U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Department of Energy Hydrogen and Fuel Cell Activities

Dr. Dimitrios Papageorgopoulos, Fuel Cell R&D Program Manager

The 30th International Electric Vehicle Symposium & Exhibition

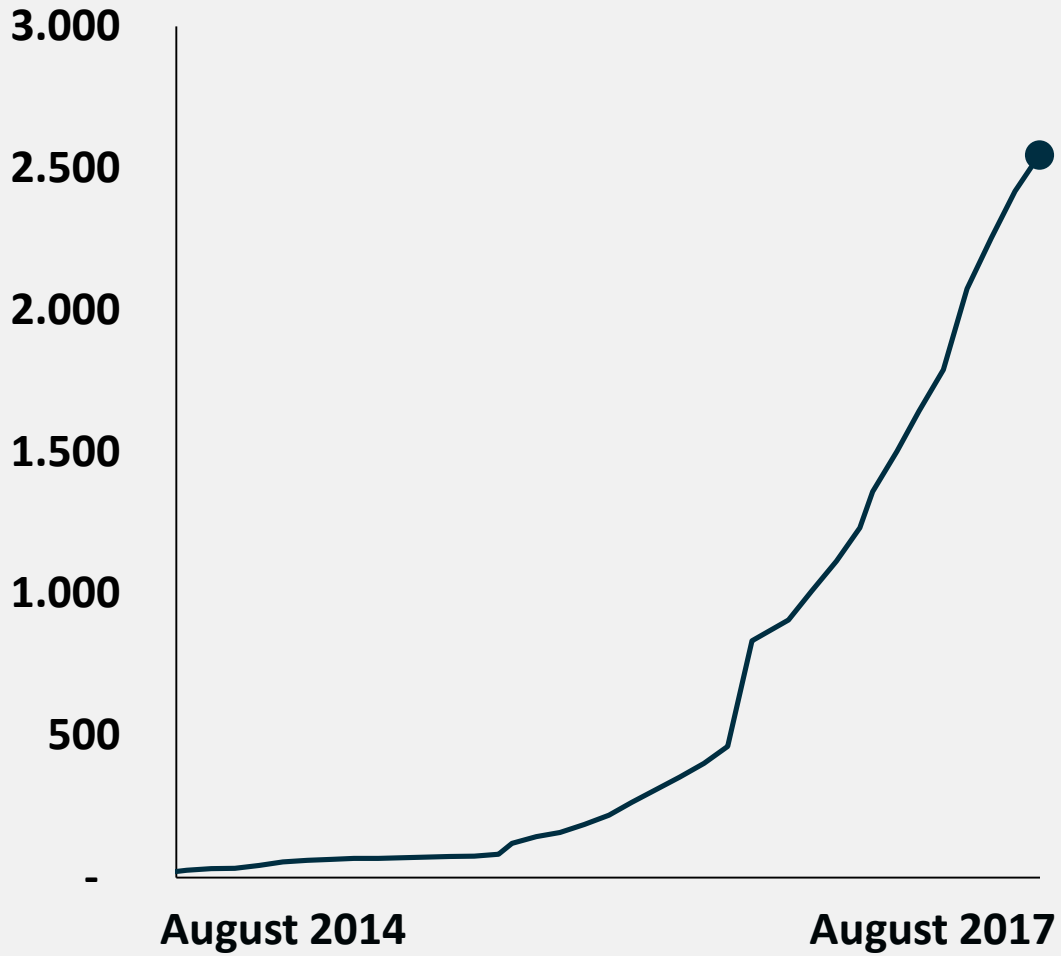
Messe Stuttgart, Germany – Oct. 11, 2017

4 Key Messages

1. Increased market growth, infrastructure progress and niche markets emerging

U.S. Fuel Cell Car Sales and Expert Outlook

Fuel Cell Car Sales Growing



Note: Cumulative number of vehicles sold/leased. Source: hybridcars.com

2,500
fuel cell cars

sold or leased in the U.S.

