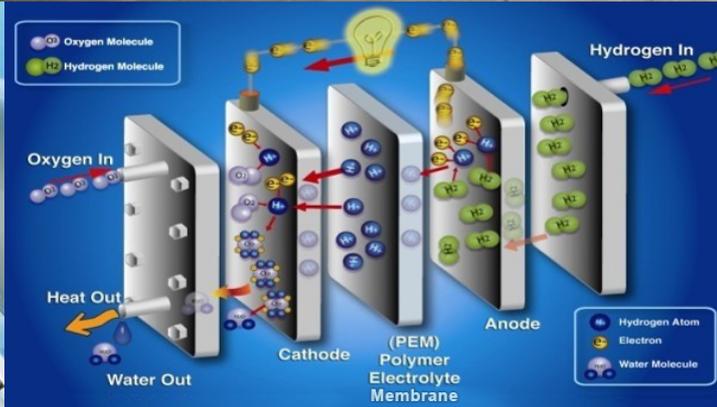


U.S. Department of Energy Fuel Cell Technologies Office

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



Hydrogen and Fuel Cell Technical Advisory Committee

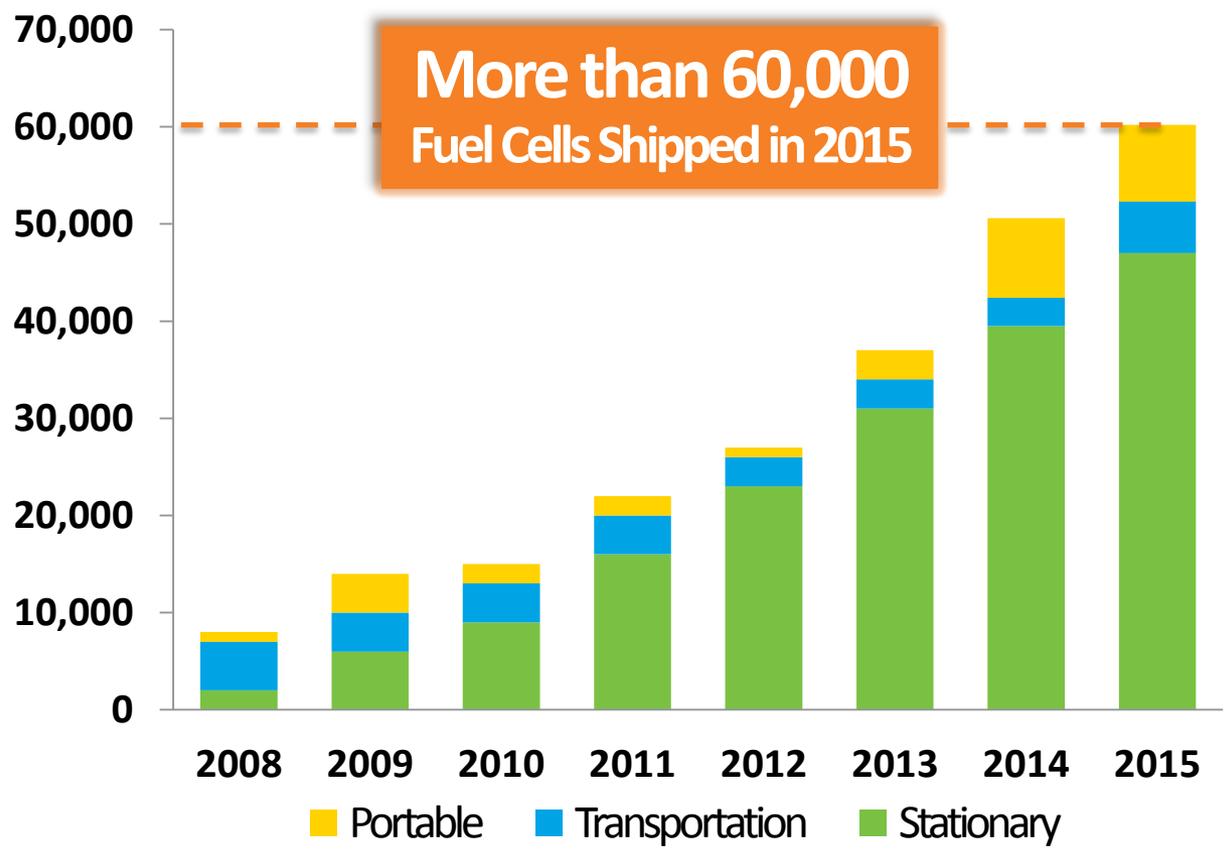
Washington, DC
December 6, 2016

Dr. Sunita Satyapal

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

Fuel Cell Market Growth

Fuel Cell Systems Shipped Worldwide by Application



**More than 60,000
 Fuel Cells Shipped in 2015**

Capacity shipped
in 2015
300 MW

↓

Approximately
2X the capacity
 shipped
in 2014

Consistent
30% annual
 growth
since 2010

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

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

