International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling Hydrogen and Fuel Cells Progress Through Global Collaboration

Dr. Sunita Satyapal – IPHE Chair

Tim Karlsson – Executive Director, IPHE Secretariat

f-cell+HFC 2019

Vancouver Canada

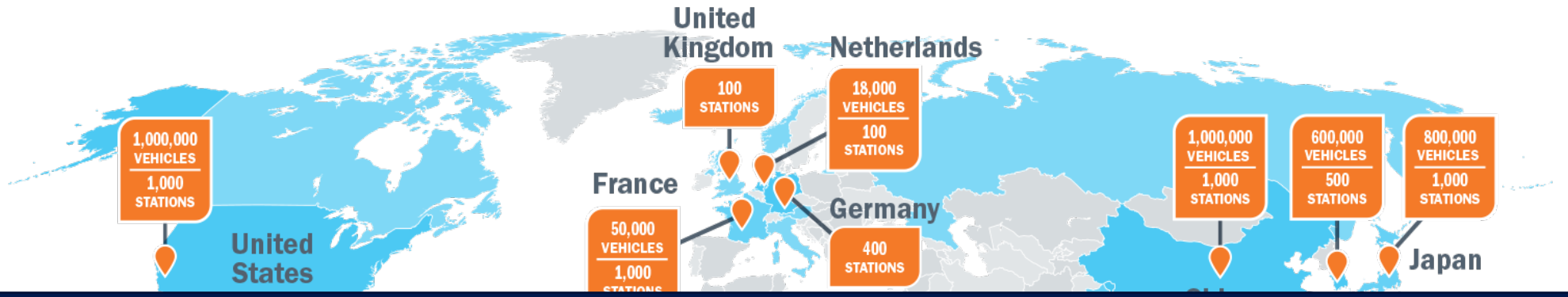
22 May 2019

IPHE – Who are we?

- **International governmental partnership** to advance hydrogen and fuel cells
- **19 member countries and the European Commission**
- Formed in 2003

More information at: www.iphe.net

IPHE Global Reach



IPHE members comprise 2/3 of the world's GDP and invest nearly $1 Billion annually on H_2 and fuel cells

[1] IPHE Country Updates

Global Activities and Commitments are Strong

Today: >11,000 FCEVs, >300 stations, >¼ million stationary fuel cells
Plans in process for millions of vehicles and thousands of stations worldwide

IPHE Member Countries

2030 Vehicles & Stations Goal[1]

[1] IPHE Country Updates

Key Drivers: Based on National Circumstances

1. **Energy Security**
   - Security of Supply and Ability to Switch
2. **Energy Efficiency and Resiliency**
   - Effective Use of Variable Generation – grid services and storage at system-wide and community scale
   - Moving from Centralized to Distributed Generation
3. **Economic Growth: Innovation & Technology Leadership**
   - New Products and Supply Chains, Same Products Made Sustainably
   - Skilled Jobs and Manufacturing Opportunities
   - Taxpayers Return on Research, Development & Demonstrations
4. **Environmental Performance**
   - Clean Air/Local Air Quality, Climate Change, Noise

Leading Economies Recognizing the Role of Hydrogen

The Strategic Road Map for Hydrogen and Fuel Cells ~ Industry-academia-government action plan to realize Hydrogen Society ~ (overall)

- In order to achieve goals set in the Basic Hydrogen Strategy,
  - ① Set of new targets to achieve (Specs for basic technologies and cost breakdown goals), establish approach to achieving target
  - ② Establish expert committee to evaluate and conduct follow-up for each field.

		Goals in the Basic Hydrogen Strategy	
Use	Mobility	FCV 200k by 2025, 800k by 2030	2025
		HRS 320 by 2025, 900 by 2030	2025
		Bus 1,200 by 2030	Early 2020s
	Power	Commercialize by 2030	2020
	FC	Early realization of grid parity	2025
Supply	Fossil Fuel +CCS	Hydrogen Cost ¥30/Nm3 by 2030 ¥20/Nm3 in future	Early 2020s
	Green H2	System cost of water electrolysis ¥50,000/kW in future	2030

Hydrogen & Fuel Cells in Republic of Korea

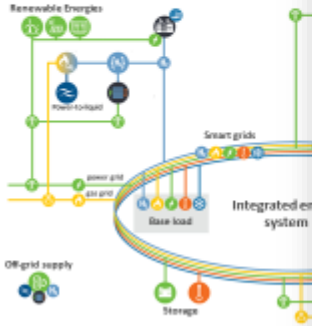
'Hydrogen Roadmap
bringing extensive co
governments, and pu

- HyNet, a special purp
responded in March b
including the installati
- Six government minist
approximately 2 trillio
- Parliament is working
expected to cover all a
transformation.

31st IPHE Steering Committee – Vienna, Austria April

Announcements and/or New Initiatives
Germany

HYLAND
Next step for the deplo
technologies



31st IPHE Steering Committee - Vienna, Austria

Announcements and/or New Initiatives
United States

Budget

- **$120M budget for 2019 under the U.S. Department of Energy** Fuel Cell Technologies Office R&D activities
- **$45M funding announced on Mar 2019** to go towards H2@Scale ($30M) and medium and heavy duty applications ($15M)

Collaborations

- **U.S. DOE and Michigan State** collaboration announced on Feb 2019
- **Global safety collaboration** (collaboration with Center for Hydrogen Safety)

New RD&D Activities and Initiatives

- **H-Mat Consortium launched** to focus on hydrogen materials compatibility issue
- **Multiple states announced activities covering energy storage, vehicles and fuels**
  - Colorado – Zero emissions vehicles mandate introduction
  - Arizona- Plans to increase energy storage capacity
  - California – Carbon intensity reduction requirement went from 10% to 20%.
- **Industry plans to build new hydrogen liquefaction plants** in CA, TX and LA.

Example of the H2@Scale System

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Unique National and Regional Circumstances Drives Actions

On-going Technology Research and Analysis of Regulations, Codes & Standards Necessary

Announcements and/or New Initiatives
UK

- Dec 2018 - Clean growth Mission to est
  one low-carbon cluster by 2030. Backed
- Dec 2018 – Publication of 'Clean Growt
  carbon heating technologies including h
- Jan 2019 – Storage at Scale Competitio
  solutions including Power-to-X (>5Mw i
- Jan 2019 – Publication of 'Maritime 205
- Feb 2019 – Winners of the Ultra-Low Er
  refuelling infrastructure.
- Mar 2019 – Offshore Wind Sector Deal
  leadership in offshore wind and advant
  role for hydrogen.
- Mar 2019 – New guidance on Renewab
- Mar 2019 – Launch of public consultati
- Apr 2019 – Launch of demo projects un
  ReFLEX Orkney project (£28.5) to create
  technologies and Smart Hub SLES proje
  innovative technologies including hydr

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Announcements and/or New Initiatives
(European Commission)

- **Investments/Funding:**

The 2019 Call for Proposals of the FCH JU was successfully
deadline for applications is 23 of April.

✓Highlights*: logistics vehicles, hybridisation, MW fuel cells f
hydrogen in NG grid (incl. PNR/standards), training of respo
✓International collaboration with IPHE countries is encourag
✓International collaboration in support of Mission Innovatio
topics (incl. funding)

- **New research & development, demonstra**

The H2PORTS kick-off meeting

The first internal technical meeting of the European project "
Technologies in Ports" was held in Valencia in February 2019.
close collaboration with the Port Authority of Valencia, and is

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Announcements and/or New Initiatives
(China)

- **Investments/Funding**

9 projects from MOST
"Renewable Energy and Hydrogen Energy Technology" Program
154.61 million RMB (US$ 22.97 million) from central finance

No.	Project name (main information)	Lead agency	Funding (million RMB) (US$ million)	Duration (year)
1	Decomposition of water to produce hydrogen by solar energy	Xi'an Jiaotong University	11.92 (1.77)	4
2	Hydrogen storage materials and hydrogen storage systems	South China University of Technology	15.75 (2.34)	3
3	Hydrogen production by solid polymer electrolyte (SPE) electrolysis water	Changchun Institute of Applied Chemistry, Chinese Academy of Sciences	17.59 (2.61)	3
4	Large-scale wind/light complementary hydrogen production (demonstration)	China Energy Group	26.18 (3.89)	3

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Examples of IPHE Activities

Regulations, Codes, Standards and Safety (RCSS)

- **Foster RCS harmonization** across countries
- **Share safety information**, best practices, lessons learned

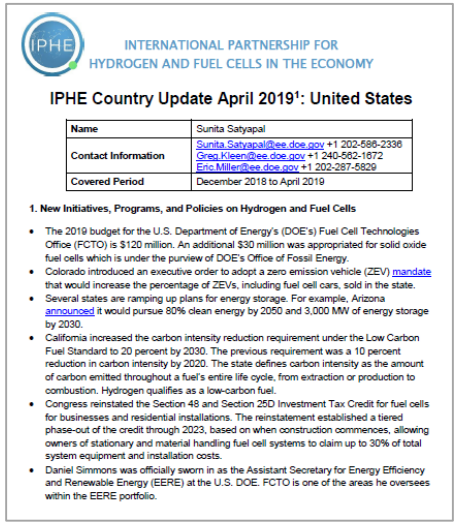
Education and Outreach (E&O)

- **Create unbiased factual** materials
- **Increase stakeholder engagement** through workshops, policy forum events, education events
- **Share information** on status, gaps, analysis, opportunities, etc.

Example of information sharing- new Center for H_2 Safety & RCSS WG

CENTER FOR Hydrogen SAFETY

Examples of IPHE Member Deliverables - Country Updates



INTERNATIONAL PARTNERSHIP FOR HYDROGEN AND FUEL CELLS IN THE ECONOMY

IPHE Country Update April 2019[1]: United States

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Covered Period	December 2018 to April 2019

1. New Initiatives, Programs, and Policies on Hydrogen and Fuel Cells

- The 2019 budget for the U.S. Department of Energy's (DOE's) Fuel Cell Technologies Office (FCTO) is $120 million. An additional $30 million was appropriated for solid oxide fuel cells which is under the purview of DOE's Office of Fossil Energy.
- Colorado introduced an executive order to adopt a zero emission vehicle (ZEV) mandate that would increase the percentage of ZEVs, including fuel cell cars, sold in the state.
- Several states are ramping up plans for energy storage. For example, Arizona announced it would pursue 80% clean energy by 2050 and 3,000 MW of energy storage by 2030.
- California increased the carbon intensity reduction requirement under the Low Carbon Fuel Standard to 20 percent by 2030. The previous requirement was a 10 percent reduction in carbon intensity by 2020. The state defines carbon intensity as the amount of carbon emitted throughout a fuel's entire life cycle, from extraction or production to combustion. Hydrogen qualifies as a low-carbon fuel.
- Congress reinstated the Section 48 and Section 25D Investment Tax Credit for fuel cells for businesses and residential installations. The reinstatement established a tiered phase-out of the credit through 2023, based on when construction commences, allowing owners of stationary and material handling fuel cell systems to claim up to 30% of total system equipment and installation costs.
- Daniel Simmons was officially sworn in as the Assistant Secretary for Energy Efficiency and Renewable Energy (EERE) at the U.S. DOE. FCTO is one of the areas he oversees within the EERE portfolio.

