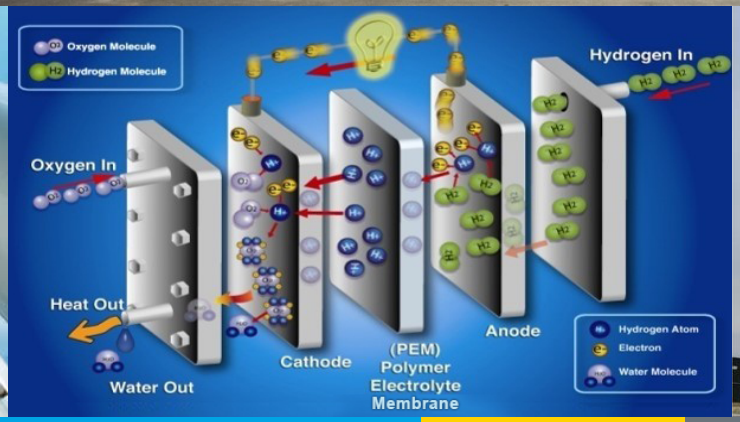
U.S. Department of Energy
Fuel Cell Technologies Office

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



Hydrogen and Fuel Cell Technical Advisory Committee

Washington, DC

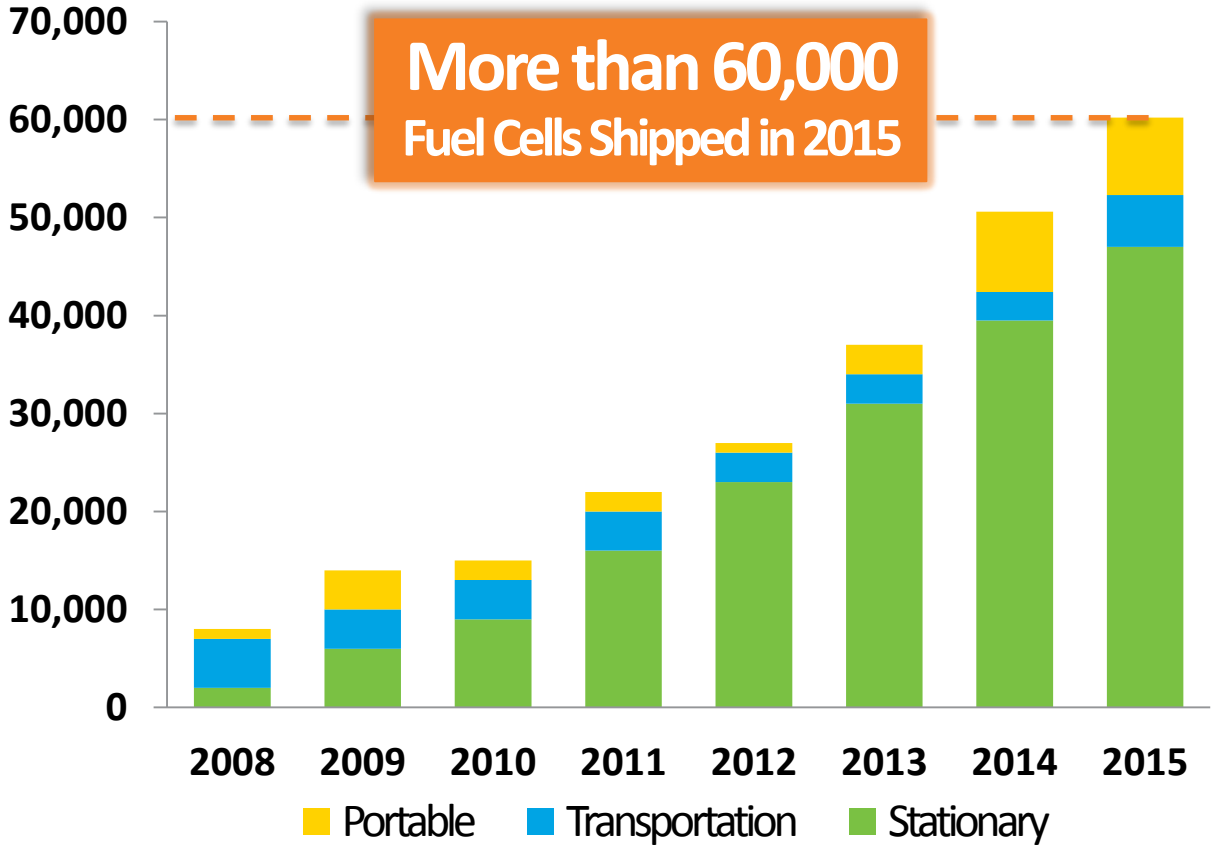
December 6, 2016

Dr. Sunita Satyapal

Director
Fuel Cell Technologies Office
U.S. Department of Energy

Fuel Cell Market Growth

Fuel Cell Systems Shipped Worldwide by Application



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

Capacity shipped
in 2015
300 MW

Approximately
2X the capacity shipped
in 2014

Consistent
30% annual growth
since 2010

Published DOE 2016 Market Report

Agenda

- **HTAC Scope**
  - **Energy Policy Act (EPACT) 2005 Title VIII**
  - **Membership**
  - **Recommendation Examples**
- **Program Updates**
- **Next Steps**

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Scope

To advise the Secretary of Energy on:

1. **The implementation of programs and activities under Title VIII of EPACT**

2. **The safety, economical, and environmental consequences of technologies to produce, distribute, deliver, store or use hydrogen energy and fuel cells**

3. **The DOE Hydrogen & Fuel Cells Program Plan**

Title VIII Sec. 802- Purposes

1. Enable and promote comprehensive **development**, **demonstration**, and **commercialization** of H_2 and fuel cells with industry

2. Make **critical public investments** in building strong links to private industry, universities and National Labs to expand innovation and industrial growth

3. Build a mature H_2 economy for **fuel diversity** in the U.S.

4. Decrease the **dependency on foreign oil & emissions** and enhance energy security

5. Create, strengthen, and protect a **sustainable national energy economy**

2016 HTAC Members

HTAC Member and Affiliation	Expertise
Ayers, Katherine Proton OnSite	**Hydrogen Production R&D**
Azevedo, Ines Co-Director of the Climate and Energy Decision Making Center, Carnegie Mellon University	**Academia/ Behavioral Science**
Clay, Kathryn American Gas Association	**Associations / Non-profits**
Dunwoody, Catherine California Air Resources Board	**Government**
Eggert, Anthony Program Director, Climateworks	**Associations/Non-Profits**
Freese, Charles F. General Motors Company	**Transportation**
Gobin, Anne Bureau of Air Management, Connecticut Department of Energy & Environmental Protection	**Government**
Kaya, Maurice Pacific International Center for High Technology; Chief Technology Officer (retired), Hawaii Dept. of Business, Economic Development, and Tourism	**Government**
Kodjak, Drew International Council on Clean Transportation (ICCT)	**Transportation**
Koyama, Harol H2 PowerTech	**Stationary Power**

HTAC Member Name and Affiliation	Expertise
Leggett, Paul Morgan Stanley, Investment Banking Division	**Venture Capital / Investment**
Lipman, Timothy Transportation Sustainability Research Center, UC Berkeley; Director, DOE Pacific Region Clean Energy Application Center	**Academia**
Markowitz, Morry Fuel Cell and Hydrogen Energy Association (FCHEA)	**Associations / Non-profits**
Novachek, Frank (Chair) Xcel Energy	**Utilities (Electricity and Natural Gas)**
Ogden, Joan Professor, Dept. of Environmental Science and Policy, UC Davis	**Academia**
Oge, Margo Office of Transportation and Air Quality, Environmental Protection Agency	**Environmental**
Powell, Joseph Chief Scientist, Shell Global Solutions	**Fuels Production**
Ratcliff, Adele Director, Manufacturing Technology Office of the Deputy Assistant Secretary of Defense	**Government**
Scott, Janea California Energy Commission	**Government**
Thompson, Levi University of Michigan	**Academia**

Indicates new members as of Dec. 2016

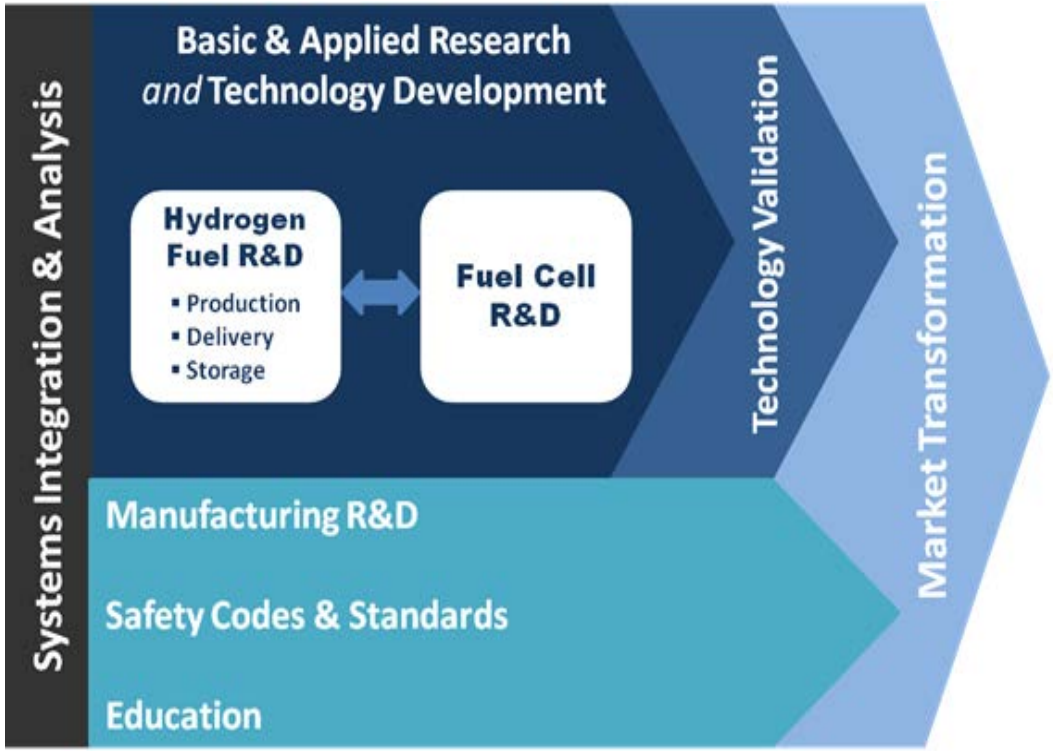
2015 Recommendations and Responses (Examples)

Recommendation	Response
The Committee recommends that **the federal tax credit for fuel cell electric vehicles be extended beyond 2016** to continue to enable fuel cell commercialization and help achieve Title VIII goals for 2020.	We agree that extension of the vehicle and state tax credits beyond December 31, 2016 would encourage continued fuel cell vehicle deployments. Tax policies set by Legislative branch but **Information related to such policies publicized.**
Provide **additional funding** to achieve 2020 Title XIII goals.	**FY 2017 FCTO Budget request: $105.5M** (higher than past few years) Launched 3 new consortia in support of DOE's **Energy Materials Network and advanced manufacturing priorities: HydroGEN, ElectroCat, and HyMARC**
Clean Cities program emphasis must actively **promote and educate consumers on FCEV** technology.	The revised **Clean Cities strategic vision plan will include additional focus on zero emission technologies including hydrogen and fuel cells,** such as funding opportunity announcements and station locations on DOE online maps.

DOE Hydrogen and Fuel Cells Program

Mission

To enable the ***widespread commercialization of hydrogen and fuel cell technologies***, which will reduce petroleum use, greenhouse gas (GHG) emissions, and criteria air pollutants, and will contribute to a more diverse energy supply and more efficient use of energy.



2020 Targets by Application

Fuel Cell Cost	$40/kW	$1,000/kW* $1,500/kW**
Durability	5,000 hrs	80,000 hrs
H_2 Storage Cost (On-Board)	$10/kWh 1.8 kWh/L, 1.3 kWh/kg	
H_2 Cost at Pump	<$4/gge <$7/gge (early market)	

*For Natural Gas
**For Biogas

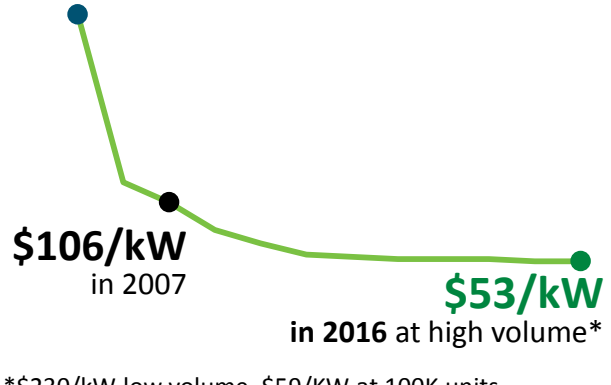
Integrated approach to widespread commercialization of H_2 and fuel cells

DOE Activities Span from R&D to Deployment

1. Research & Development

Fuel Cells

- **80% lower cost** since 2002
- **5X less platinum** since 2005
- **4X increase in durability** since 2006



*$230/kW low volume, $59/KW at 100K units

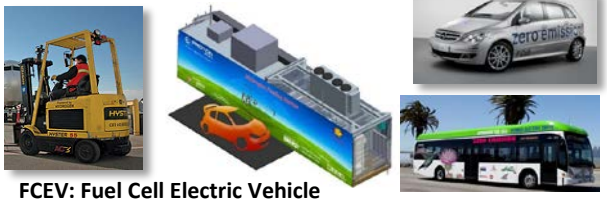
2. Demonstration

Forklifts, back-up power, airport cargo trucks, parcel delivery vans, marine APUs, buses, mobile lighting, refuse trucks

>220 FCEVs, >30 stations, >6M miles traveled

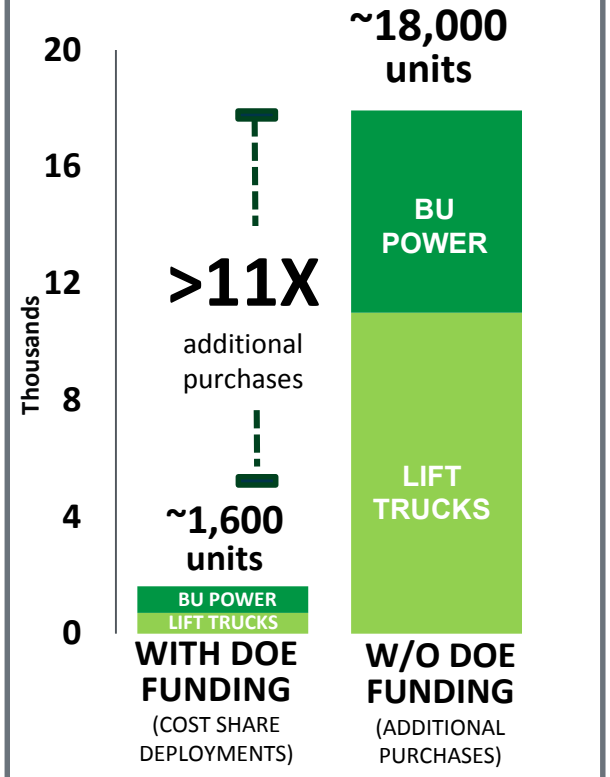
World's first tri-gen station

H_2 technology station in Washington D.C.



