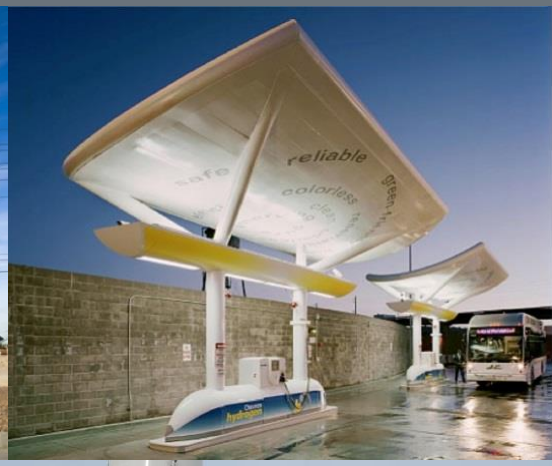
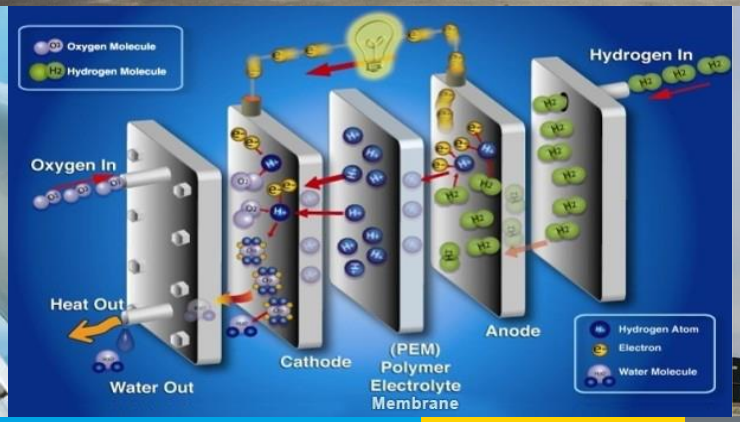
U.S. Department of Energy
Fuel Cell Technologies Office

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy





H_2 and Fuel Cell Revolution

Washington, DC

January 10, 2017

Dr. Sunita Satyapal

Director

Fuel Cell Technologies Office

U.S. Department of Energy

The beginning of the DOE Fuel Cell Program…

1970s A group of scientists and DOE managers met at Los Alamos to set the foundation for DOE fuel cell programs

Lab researchers taught scientists around the world how to fabricate fuel cell electrodes. GM relocated to Los Alamos.

For the first time in history: Commercial FCEVs

Hyundai Tucson Fuel Cell SUV

Toyota Mirai

Honda FCV

Commercial FCEVs are here **today!**

Can reduce total GHG emissions 50-90% vs. today's gasoline vehicles

FCEV: Fuel Cell Electric Vehicle
GHG: Greenhouse Gases

Power, Performance & Pollution-Free

Fuel Cell Electric Vehicles can:

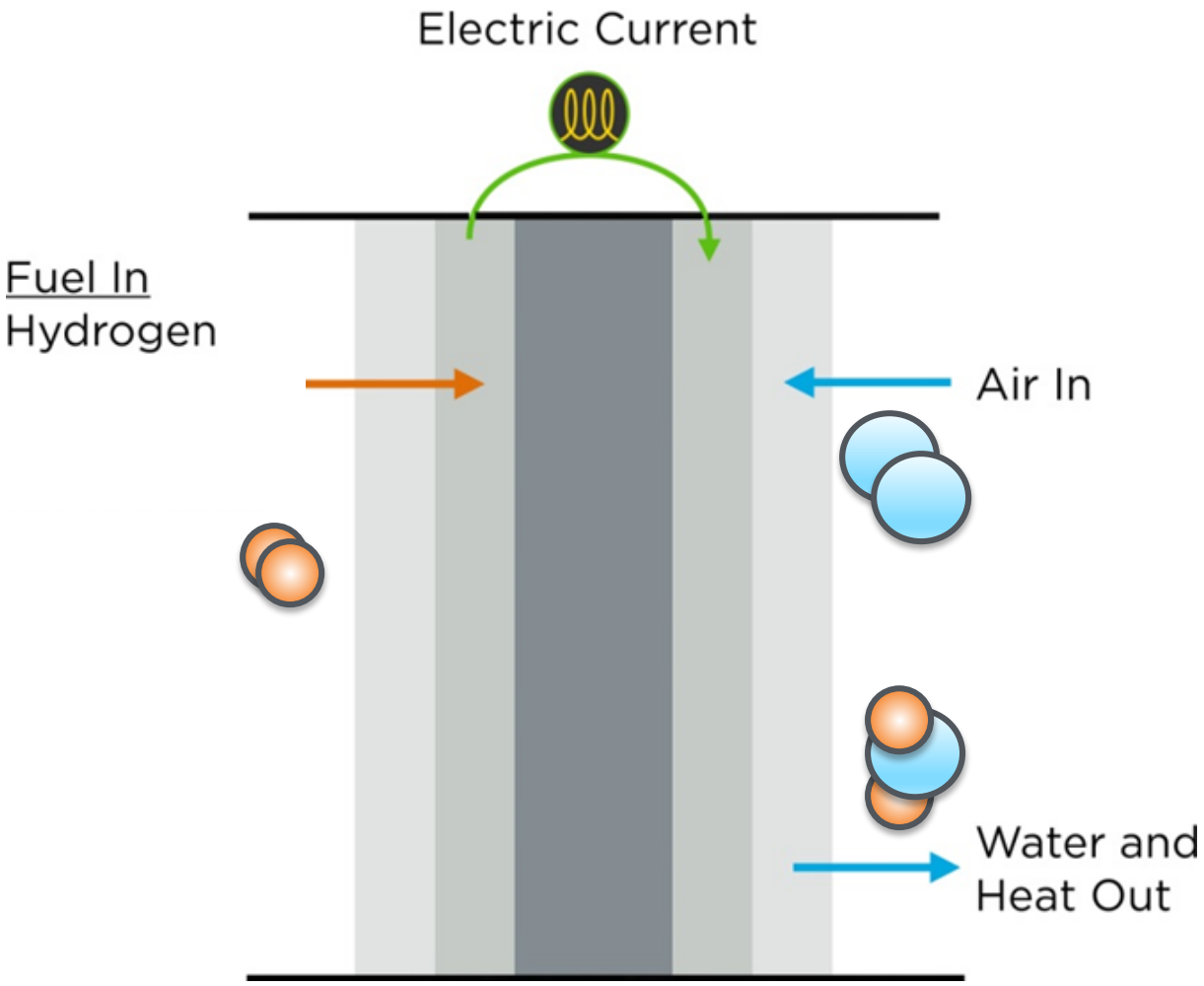
- ✓Refuel in minutes
- ✓Have a 300+ driving range
- ✓Get more than 65 miles per gallon (equivalent)
- ✓High power (torque and acceleration)