International Collaborations

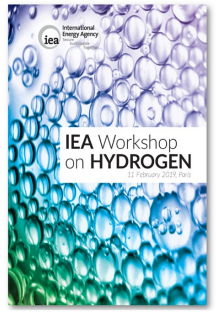
Government- Led

CLEAN ENERGY MINISTERIAL
Advancing Clean Energy Together

Focus areas

2019

H_2



International Energy Agency
Secure • Sustainable • Together

R&D TCPs, policy, analysis, reports

FC H_2

MISSION INNOVATION
Accelerating the Clean Energy Revolution

2017

H_2

Hydrogen Energy Ministerial (HEM)

First meeting- October 2018

IPHE

Formed in 2003, over
20 countries and EC
2/3 of world's GDP
~ $1B/year in funding

www.iphe.net

UN Global Technical Regulations (GTR) H_2

Industry- Led

Industry Associations

Hydrogen Council

Launched in 2017
Over 50 CEOs

Center for Hydrogen Safety

Launched in 2019
Industry & Govt

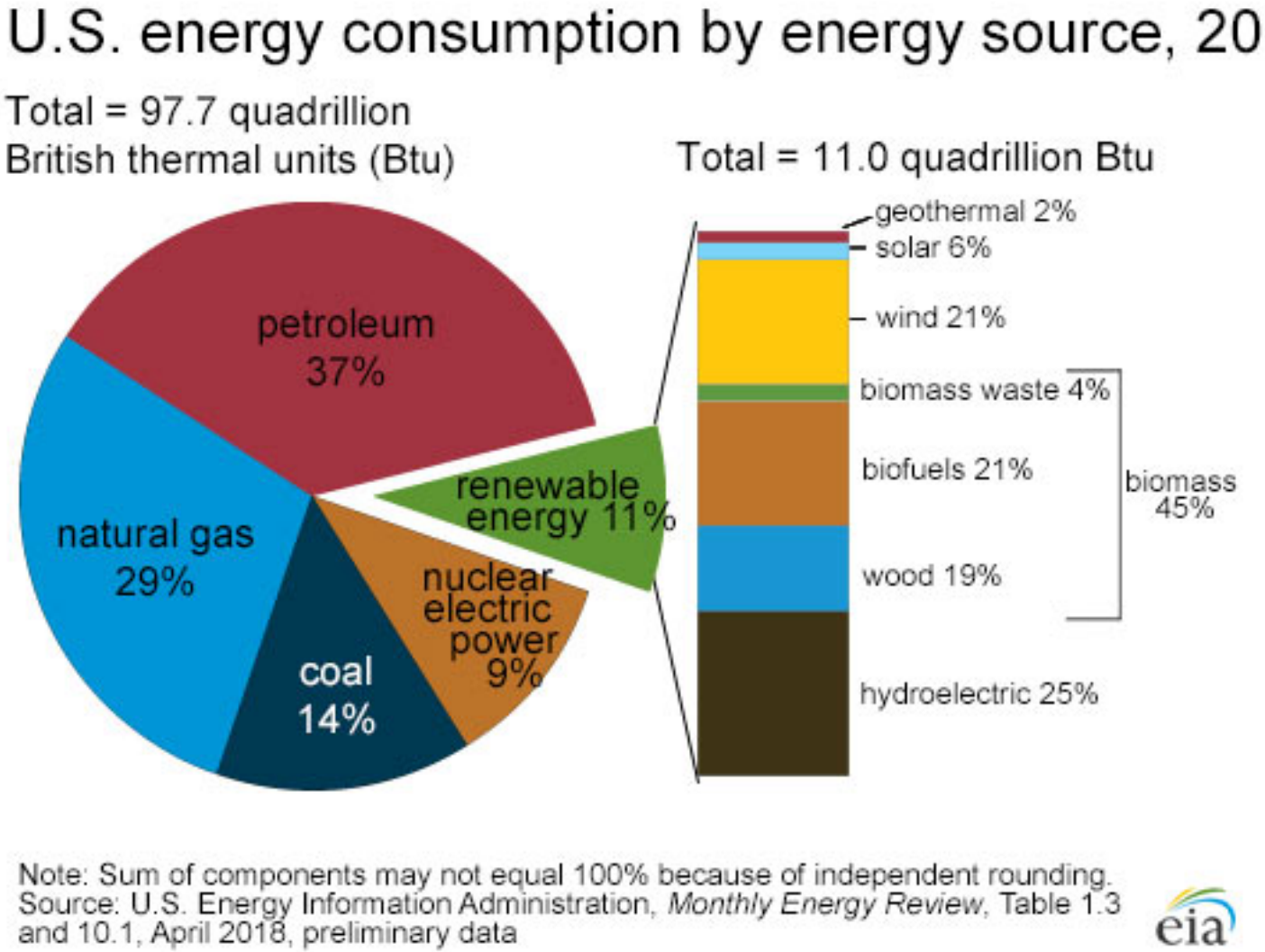
Widespread Commercialization

Increasing Priority: Enabling and Harmonizing Regulations, Codes and Standards

Hydrogen and Fuel Cells Focus

U.S. Perspective

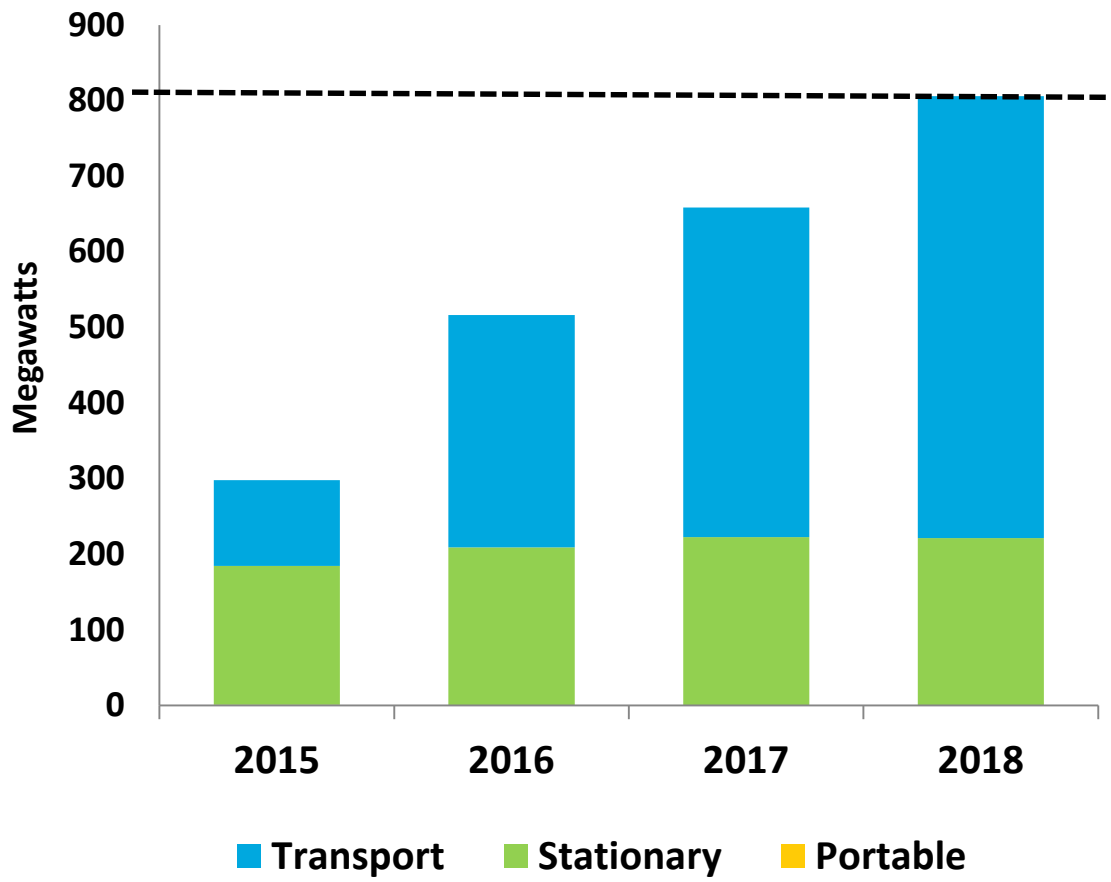
U.S. All of the Above Energy Portfolio



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

Progress

Global Fuel Cell Shipments - Growth by Application



800 MW
fuel cell power
shipped worldwide

68,500
fuel cell units
shipped worldwide

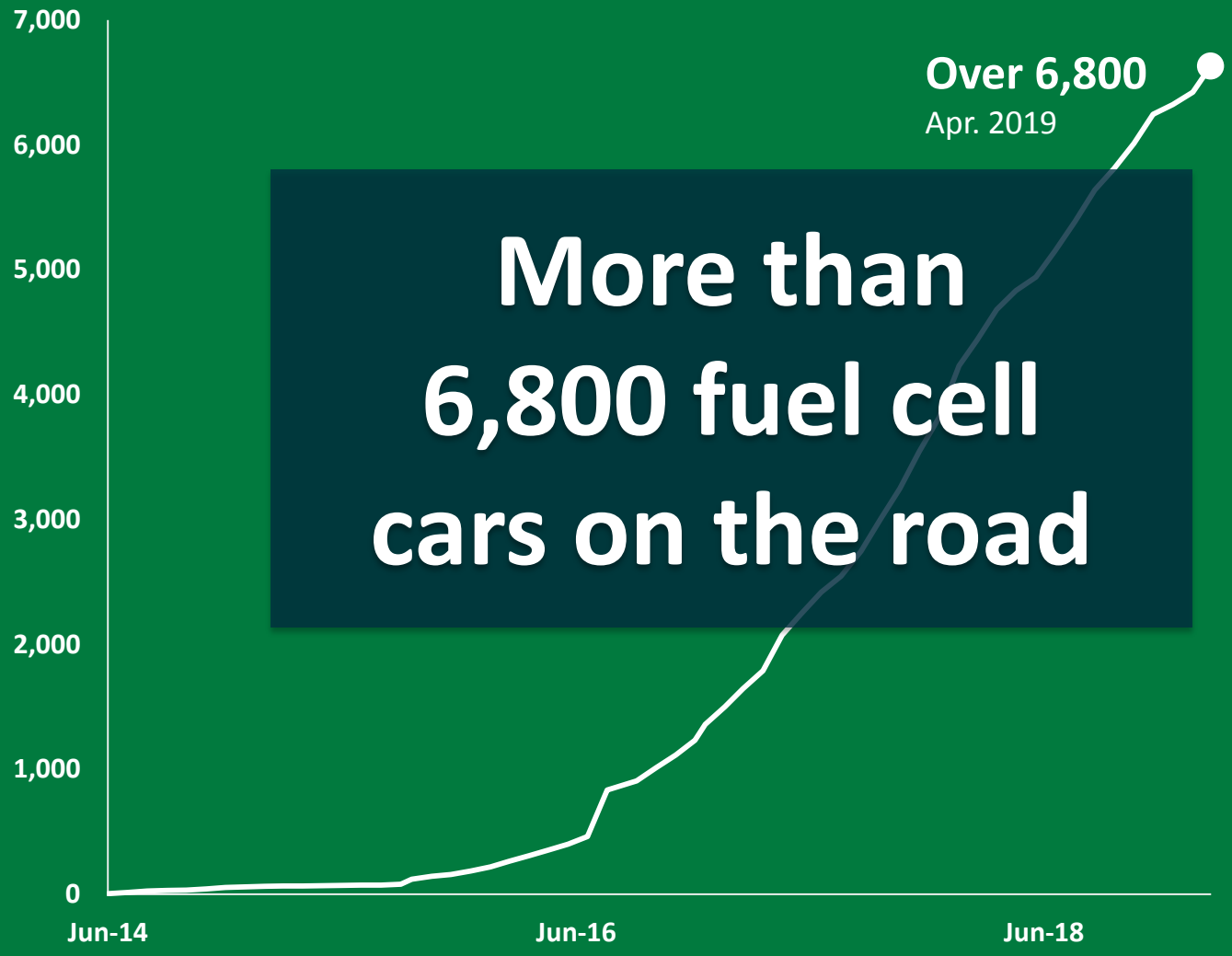
Approximately
$2.3 Billion
fuel cell revenue*