FCEV: Fuel Cell Electric Vehicle

3. Deployment



BU: Back Up Power

Examples of consortia supporting R&D

- **Fuel Cell Performance & Durability** — FCPAD Fuel Cell Performance and Durability
- **Advanced H_2 Storage Materials** — HyMARC Hydrogen Materials Advanced Research Consortium
- **PGM-Free Catalysts for Fuel Cells** — ElectroCat Electrocatalysis Consortium
- **Renewable H_2 Production** — HydroGEN Advanced Water Splitting Materials

Supporting Deployment

H_2 USA

Collaboration to address H_2 Infrastructure Barriers

Hydrogen & Fuel Cells Budget

Key Activity	FY 15	FY 16	FY17
	($ in thousands)		
	Approp.	Approp.	Request
Fuel Cell R&D	33,000	35,000	35,000
Hydrogen Fuel R&D[1]	35,200	41,050	44,500
Manufacturing R&D	3,000	3,000	3,000
Systems Analysis	3,000	3,000	3,000
Technology Validation	11,000	7,000	7,000
Safety, Codes and Standards	7,000	7,000	10,000
Market Transformation	3,000	3,000	3,000
Technology Acceleration	0	0	13,000[2]
NREL Site-wide Facilities Support	1,800	1,900	N/A
Total	97,000	100,950	105,500

Office	FY 2016*
EERE	$101.0M
Basic Science	$18.5M
Fossil Energy, SOFC	$30.0M

FY 2016 DOE Total: ~$150M

*Estimated for BES funding (based on FY15)

New in FY17 Request

[1]Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D

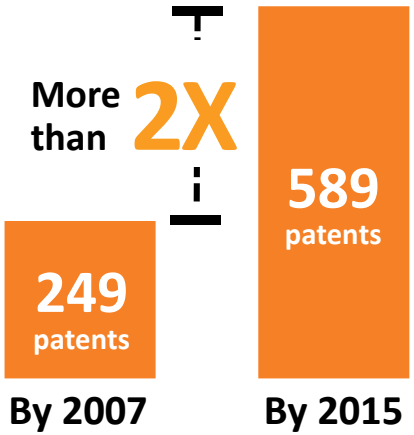
[2]Combines Manufacturing R&D, Technology Validation, Market Transformation.

Sustained, stable funding requests and appropriations

DOE Impact- H_2 and Fuel Cells

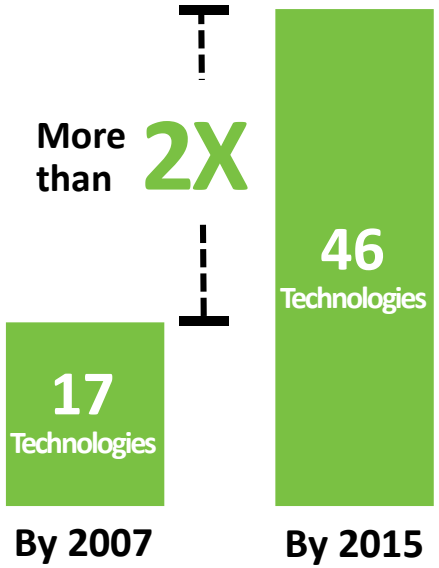
Innovation

Cumulative Number of Patents



Commercialization

Cumulative Number of Commercial Technologies Entering the Market



Jobs

From DOE-supported Commercial Technologies:

450 jobs
average per year

From ARRA-supported Technology Deployments

1,400 jobs
created or sustained

ARRA: American Recovery and Reinvestment Act

Examples of Commercial Technologies

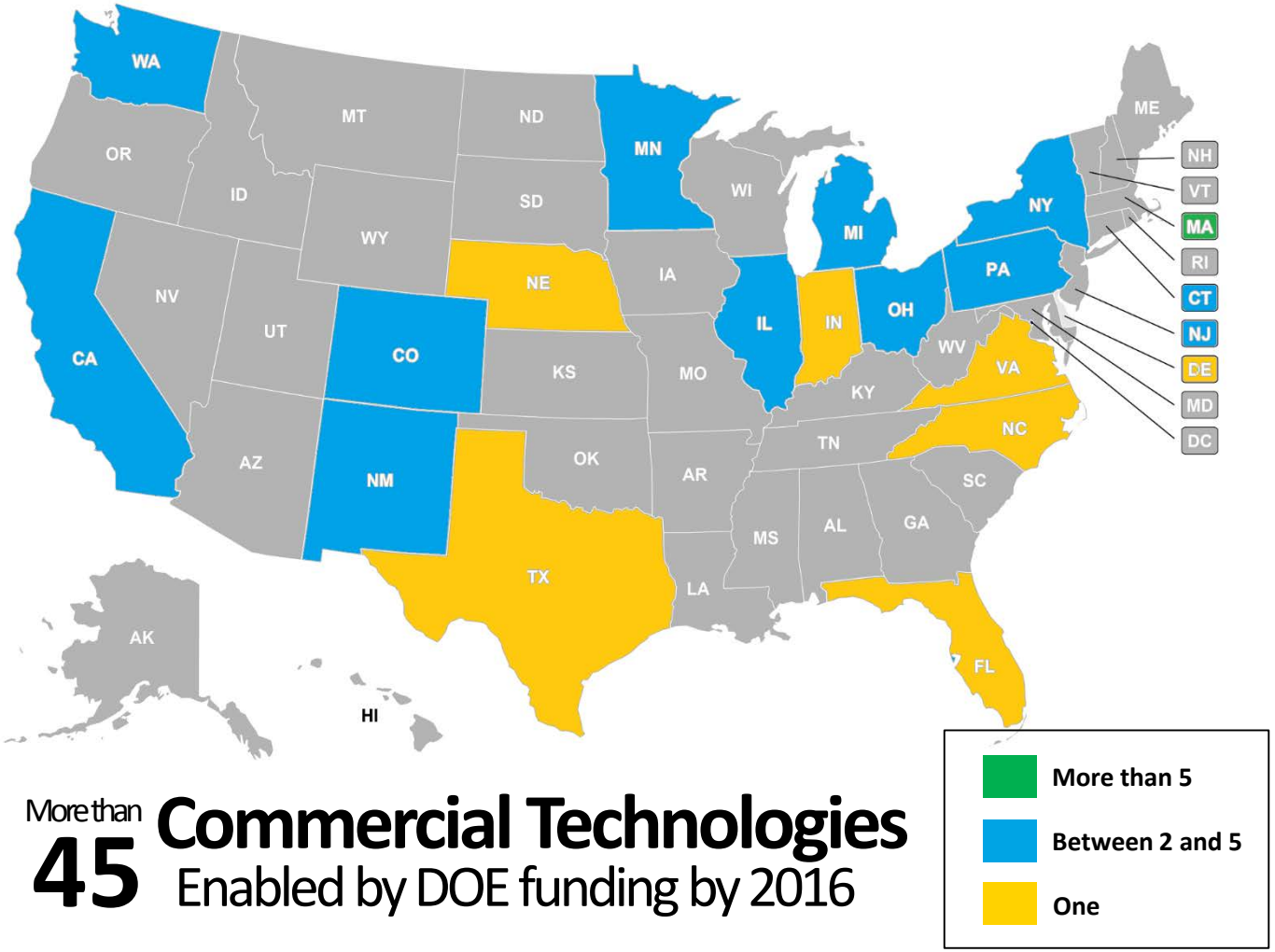
- Catalysts
- Fuel Cell System Components
- Tanks
- Electrolyzers

Impact of DOE Investment on Industry

Revenues	Additional Investment
More than 7X the DOE Investment	More than 5X the DOE Investment