And all with zero pollution from the tailpipe- only clean water vapor

FCEV Ride-n-Drive at DOE Headquarters

Watch Secretary Moniz driving the Mirai!
http://energy.gov/eere/fuelcells/test-driving-toyota-mirai

Fuel Cells: What are they and how do they work?



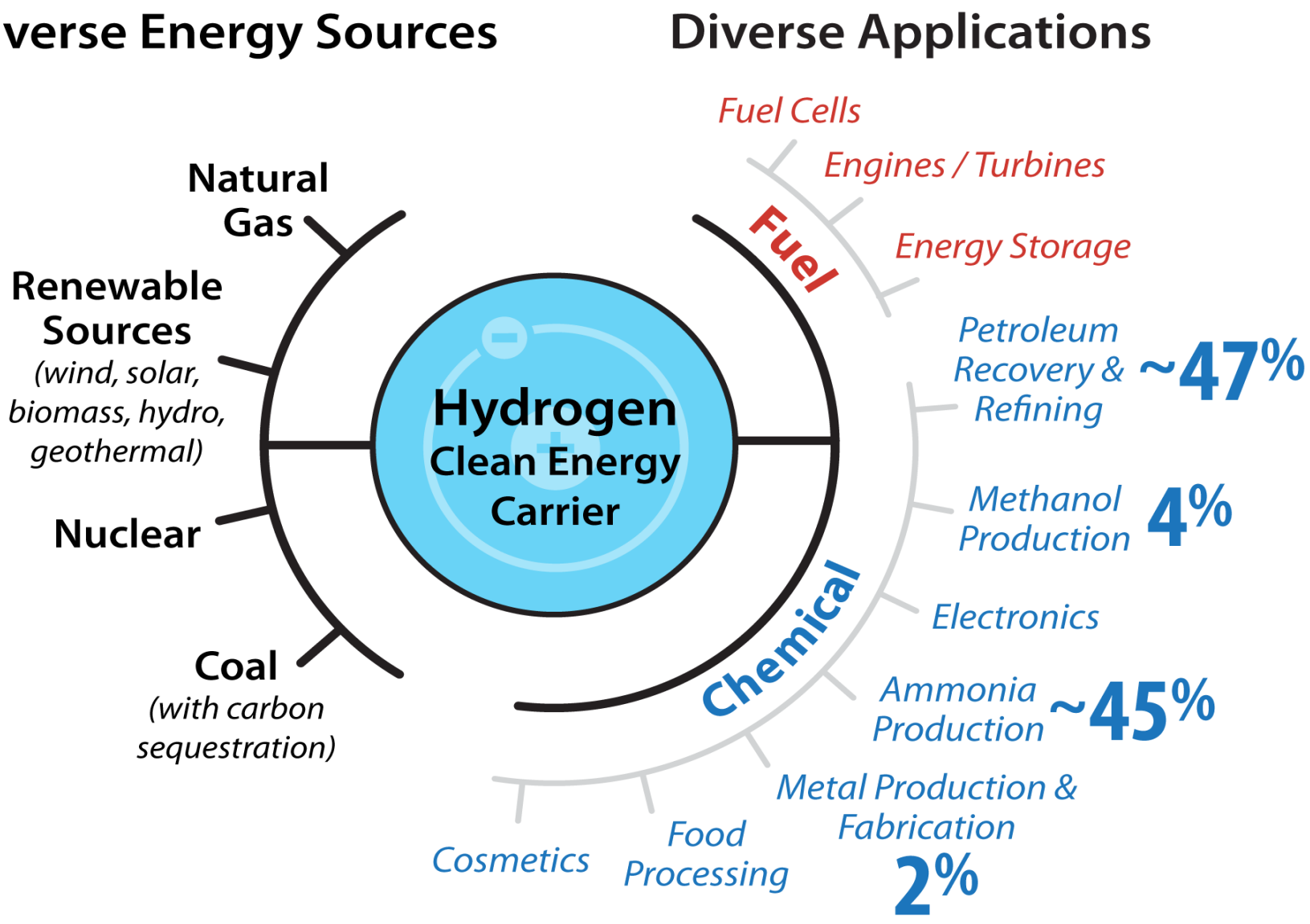
No combustion involved

Electricity produced **directly**

Twice as efficient as today's combustion engines

Fuel Cells produce electricity like batteries but don't need to be plugged in

Hydrogen- A Clean, Flexible Energy Carrier



Source: DOE, NREL, Hydrogen and Fuel Cell Program

Hydrogen Production Nationwide

We already produce **~ 10M metric tons of H_2** per year

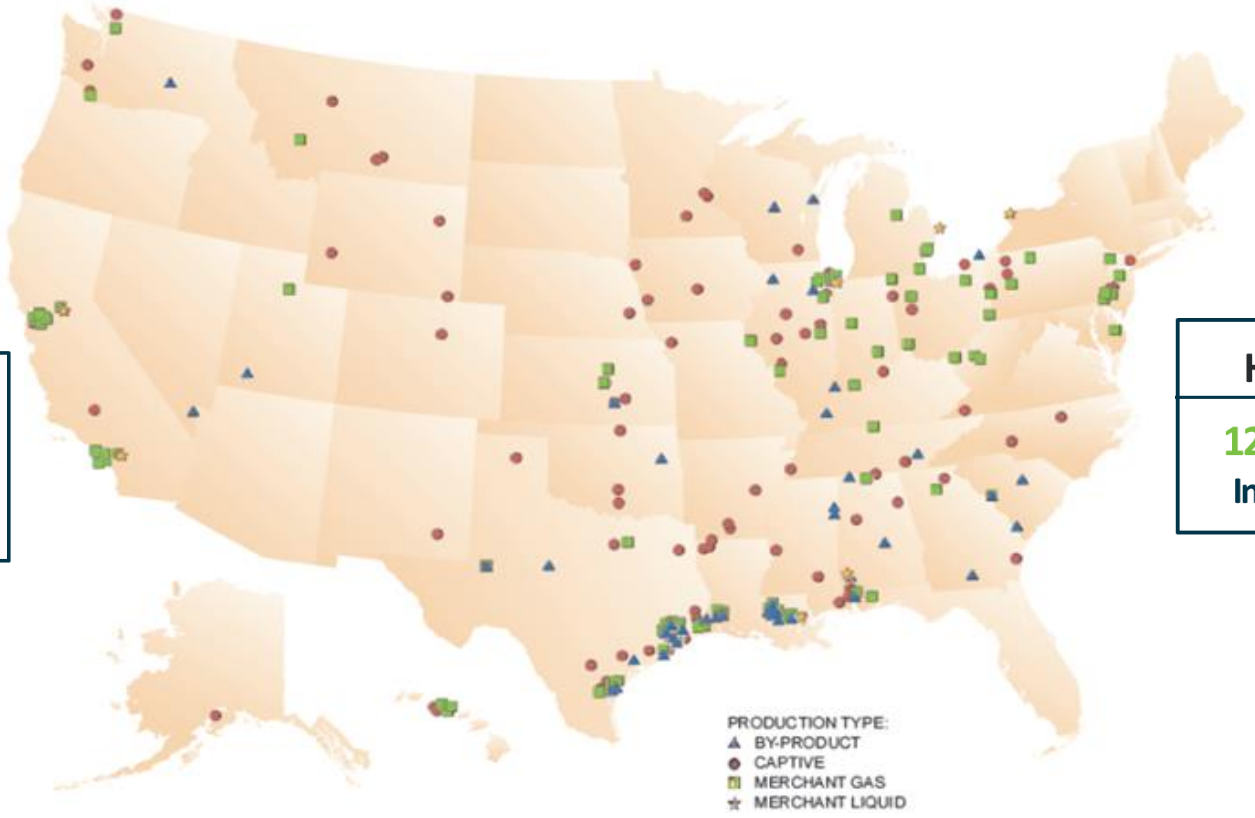
Today there are **more than 1600 miles of H_2 pipeline**