* Revenue from publicly available

Source: DOE and E4Tech

Fuel Cell Passenger Vehicles Status

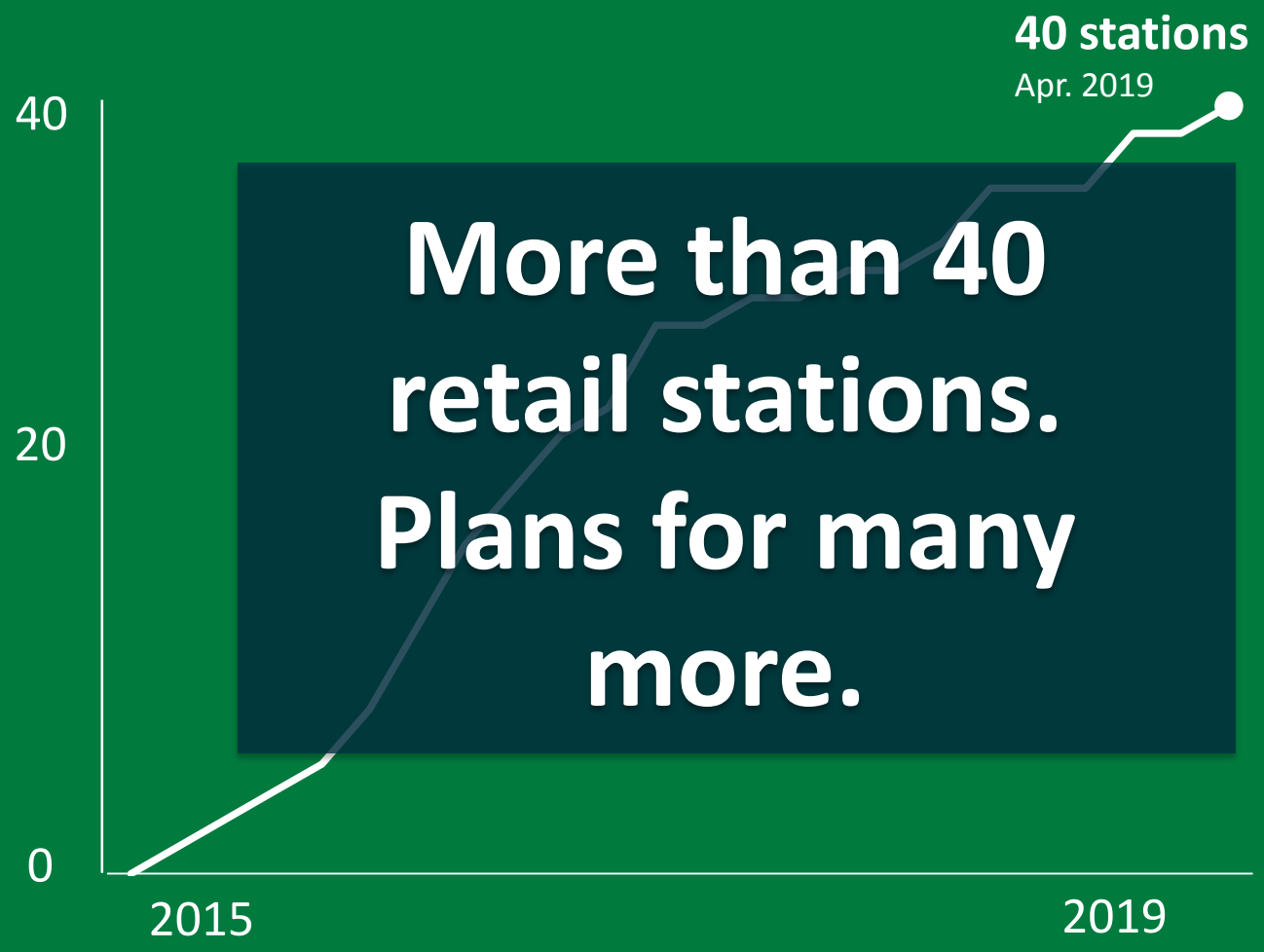
Fuel Cell Cars in the U.S.



More than 6,800 fuel cell cars on the road

Hydrogen Infrastructure Status

Retail Hydrogen Stations in the U.S.



More than 40 retail stations. Plans for many more.

Real World Applications – In the U.S.

Photo Credit: UPS

Fuel cell parcel delivery trucks starting deliveries in CA and NY

Photo Credit: FedEx

First fuel cell tow truck fleet at airport in Memphis

World's first fuel cell for maritime ports in Hawaii

Photo Credit: Sandia National Laboratories

Real World Applications – In the U.S.

Industry demonstrates heavy duty fuel cell trucks

Photo Credit: Toyota

ZH2: U.S. Army and GM collaboration First of its kind

Photo Credit: General Motors

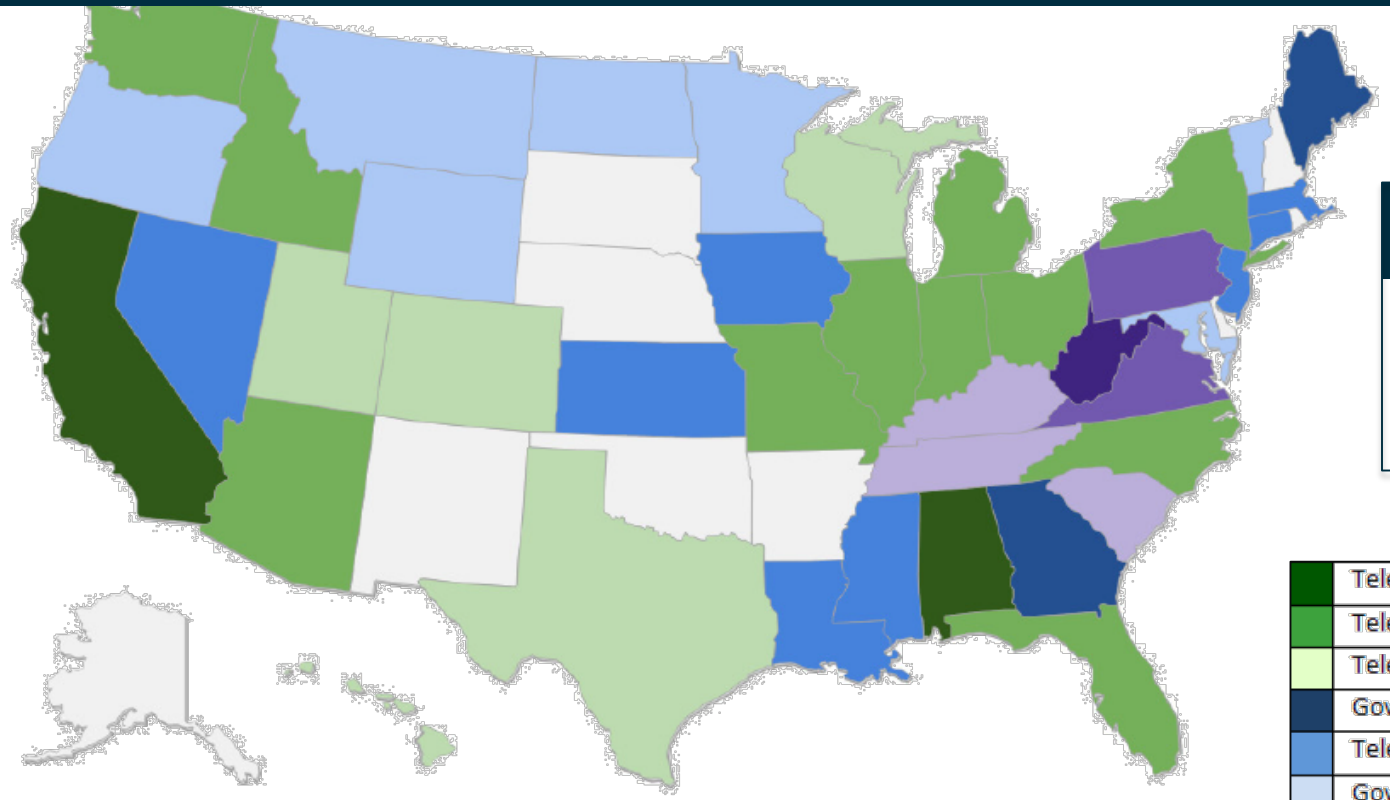
Fuel cell powered lights at Super Bowl

Fuel cell buses in California surpass 20 million passengers

Photo Credit: NREL

Fuel cells for Stationary and Backup Power

Fuel cells used for backup power in more than 40 states



Over 240MW

in stationary fuel cell power installed

Telecom, Government, Railroad, Utility sites
Telecom, Government, Railroad sites
Telecom and Government sites
Government, Railroad, Utility sites
Telecom sites
Government sites
Railroad sites
Utility sites
Government and Railroad sites
Telecom and Railroad sites

Over 8,000 backup power units

deployed or on order

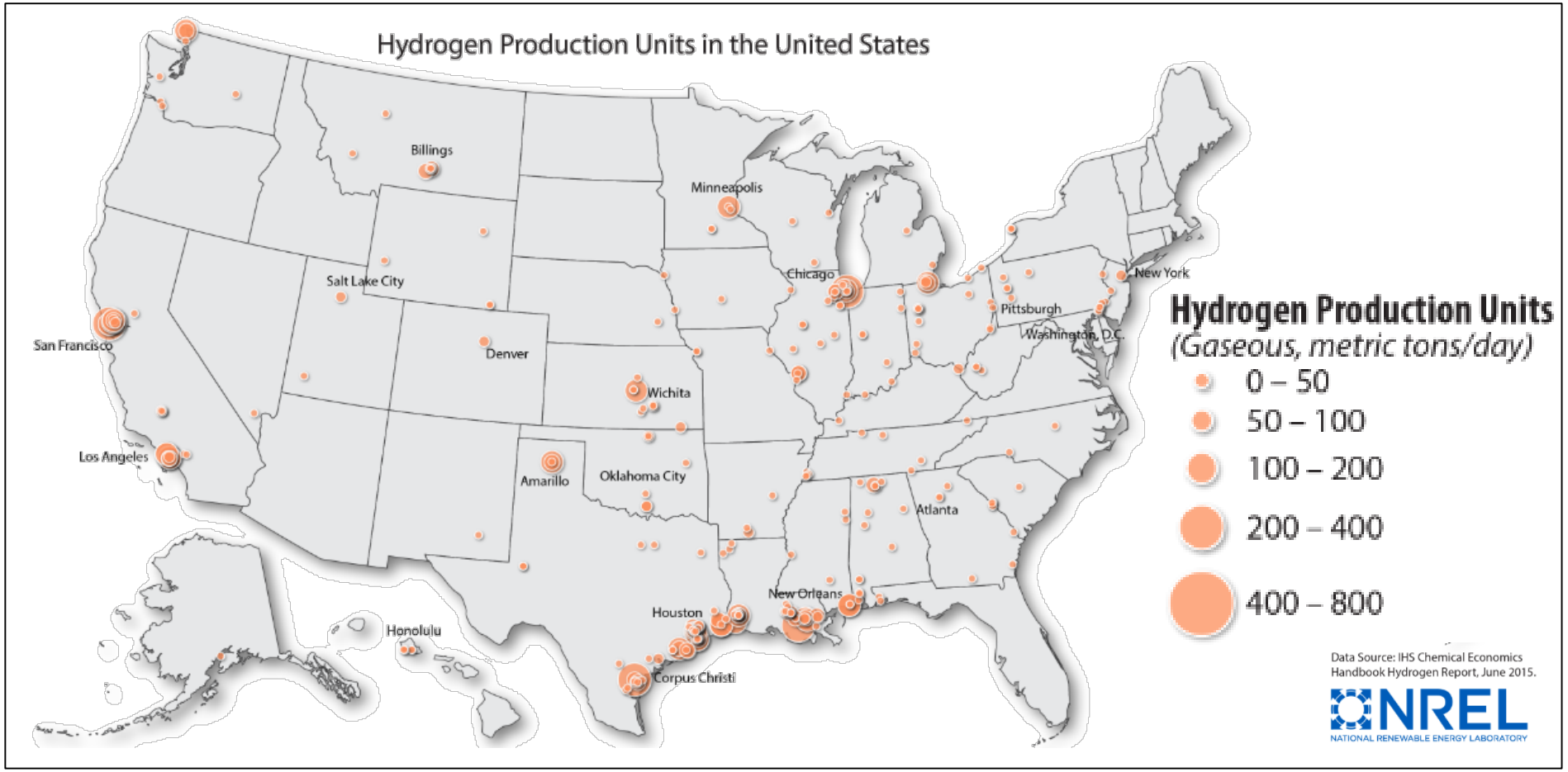
Source: DOE State of the States: Fuel Cells in 2016 Report