To advise the Secretary of Energy on:

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

1. Enable and promote comprehensive **development, demonstration, and commercialization** of H₂ 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 H₂ 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**

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

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**

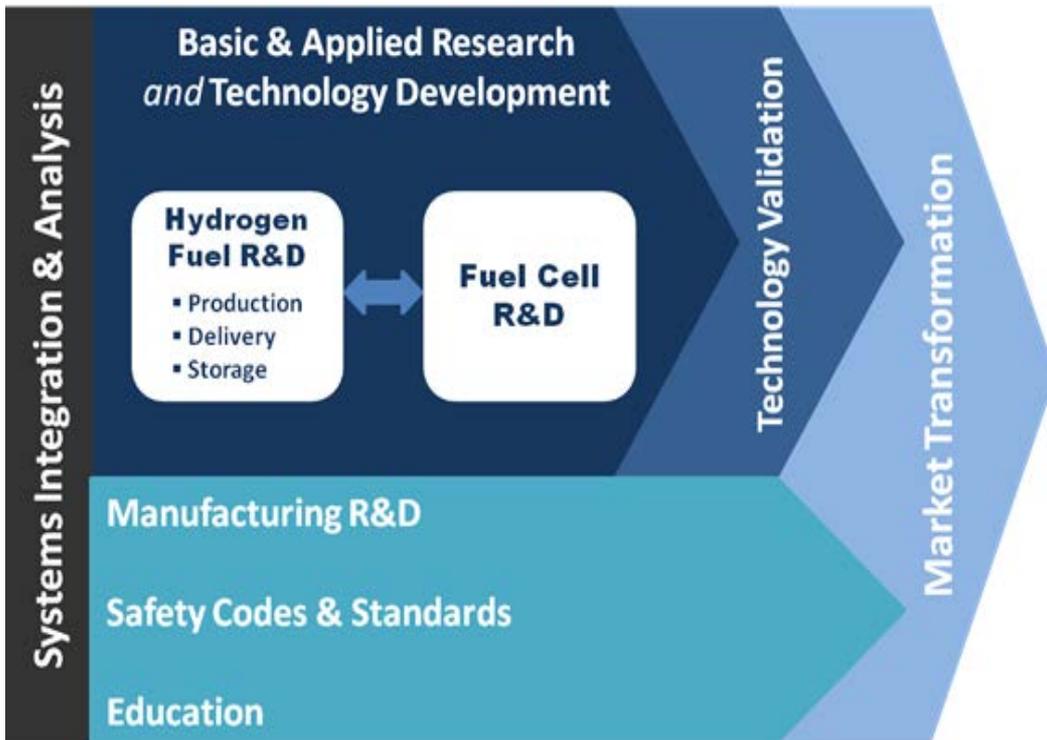
Clean Cities program emphasis must actively **promote and educate consumers on FCEV** technology.

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 H₂ and fuel cells

DOE Activities Span from R&D to Deployment

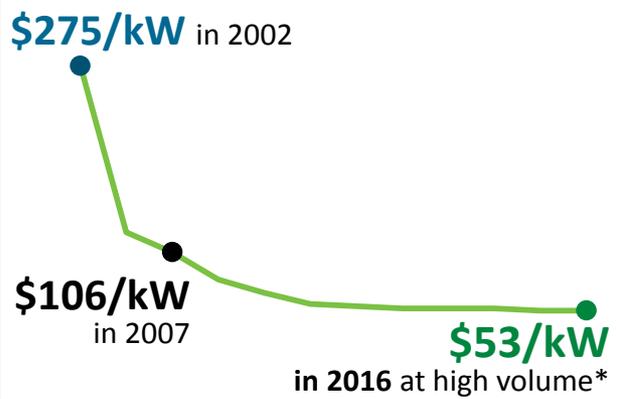


1.

