U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

U.S. Hydrogen and Fuel Cell Overview

Jay Keller – Consultant to the Fuel Cell Technologies Office

U.S. Department of Energy

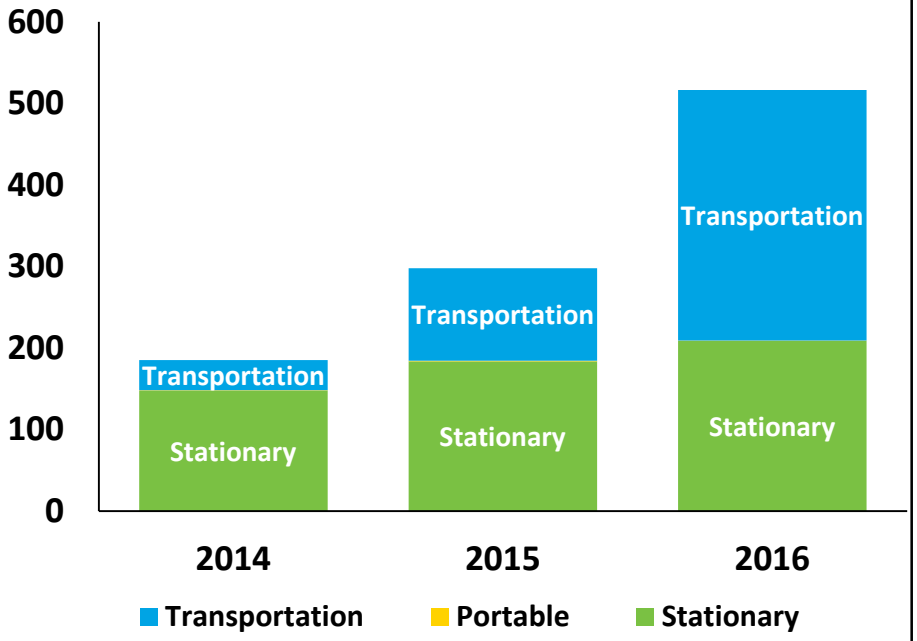
IPHE Workshop, Koriyama, Japan

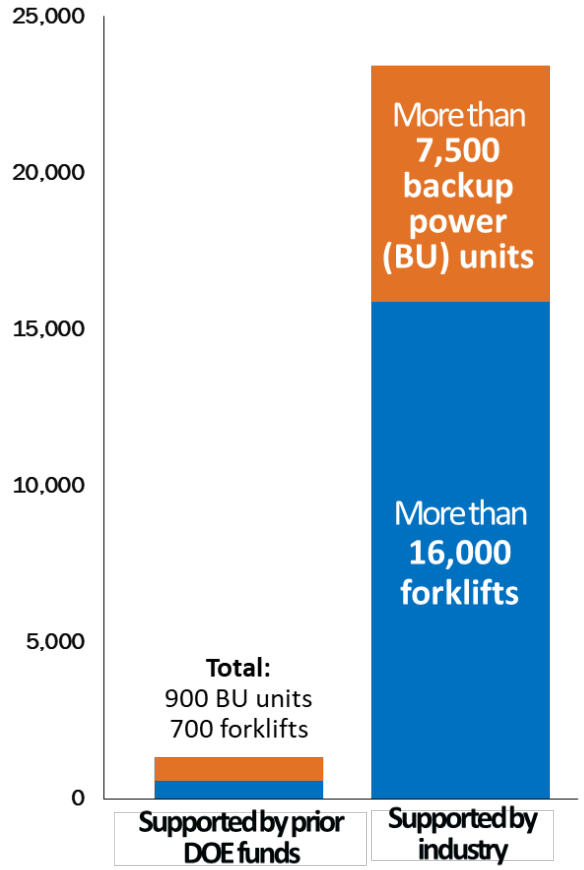
May 9, 2018

Unprecedented Growth in the Fuel Cell Industry

Total power (in MW) shipped by application

Growth in Transportation





500 MW fuel cell power shipped worldwide

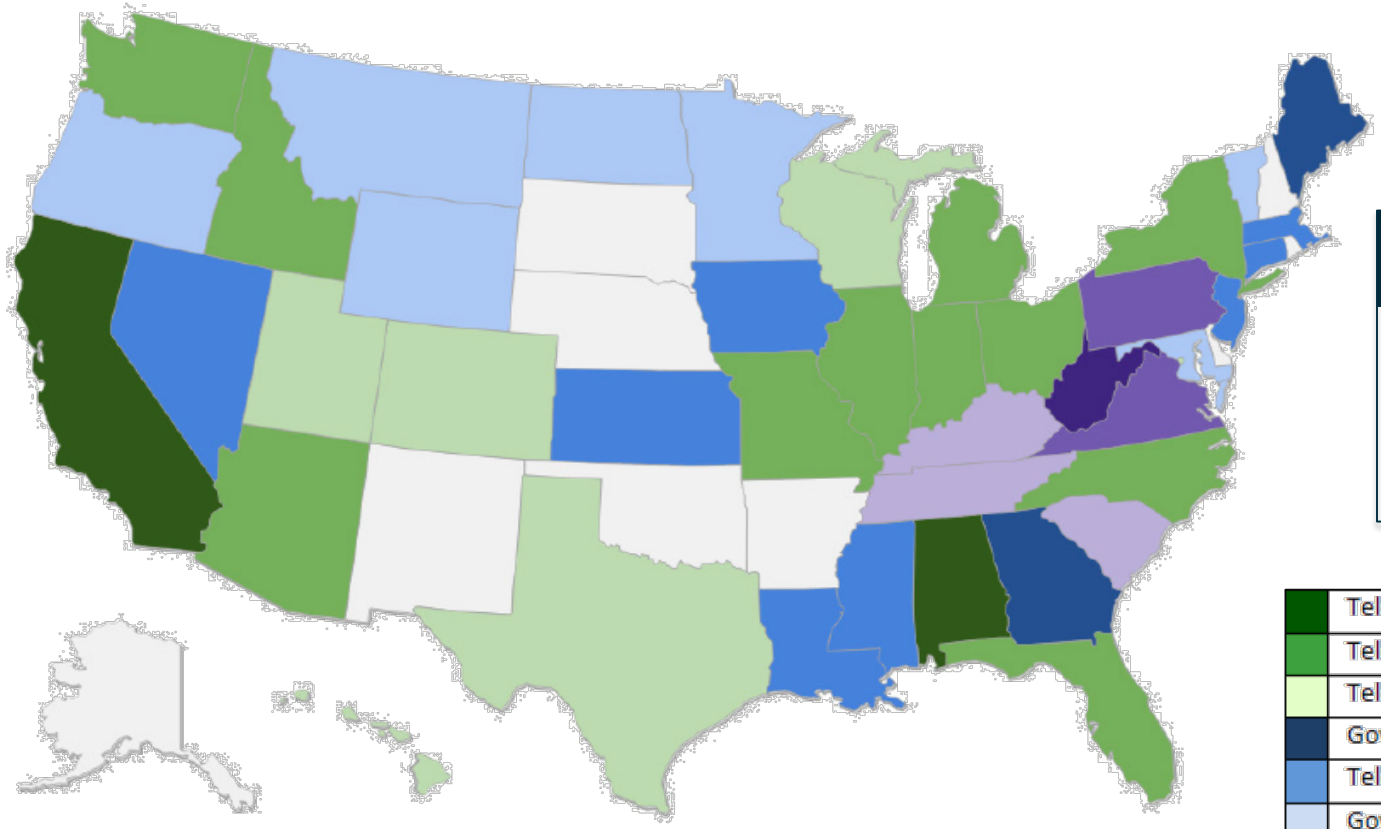
62,000 fuel cell units shipped worldwide

Approximately **$1.6 Billion** fuel cell revenue

Source: DOE Fuel Cell Technologies Market Report. Available at: https://energy.gov/eere/fuelcells/market-analysis-reports

Fuel cells operating all over the U.S.

