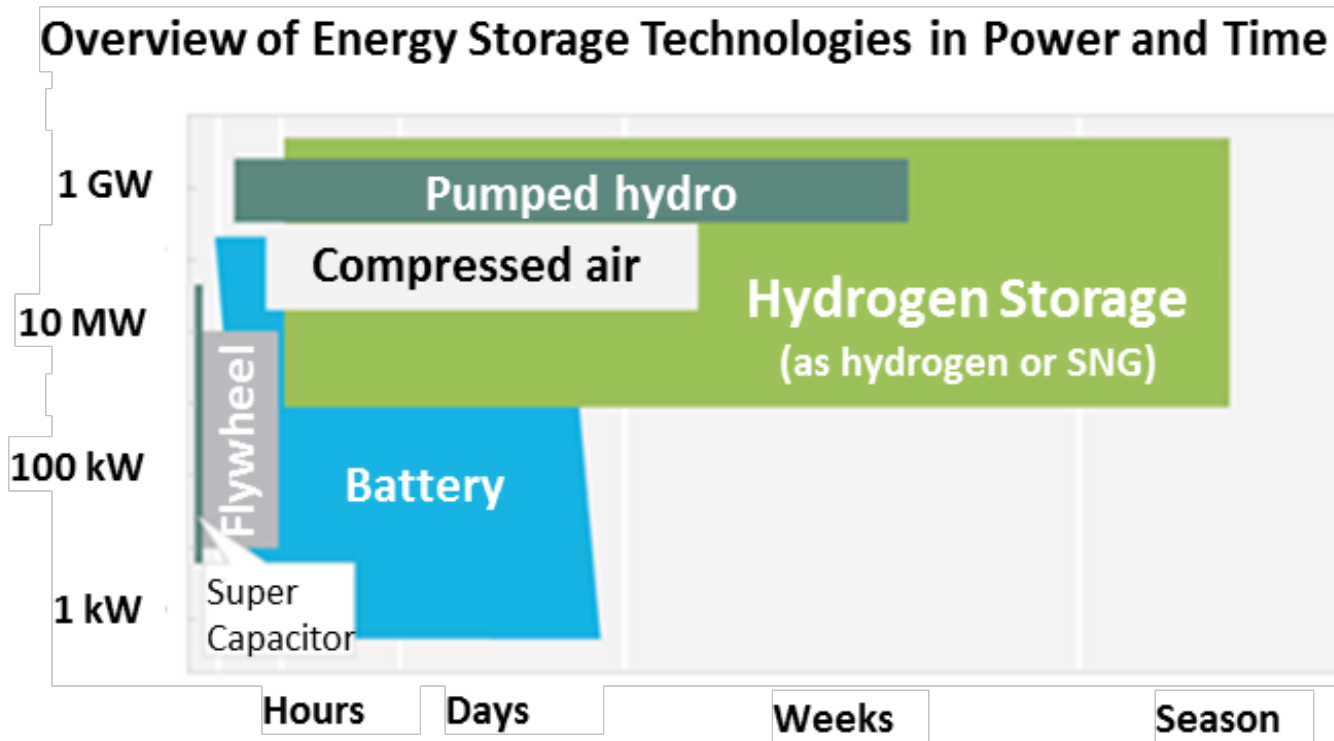


System integrates:

1. **Autonomous controlled hydrogen export terminal**
2. **Frequency regulation and demand response** through control and dispatch of electrolyzer and battery systems
3. **Optimized dispatch of electricity** to meet customer demand.

Impact: Reduced operating costs, increased renewable H₂ production from highly integrated projects