H_2 Stations

25 retail in CA

Approx. 50 underway

Funding for: 100



H_2 Stations

12- 25 planned

In the Northeast

Centralized H_2 Production Facilities

Many states already produce many metric tons of hydrogen

Life-cycle GHG Emissions- Today's Cars

Low, Medium & High GHGs/Mile for 2015 Technology

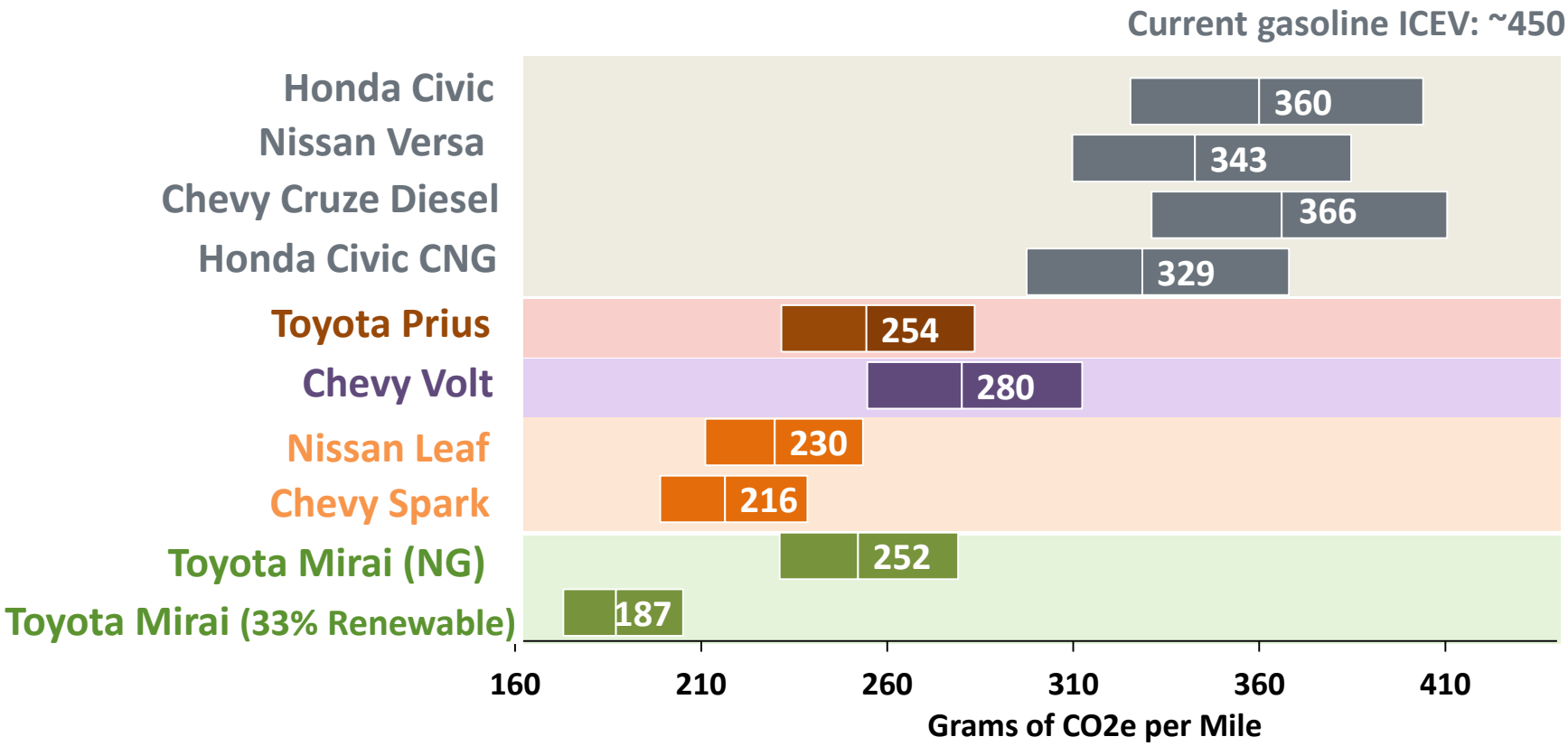
Internal Combustion Engine

Hybrid Electric

Extended-Range Electric

Battery Electric

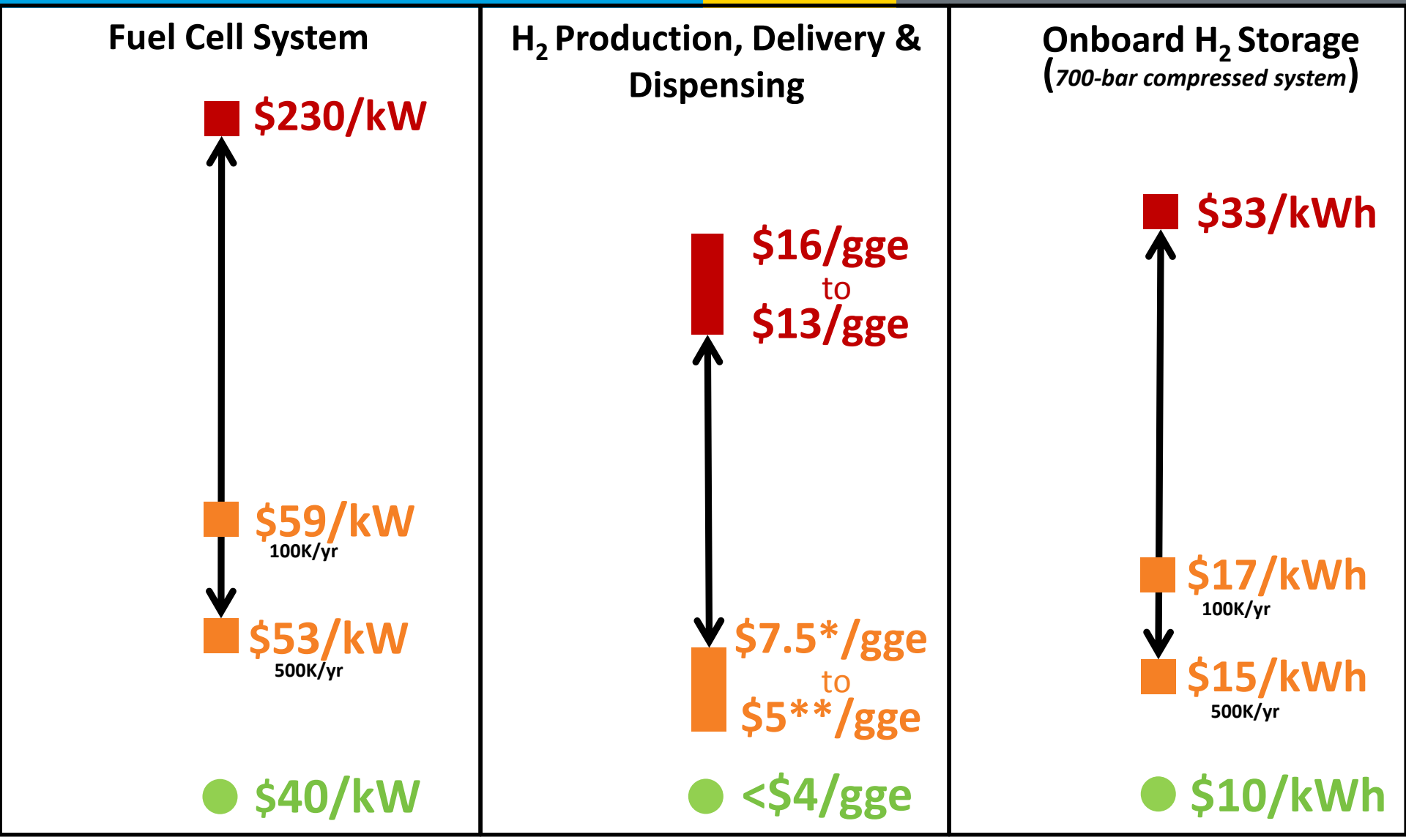
Fuel Cell Electric



Joint VTO-FCTO Analysis Example

Source: Program Record 16004