Fuel cells used for backup power in more than 40 states



Over 235MW

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

Commercial Fuel Cell Cars on U.S. Roads

Honda Clarity

Nearly **4,500** | **sold or leased** in the United States

As of Dec 2017

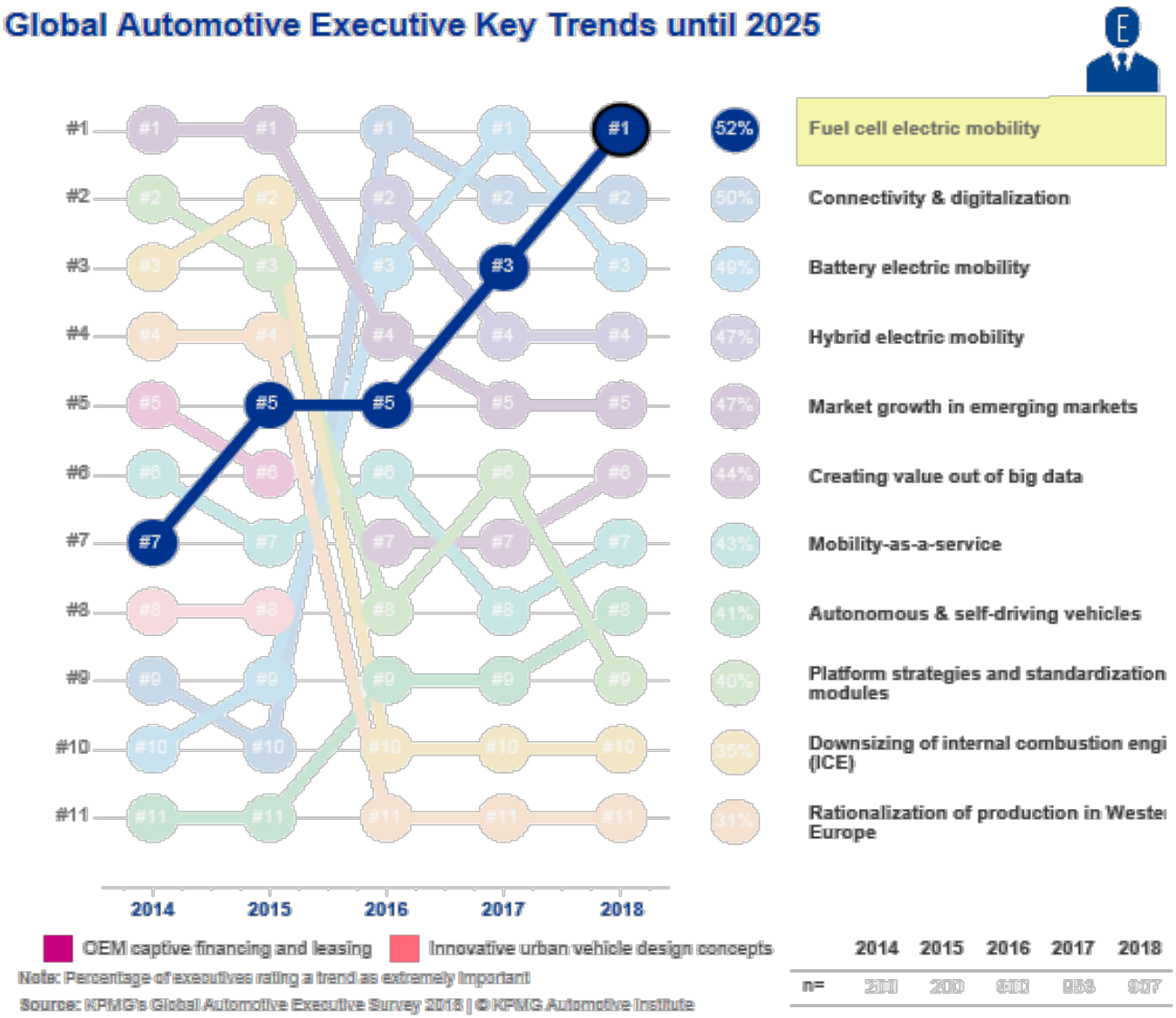

Hyundai Tucson Fuel Cell SUV

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

Global Automotive Executives Survey Results



Source: KPMG Global Automotive Executive Survey 2018

Fuel Cell Electric Mobility ranked #1 key trend among executives

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

Hydrogen and Fuel Cell Applications in the U.S.

U.S. Snapshot

>235MW
Backup Power

>16,000
Forklifts

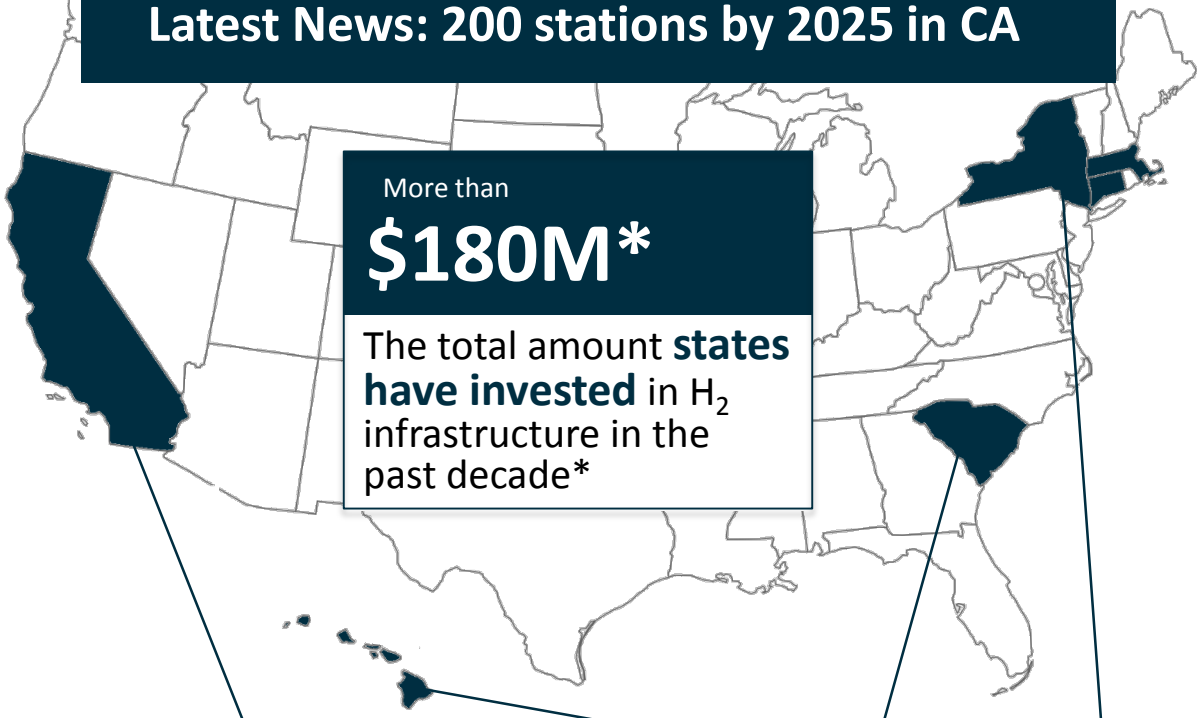
>25
Fuel Cell Buses

>30
H_2 retail stations

Nearly
4,500
fuel cell cars

Cumulative State Funding

Latest News: 200 stations by 2025 in CA



More than
$180M*

The total amount **states have invested** in H_2 infrastructure in the past decade*