Hydrogen Energy Storage is Scalable



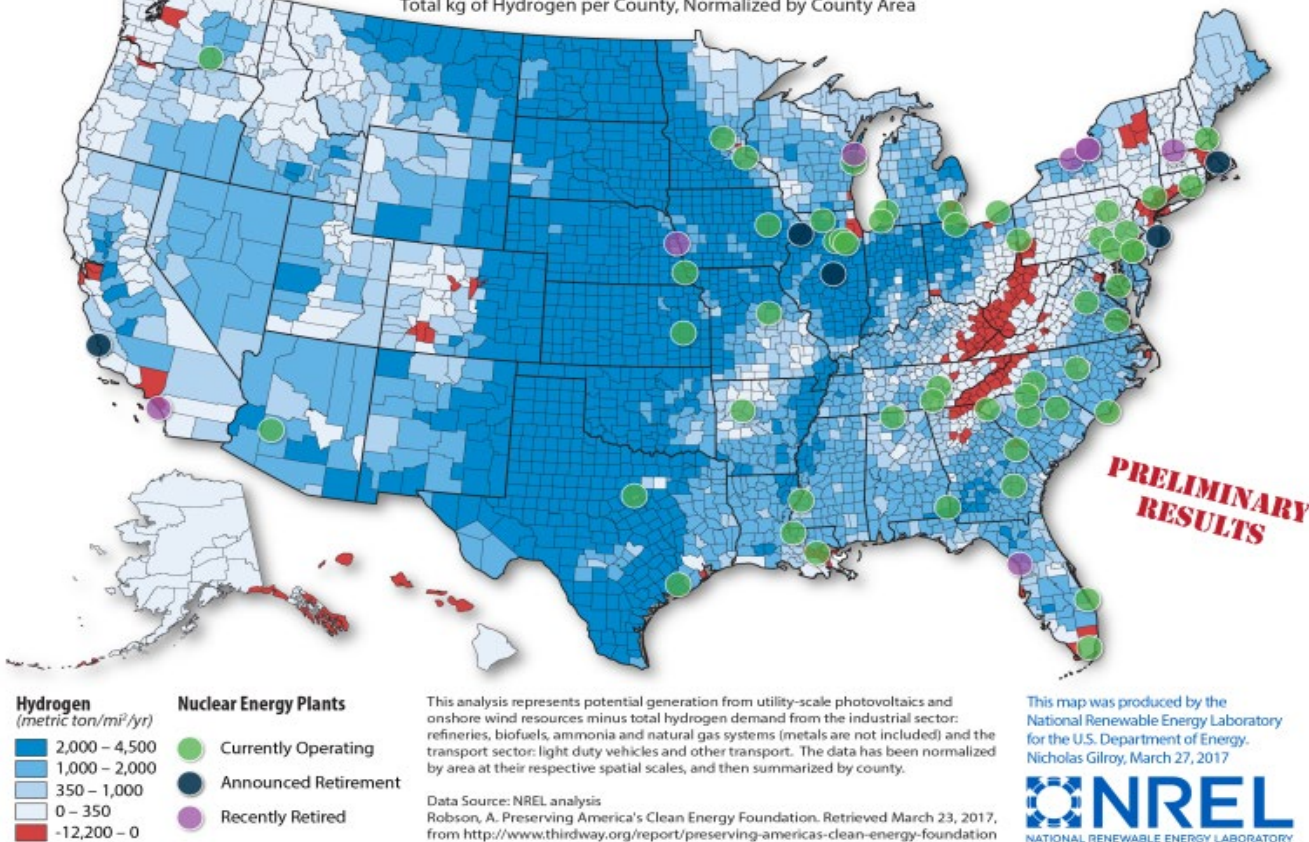
One hydrogen cavern could provide ~ 100 GWh energy storage

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.

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

H₂@Scale: Value to industrial processes?

Electrical power plant cooling

- **Over 16,000 H₂ cooled generators worldwide**
- **Less delivery logistics, inventory management, 1-2 yr payback and improved efficiency**
- **Potential \$2B addressable market**

Source: Proton



Iron Refining, Steel manufacturing

- **More energy efficient when hydrogen used as reductant at high temperatures**
- **Potential annual savings of over \$100,000 for a 100,000 ton/year plant**