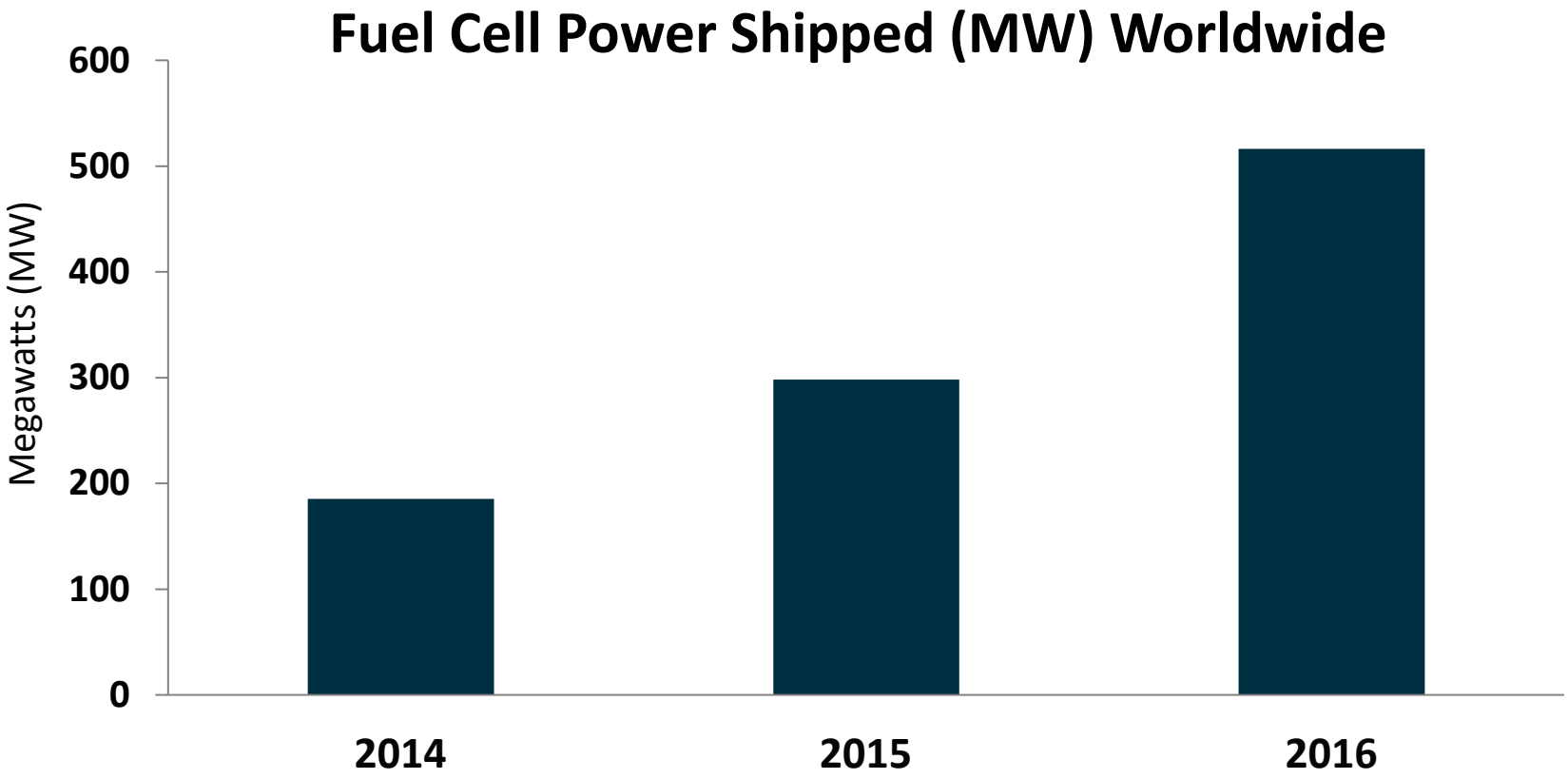
78%
of executives

Absolutely or partly
agree that

Fuel cell cars will be the real breakthrough for electric mobility

KPMG, Global Automotive Executive Survey 2017 (Jan. 2017)