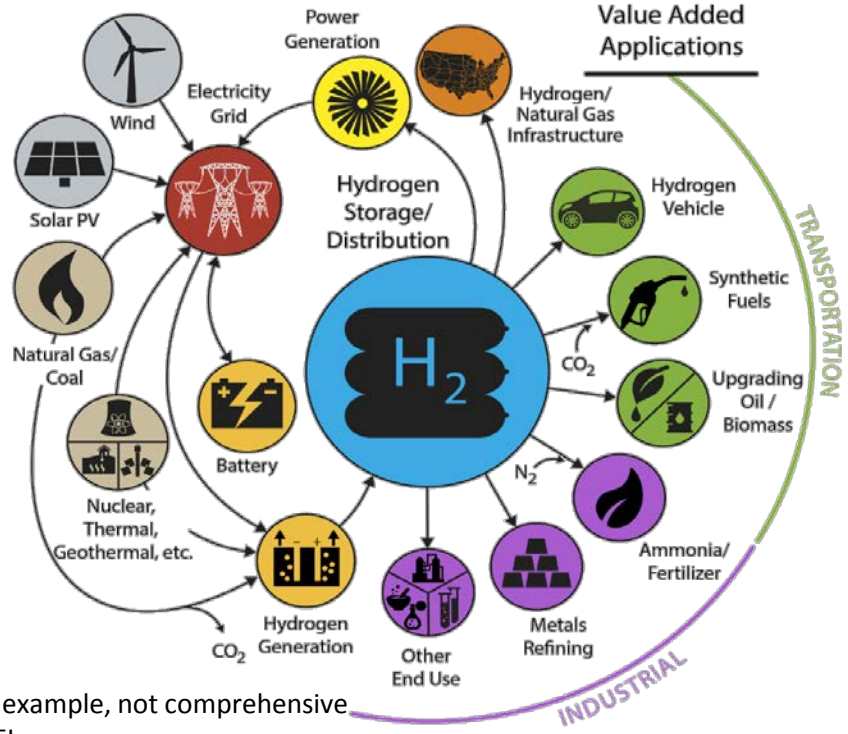
CA
- 200 stations planned
- Over 30 public stations open
- $150M invested
- $235M announced in 2018

HI, SC, NY, CT, MA and others
- Over $27M invested
- 12-25 stations planned in the NE

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

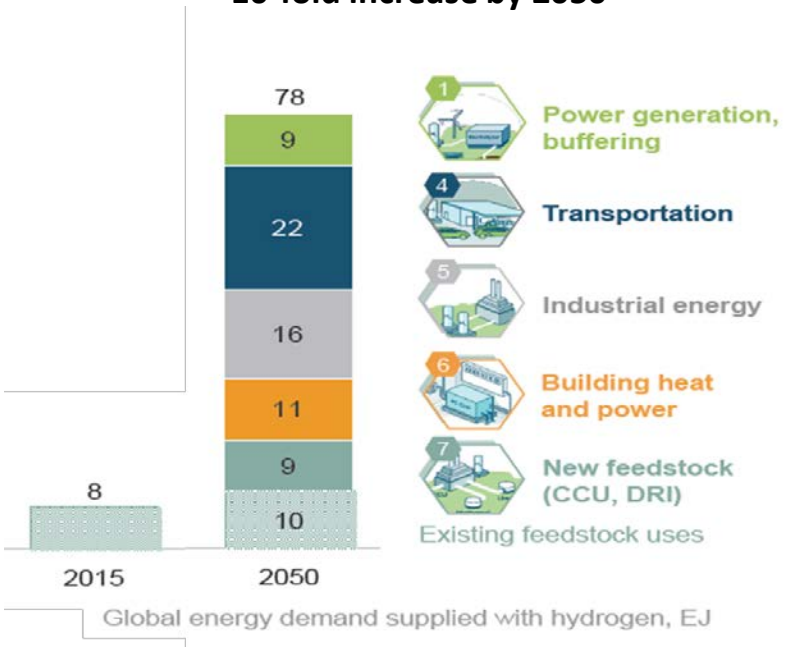
Focus: H2@Scale & Alignment with U.S. Priorities

Hydrogen can enable use of diverse domestic resources and address priorities of energy security, energy storage, resiliency and economic prosperity. R&D is required. Aligns with national & DOE priorities.