(https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf)

Cost Status and Targets



*Based on Electrolysis **Based on NG SMR

*For illustration purposes only, not drawn to scale

Fuel Cells: Big Leaps in the Last Year

Fuel cell buses surpass 15 million passengers

Fuel Cells: Big Leaps in the Last Year

Over 10,000 fuel cell forklifts

Over 1.5 million H_2 refuelings

Fuel Cells: Big Leaps in the Last Year

Fuel cell powered lights at the Super Bowl

Fuel Cells: Big Leaps in the Last Year

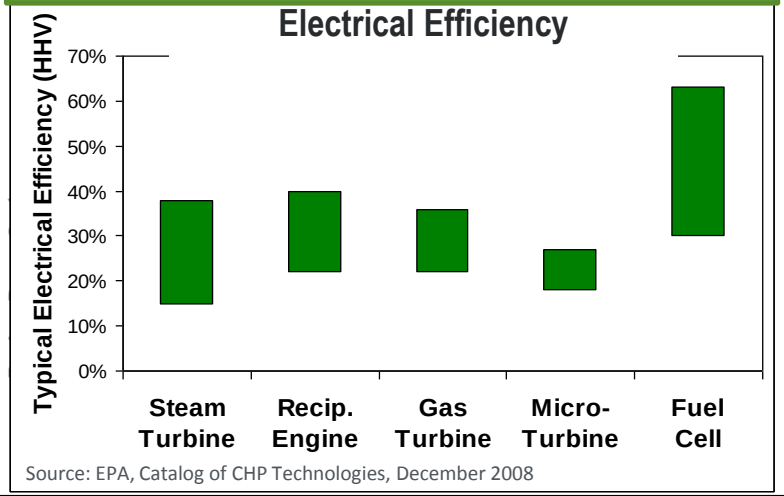
World's first hydrogen fuel cell train in Germany