Consistent Fuel Cell Market Growth Continues



500 MW fuel cell power shipped worldwide

62,000 fuel cell units shipped worldwide

Approximately **$1.6 Billion** fuel cell revenue

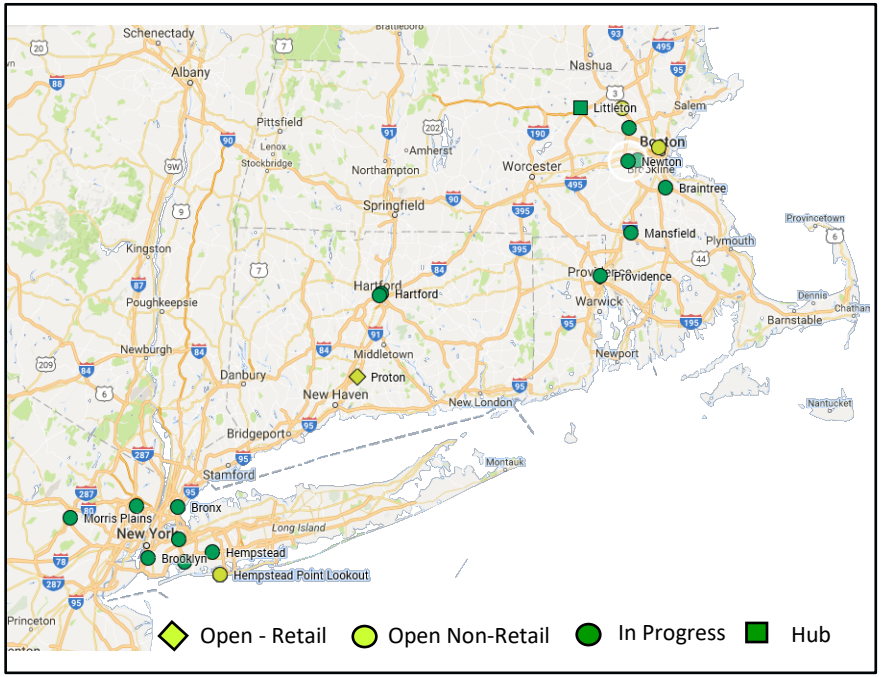
Source: DOE and E4Tech

Hydrogen refueling stations: strong State support

California

Over 30 open retail

Funding for 100

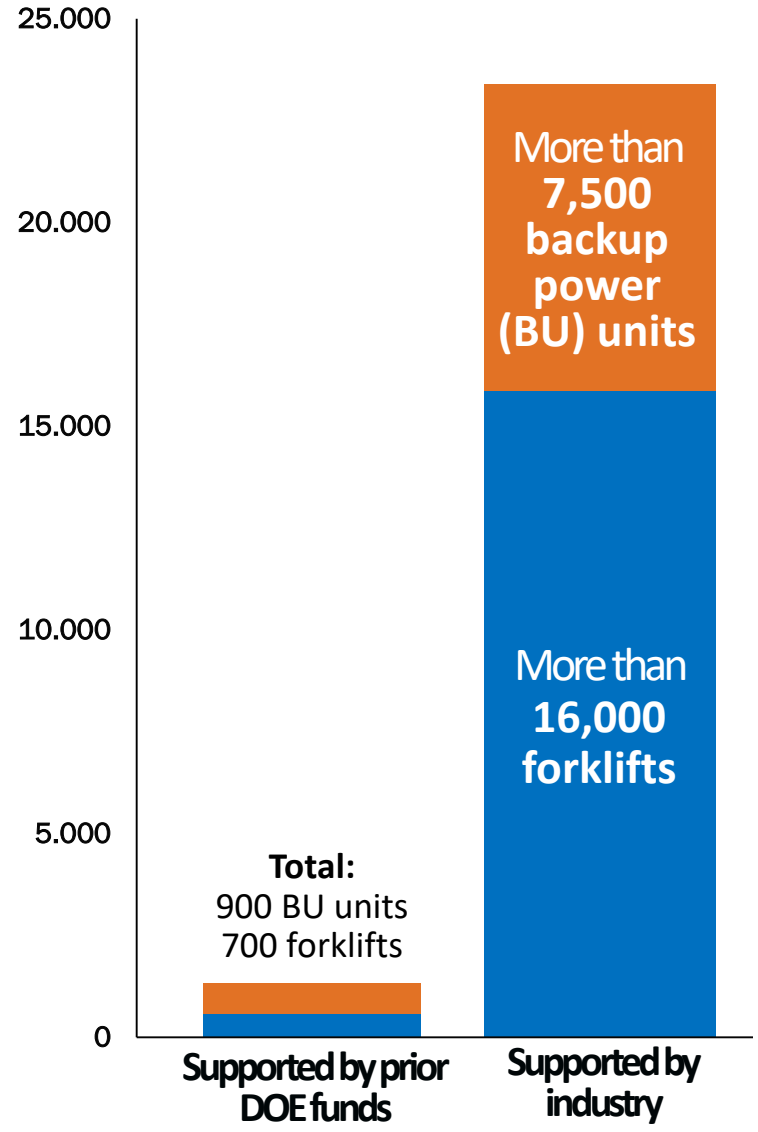


Northeast

Approx. 12 to 25 stations planned

Others with interest: Hawaii, Ohio, Texas, Colorado, South Carolina, and others

Catalyzing Early Markets for Fuel Cells



Heavy Duty Vehicle Applications Emerging

Fuel cell delivery and parcel trucks starting deliveries in CA and NY

Fuel cell buses in CA surpass 17M passengers

Industry demonstrates first heavy duty fuel cell truck in CA

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

Stationary Power Applications Emerging – Examples

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

Fuel cells used to power new World Trade Center in NYC

Fuel cell power for maritime ports demonstrated in Honolulu, Hawaii

Over 235 MW of fuel cell stationary power installed across more than 40 US states