*Illustrative example, not comprehensive
Source: NREL

Potential for Global H2 Demand
10-fold increase by 2050

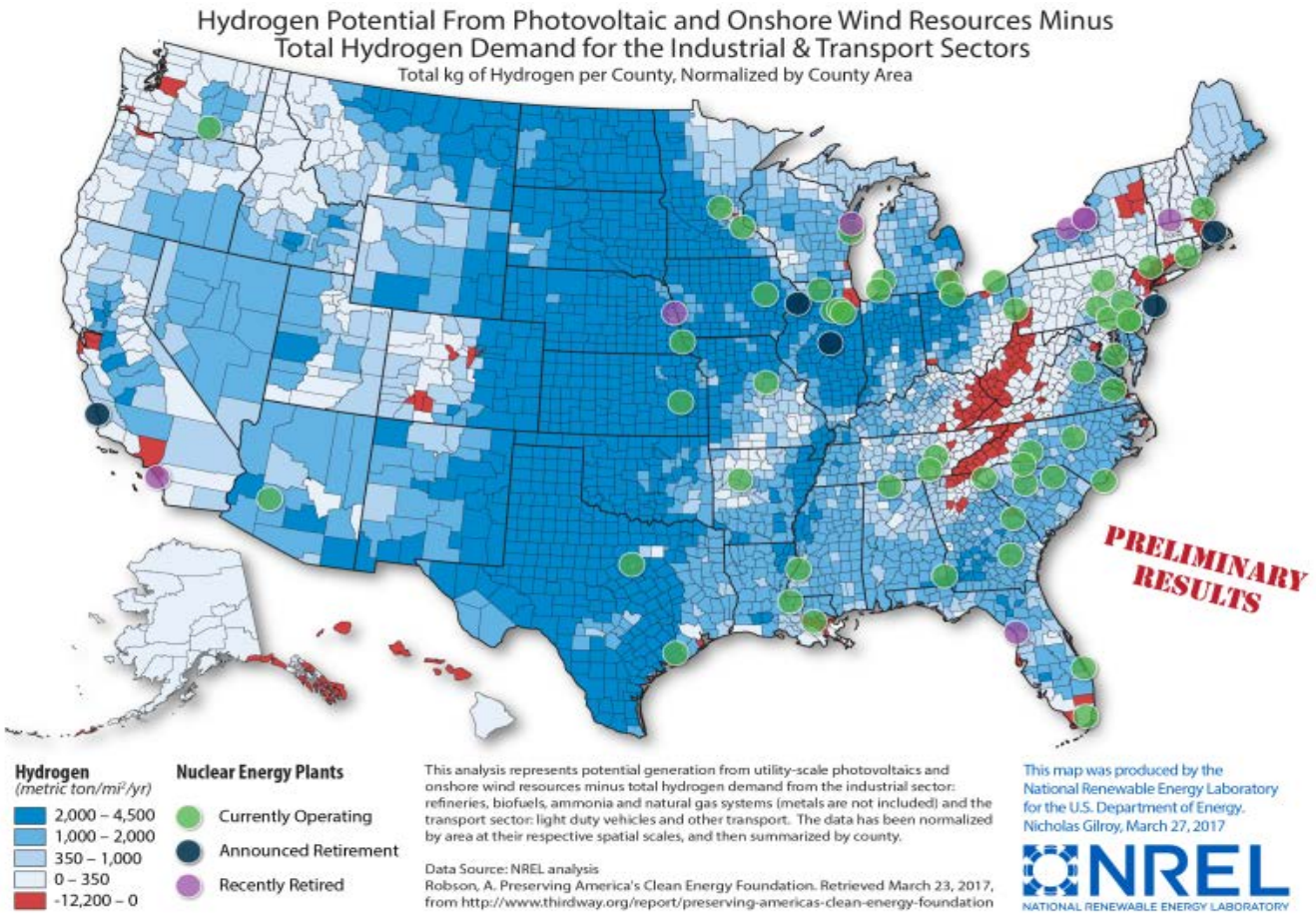


Source: Hydrogen Council

"Agencies should invest in early-stage, innovative technologies that show promise in harnessing American energy resources safely and efficiently."