Fuel Cells: Big Leaps in the Last Year

World's largest town running on hydrogen in Fukuoka, Japan

Opportunities for Distributed Generation (DG) and Efficient use of Natural Gas- and Biogas

Range of electrical efficiencies for DG technologies



Source: EPA, Catalog of CHP Technologies, December 2008

Examples of fuel cell deployments using natural gas

Supermarkets *– growing interest for reliable power*

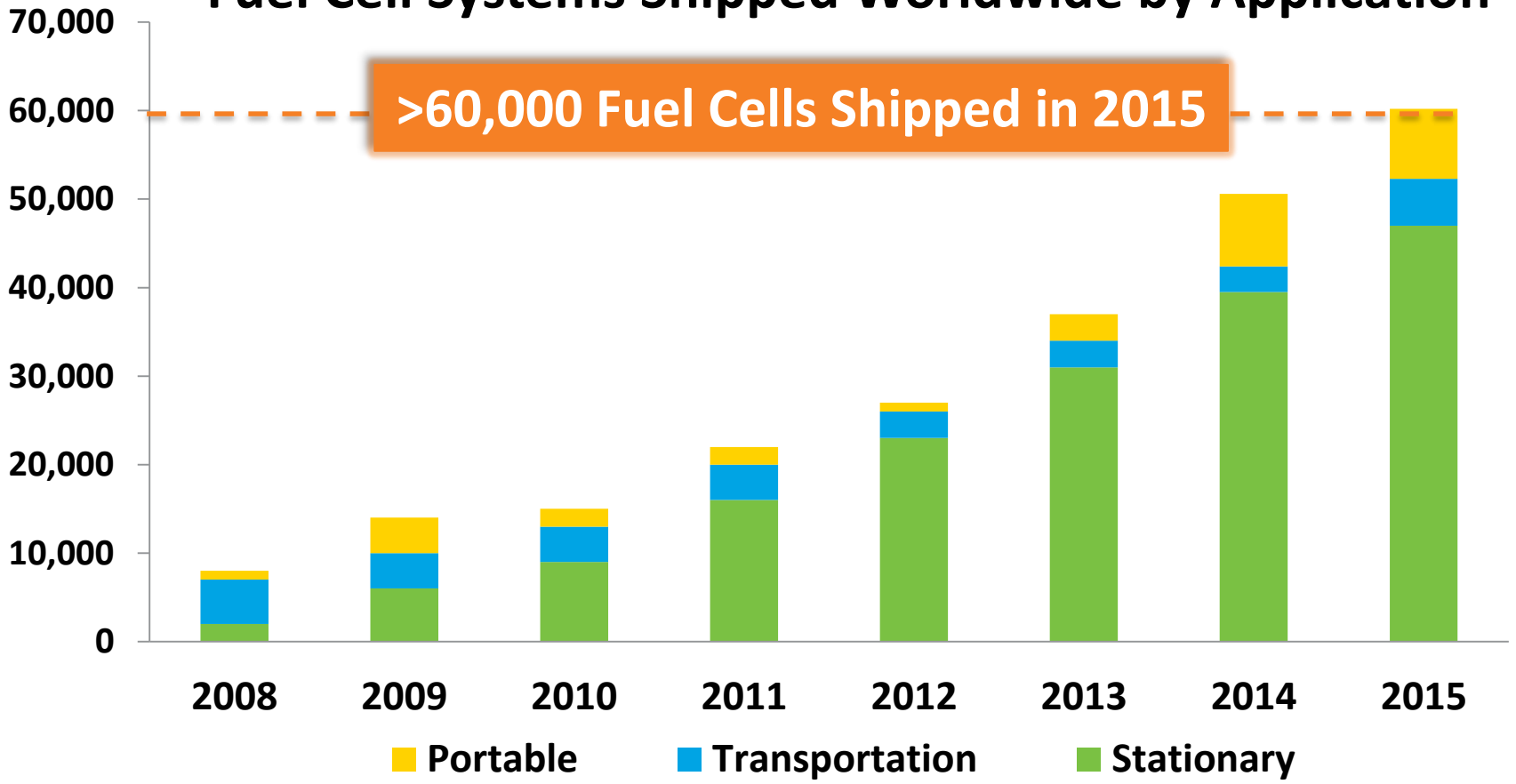
Critical Loads- e.g. banks, hospitals, data centers

New World Trade Center ***using fuel cells***

During Hurricane Sandy, fuel cells provided backup power for many in NY, NJ, and CT.
>60 fuel cells as backup power for cell phone towers.
>20 fuel cells provided continuous power to buildings

Market Growth in Fuel Cell Sales

Fuel Cell Systems Shipped Worldwide by Application



Capacity shipped **in 2015** → Approximately **300 MW** & **~2X** → the capacity **in 2014**

Source: Navigant Research (2008-2013) & E4tech (2014-2015)

Consistent ~30% annual growth since 2010

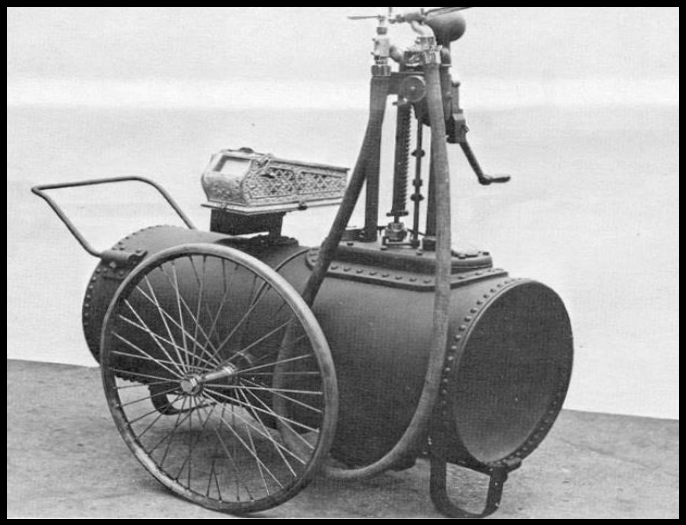
What can we learn from history?