*for selected companies

DOE-Enabled Commercial Technologies by State

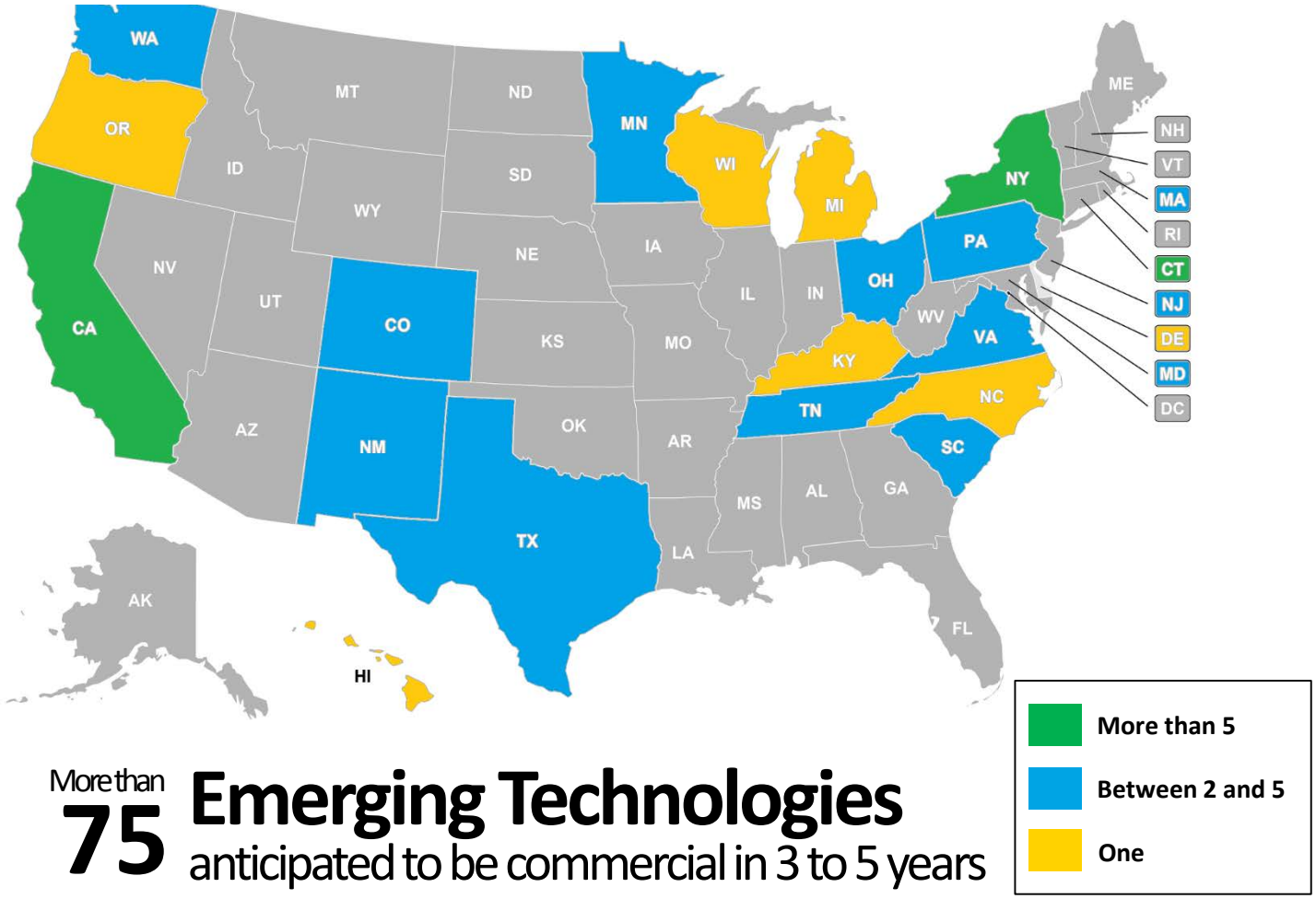


More than **45** **Commercial Technologies** Enabled by DOE funding by 2016

State	Total
MA	9
CT	5
OH	5
NY	4
CO	3
NJ	3
CA	2
IL	2
MI	2
MN	2
NM	2
PA	2
WA	2
DE	1
FL	1
IN	1
NC	1
NE	1
TX	1
VA	1

Source: 2016 Pathways to Commercialization Report

DOE-Enabled Emerging Technologies by State

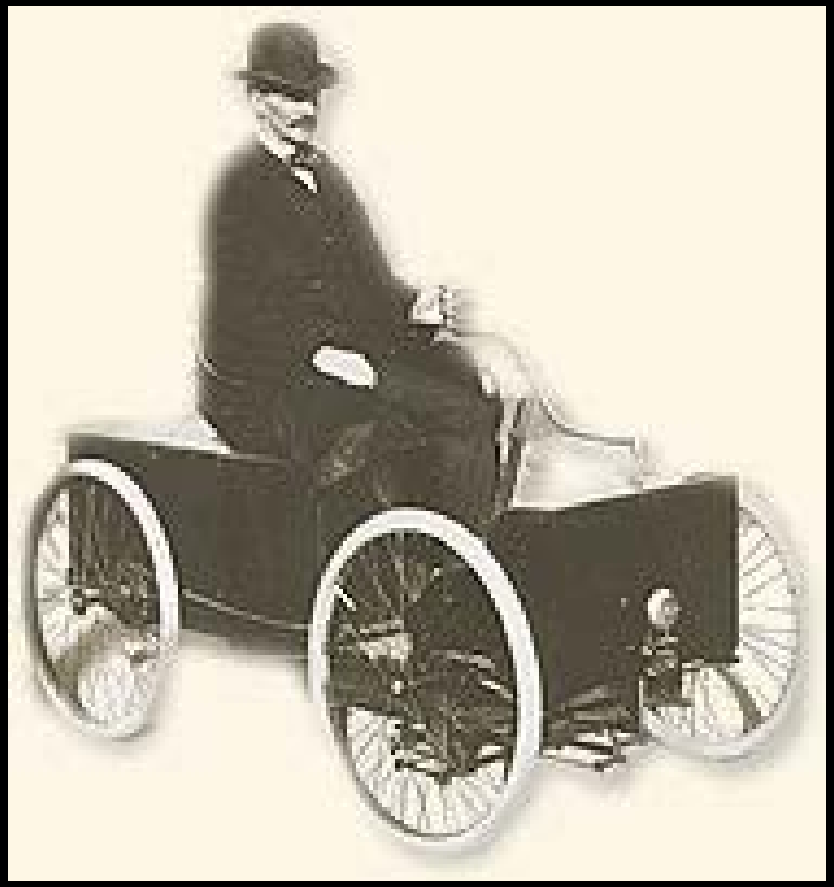


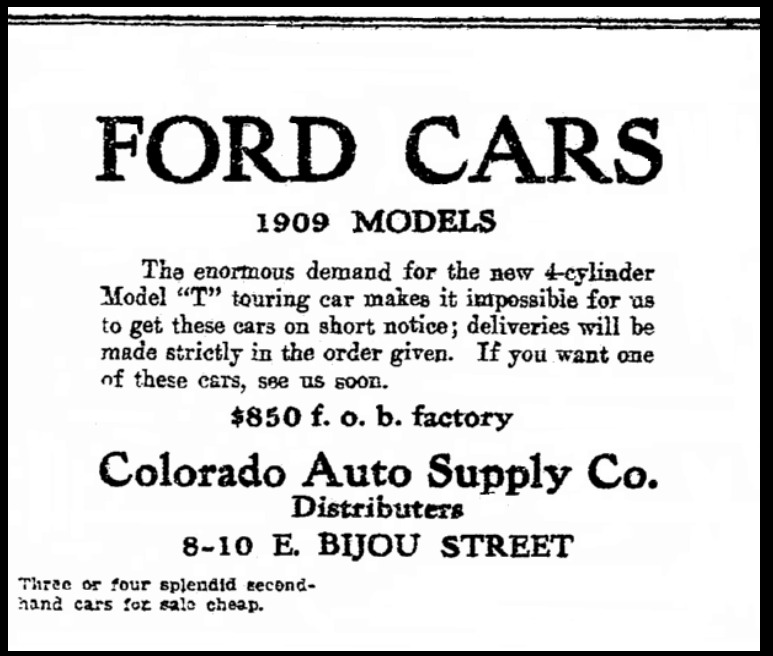
State	Total
CA	12
CT	9
NY	8
CO	5
MA	5
TN	5
PA	4
WA	4
MN	3
OH	3
SC	3
MD	2
NJ	2
NM	2
TX	2
VA	2
DE	1
HI	1
KY	1
MI	1
NC	1

More than **75** **Emerging Technologies**
anticipated to be commercial in 3 to 5 years

Source: 2016 Pathways to Commercialization Report

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





FORD CARS

1909 MODELS

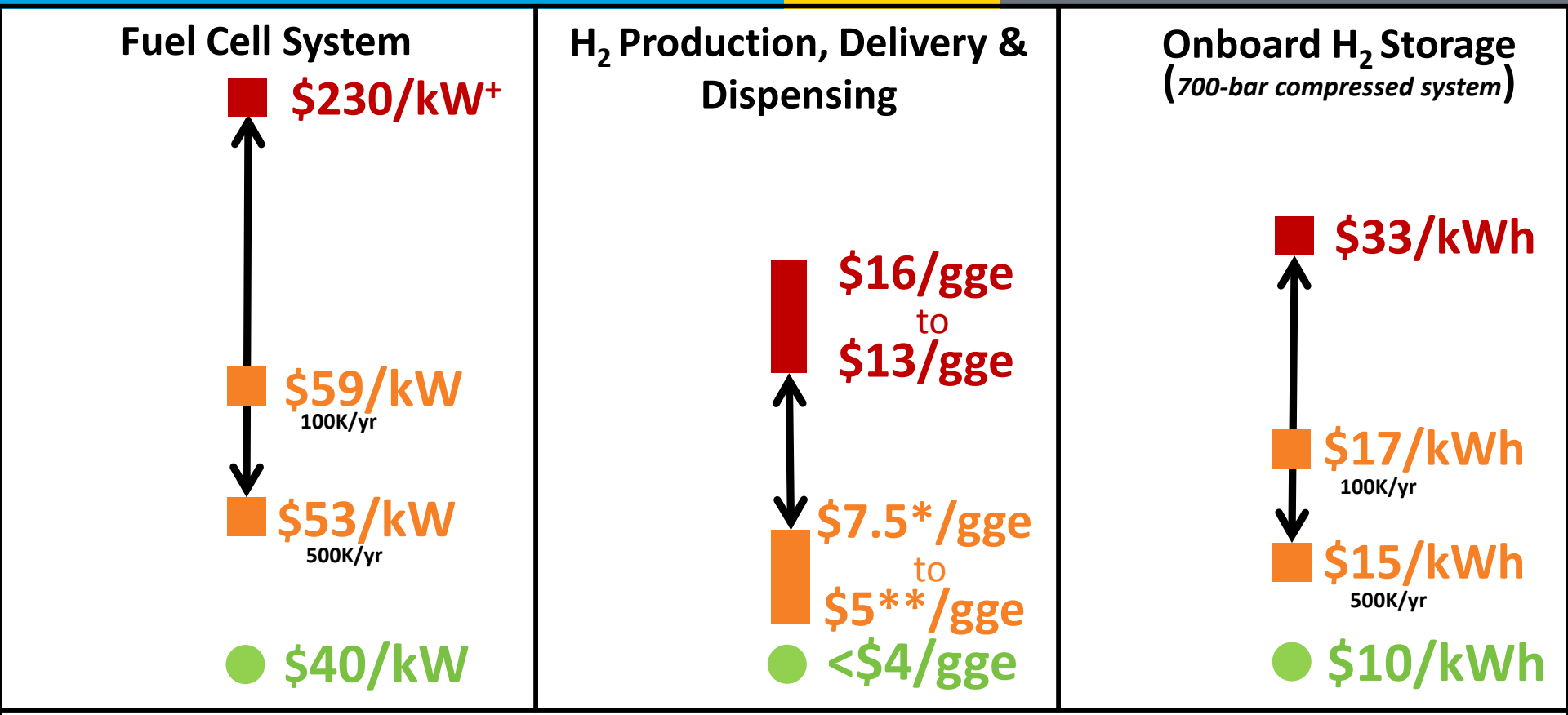
The enormous demand for the new 4-cylinder Model "T" touring car makes it impossible for us to get these cars on short notice; deliveries will be made strictly in the order given. If you want one of these cars, see us soon.

$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 Targets and Status



Key Challenges- Examples

- PGM loading
- Catalyst and membrane durability
- Electrode performance and durability

- Efficiency and Reliability
- Feedstock and Capital Costs
- Compression, Storage and Dispensing (CSD) Costs

- Carbon fiber precursors and conversion
- Composite/resin materials
- BOP and assembly costs

*Based on Electrolysis ** Based on NG SMR + Based on 2016 Program Cost Record (preliminary)

DOE H_2 Infrastructure Roadmap Development

Purpose

Align RD&D across sub-programs to enable H_2 fueling station deployment in the near-term

Feedback guiding process

- **June 2016: Infrastructure Review Meeting**
  - Industry (27), national labs (13), government (5)
- **July 2016: Infrastructure Request for Information**
  - Industry (14), academia/labs (8), government (2)
- **October 2016: 2-Day H2FIRST Gap Analysis**
  - DOE-funded projects, Infrastructure priorities, and National Laboratory R&D Capabilities
- **Early 2017: Development of Technology-Specific Targets to Address R&D Critical Barriers**
  - Led by H2FIRST national laboratory team

Barriers

- **Reliability**
- **Cost**
- **Financing**
- **Workforce**
- **Fuel Quality**
- **Footprint**

Planned to complete by late 2017

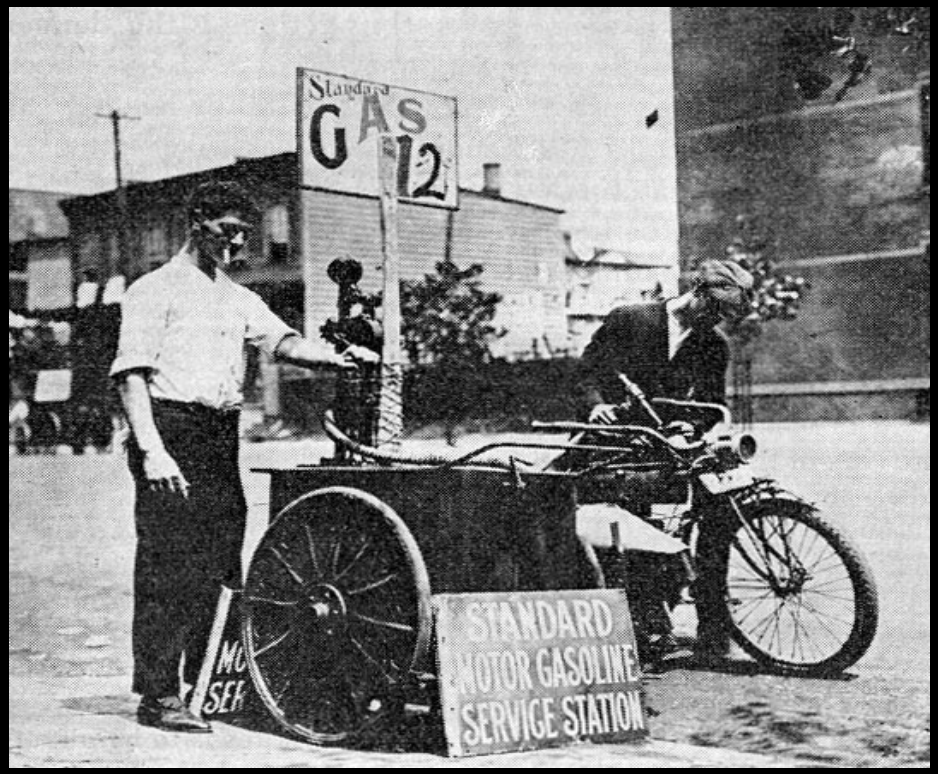
DOE H_2 Infrastructure Strategy

KEY CHALLENGES	DOE ACTIVITIES	EXAMPLES
1 Station Cost	✓ Components R&D ✓ Systems R&D	H2FIRST ▪ HySTEP ▪ Reference Station Design ▪ Contaminant Report
2 Station Reliability	✓ Contaminant Detection ✓ Sensors Testing	**SHOWCASE STATION** (HyTEST)
3 Station Rollout	✓ Safety Awareness ✓ Codes and Standards Harmonization ✓ Training & Education	**TOOLS** (HyRAM- Hydrogen Risk Assessment Models)

DOE efforts support public-private partnership: H_2 USA

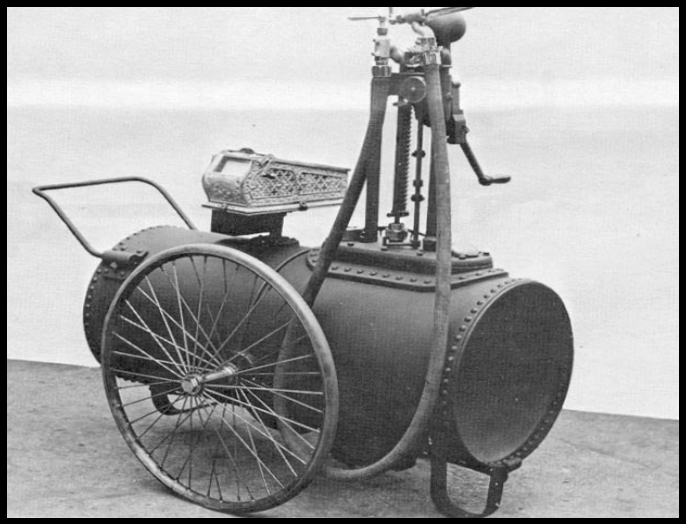
Gasoline History: Many diverse options

Cans, barrels, home models, mobile refuelers



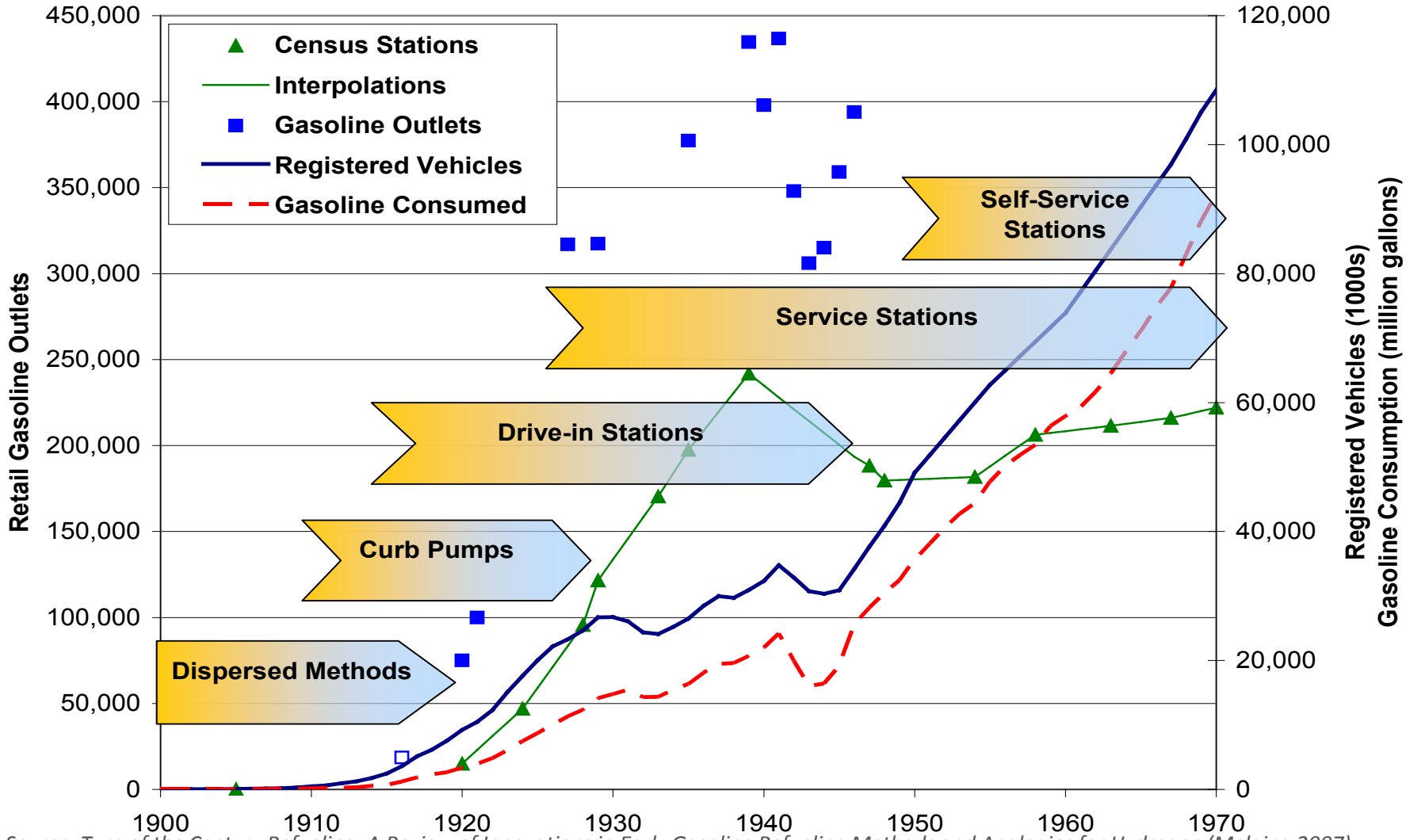
Source: M. Melaina 2008.