Source: EERE Advanced Manufacturing Office, Berry Metal

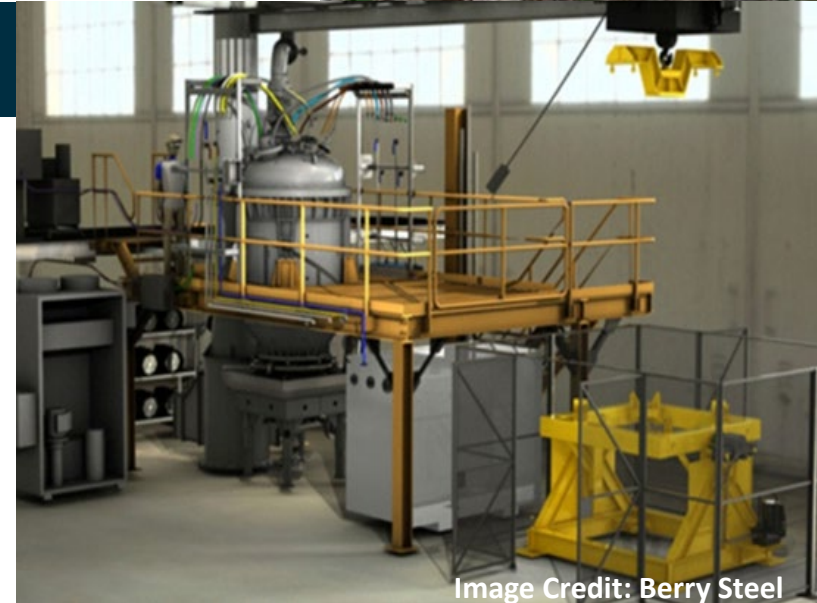
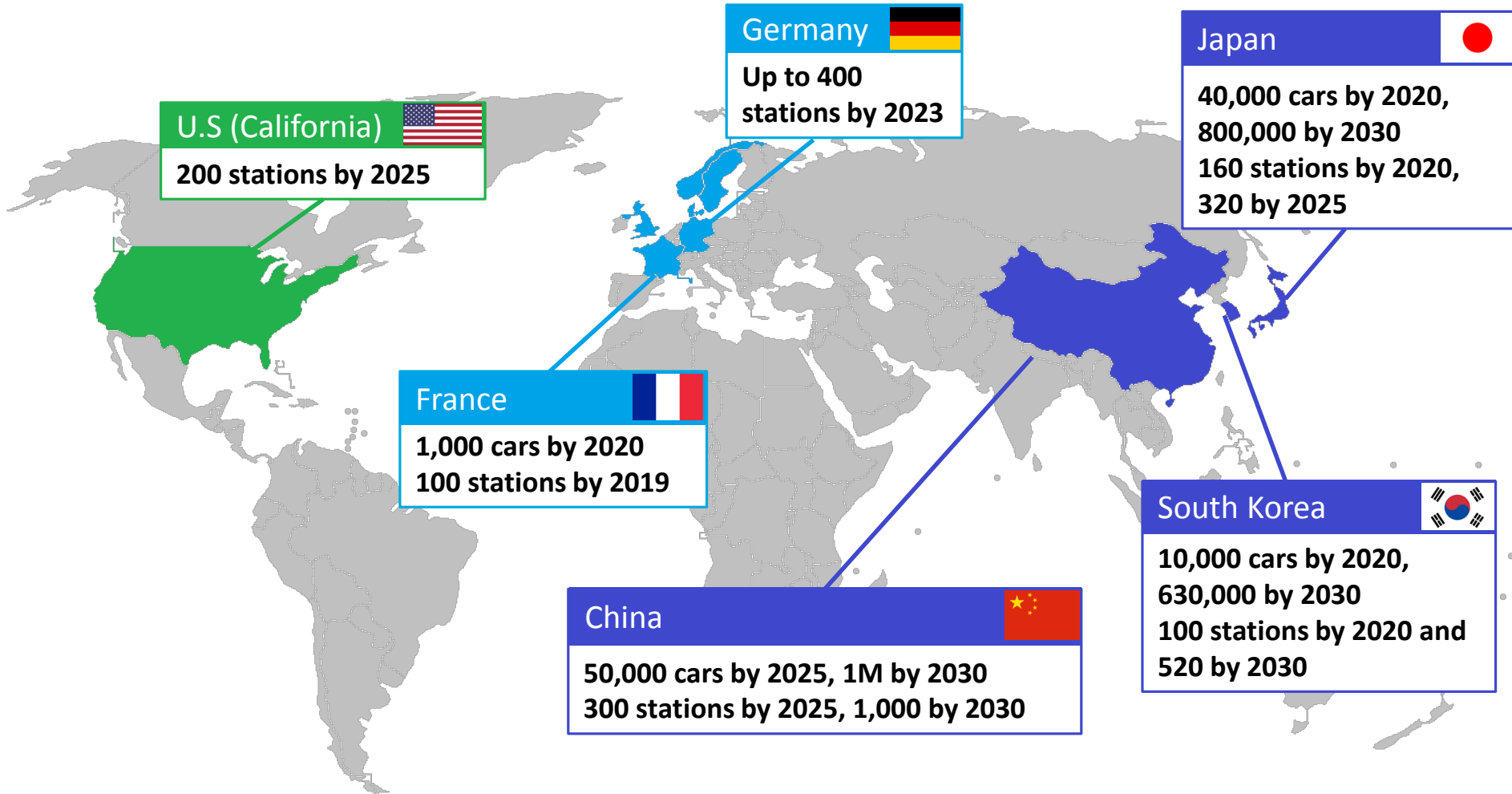


Image Credit: Berry Steel

Global Hydrogen Infrastructure Activity Underway



IPHE: International Partnership for H₂ and Fuel Cells in the Economy

- **Share** information on H₂ 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

H₂@Ports and H₂@Rail Initiatives

- Collaboration with DOT-Maritime Administration (maritime) & DOT-Federal Railroad Administration (rail)
- Conduct R&D to assess the technical and economic potential of hydrogen use for:



Seaport Applications



Prime propulsion & auxiliary railway locomotives



Photo Credit: EPA



Photo Credit: New York Times

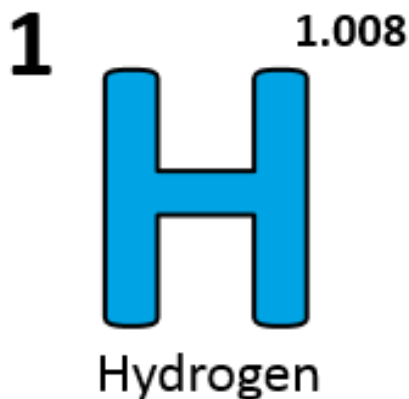
Opportunities for outreach and to increase awareness

Celebrate National Hydrogen & Fuel Cell Day

October 8 or 10/08

(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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