Gasoline History: Many diverse options

Cans, barrels, home models, mobile refuelers

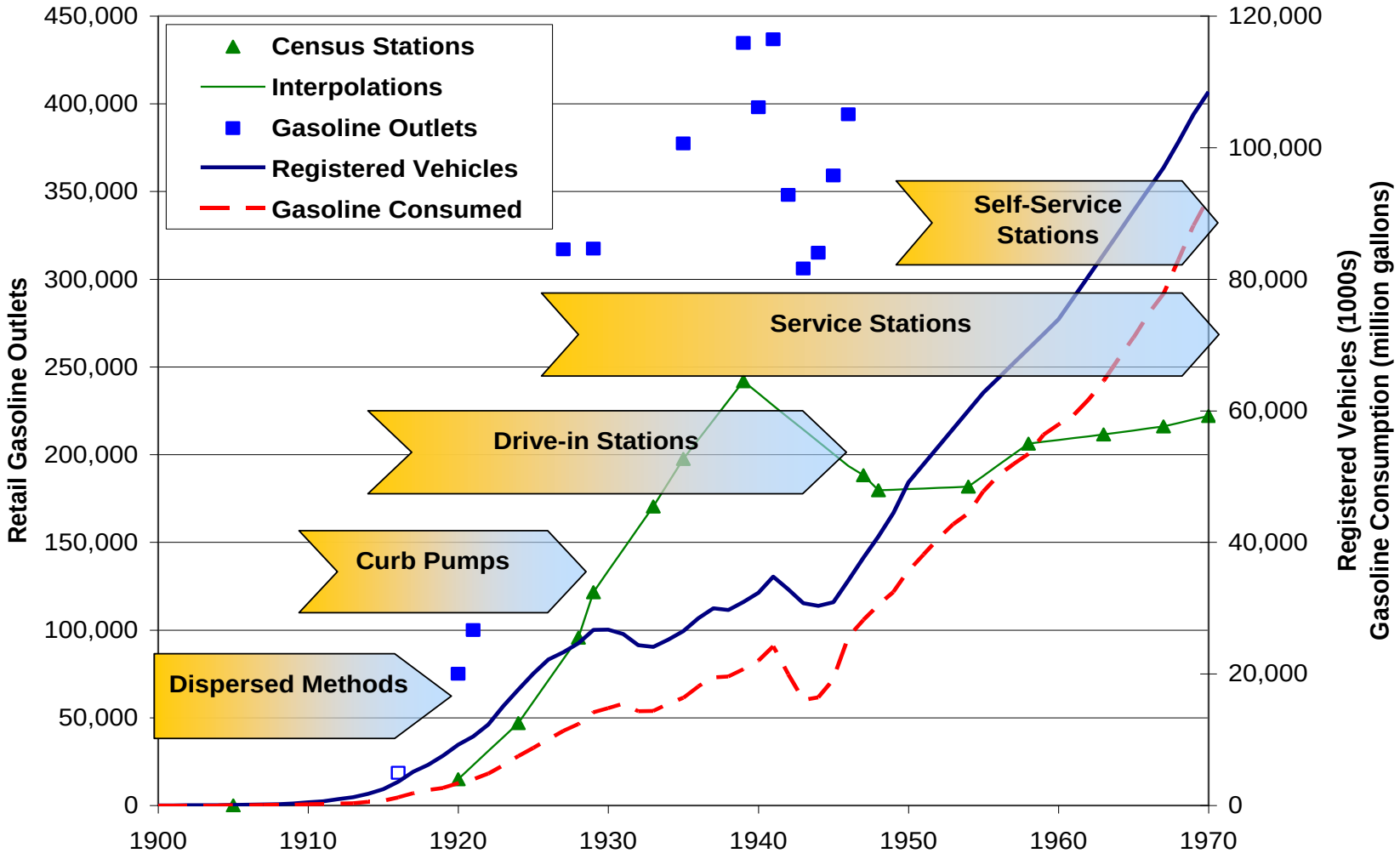
Source: M. Melaina 2008.