Source: Vieyra, 1979



Source: Milkues, 1978

Refueling Methods Evolved Over Time



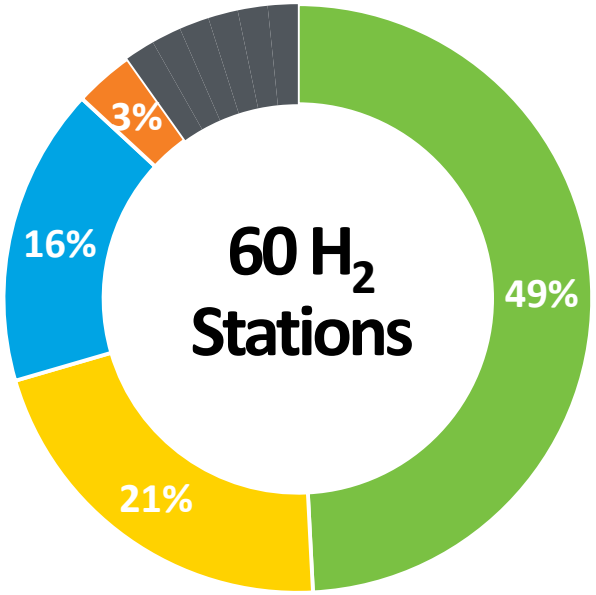
Source: Turn of the Century Refueling: A Review of Innovations in Early Gasoline Refueling Methods and Analogies for Hydrogen (Melaina 2007)

History shows phased introduction of different refueling methods

U.S. Hydrogen Infrastructure

- **California** : 25 retail stations now, 100 planned
- **U.S. Northeast :** 12 to 25 stations planned
- Approx. **10M metric tons of H_2 produced** annually
- **1,600 miles of H_2 pipeline** already in place

A variety of H_2 stations demonstrated to date:



Delivered Compressed Steam Methane Reforming

On-Site Electrolysis

Delivered Liquid SMR

On-Site SMR

Other

- Delivered Pipeline
- Delivered Liquid By-Product
- Delivered Compressed By-Product
- On-Site Tri-Gen
- Mobile Fueler
- Trailers

*Includes current (21), future (38) and retired (2) stations

NREL cdp_infr_11
Created: Mar-30-16 11:06 AM | Data Range: 2008Q3-2015Q4

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
- Finalist selected January 2016
- Testing phase in progress
- Finalist must meet technical & cost criteria to win $1M prize
- Outcome announcement expected early 2017

Ribbon Cutting at H-Prize Open House on November 2016
Team: Ivys, PDC, McPhy

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

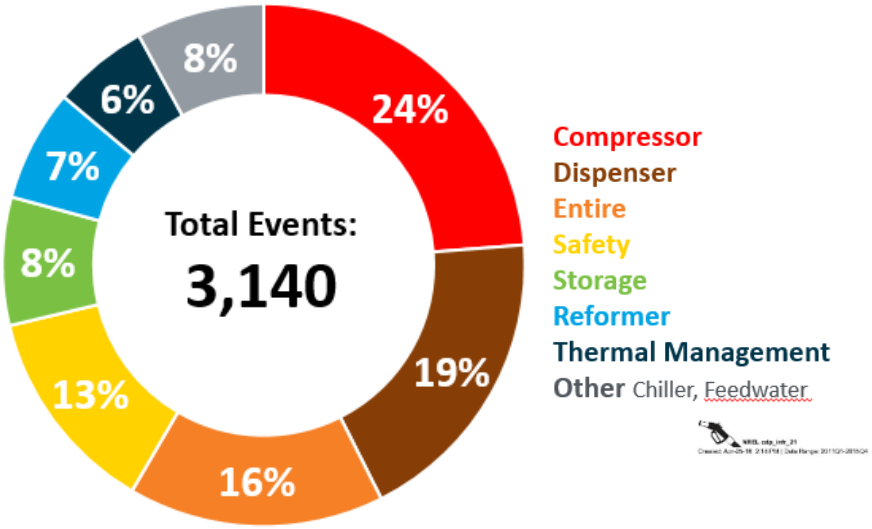
To Participate

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

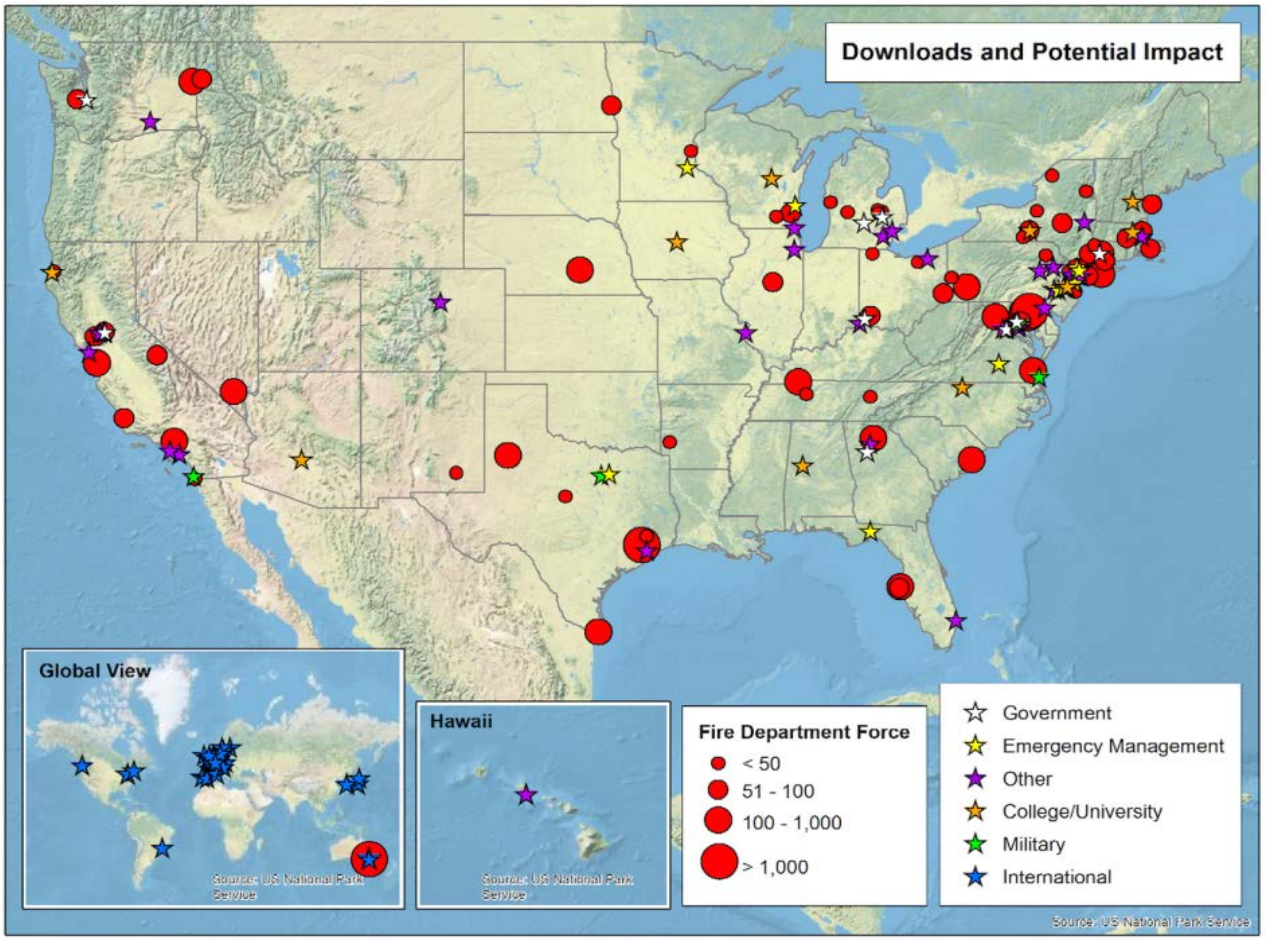


Most maintenance related to compressors and dispensers

H_2Tools: One-stop for H_2 safety knowledge

h2tools.org

- Includes resources on **safety** best practices, **first responder training**, and **H_2 codes & standards**
- **36,000 code officials and first responders trained**



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

Enabling dissemination of safety information around the world

New DOE Efforts to enable robust supply chain

Integrated Network of Regional Technical Centers

Locations

- East Coast (CCAT)
- Midwest (OFCC)
- Central States (NREL)
- West Coast (UC Irvine)

Activities (Examples)

- Hold supply chain exchanges
- Promote cooperation between suppliers & developers, and standardization of component specifications

Global Competitiveness Analysis

including:

GLWN.org

- Global Cost Breakdown
- Design for Manufacturing & Assembly
- Value Stream Mapping

Fuel Cell and H_2 Opportunity Center

JAMES MADISON UNIVERSITY
Virginia Clean Cities

- Comprehensive **online database**
- **Project activities include:**
  - Encourage **supplier engagement**
  - Release and maintain **public directory**
  - Conduct **outreach campaign** (social media, etc.)

Recent Workshops

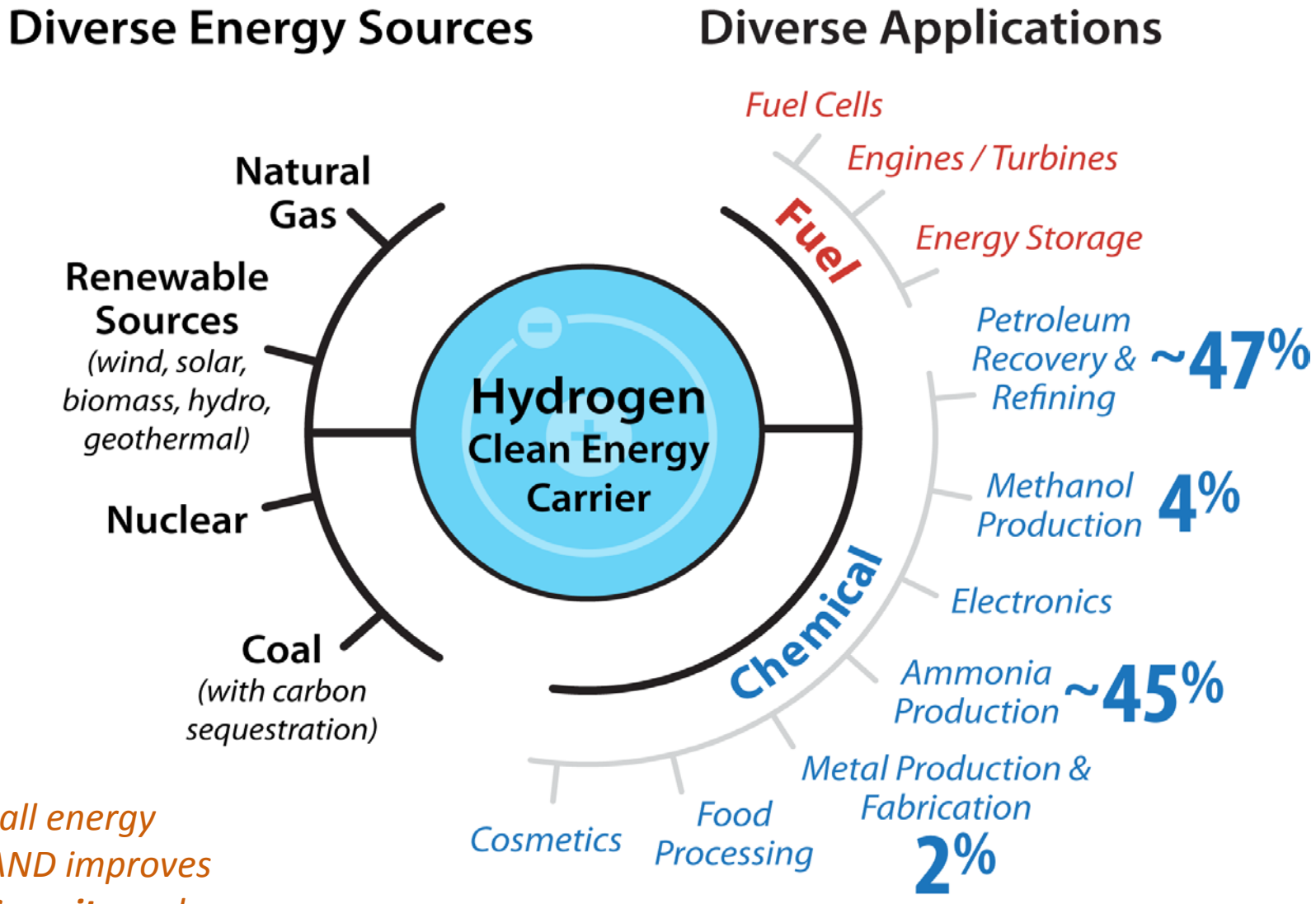
- **Ohio Fuel Cell Symposium- Sept 2016**
- **Connecticut- CCAT- Nov 2016**

Objectives

- Identify gaps, needs and opportunities
- Enhance interaction between supply chain stakeholders

Workshop proceedings available at http://energy.gov/eere/fuelcells/downloads/2016-ohio-fuel-cell-symposium

H2@Scale Concept



Services all energy sectors AND improves ***Energy Security*** *and* ***Domestic Economy***

Source: DOE, NREL, Hydrogen and Fuel Cell Program

How much H_2 is needed?