Material handling Applications

More than **25,000 forklifts**

Over **19 million refuelings**

Hydrogen in the United States Today



U.S. annual hydrogen production

10 million metric tons

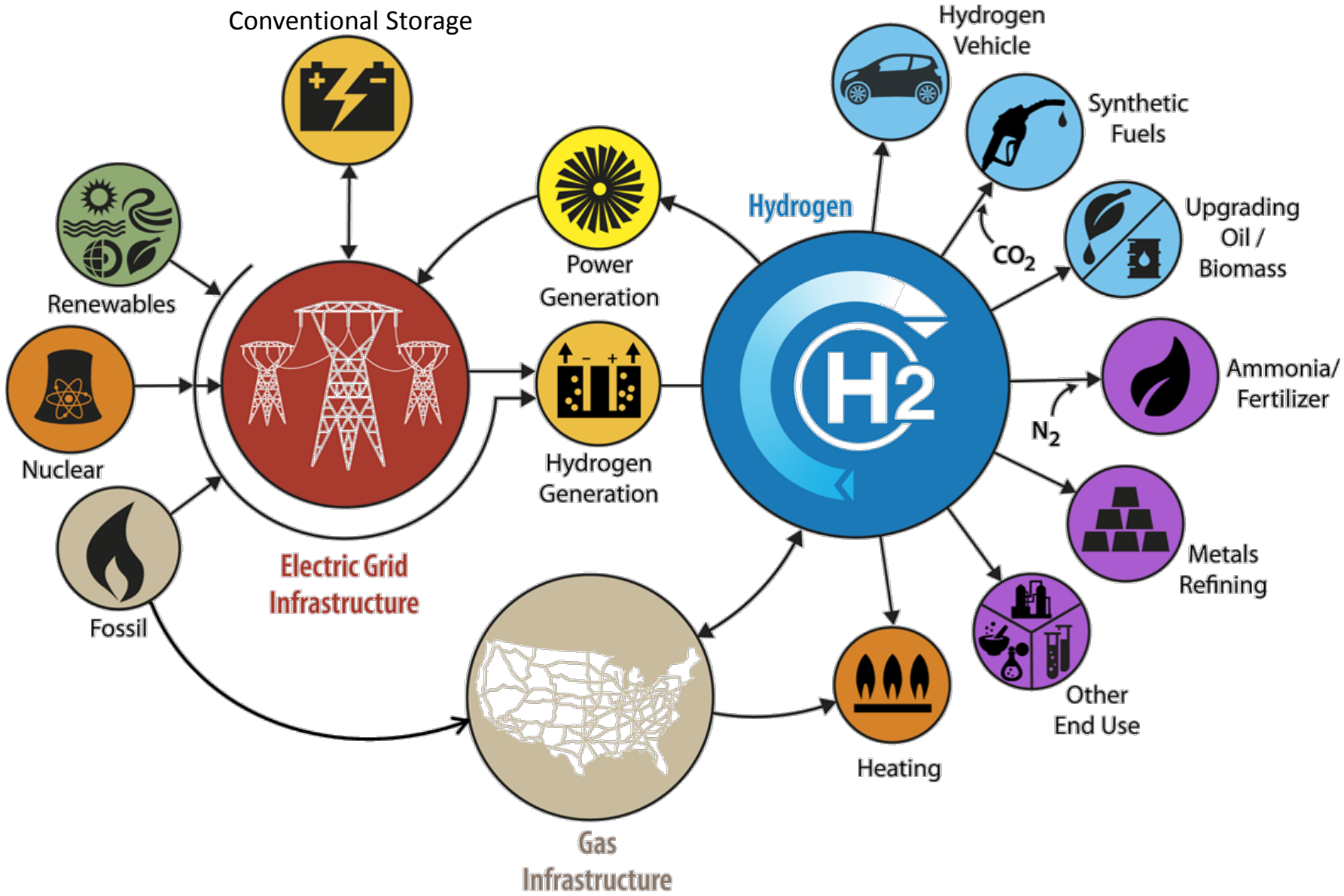
Largest Users in the U.S.

Petroleum Processing	68%	Fertilizer Production	21%

H_2@Scale Initiative

Enable affordable, reliable, clean and secure energy across sectors

H_2@Scale: Enabling affordable, reliable, clean, and secure energy across sectors



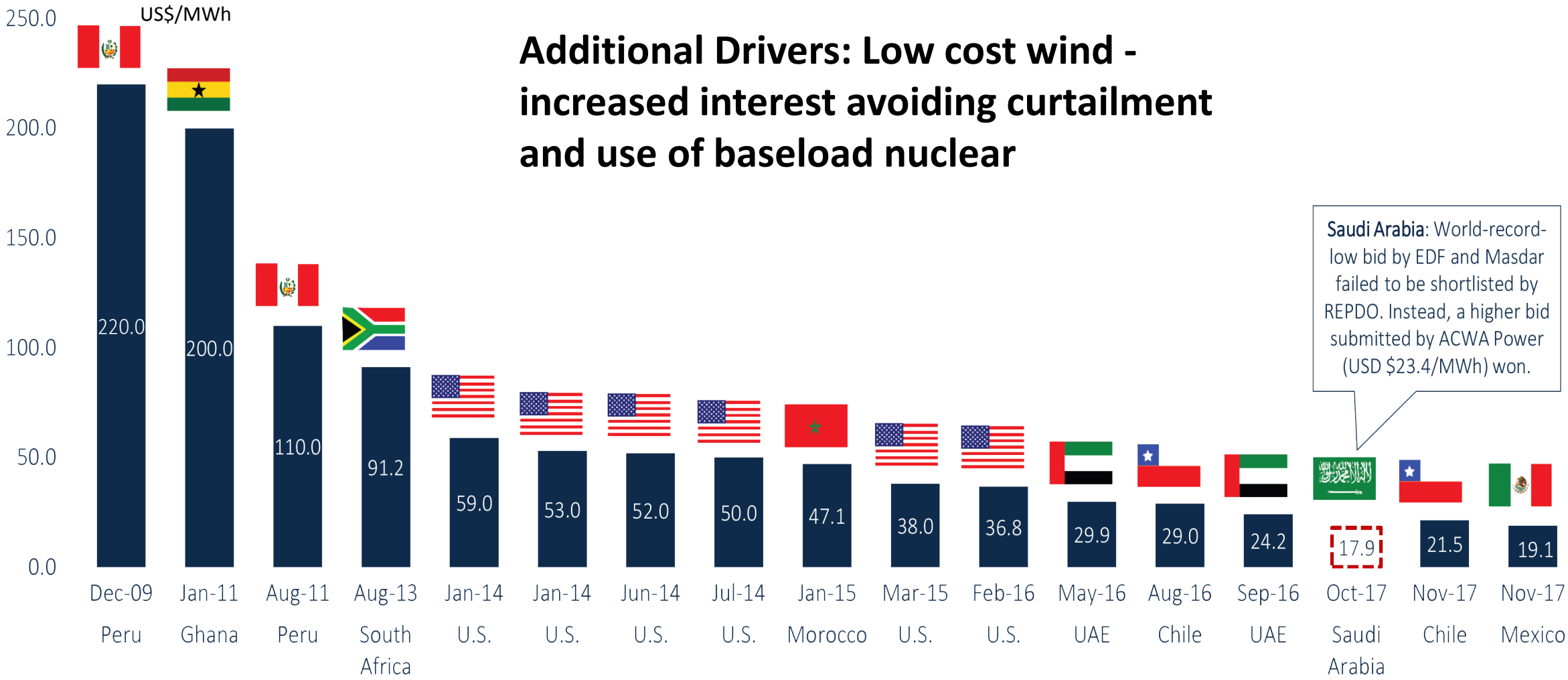
Versatility

Volume

Value Proposition

What is different now?

Record-Low Prices for Utility-Scale Solar

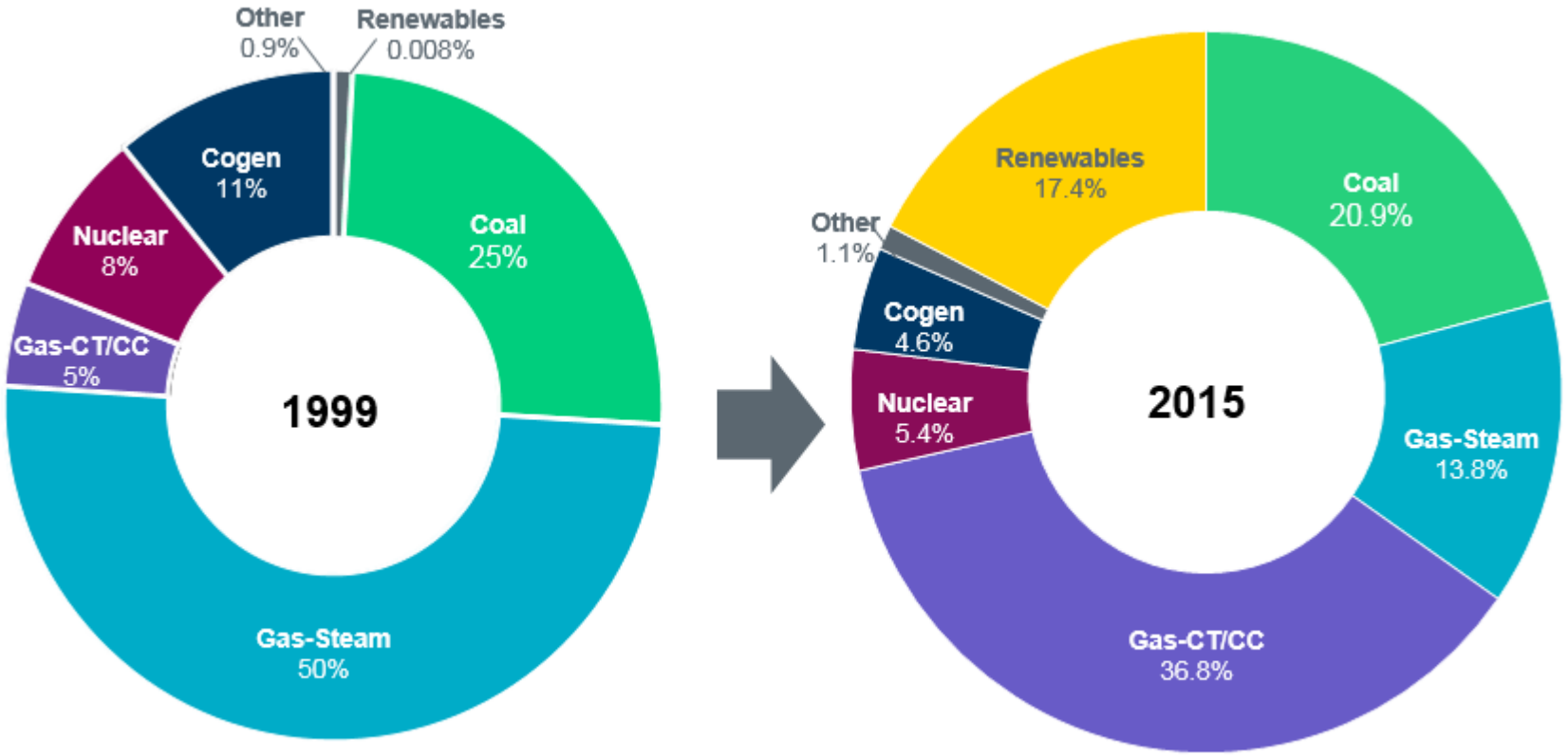


Additional Drivers: Low cost wind - increased interest avoiding curtailment and use of baseload nuclear