2. Strong global support and growing collaboration

A Global Initiative Supporting H2

The Hydrogen Council

Investment

Over $10B

towards

hydrogen and fuel cells

Members

16 companies

representing

$1T in revenues and 1.7M jobs

More information: hydrogeneurope.eu

3. Continued collaboration to address remaining technical challenges

DOE Hydrogen and Fuel Cells Program

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

PGM = Platinum group metals

MEA = Membrane Electrode Assembly

Early R&D Impact

60% Lower Fuel Cell Cost

Greater Fuel Cell Durability

4X more hours

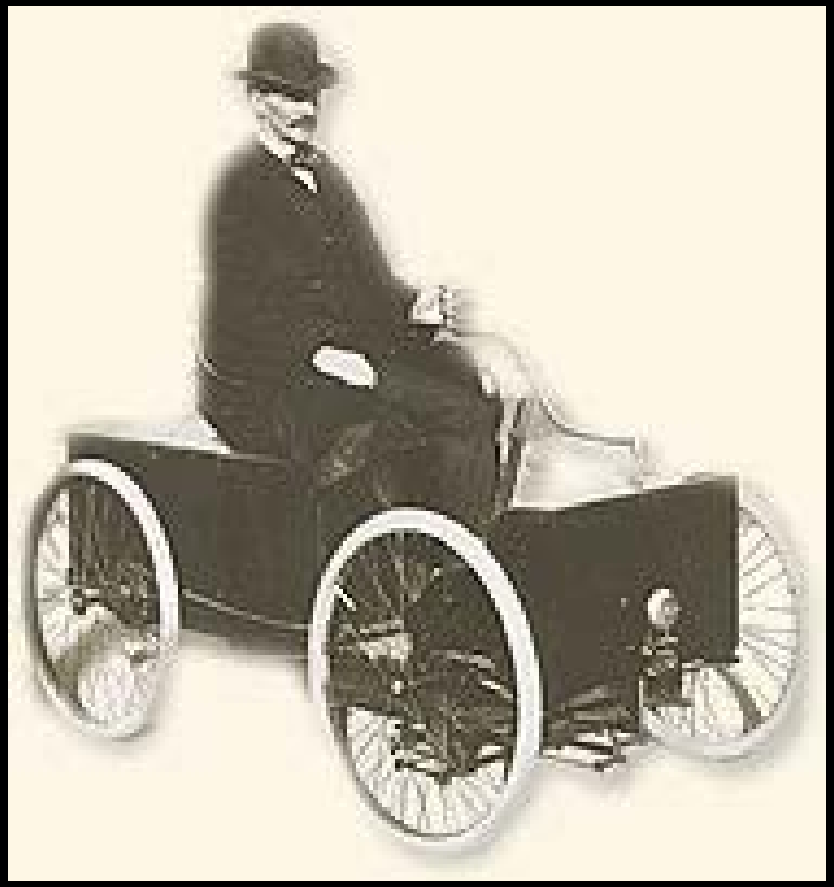
of fuel cell lifetime since 2006

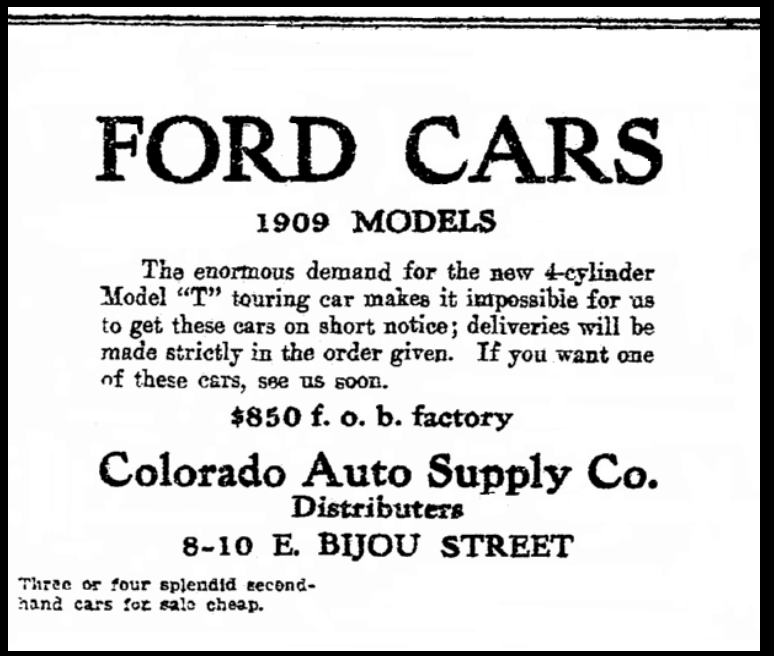
80% Lower Electrolyzer Cost

for H_2 production since 2002

What can we learn from history?

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





FORD CARS

1909 MODELS

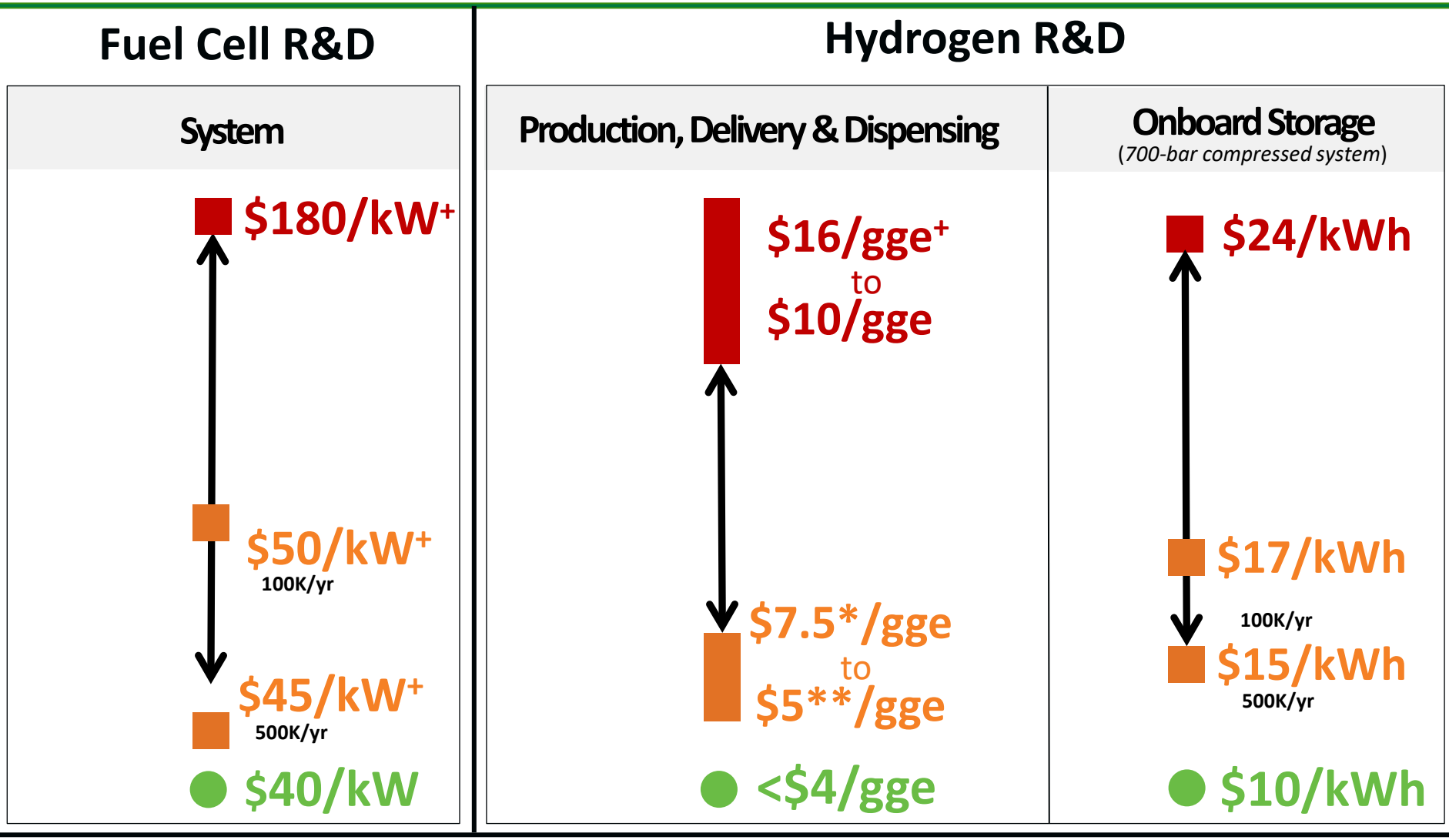
The enormous demand for the new 4-cylinder Model "T" touring car makes it impossible for us to get these cars on short notice; deliveries will be made strictly in the order given. If you want one of these cars, see us soon.