How much hydrogen for 1 car?

$$\frac{\textbf{12,000 miles} \text{ per year}}{\textbf{60 miles} \text{ per kilogram}} = \textbf{200 kg} \text{ per year} \quad \textbf{or} \quad \textbf{0.2 tonnes} \text{ per year}$$

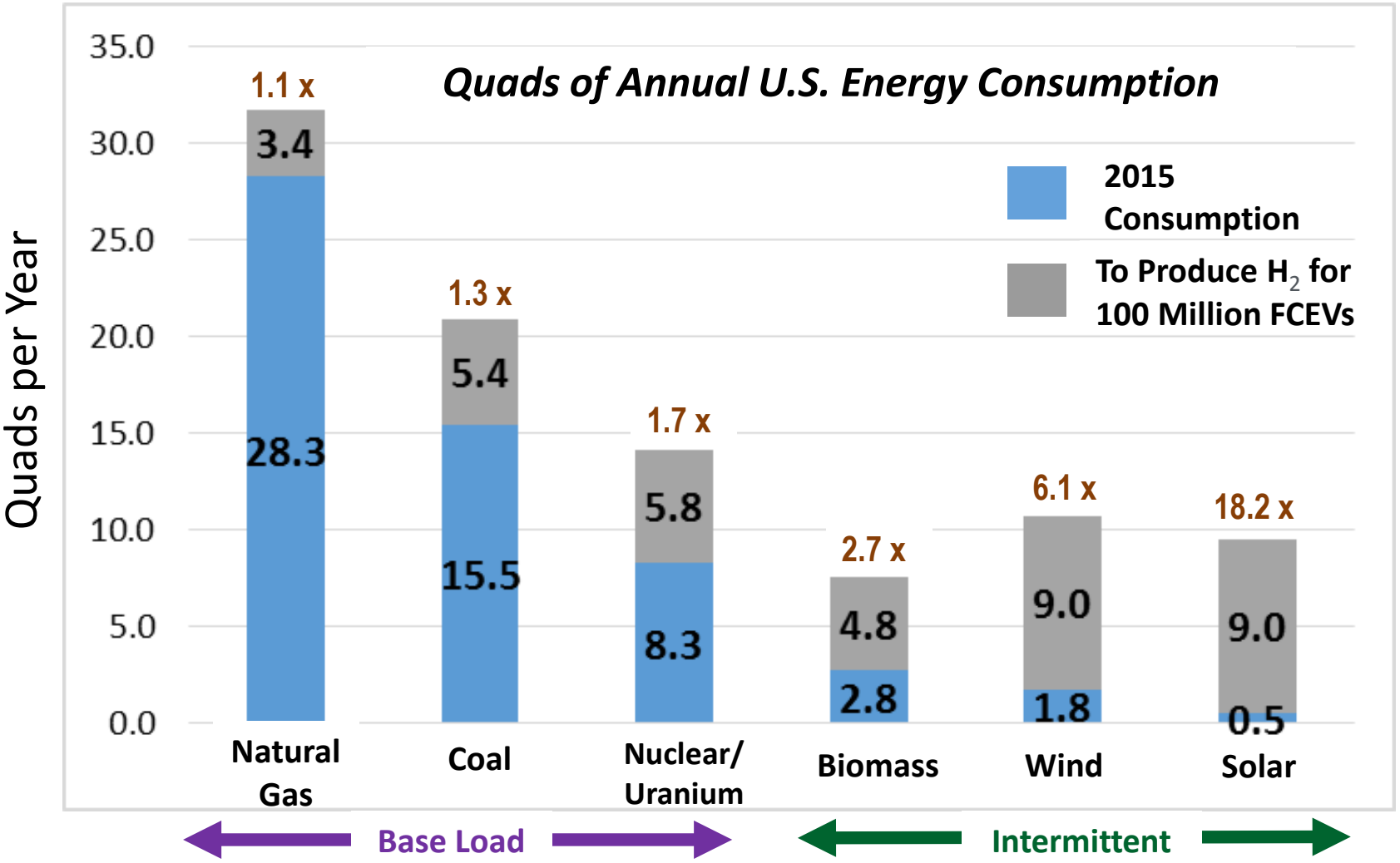
How much hydrogen for many cars?

1 M cars	0.2 M tonnes H_2 per year 200 M kg H_2 per year
= 100,000 cars	

100 M cars	20M tons H_2 per year 20 B kg H_2 per year
= 10M cars	

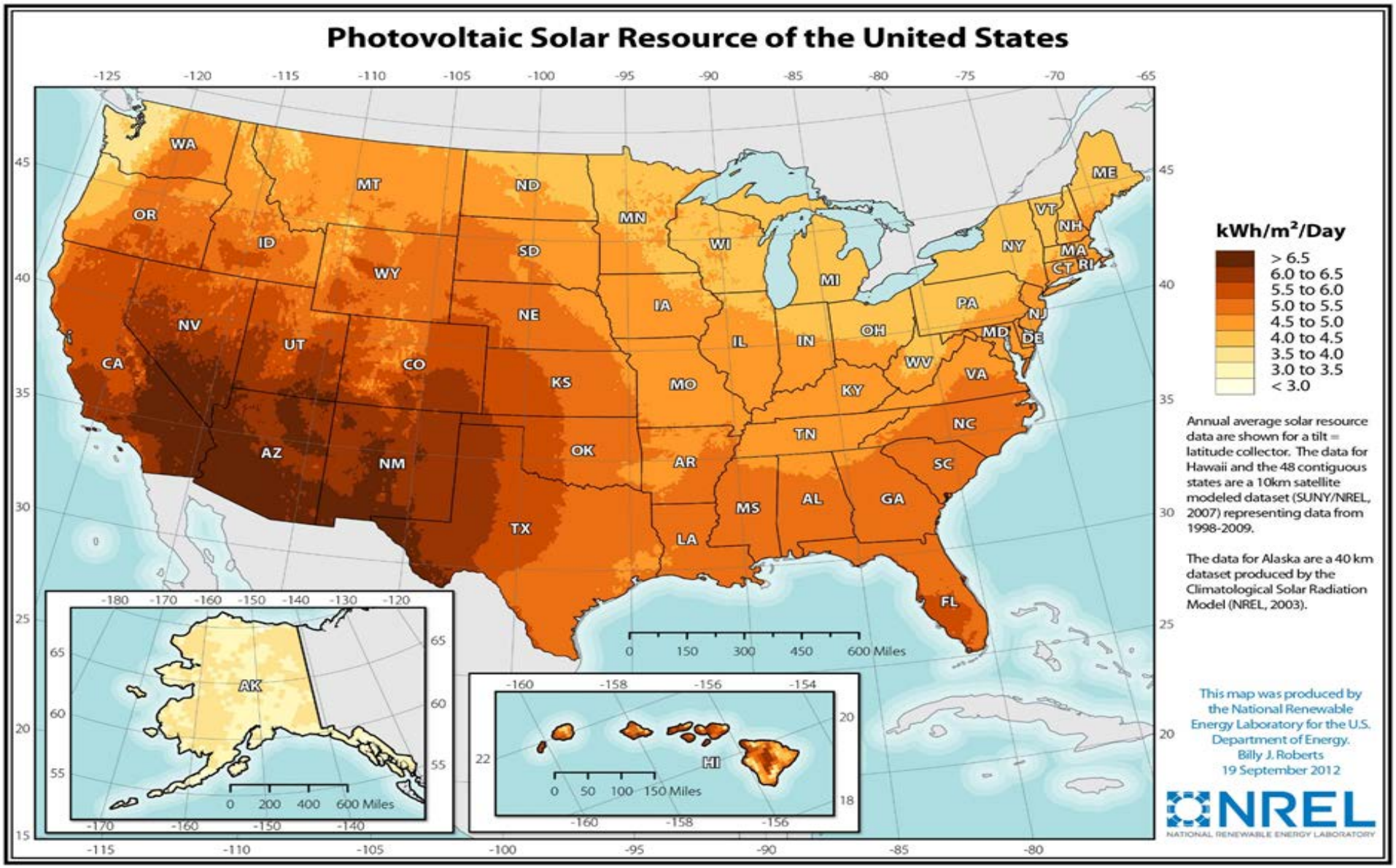
How much H_2 is needed?

How to get hydrogen for 100M FCEVs?



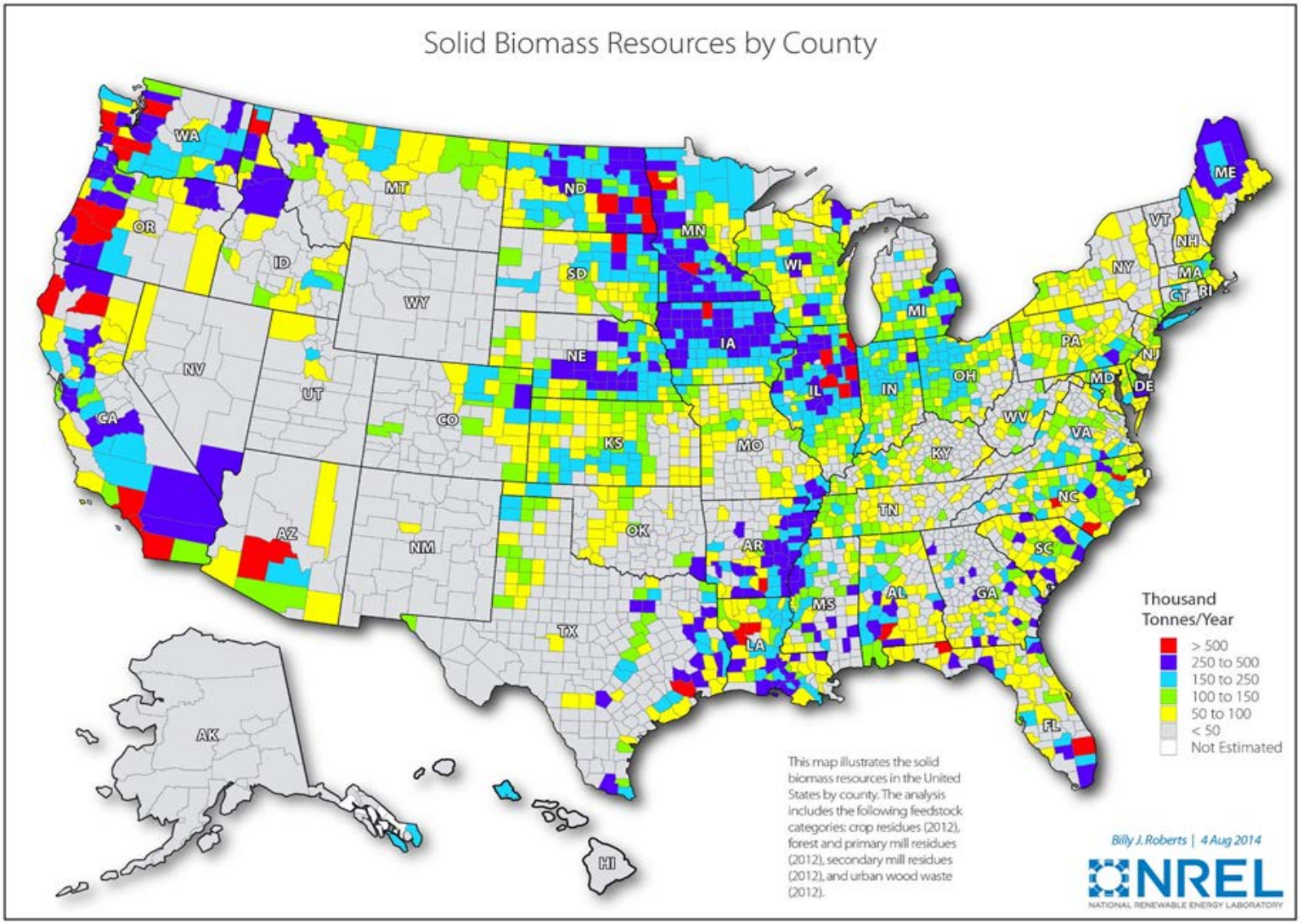
Source: Resource Assessment for Hydrogen Production: Hydrogen Production Potential from Fossil and Renewable Energy Resources. M. Melaina, M. Penev, D. Heimiller, National Renewable Energy Laboratory 2013; Annual Energy Outlook 2016; http://www.eia.gov/renewable/