Source: GTM, DOE Solar Technologies Office

Electricity Mix is Changing

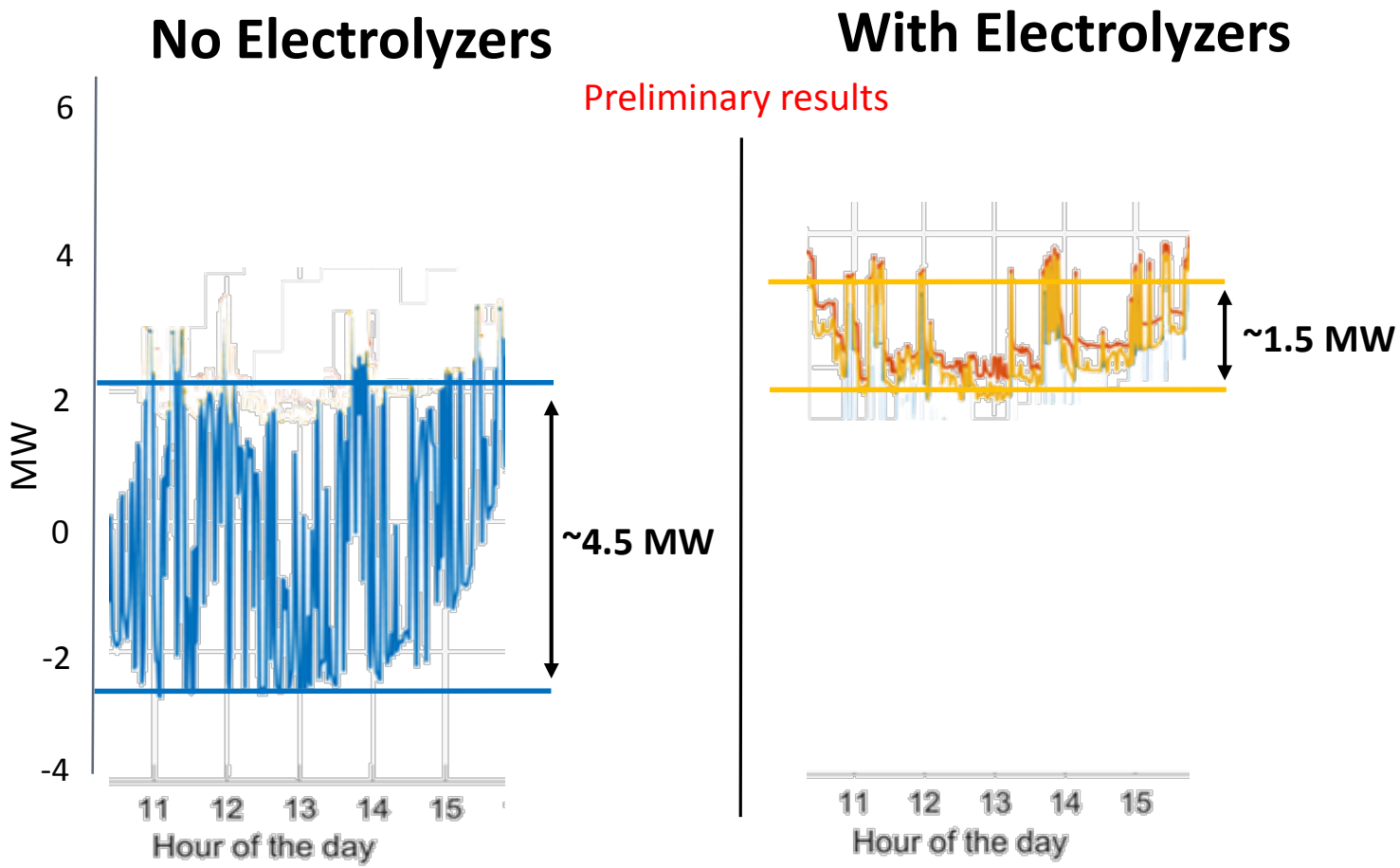
Example: Installed Capacity in Texas



Source: ERCOT, DOE H2@Scale Workshop, TX

Example: Hydrogen can help address grid needs

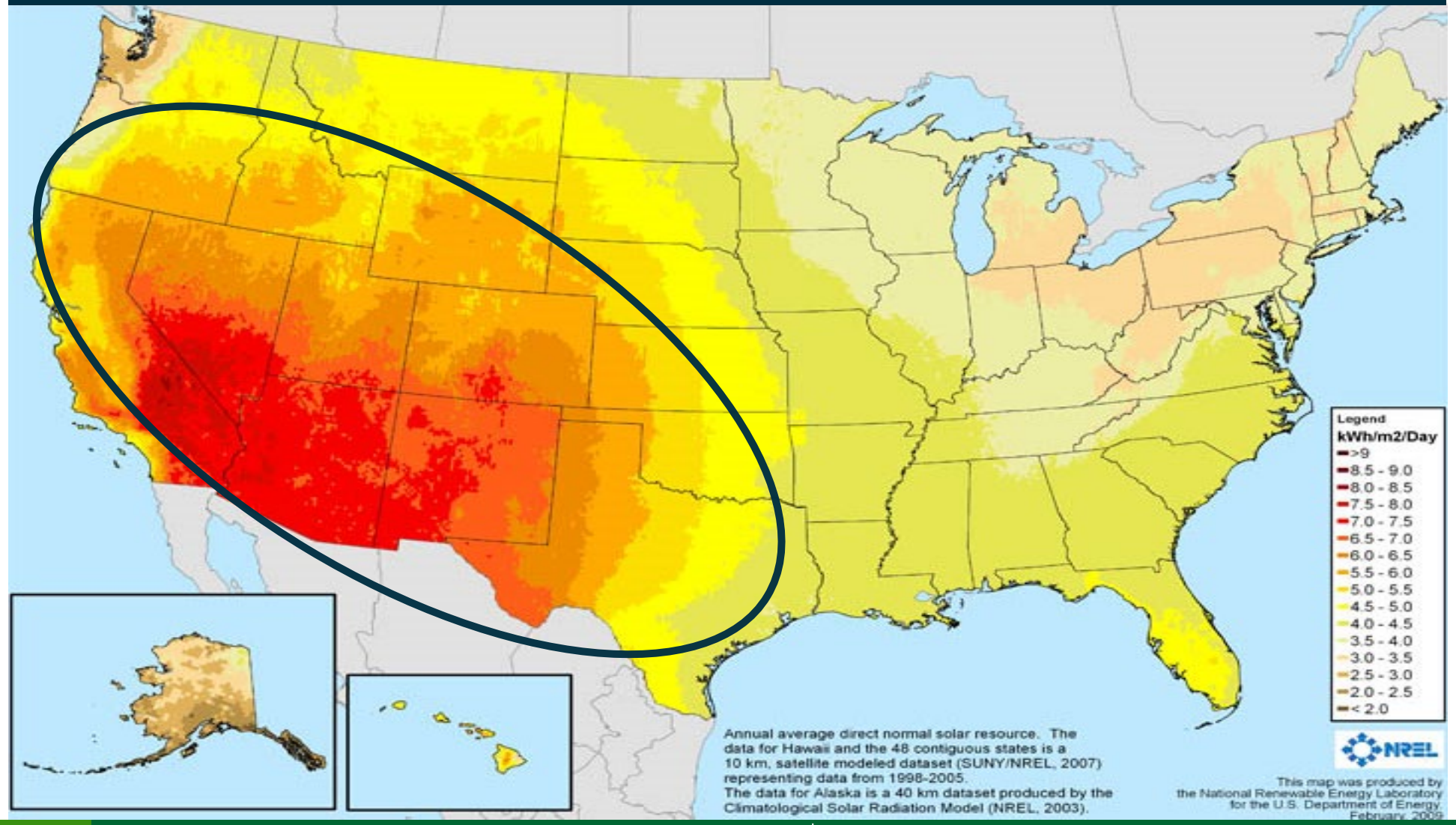
Preliminary study shows electrolyzers can reduce amplitude of power fluctuations by up to 65% in a grid with high renewables



Source: D. Murphy, et al, NREL and INL. Specific case with high solar penetration and electrolyzers used to compensate for power fluctuations

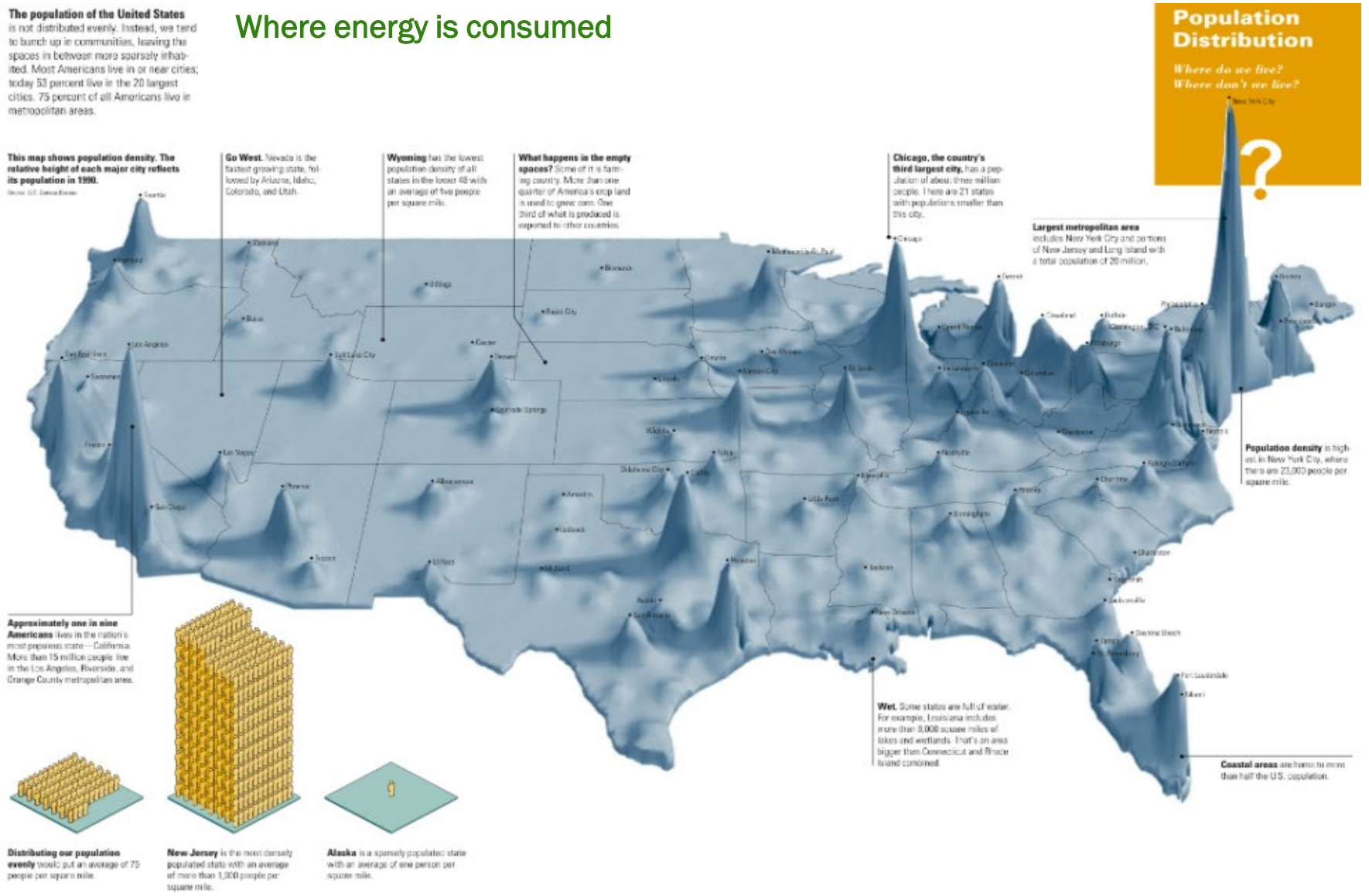
H_2@Scale: Enabling renewable energy transport?

Where we find abundant solar and wind energy



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

Where energy is consumed



H2@Rail and H2@Ports Initiatives

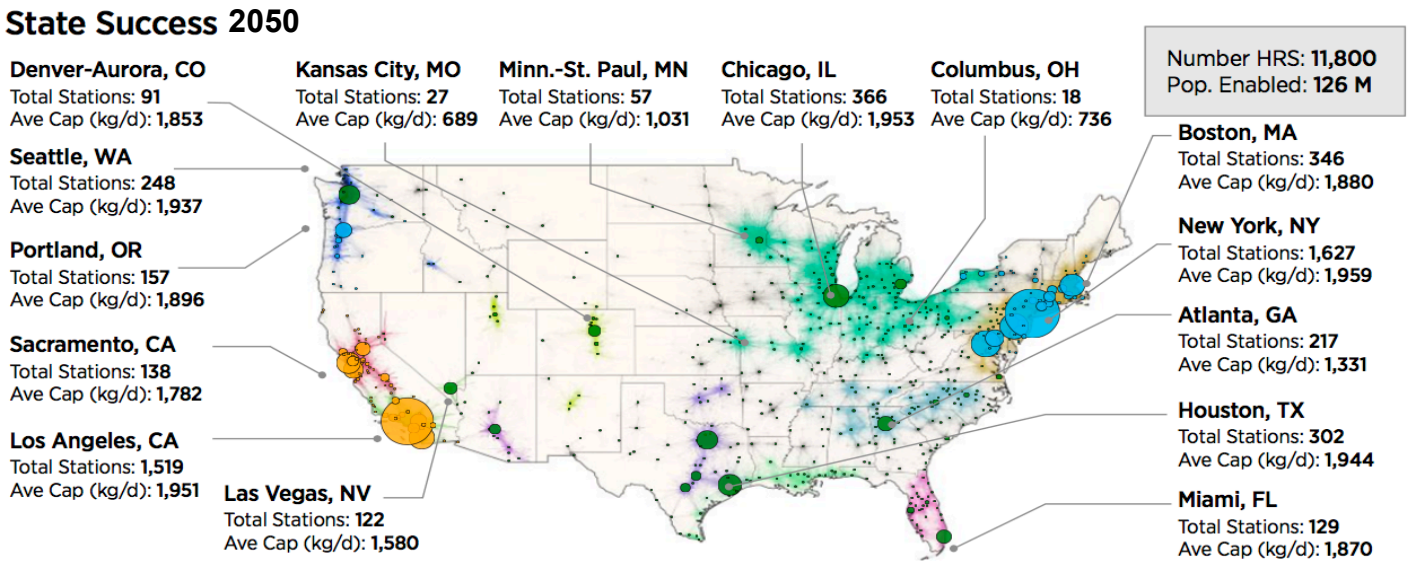
- U.S. DOE in collaboration with:
  - Dept. of Transportation (DOT)-Federal Railroad Administration
  - DOT-Maritime Administration