$850 f. o. b. factory

Colorado Auto Supply Co.
Distributers
8-10 E. BIJOU STREET

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

DOE Cost Status and Targets



*Based on Electrolysis **Based on NG SMR + Preliminary, updates underway
Onboard storage cost status from DOE Program Record 15013

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

Techno-Economic Analysis Guides R&D Portfolio

Fuel Cells

Bipolar Plates
Membranes
BOP
MEA
Frames/Gaskets
GDLs

Focusing on…

Low and Non PGM Catalysts,

Alkaline Membranes

H_2 Station

Storage
Cooling
Dispensing
Other

Advanced Compression

Alternate Approaches

H_2 Storage

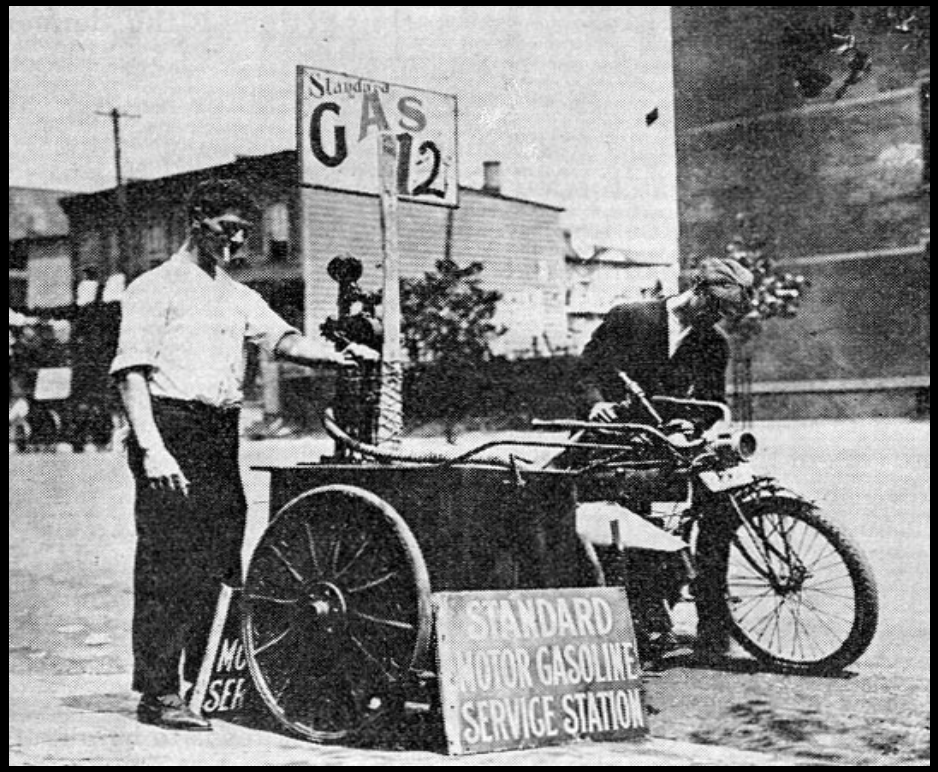
BOP/Assembly
Other processing
Resin

Low Cost Carbon Fiber (CF)

Long term Materials Approaches

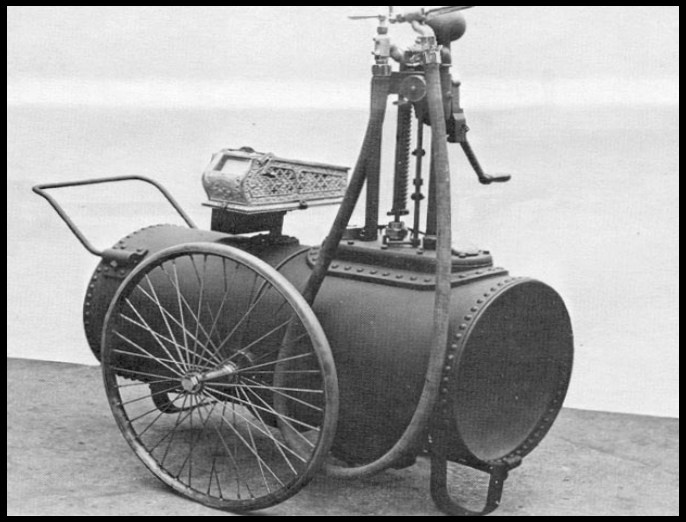
Gasoline History: Many diverse options

Cans, barrels, home models, mobile refuelers



Source: M. Melaina 2008.