Solar Sources: Opportunity for Renewable H_2



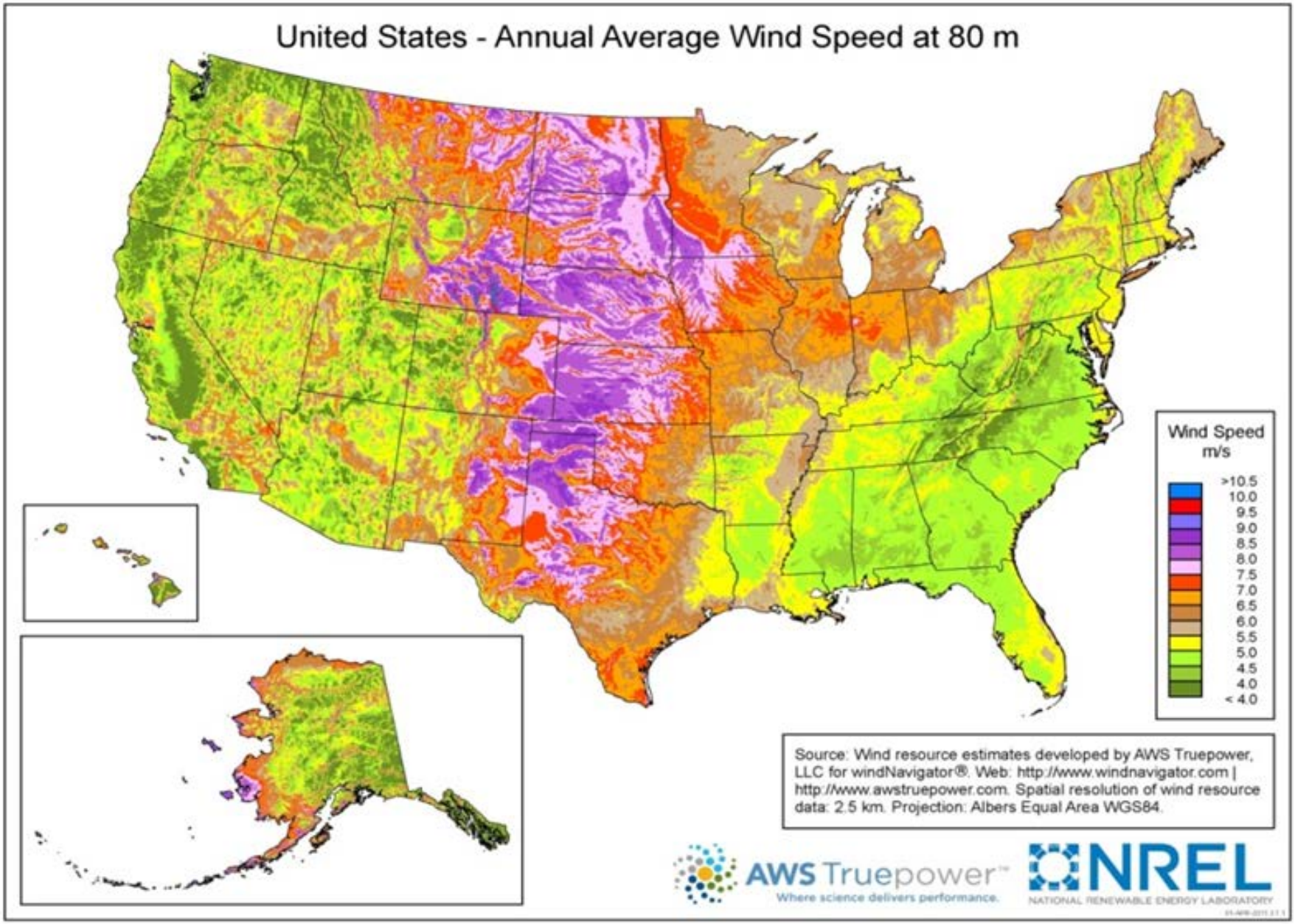
Resource analysis underway

Biomass Resources: Opportunity for Renewable H_2



Bio-feedstock reforming is a near term option

Wind Resources: Opportunity for Renewable H_2



Next Steps…

H2@Scale RD&D Roadmap that addresses issues including:

- ✓ **Hydrogen production from diverse domestic sources**
- ✓ **Hydrogen for grid stability and energy storage**
- ✓ **Development of industrial scale hydrogen delivery and storage infrastructure**
- ✓ **Penetration of clean/sustainable (including renewable) hydrogen in current and future end-use markets- e.g. industrial applications**

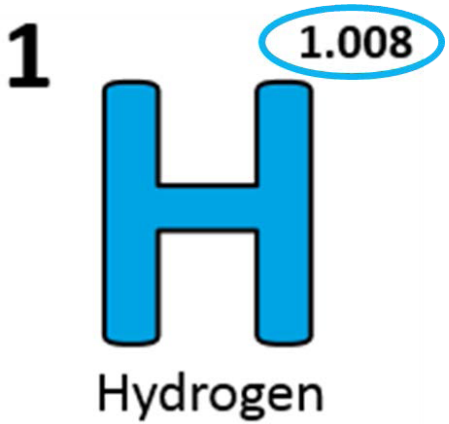
H2@Scale requires collaboration across stakeholders!

A Week of Hydrogen and Fuel Cells Celebration

ENERGY.GOV
Office of Energy Efficiency & Renewable Energy
Fuel Cell Technologies Office

3 Questions with a 'Founding Father' of Hydrogen and Fuel Cells: Byron McCormick

Energy.Gov Blogs



Hydrogen Fuel Cell Car Ride & Drives

Twitter

National Hydrogen & Fuel Cell Day | 10·08

Facebook Live

Informational Events

Reached Half a Million

Announcements

Direct Outreach

Going Forward

- **Continue to strengthen R&D activities**
  - **H_2, fuel cells, safety, manufacturing, etc.**
  - **Cost, performance, durability need to be addressed**
- **Develop Infrastructure and H2@Scale strategies & roadmaps**
- **Continue to conduct key analyses to guide RD&D and path forward**
  - **Life cycle cost; infrastructure, economic & environmental analyses, etc. (e.g. Medium/heavy duty vehicle target setting underway)**
- **Address HTAC comments on safety & event response**
- **Leverage activities to maximize impact**
  - **U.S. and global partnerships, H2USA, States**

Save the date: Annual Merit Review (AMR)
Week of June 5, 2017- Washington DC

Thank You

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Additional Information

Fuel Cells FY17 Senate/House Report Language Summary

Senate Report

- The Committee recommends **$92,000,000 for Hydrogen and Fuel Cell Technologies.**
- Within available funds, the committee recommends not less than **$7,000,000 to demonstrate an integrated hydrogen renewable energy production, storage, and transportation fuel distribution and retailing system.**
- **Within Hydrogen Fuel research and development, the Committee recommends $3,000,000 for carbon-free production of hydrogen** using new chemical synthesis methods that break apart natural gas to solid carbon and hydrogen.
- The Committee recommends **$7,000,000 for Safety, Codes, and Standards.**

House Report

- The Committee recommends **$97,000,000 for Hydrogen and Fuel Cell Technologies.**
- Within available funds, the recommendation includes **$13,000,000 for Technology Validation, of which $2,000,000 is for the EERE share of the integrated energy systems work with the Office of Nuclear Energy and $7,000,000 is to enable integrated energy systems using high and low temperature electrolyzers with the intent of advancing the H2@Scale concept.**
- The Committee recognizes the progress of the program and **expresses continued support for stationary, vehicle, motive, and portable power applications of this technology.** The Department is **encouraged to explore technologies that advance the storage and transportation fuel distribution and retailing systems.**
- The Committee recognizes the need to support the development of alternative fueling infrastructure for U.S. consumers. Accordingly, the **Department is encouraged to collaborate with the National Institute of Standards and Technology to allow accurate measurement of hydrogen at fueling stations.**
- The Department is encouraged to **engage the appropriate national laboratories to pursue novel advanced demonstrations that validate how integrated, renewable hydrogen production and storage infrastructure supports transportation and non-transportation applications. The Department is directed to submit not later than 180 days after the enactment of this Act a report on its efforts a report on its efforts to deploy hydrogen infrastructure.**

DOE H_2 and Fuel Cells Strategy

BARRIERS		NEAR TO MID-TERM	LONG-TERM
R&D	Fuel Cell Cost and Durability	Low PGM catalysts, MEAs, durability, components	PGM-free catalysts, advanced membranes, AEMs, MEAs
	Hydrogen Storage	700 bar tanks, composites	Materials R&D for low P storage, cold/cryo-compressed
	Hydrogen Production and Delivery	H_2 from NG/electrolysis; delivered H_2, high P, compression	H_2 from renewables (PEC, biological, etc.), pipelines, low P option
ADDITIONAL	Infrastructure Development	Enablers: H2FIRST-station validation, metering, sensors, etc.	Materials compatibility, station innovation, cost reduction- H-Prize
	Manufacturing and Supply Chain	Catalyst, MEA and tank manufacturing; QC; cost & reliability; supply chain	Mfg. processes and scale up; strong supply base- H_2 and fuel cells
	Safety, Codes and Standards (SCS)	Set back distances, fueling protocols; safety dissemination	Risk mitigation; National and International harmonization of SCS
	Public Acceptance and Awareness	H_2Tools, code officials, responders; early markets; H_2USA	Widespread Outreach, Education & Social Acceptance

Level of Difficulty

- High
- Medium
- Low to Medium

Funding Announcements for 2017

$30 million in funding to

- **Leverage hydrogen and fuel cell lab consortia** under DOE's Energy Materials Network (EMN)
  - **ElectroCat**: PGM-free catalysts (Topic 1)
  - **HydroGEN:** Advanced water splitting materials (Topic 2)
  - **HyMARC:** Solid-state materials for H_2 storage (Topic 3)
- **Develop precursors for low cost, high strength carbon fiber** for high pressure H_2 storage vessels (Topic 4)

Deadlines

- **Concept papers:** Dec. 20, 2016 5:00 PM ET
- **Full application:** Feb. 21 , 2017 5:00 PM ET

More Information

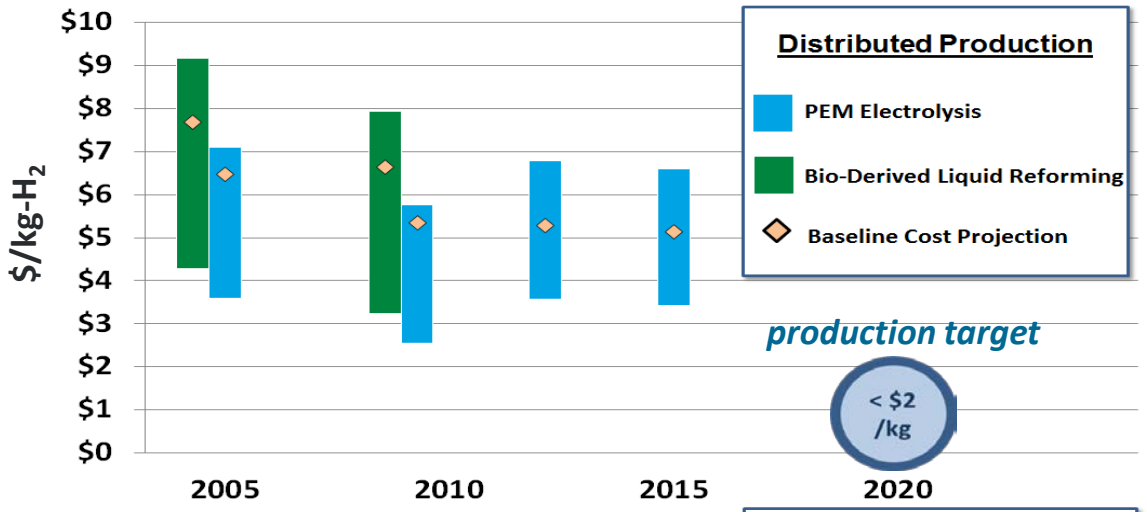
Visit EERE Exchange website at

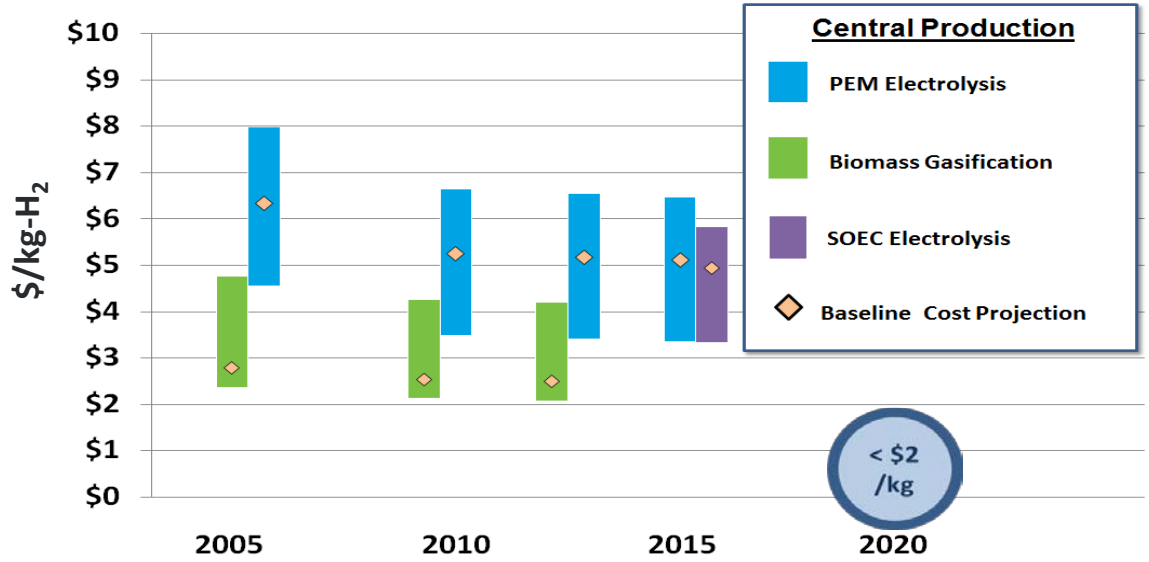
eere-exchange.energy.gov

DE-FOA-0001647

Highlights: Renewable H_2 Production

Cost* Renewable H_2 Production Pathways





*high volume cost projections. See DOE Record for details.