-Aug. 17, 2017 OMB/OSTP Memo

H2@Scale: Nationwide Resource Assessment



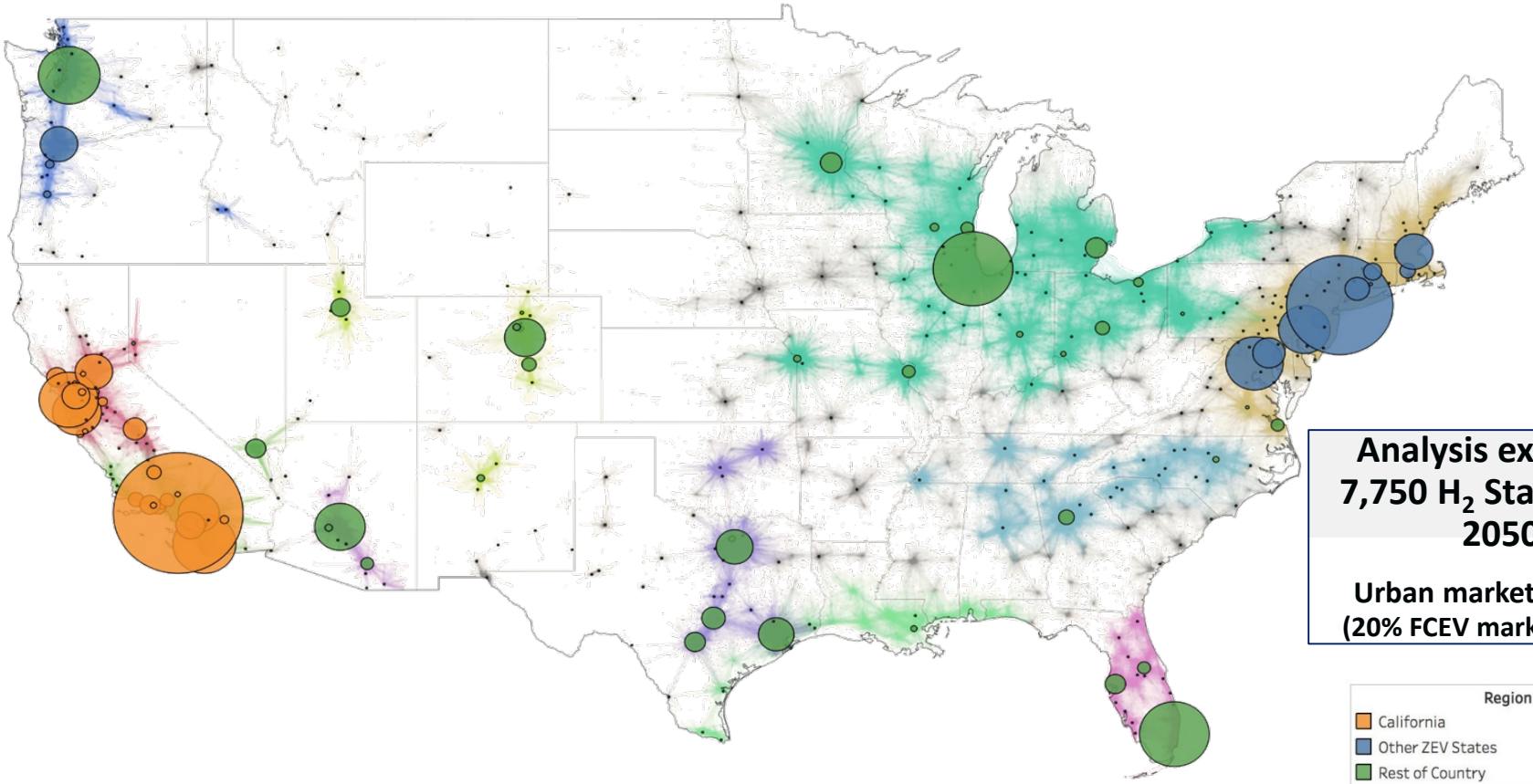
Lab PIs: Mark Ruth, Bryan Pivovar, Richard Boardman, et al

Labs assess resource availability. Most regions have sufficient resources.