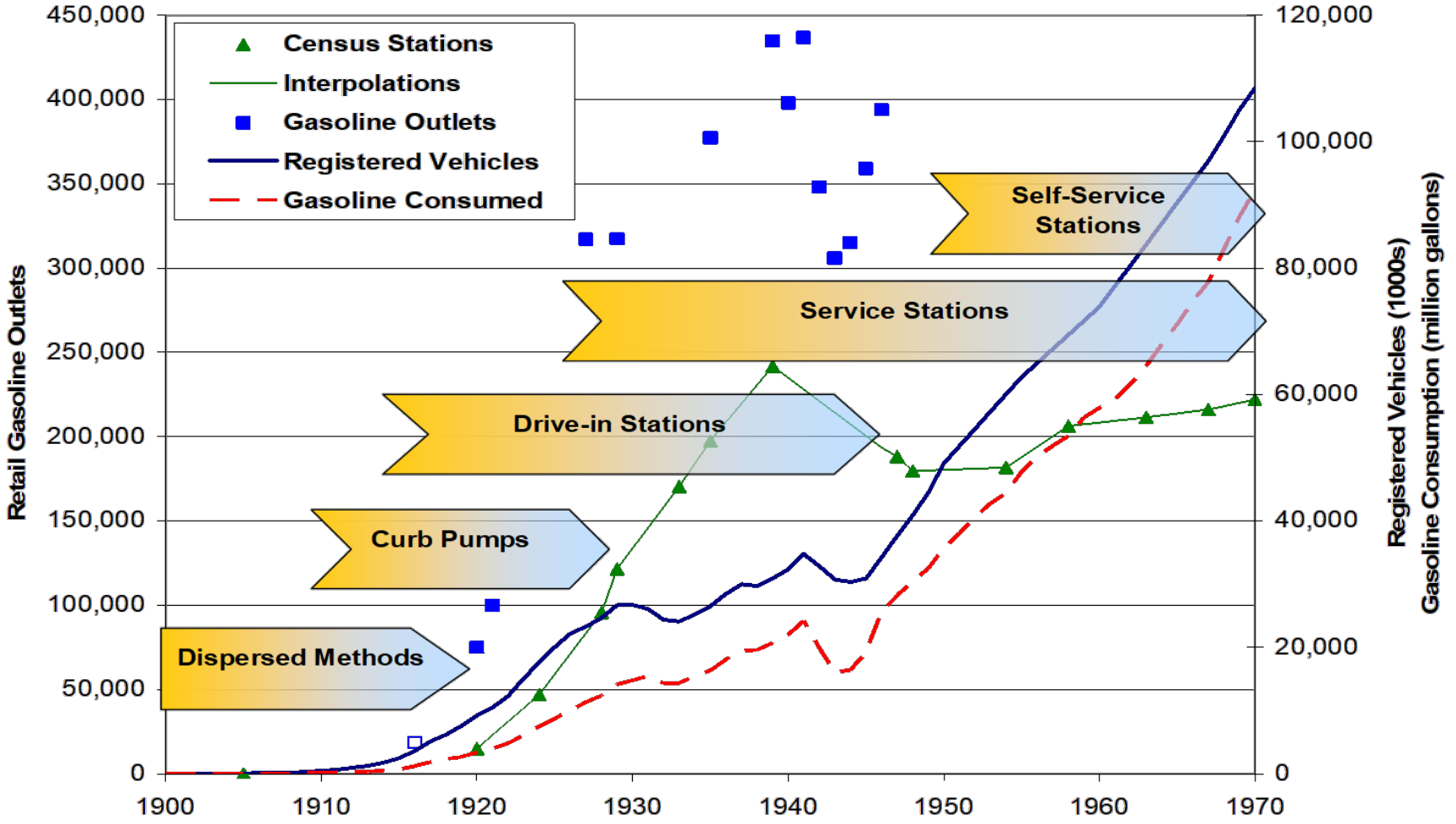
Source: Vieyra, 1979



Source: Milkues, 1978

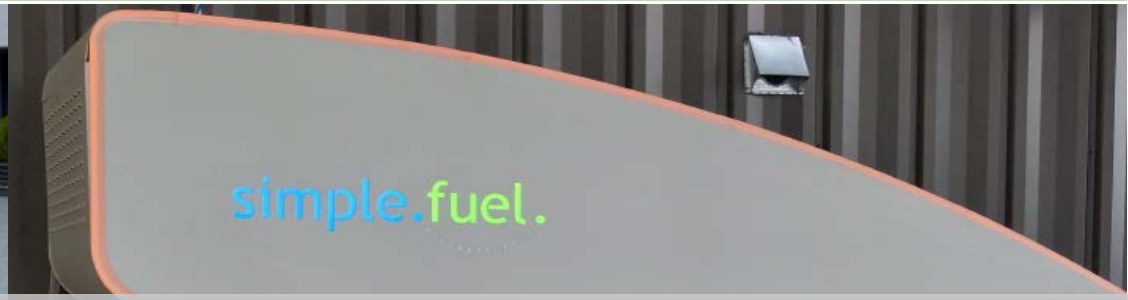
Refueling Methods Evolved Over Time

History shows phased introduction of different refueling methods



Source: Turn of the Century Refueling: A Review of Innovations in Early Gasoline Refueling Methods and Analogies for Hydrogen (Melaina 2007)