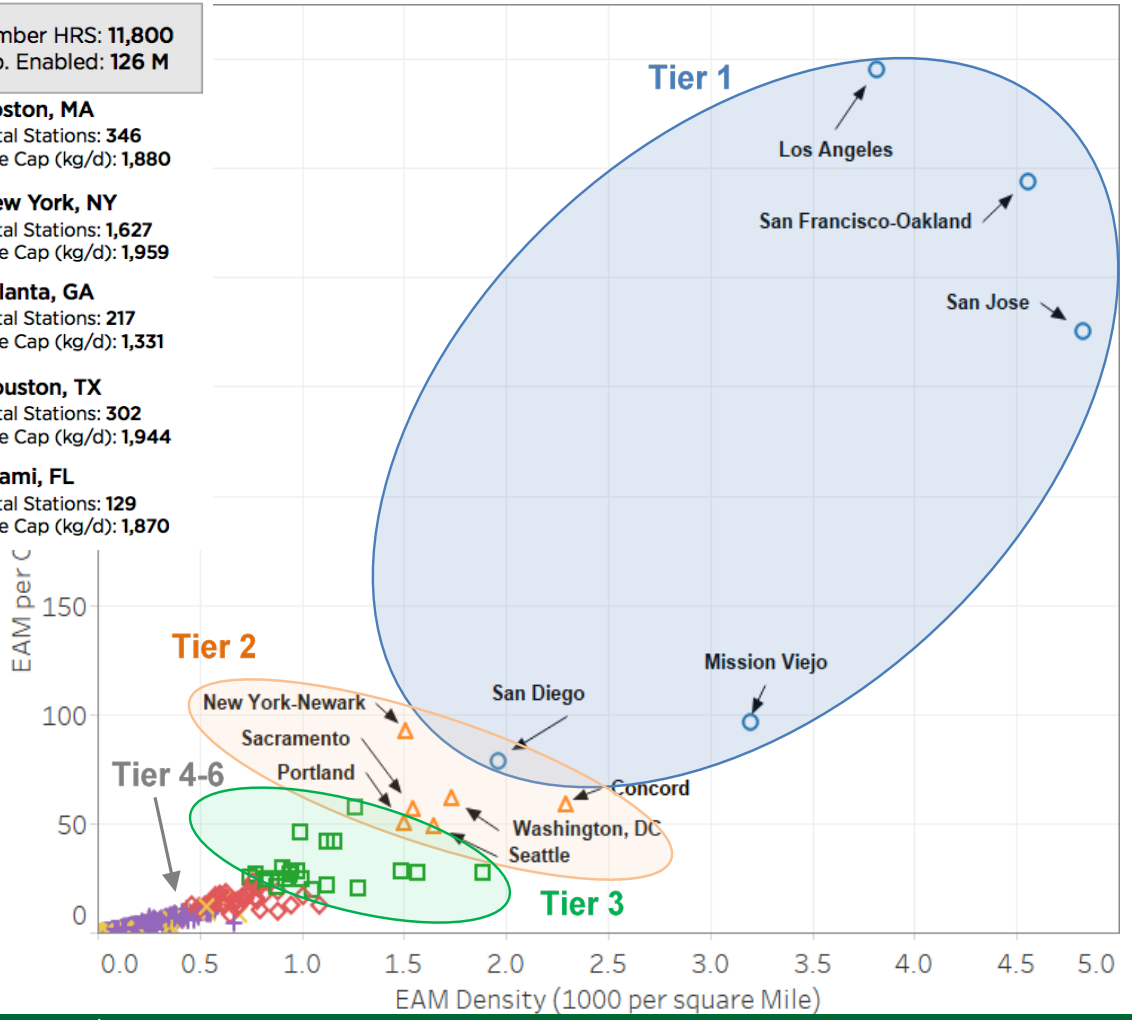
Data Centers and Energy Storage Applications

Source: DOT-FRA (top) & SNL (bottom)

Scenario Analysis for Hydrogen Fueling Station Rollout

Modeling the optimal size and placement of hydrogen stations over time under various scenarios





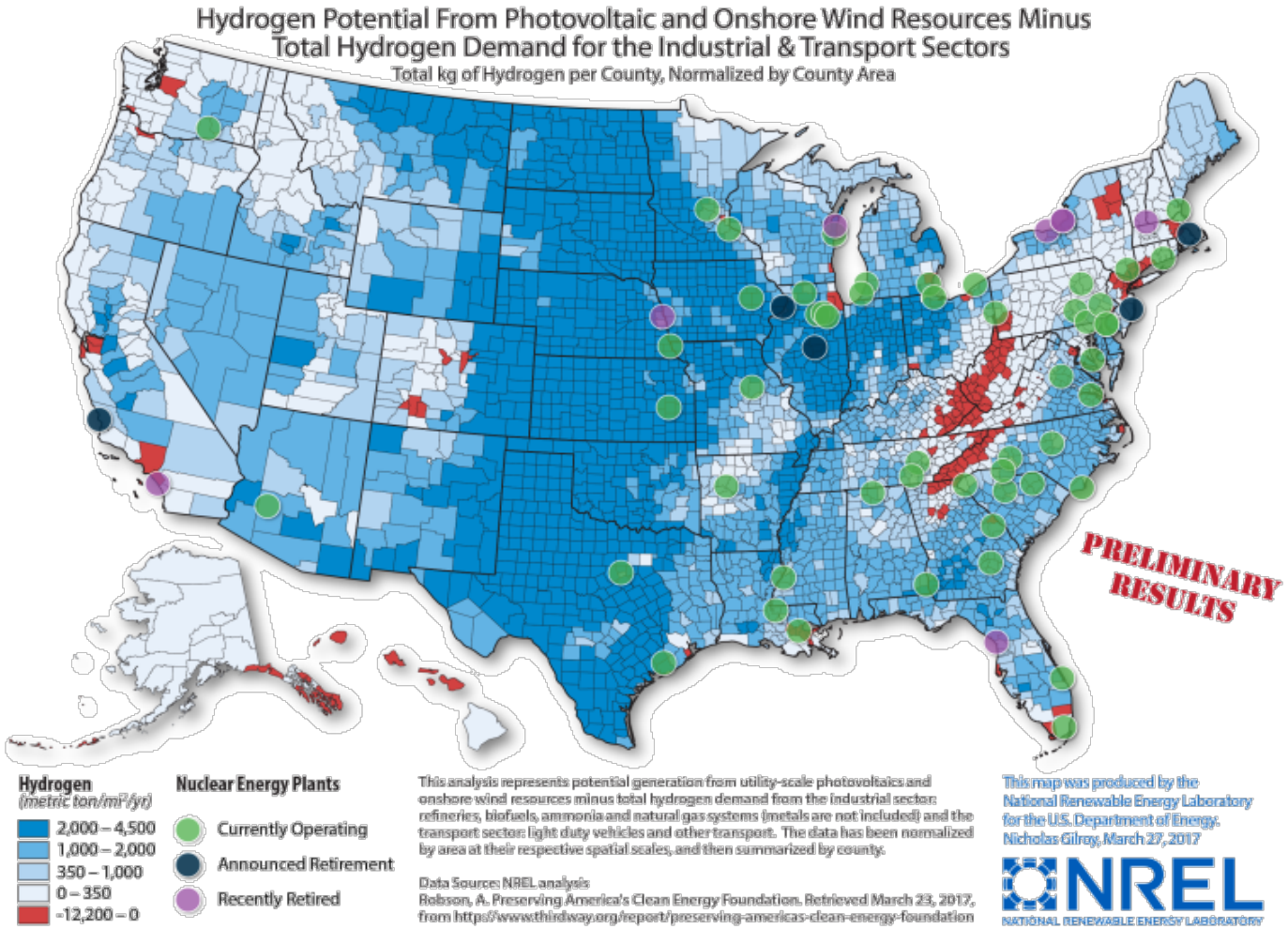
SERA

NREL

Tiers represent clusters of sequential FCEV introduction, based on **early adopter metrics,** industry input, and geographical considerations.

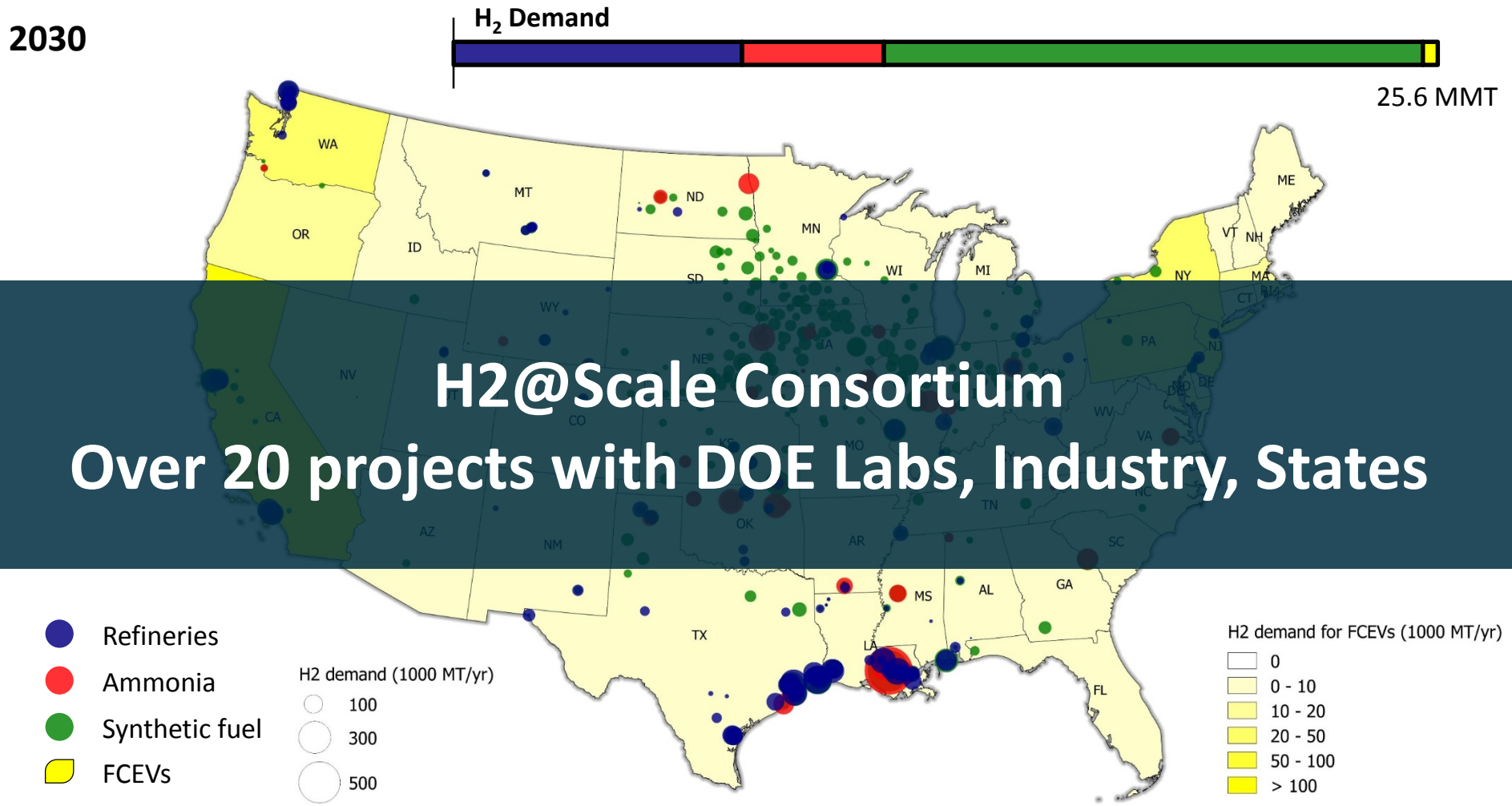
H_2@Scale: Supply and Demand Assessment

Assessing resource availability- most regions have sufficient resources



Red: regions where projected industrial & transportation demand exceeds supply for given scenario