Red: Only regions where projected industrial & transportation demand exceeds supply.

Hydrogen Station Analysis - Example

NREL's Station Rollout Scenario Analysis in support of H_2USA



Analysis example: 7,750 H_2 Stations by 2050

Urban markets scenario (20% FCEV market share*)

*Nationwide

Region
- California
- Other ZEV States
- Rest of Country

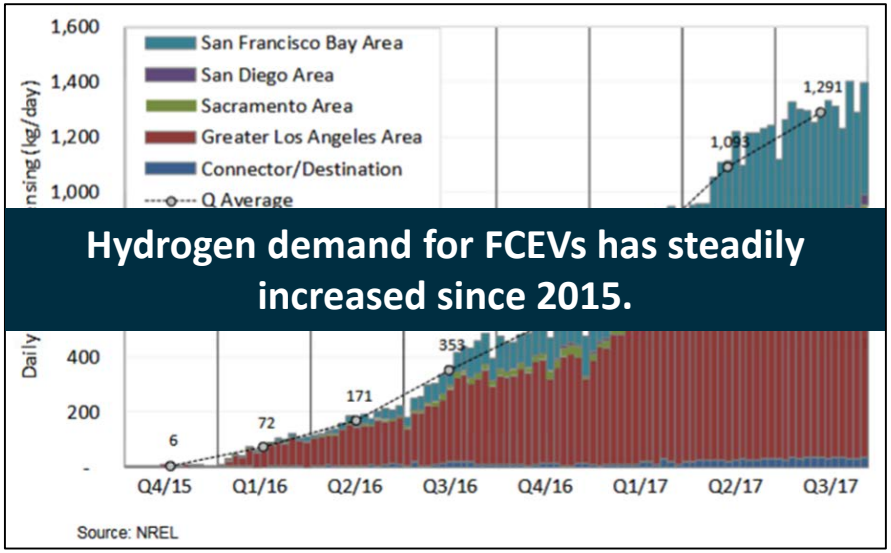
Total Capacity (kg/day)
- 180
- 1,000,000
- 2,000,000
- 3,000,000
- 4,000,000

Examples of variables considered in scenarios:

- Consumer adoption
- Station Expansion Network

Source: Marc Melaina, et al, NREL

Growing Demand for Hydrogen: FCEVs



Hydrogen demand for FCEVs has steadily increased since 2015.

Over 30 retail stations in California
4 stations built in Northeast

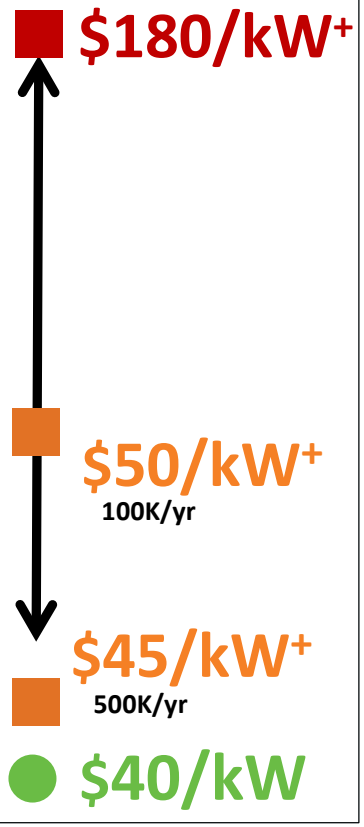
- Retail stations currently expected reach **80% utilization in average of 5 years**.[1]
- High-throughput hydrogen fueling stations (e.g. **1,000 kg/day**) of interest.
- **Over 2,000 tonnes/year of <u>renewable</u> hydrogen needed by 2022** to satisfy FCEV demand. [1]
- Emergence of **medium- and heavy duty fleets would bolster demand**.

[1]http://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf

DOE Cost Status and Targets for R&D

Fuel Cell R&D

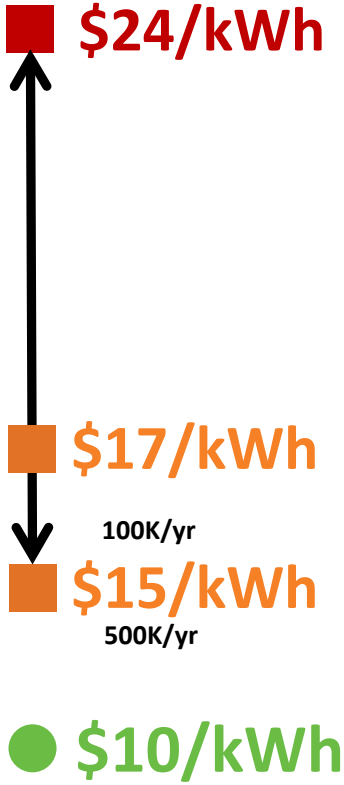
System



Hydrogen R&D

Production, Delivery & Dispensing

Onboard Storage
(*700-bar compressed system*)



Targets | High-Volume Projection | Low-Volume Estimate

*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.
Data through 2017

Examples of Areas Requiring R&D

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)