Source: Vieyra, 1979



Source: Milkues, 1978

Refueling Methods Evolved Over Time



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

History shows phased introduction of different refueling methods

Complementing Retail Stations: H_2 Refuel H-Prize

H2refuel
U.S. Department of Energy

$1M Competition: On-site H_2 fueling

Finalist Team
More at hydrogenprize.org

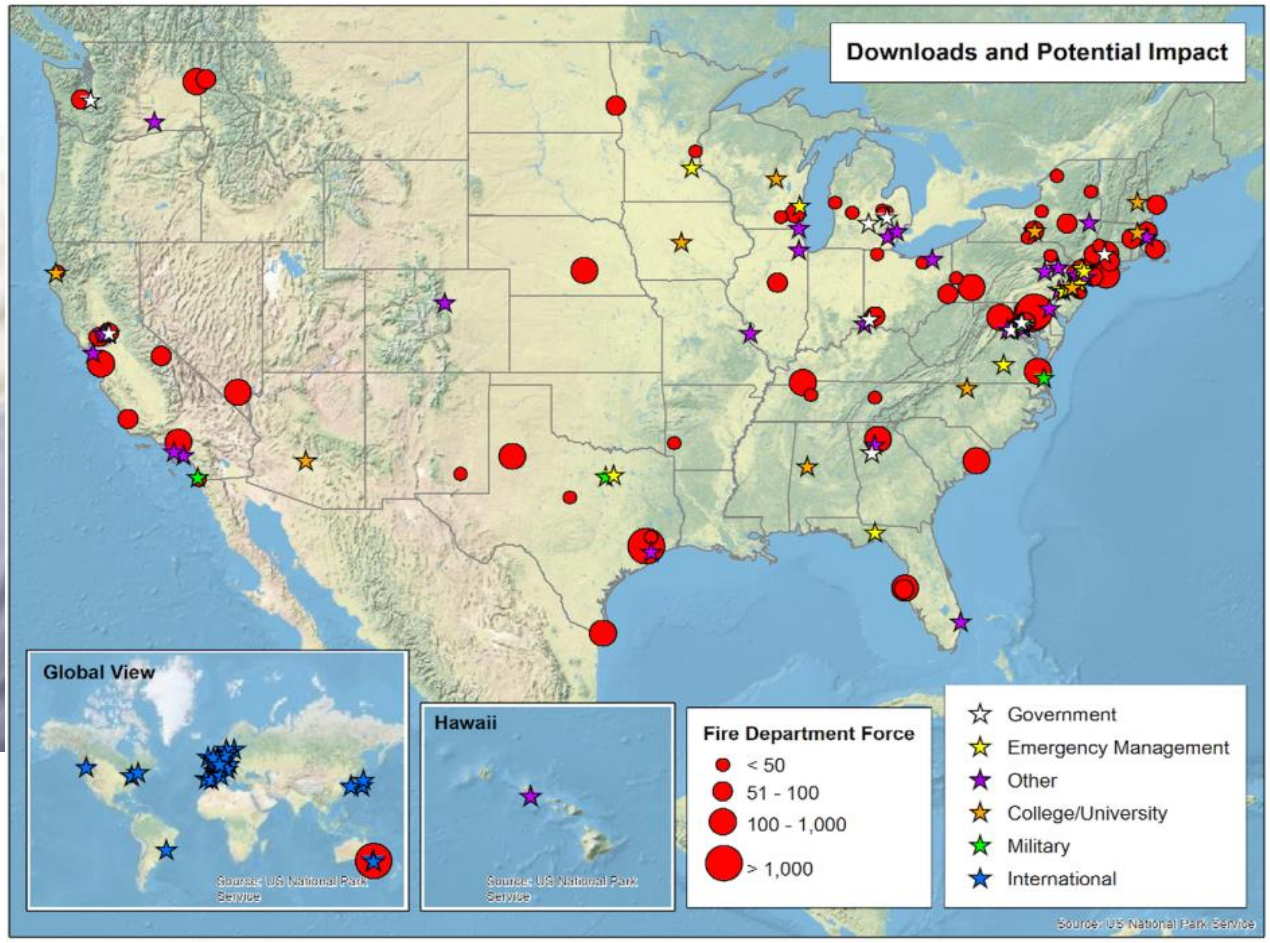
simple.fuel.™

- Launched October 2014
- Outcome announcement expected early 2017

Information sharing and outreach are critical

H_2Tools: One-stop for H_2 safety knowledge

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



- Tracked downloads from **Europe and Japan**
- Resource **translated in Japanese**
- **50%** of visits are **international!**

Enabling dissemination of safety information around the world

Portfolio Approach: The Narrative

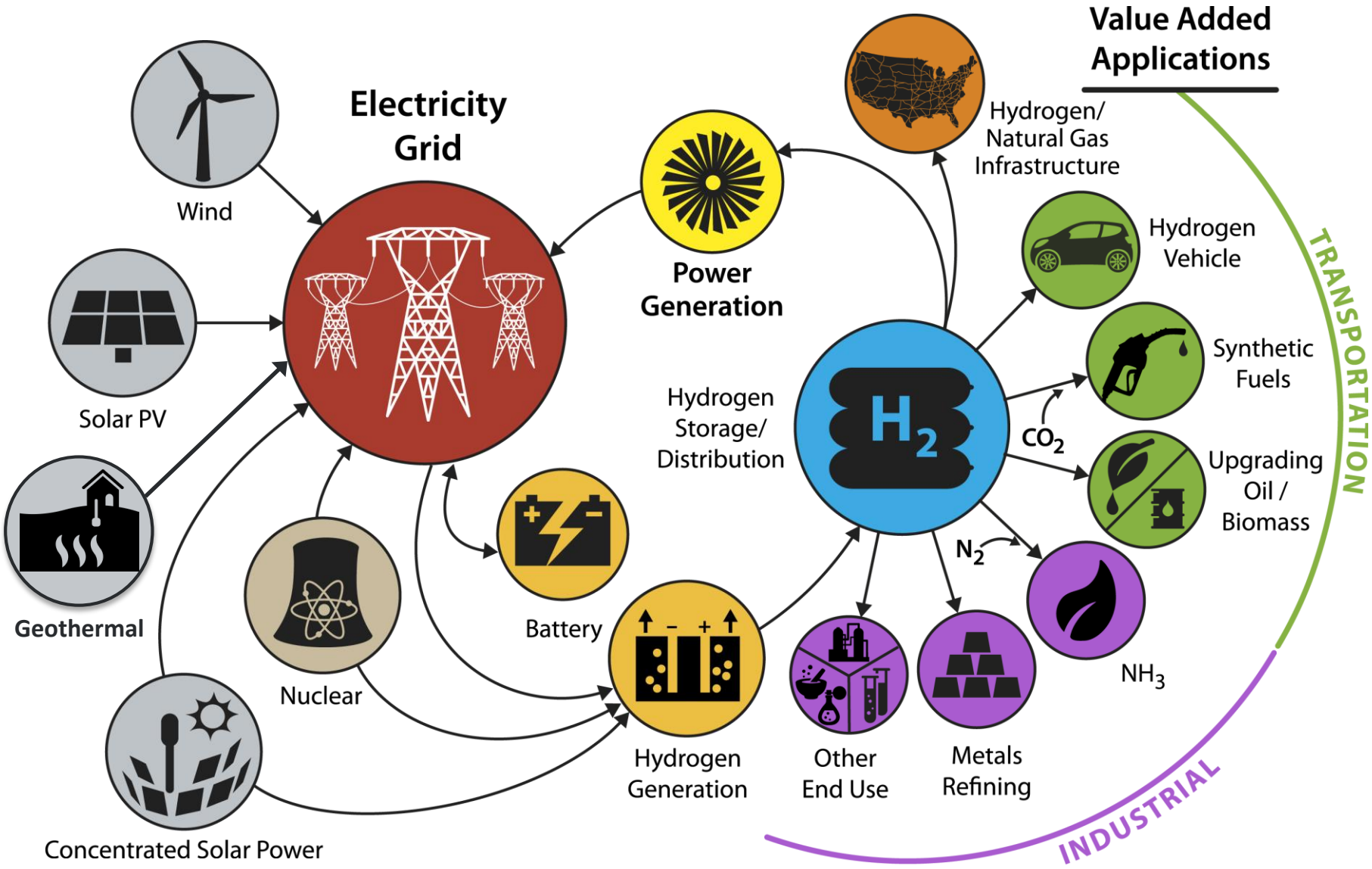
Batteries and Fuel Cells

Electricity and Hydrogen

... and Net Zero Carbon Fuels (Solar2Fuels, etc.)