World Record

Solar-to-hydrogen Efficiency

16.4%

Benchmarked under **outdoor sunlight** at NREL

Source: NREL

H_2 Cost* Targets

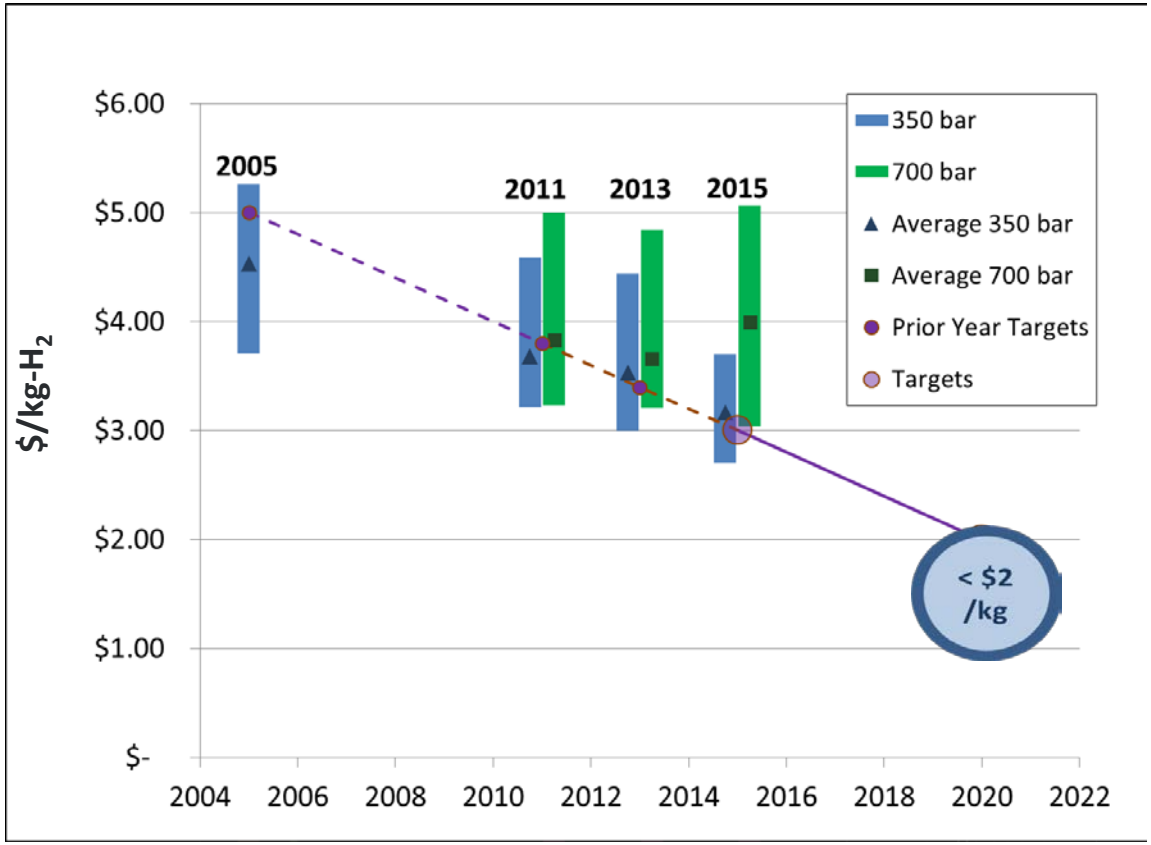
Less than **$4/gge** by 2020

Less than **$7/gge** Early Market

*at the pump

Highlights: H_2 Delivery

Cost of Delivering and Dispensing H_2 from Central Production



- Projected to **high volume with economies of scale**
- **Delivery/dispensing** apportionment of the **<$4/kg P&D target**

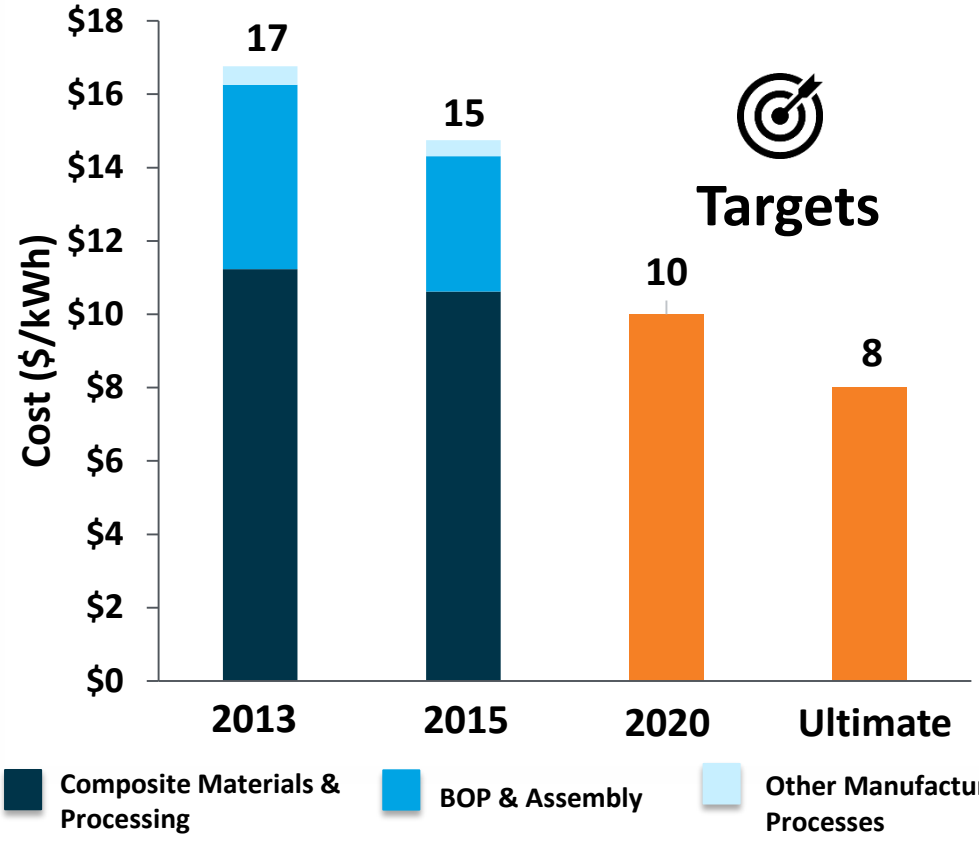
World Record

- **First ever liquefaction of a gas from room temperature with magnetocaloric cooling**
- **Record breaking 100˚C** temperature span

Source: PNNL, Emerald Energy , Ames Laboratory

Highlights: H_2 Storage

Cost* of High Pressure H_2 Storage System

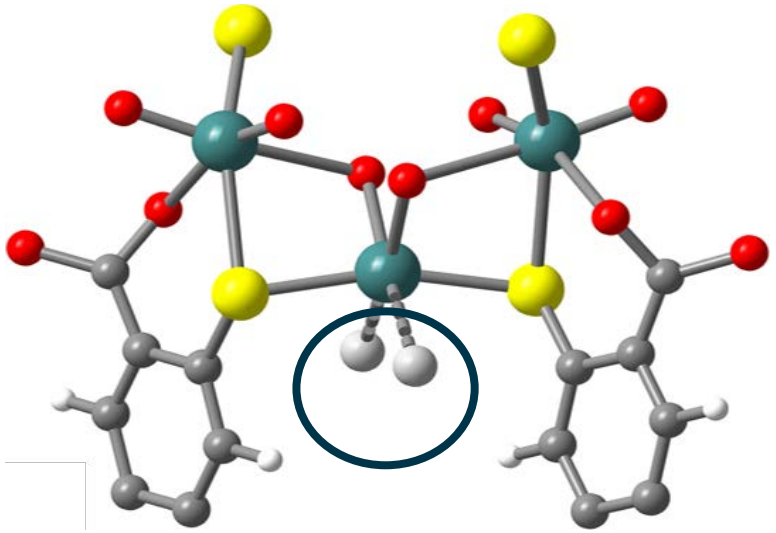


*Assumes high volume (500K/yr.), 2007$, 700-bar type IV single tank system. Based on program record 15013

12% **Net Cost Reduction** since 2013 for H_2 storage systems

World's First

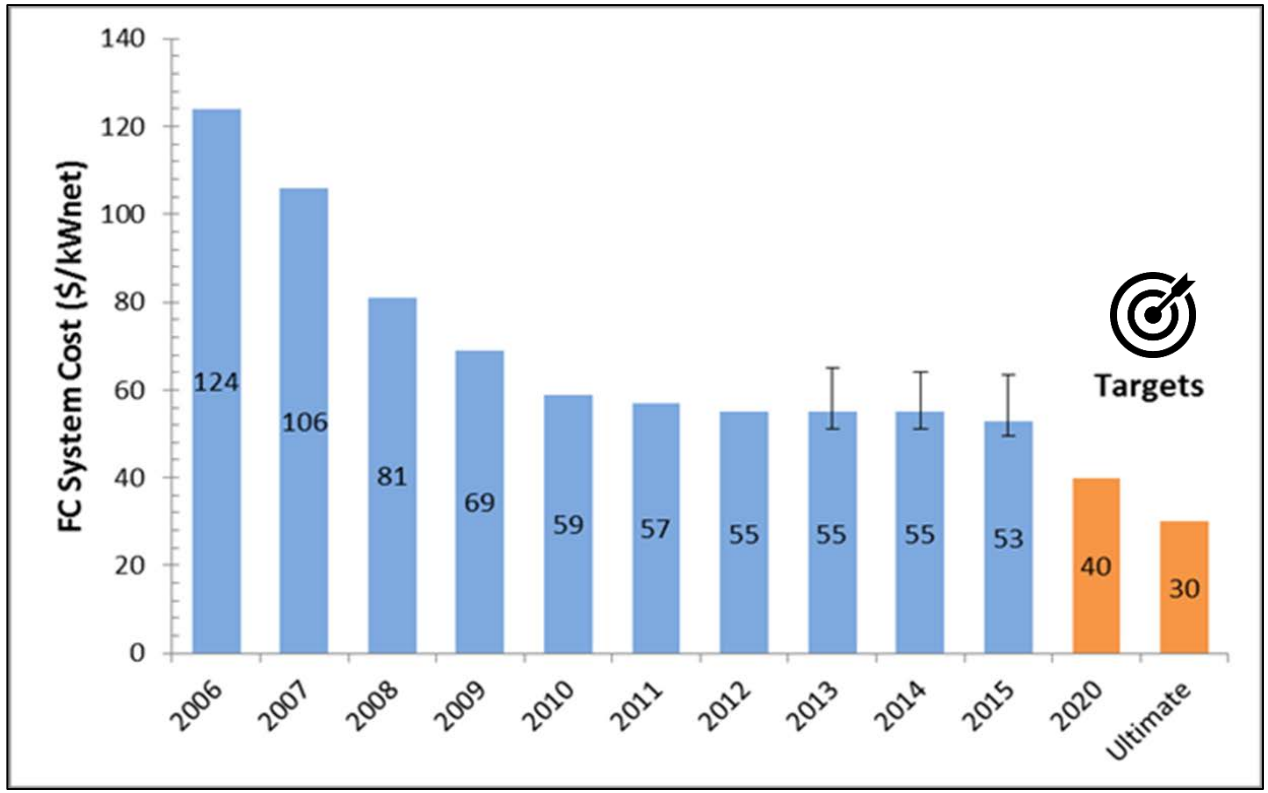
- **Two H_2 molecules adsorbed** at a **single metal site**
- Synthetic path to materials with **higher densities** of adsorbed H_2



Source: Runčevski, T.; Kapelewski, M. T.; Torres-Gavosto, R. M.; Tarver, J. D.; Brown, C. M.; Long, J. R. *Chem. Commun.*, submitted.

Highlights: Fuel Cells

Modeled Cost* of Fuel Cell System Over Time



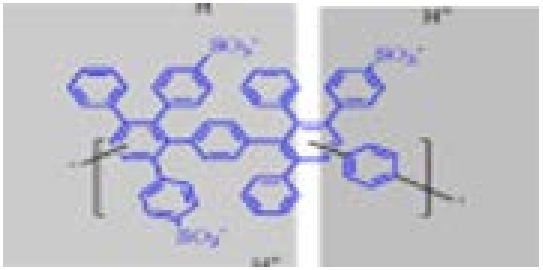
* 80-kW_{net} PEM fuel cell system projected to high-volume* manufacturing

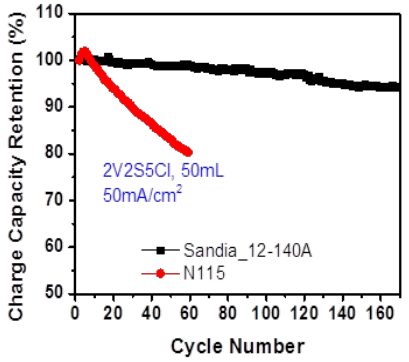
8,000 Hrs.

Ultimate Durability
Target Established

World Record

- **Alkaline exchange Membrane**
- Record breaking durability
- Opportunities in flow batteries/electrolysis





Source: SNL

Tools, Models and Databases Online

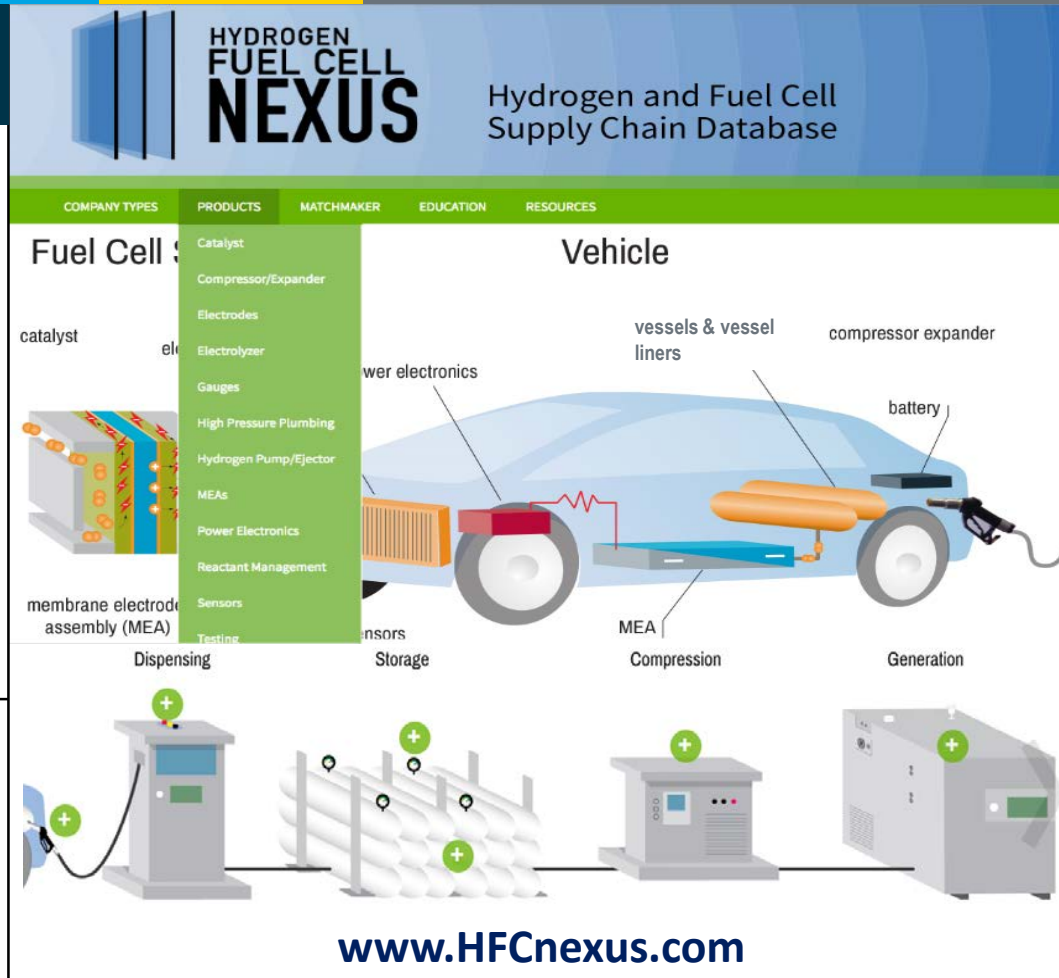
Resources

"Toolbox" online:

- HyRAM
- HDSAM
- H2FAST
- H2A
- JOBS and more

Available now at:
http://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox

H2Tools.org



www.HFCnexus.com

September/October 2016: Supply Chain Exchange and Partnership Development Regional Forum- North Canton, OH

Organized by Ohio Fuel Cell Coalition (OFCC) and Partners

Supplier engagement & collaboration & information readily and publicly accessible

Update: Fuel Cell Buses Status

AC TRANSIT **FLEET**

Largest in North America

AC Transit Fuel Cell Electric Bus

FTA Funding and Collaboration with DOE- NREL Data collection

RECORDS

Record **Durability**:
More than
23,000 hours

Driven for
approximately
1.8M miles

More than
15 million
passengers

As of November, 2016

Reliability and durability demonstrated in fuel cell electric buses

First Lady's and Dr. Jill Biden's Initiative: Joining Forces

Supporting veterans and their families in 3 areas:

Wellness

Employment

Education

Strong Commitment by the H_2 and Fuel Cells Community

Air Liquide and PDC committed to hiring veterans for 10% of their workforce

Job Resources and Outreach for Veterans

Outreach & Education

- **San Diego Military Community** Transition Summit: April 21. California
- **Camp Pendleton Military Summit**: Sep. 28-29, California
- **Joint Base Lewis McChord Military** Summit: Oct. 12-13, Tacoma, WA
- **Hawaii Transition Summit**, October 18, 19, Honolulu, Hawaii

Resources & Models

- **JOBS Models**
  - JOBS and economic impacts of Fuel Cells (JOBS FC)
  - JOBS and economic impacts of Hydrogen infrastructure (JOBS H2)
  - http://JOBSmodels.es.anl.gov
- **Employment Report Update Underway**
  - Planned release late 2017/early 2018

Key Tasks:

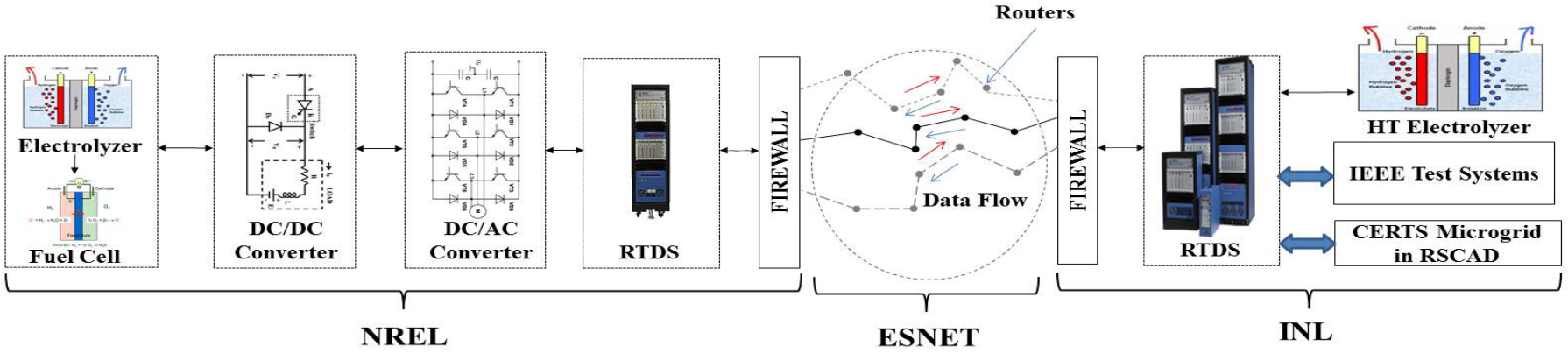
1. Economic criteria that must be met for H2@Scale.
2. Forecast hydrogen supply curves.
3. Forecast hydrogen demand curves.
4. Determine economic penetration of hydrogen.
5. Develop Sankey diagrams, and down-select scenarios.
6. Analysis of down-selected scenarios.
7. Analyze spatial issues of H2@Scale (e.g. proximity of supply and demand).
8. Comparison of H2@Scale impact with base case business as usual.

Techno-economic analysis will forecast the resource requirements and impact of H2@Scale

Demonstration of Electrolyzer Grid Integration

NREL

INL



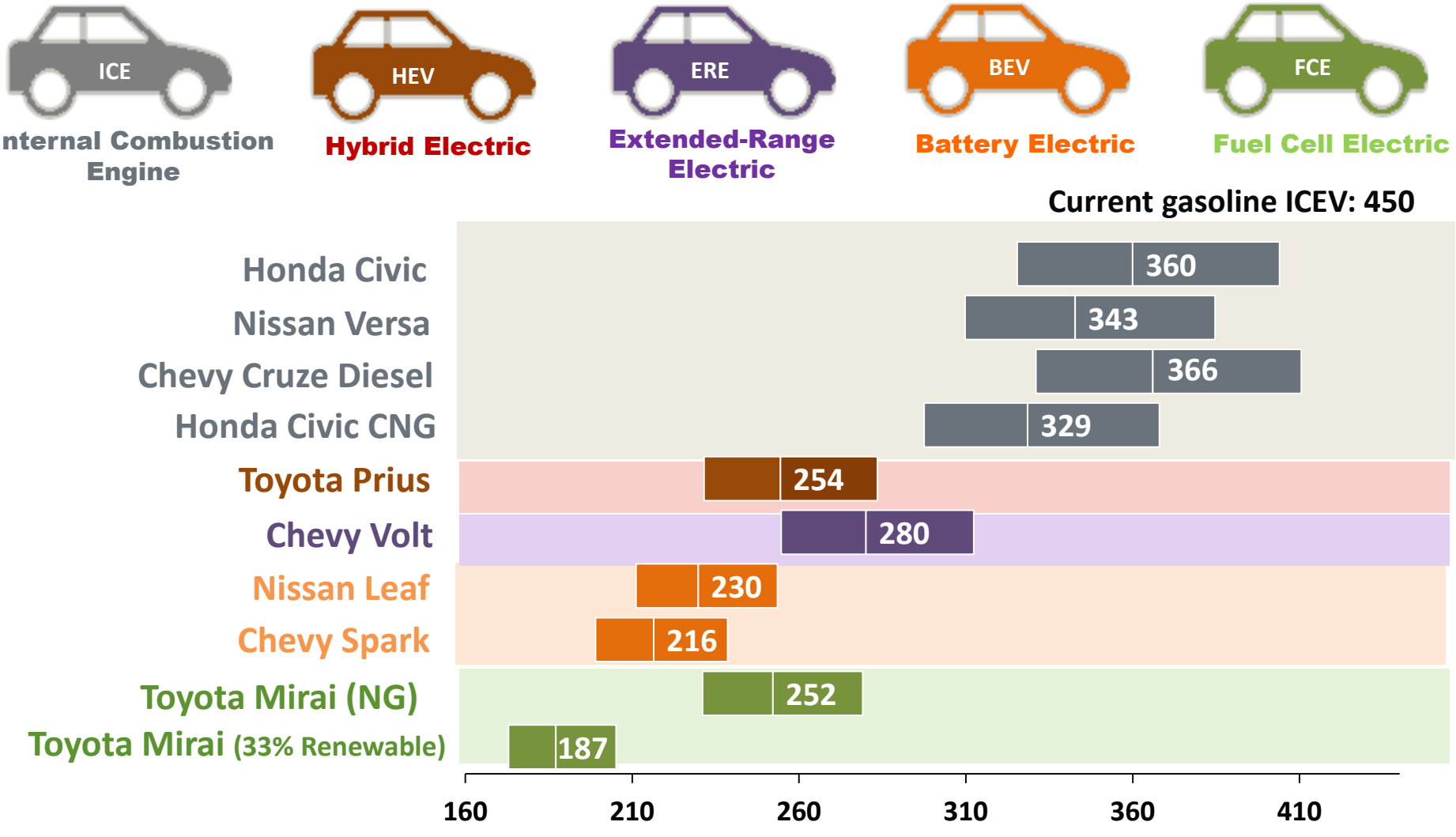
FCTO is validating electrolyzer potential in energy storage.

H2@Scale RFI Key Themes – Interest in:

1. **Innovative H_2 production technologies**
   - Electrolyzer cost reduction
   - Alternative feedstocks (e.g. solid and liquid waste, process gases)
   - Integrate H_2 production with waste heat (e.g. from nuclear or steelmaking)
2. **Integrated H_2 systems (e.g., reversible fuel cells,)**
3. **Innovative H_2 storage and delivery technologies**
   - Liquid organic carriers, metal organic frameworks; bulk storage
4. **Use of H_2 to enable grid stability and energy storage**
5. **Data collection & sharing on the value proposition and feasibility of H2@Scale**
   - Demonstration of electrolyzer integration with the grid; RD&D on power-to-gas
6. **Deployments of H_2 in near-term markets, including for buses, ammonia, & steel**

RFI & workshop will guide cross-cutting H2@Scale RD&D Roadmap

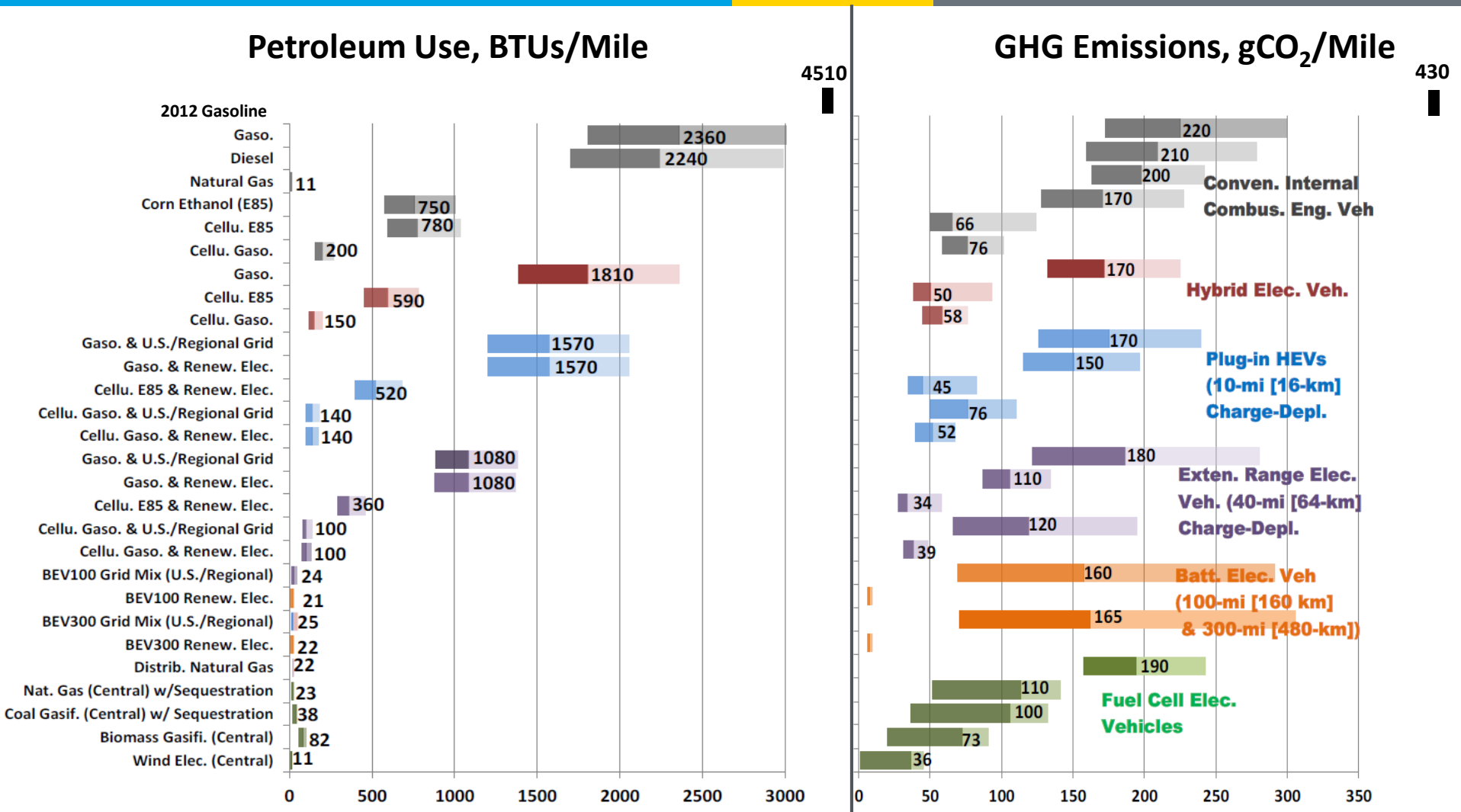
Life-Cycle GHG Emissions- Today's Cars



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

Almost 50% reduction in GHG can be achieved with today's FCEVs.

Well to Wheels Emissions and Petroleum Use*



Program Record #13005: http://www.hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

***2035 Technology except for 2012 gasoline**

Electric Drive With Low Carbon Fuels - Pathway with lowest GHG emissions and petroleum use

Collaborations and Partnerships

R&D → Demonstration & Deployment → Accelerated Commercialization

USDRIVE
DRIVING RESEARCH AND INNOVATION FOR VEHICLE EFFICIENCY AND ENERGY SUSTAINABILITY

- Pre-Competitive R&D
- USCAR, energy companies, EPRI and utilities

iea International Energy Agency

- Implementing Agreements
- 25 countries

California Fuel Cell Partnership

Connecticut Hydrogen-Fuel Cell Coalition
Massachusetts Hydrogen Coalition
SC Hydrogen & Fuel Cell Alliance www.SCHydrogen.org
OFCC Ohio Fuel Cell Coalition
H2I Hawai'i Hydrogen Initiative

- State Partnerships and Collaborations

IPHE

- International Government Coordination
- 18 countries and European Commission

H2USA

- Public-Private Partnership
- More than 50 partners
- FCHEA (trade association)

Hydrogen and Fuel Cells Technical Advisory Committee (HTAC)

Industry, academia and state & federal stakeholders working together