Enabling Infrastructure: H-Prize



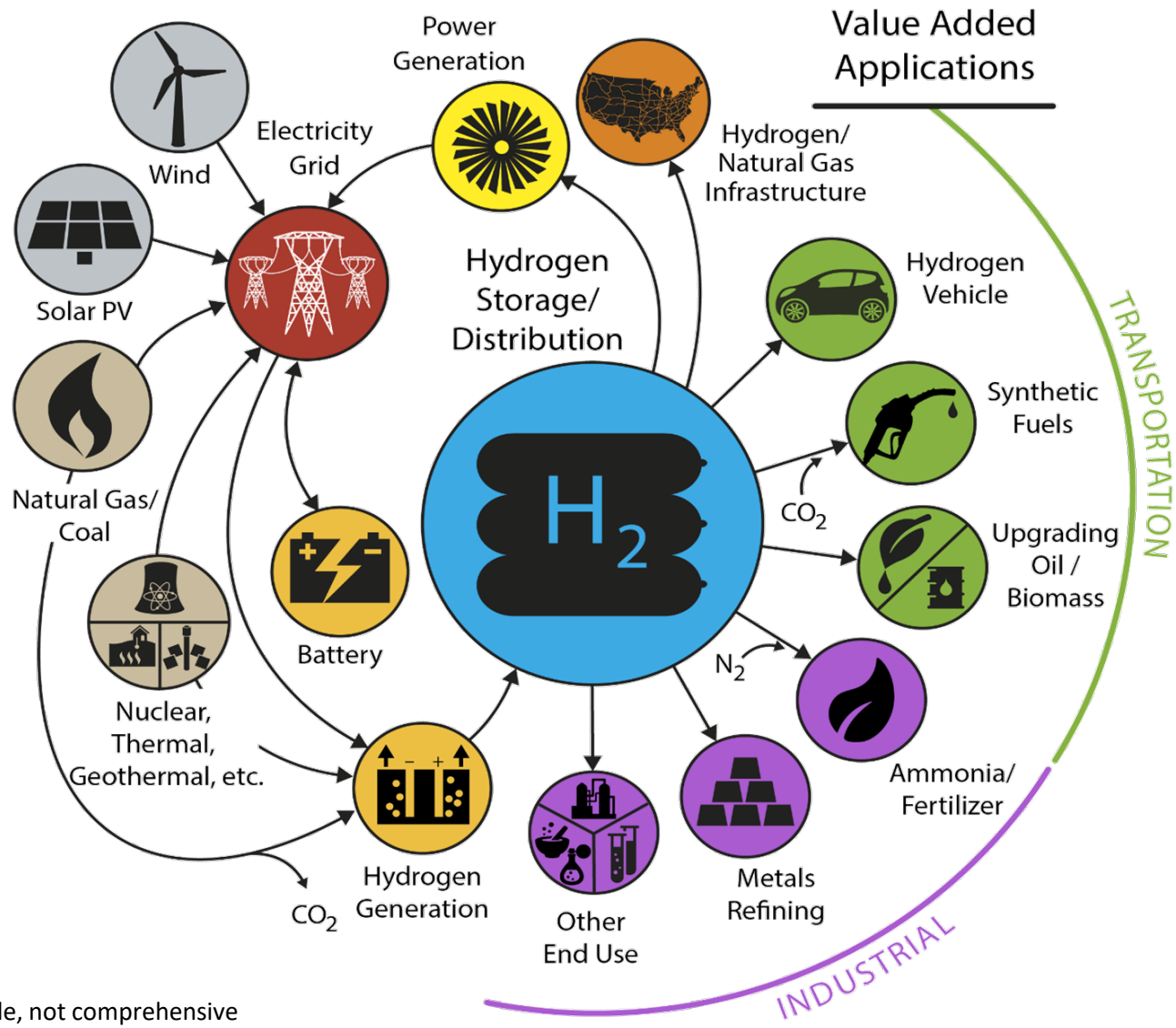
DOE awards $1M H-Prize to Simple Fuel for winner small-scale H_2 fueling design

H2refuel
www. hydrogenprize.org

simple.fuel.™
Email: connect@ivysinc.com
More info: www.teamsimplefuel.com

Ivys Energy Solutions (MA)
McPhy Energy (MA)
PDC Machines (PA)