Analysis and R&D Projects Underway

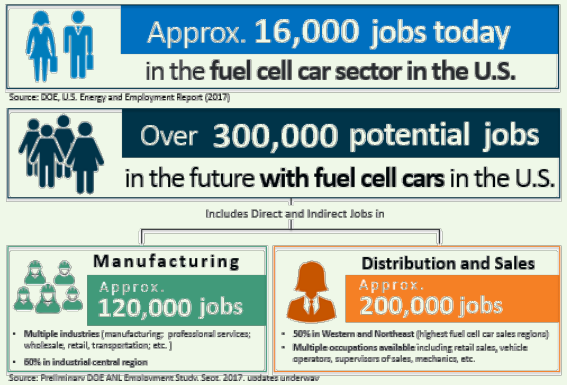


H2@Scale Consortium
Over 20 projects with DOE Labs, Industry, States

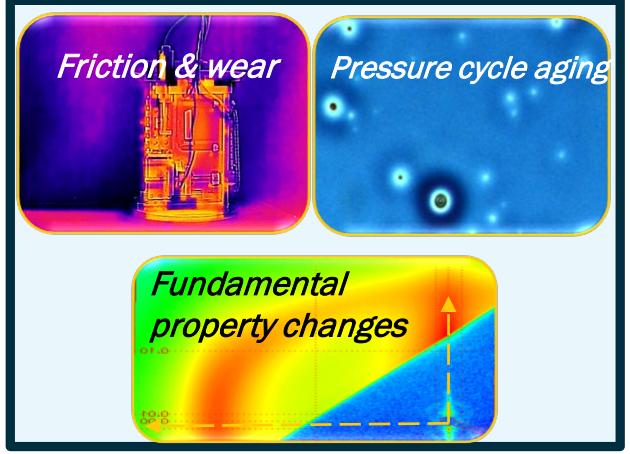
Source: Elgowainy, et al, ANL

Requests from Industry: Work with National Labs on…

Techno economic Modeling and Analysis



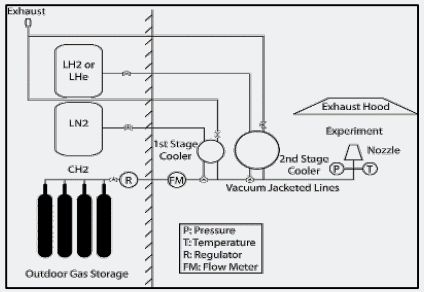
Hydrogen Materials R&D



Grid simulation and Testing R&D

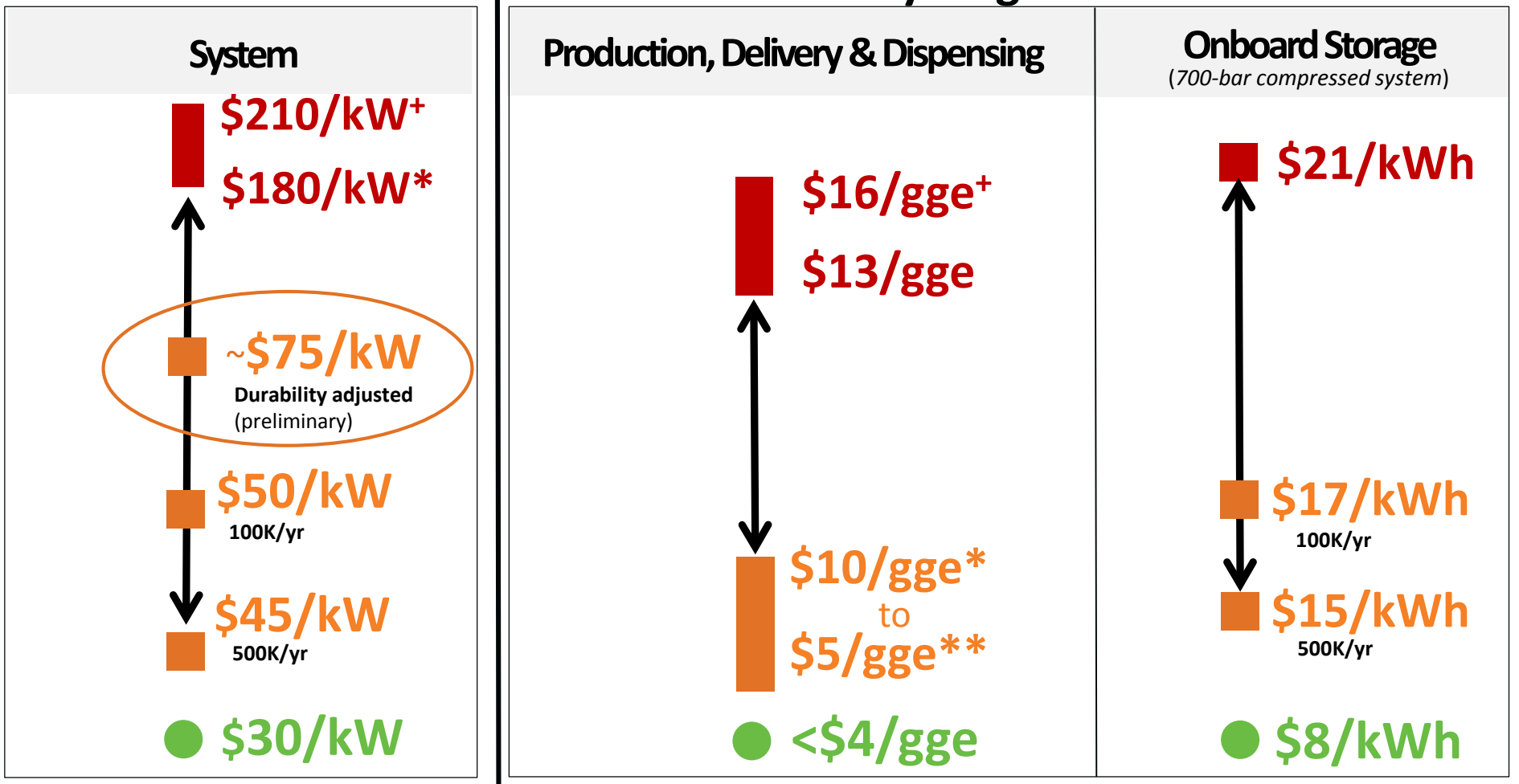
Safety and Infrastructure R&D

HyRAM
HYDROGEN RISK ASSESSMENT MODELS



Challenges

DOE Cost Status and Targets for R&D



+Based on commercially available FCEVs

*Based on state of the art technology

+Range assumes current production from NG and delivery and dispensing.

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

** 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

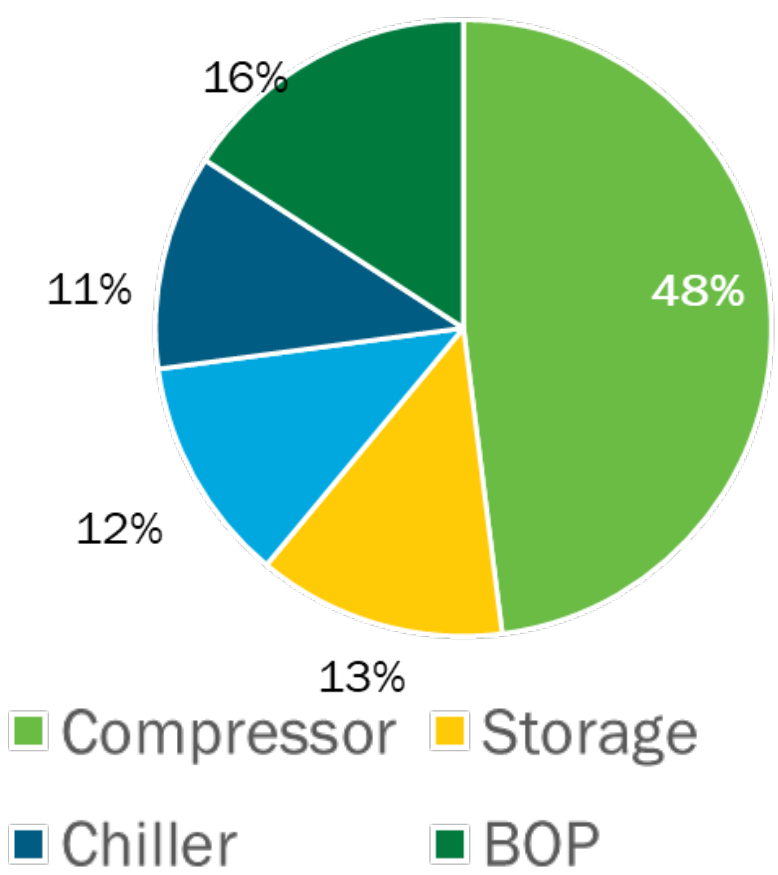
Notes: Graphs not drawn to scale and are for illustration purposes only. gge: gallon of gasoline equivalent

Typical Example from Reliability Engineering

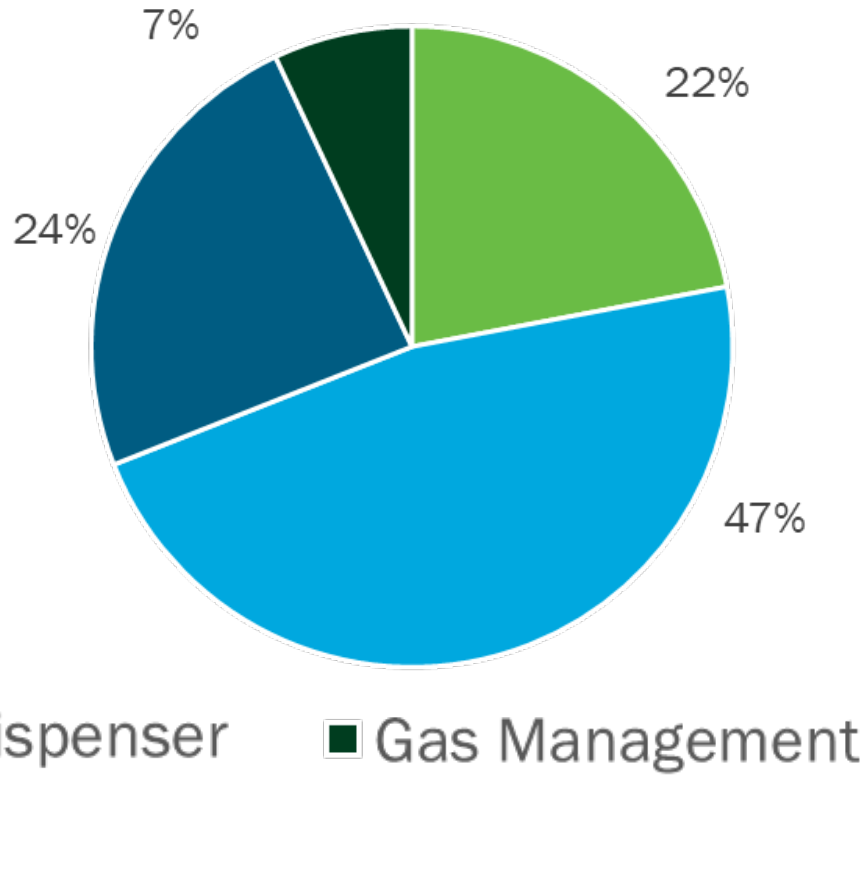
Need to increase useful life, improve reliability, durability, increase global supply chain

Real World Data and Analysis Guides R&D

Capital Costs of Gaseous Stations[1]



Maintenance Hours at Fueling Stations[2]



1. Assumes 180 kg/day station supplied by tube trailer. Source: HDSAM, ANL https://hdsam.es.anl.gov/index.php?content=hdsam

2. Composite Data Product 21, NREL https://www.nrel.gov/hydrogen/hydrogen-infrastructure-analysis.html

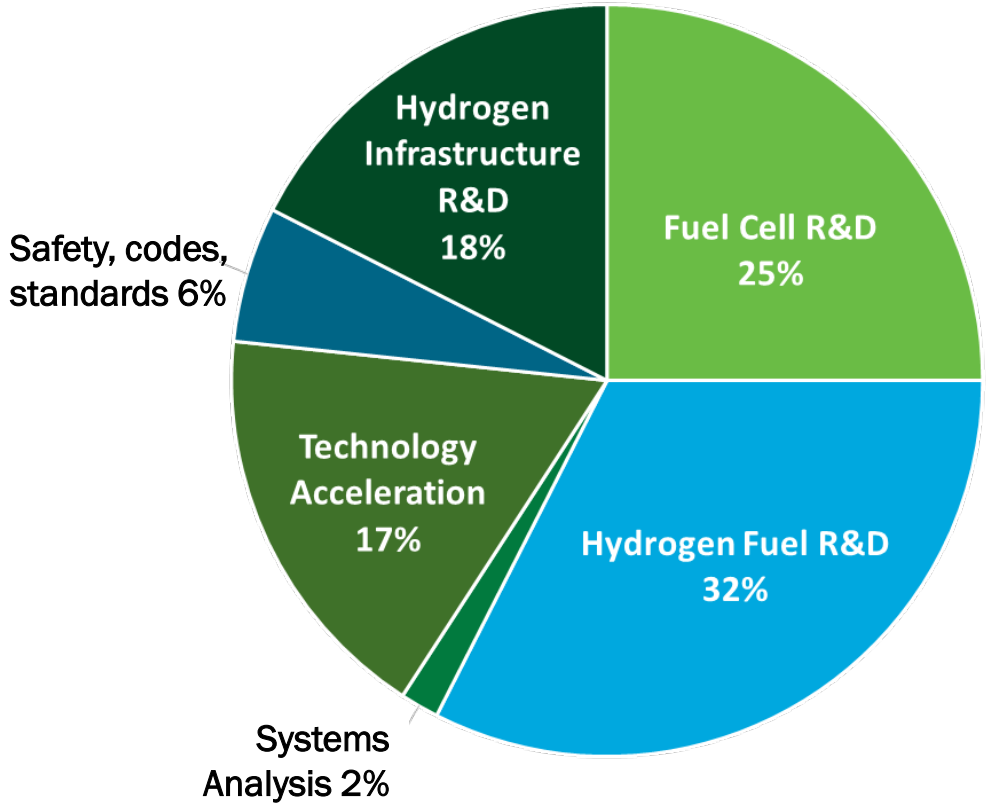
DOE Hydrogen and Fuel Cell Funding Appropriations

EERE – Fuel Cell Technologies Office (FCTO)

Key Activity	FY 2017	FY 2018	FY 2019
	($ in thousands)		
Fuel Cell R&D	32,000	32,000	30,000
Hydrogen Fuel R&D	41,000	54,000	39,000
Hydrogen Infrastructure R&D	-	-	21,000
Systems Analysis	3,000	3,000	2,000
Technology Acceleration	18,000	19,000	21,000
Safety, Codes and Standards	7,000	7,000	7,000
Total	101,000	115,000	120,000

EERE: Office of Energy Efficiency and Renewable Energy

New in 2019: Infrastructure R&D



Additional funding for basic science, SOFC, ARPA-E- roughly 40M, subject to yearly appropriations and projects


Collaboration &
Resources

What can you do?