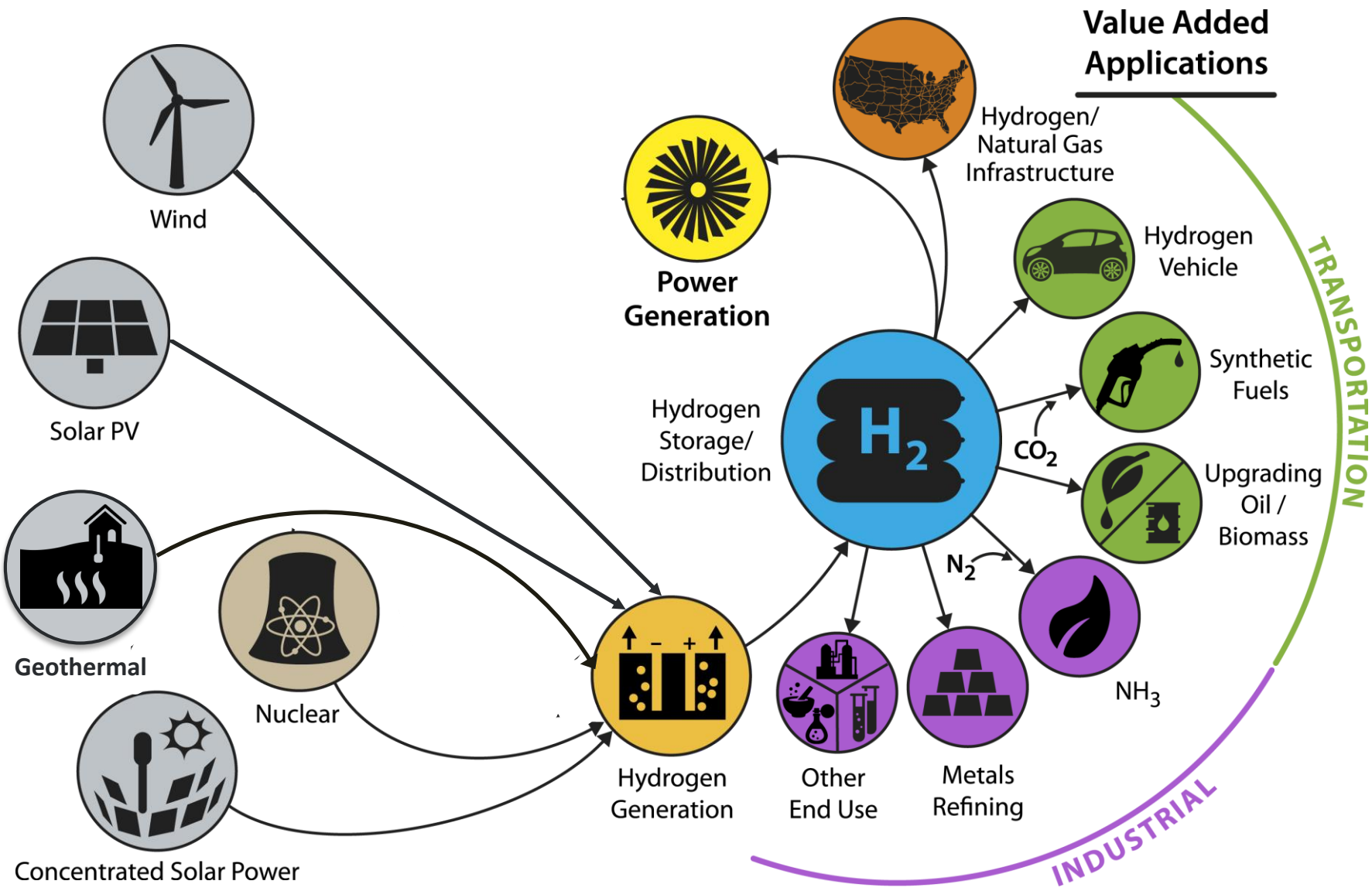
Low carbon electrons to electrified powertrains

H_2 at Scale Energy System Vision



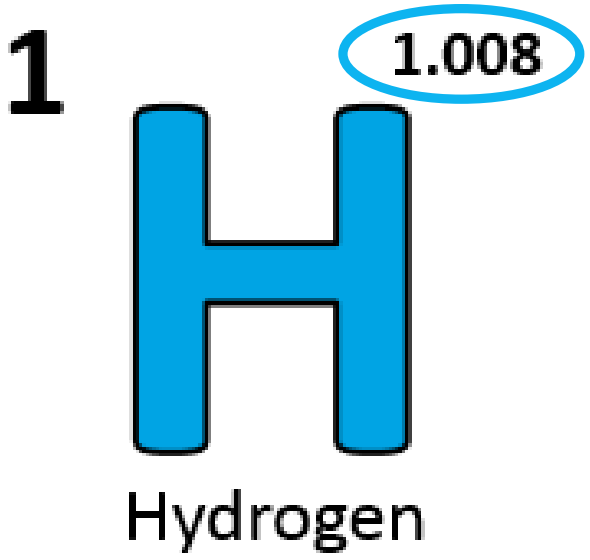
*Illustrative example, not comprehensive
Source: NREL

Conceptual H_2 at Scale Energy System



What can you do? Spread the Word

National Hydrogen & Fuel Cell Day | 10·08



Celebrate National Hydrogen & Fuel Cell Day on 10/8 (Held on its very own atomic- weight-day)

Learn more: energy.gov/eere/fuelcells


INCREASE YOUR
H2IQ
www.hydrogen.energy.gov

We need your help!

Thank You

Fuel Cell Technologies Office

hydrogenandfuelcells.energy.gov