H_2 at Scale Energy System



*Illustrative example, not comprehensive
Source: NREL

4. Information sharing and education are critical as we move forward

Technology Data, Models and Resources Available

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

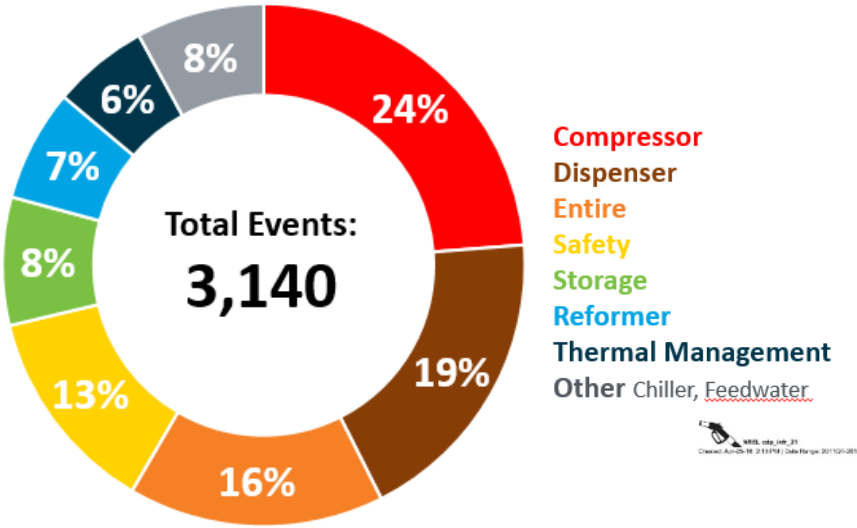
To Participate

techval@nrel.gov

Models "Toolbox" Online

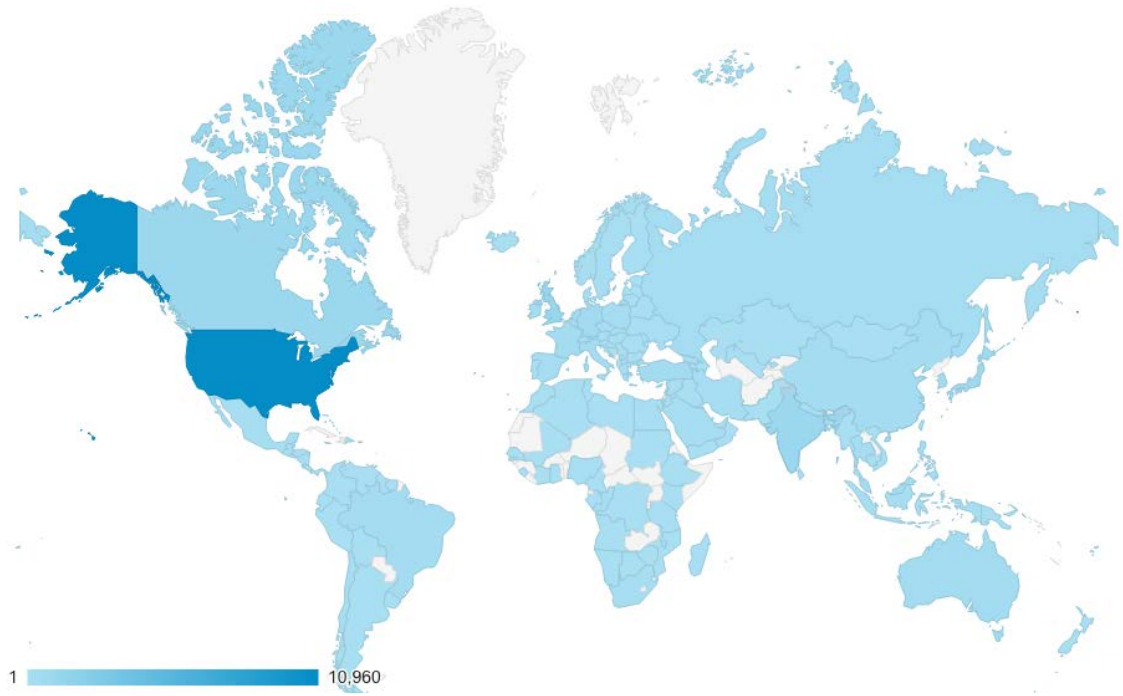
- Financial, technical and economic models covering H_2 infrastructure, jobs, and more.
- Visit: **energy.gov/eere/fuelcells/hydrogen-analysis-toolbox**

Example: Sources of H_2 Infrastructure Maintenance



Most maintenance related to compressors and dispensers

H2Tools: One-stop for H2 safety knowledge



- Includes resources on **safety** best practices, **first responder training**, and **H_2 codes & standards**

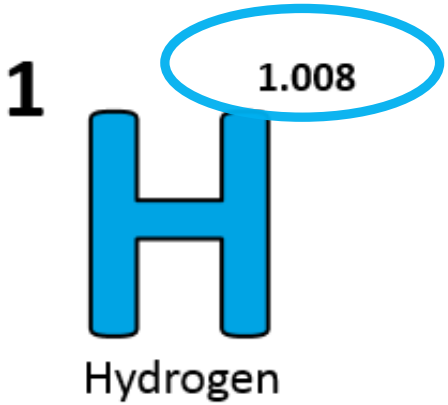
- Site visit tracking shows a **global reach: 50%** of visits are **international!**
- Over **31,000 site visits** in the first year alone
- Training resource **translated into Japanese**

Ways to Spread the Word

Celebrate Hydrogen & Fuel Cell Day

October 8 or 10/8

(Held on its very own atomic- weight-day)



Learn more:

energy.gov/eere/fuelcells

Give a *Increase your H2IQ* presentation in your community!

INCREASE YOUR H2IQ

Download for free at:

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

Summary

- **Enable early R&D innovation**
  - Hydrogen fuel
  - Fuel cells
  - H2@Scale
- **Leverage activities to maximize impact**
  - Enable infrastructure and cross-sector impacts
  - Partnerships- other agencies, industry, states, etc.
  - Collaboration on safety R&D and information sharing

Thank You

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