Get involved and help spread the word!

Real World Example: Share Lessons Learned, Best Practices

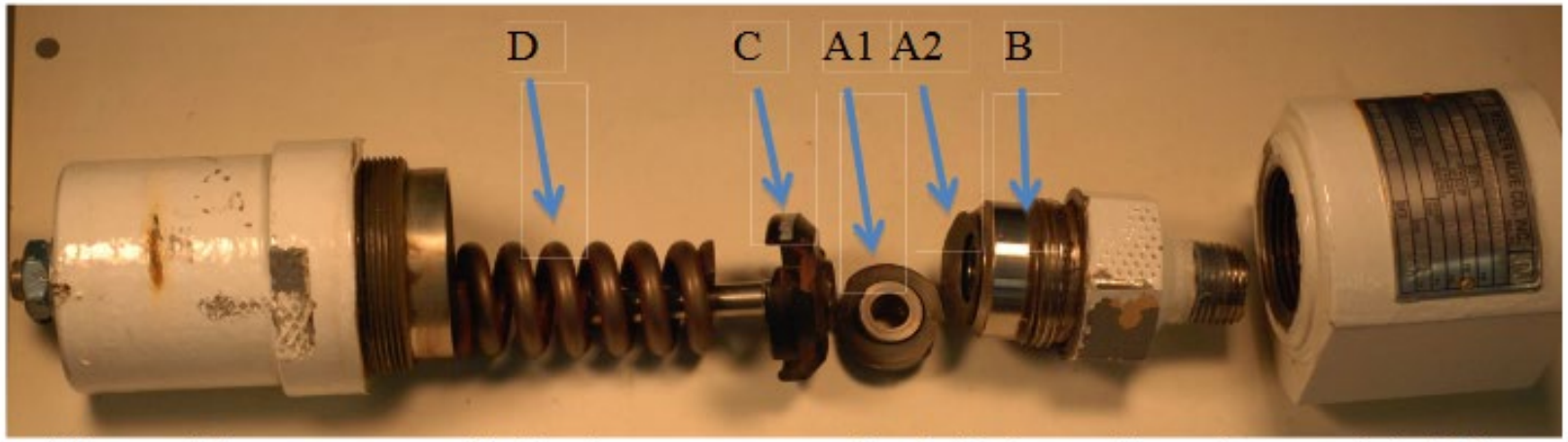


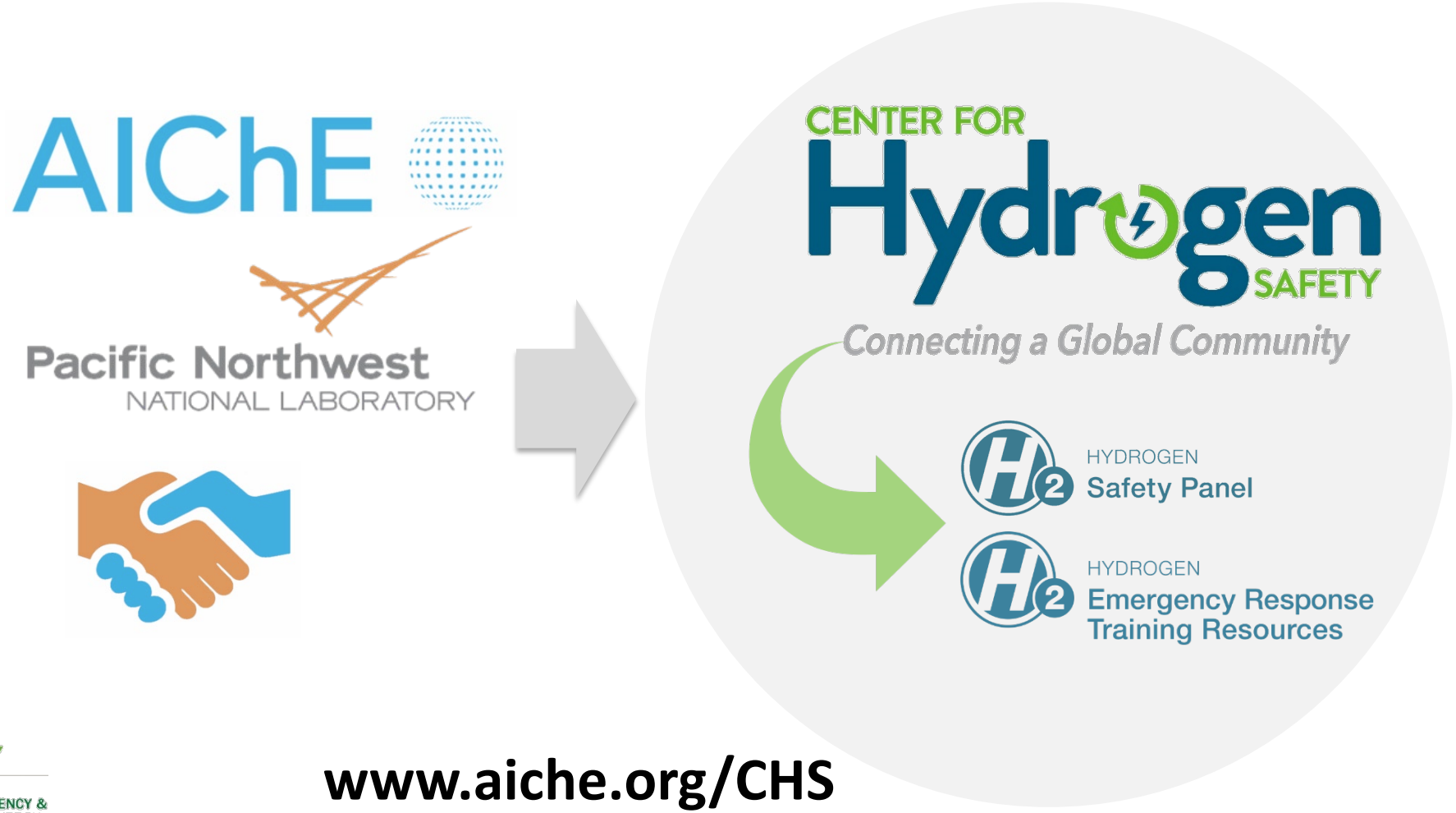
Figure A2. pressure relief valve components: failed nozzle subassembly (A1 and A2); inlet base (B); disk subassembly (C); set spring (D).

Pressure Relief Valve failure caused hydrogen release- major safety response and evacuation

Type 440C stainless not suitable for ths application

New Global Safety Partnership: Center for Hydrogen Safety (CHS)

Industry, governments partner: Access to 110 countries, 60,000 members through AIChE



U.S. DEPARTMENT OF ENERGY
Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

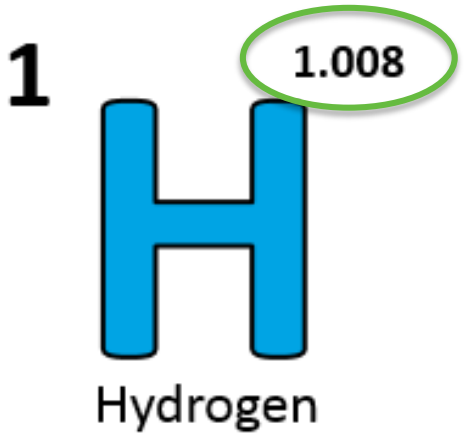
www.aiche.org/CHS

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 H_2IQ

Save the Date: May 18-21 2020
Annual Merit Review
Washington DC

Learn more at: energy.gov/eere/fuelcells

International government collaboration to accelerate progress

The International Partnership for Hydrogen and Fuel Cells in the Economy

Enabling the global adoption of hydrogen and fuel cells in the economy

www.iphe.net

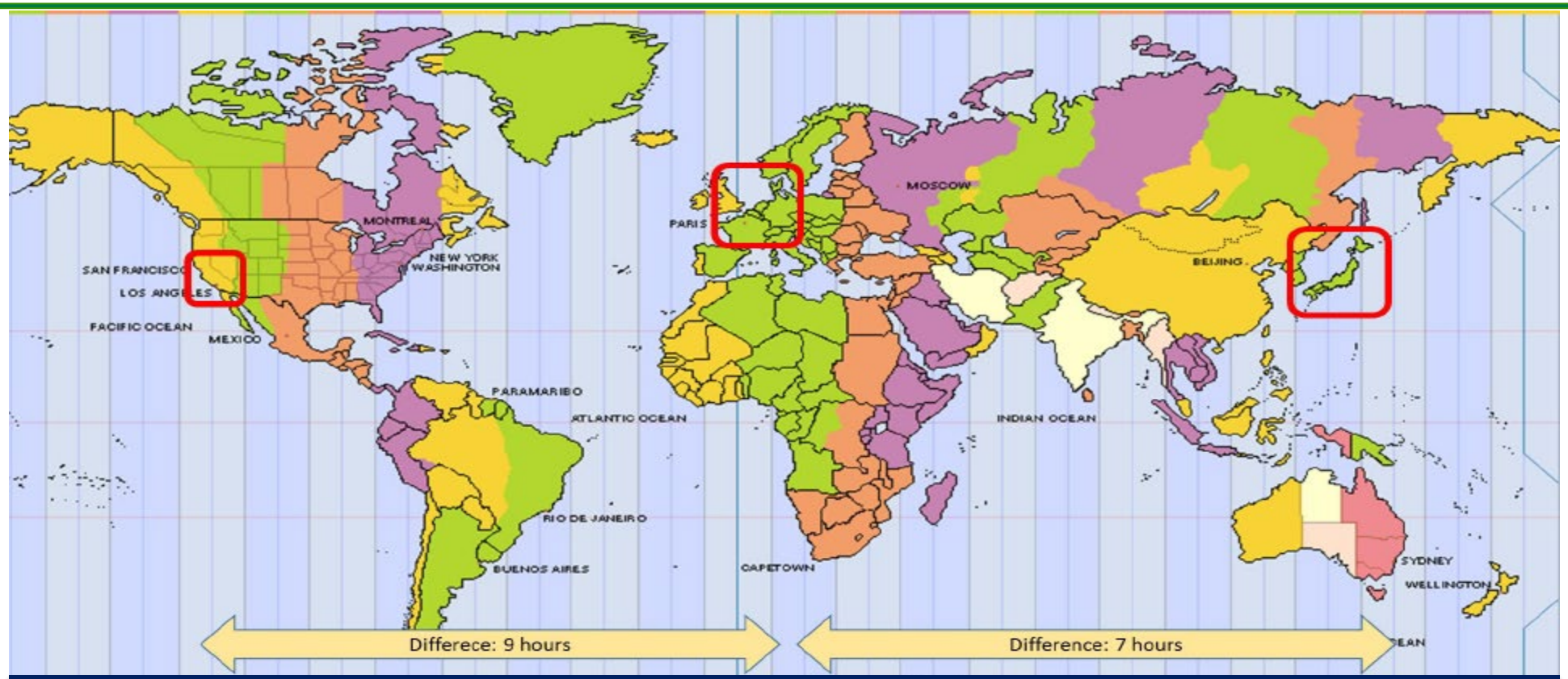
Working Groups: Education & Outreach
Regulations, Codes, Standards & Safety

Save the Date:
Oct 23
In Seoul, ROK
IREC+IPHE

Find IPHE on Facebook, Twitter and Linkedin
Follow IPHE **@The_IPHE**

Formed 2003
Over 20 Countries

Hydrogen and Fuel Cell Day Challenge on Oct 8.



- Builds on H2 Challenge in Netherlands
- Teams drive 10.08 hours and score points along the way
- Start in Japan, continue in Europe and finish in the U.S.
- Players share experience in social media

Δt

~2000 to Today

=

Today to 2040

Thank you

International Partnership
for Hydrogen and Fuel Cells
in the Economy