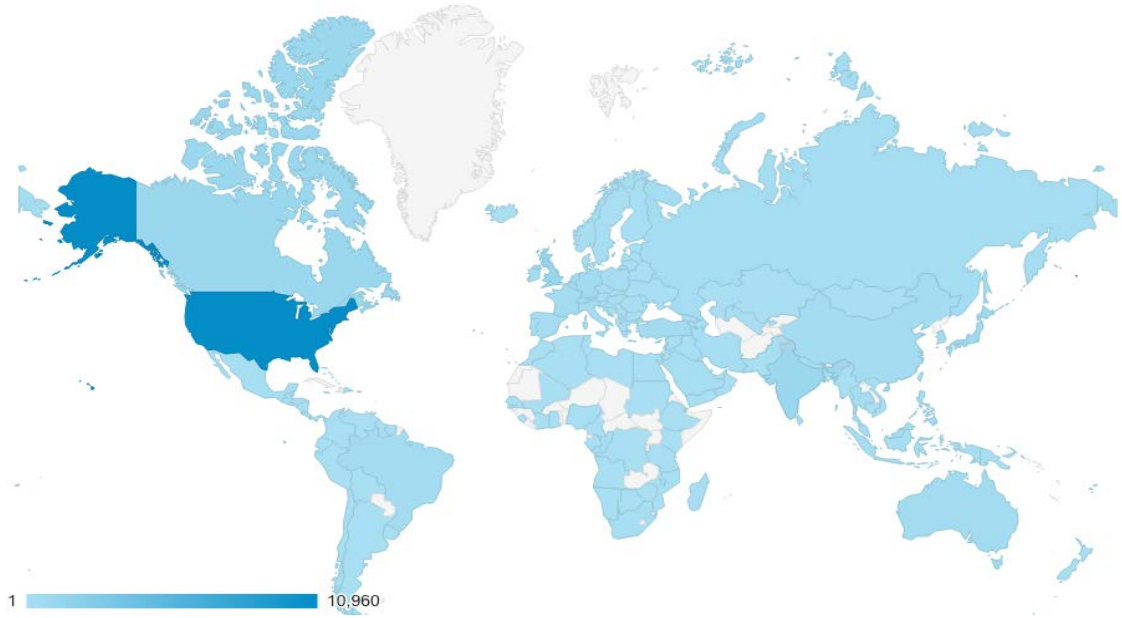
Long term Materials Approaches

Collaboration Tools: H_2 Safety Information Sharing

H_2Tools.org : A one stop resource for hydrogen safety

h2tools.org

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



- Site visit tracking shows a **global reach: 50%** of visits have been **international after launch**
- Roughly **300,000 site visits**
- Training resource **translated into Japanese. Interest in other languages.**

Upcoming

First time ever
Multiple Agencies at Annual Merit Review (AMR) and National Hydrogen and Fuel Cell Forum

June 12-15, 2018
Washington, DC
www.hydrogen.energy.gov

Plans

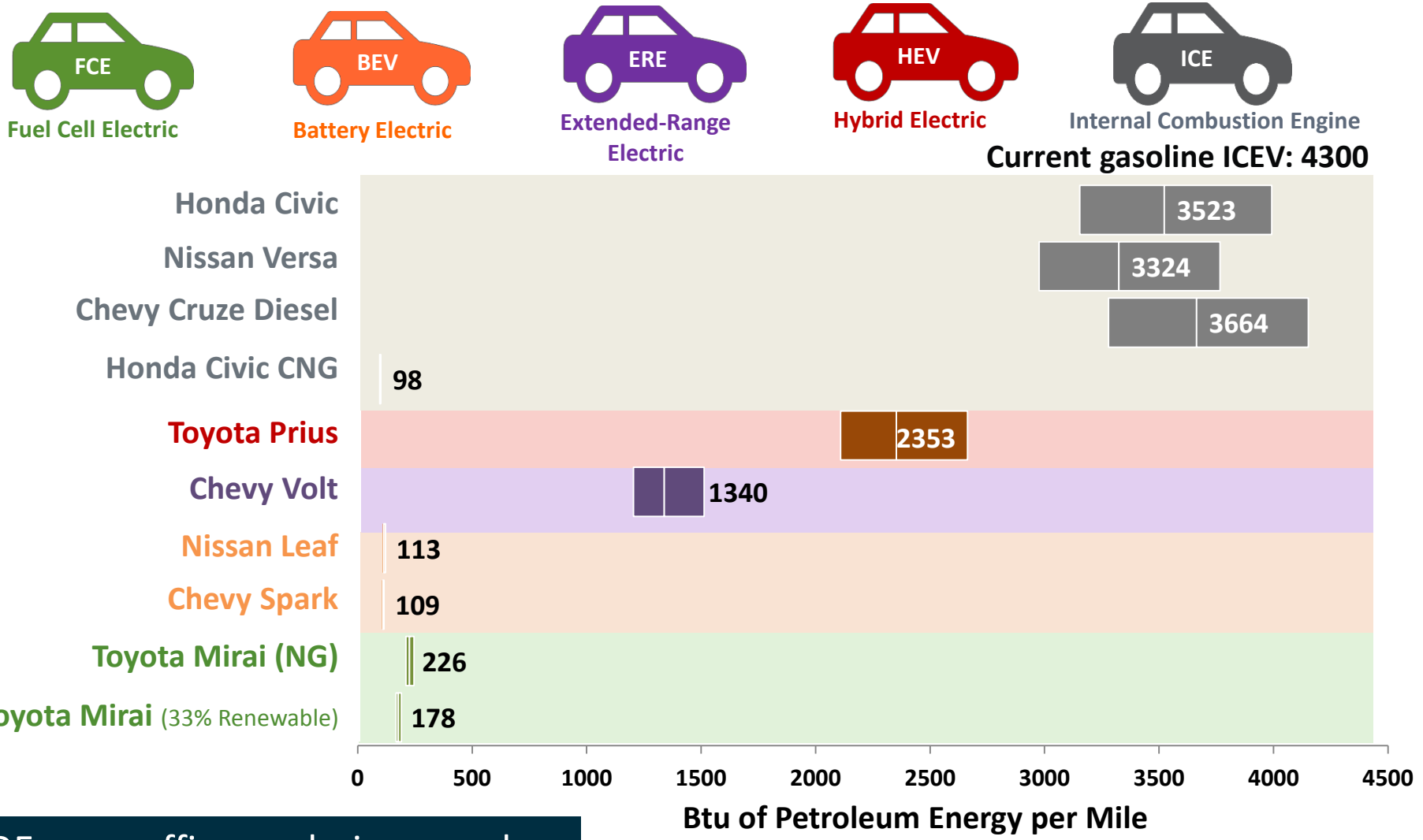
- **Identifying priorities for reducing barriers to deployment of infrastructure**
- **Identifying resources for H_2**
- **Roadmap and goal-setting underway in FY18-19**
- **Continue early-stage R&D and leverage partnerships**

Thank You

energy.gov/eere/fuelcells

Life-cycle Petroleum Use- Today's Cars

Low, Medium & High Petroleum Energy/Mile for 2015 Technology



DOE cross office analysis example

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

Life-cycle Emissions- Today's Cars

Low, Medium & High Emissions/Mile for 2015 Technology

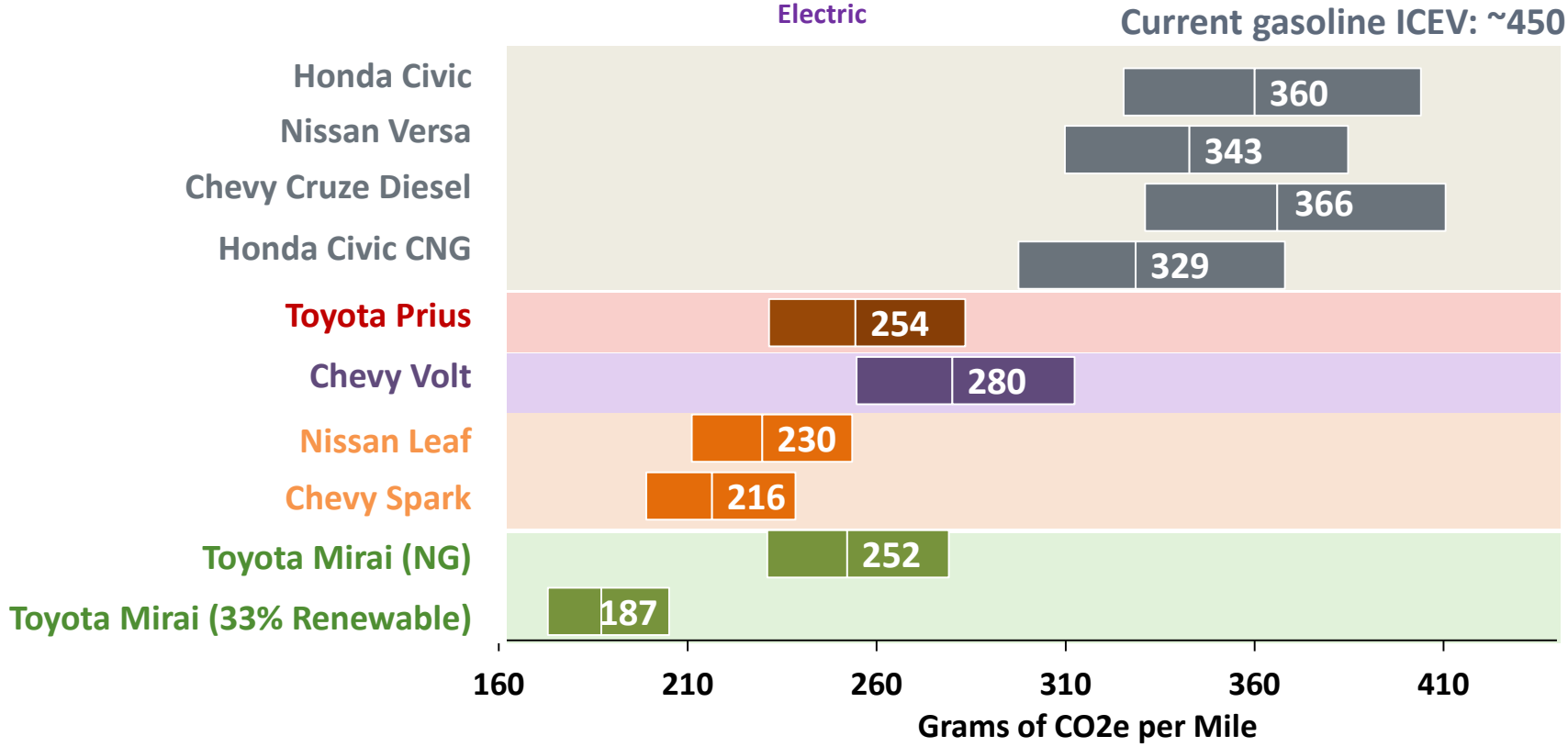
Fuel Cell Electric

Battery Electric

Extended-Range Electric

Hybrid Electric

Internal Combustion Engine



DOE cross office analysis example

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