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 H₂ technology station in Washington D.C.

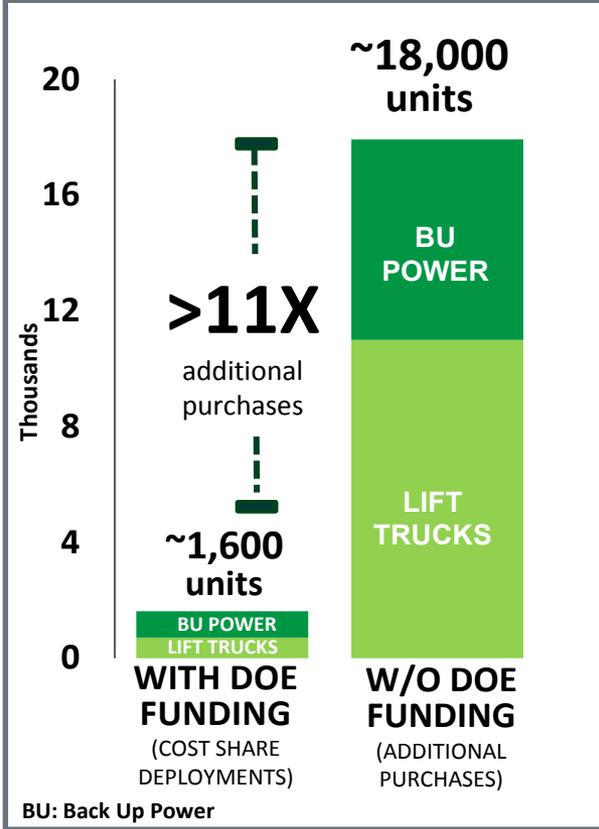


FCEV: Fuel Cell Electric Vehicle



3.

Deployment



BU: Back Up Power

Examples of consortia supporting R&D

FCPAD
FUEL CELL PERFORMANCE AND DURABILITY
Fuel Cell Performance & Durability

HYMARC
Hydrogen Materials Advanced Research Consortium
Advanced H₂ Storage Materials

ElectroCat
Electrocatalysis Consortium
PGM-Free Catalysts for Fuel Cells

HydroGEN
Advanced Water Splitting Materials
Renewable H₂ Production

Supporting Deployment



Collaboration to address H₂ 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

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

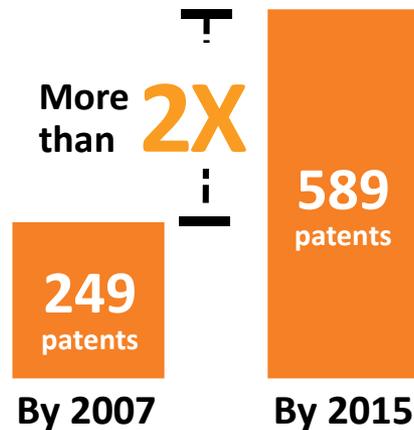
²Combines Manufacturing R&D, Technology Validation, Market Transformation.

Sustained, stable funding requests and appropriations



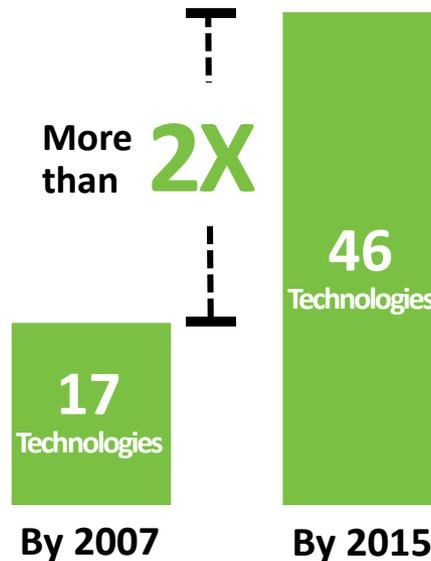
Innovation

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

More than **7X** the DOE Investment

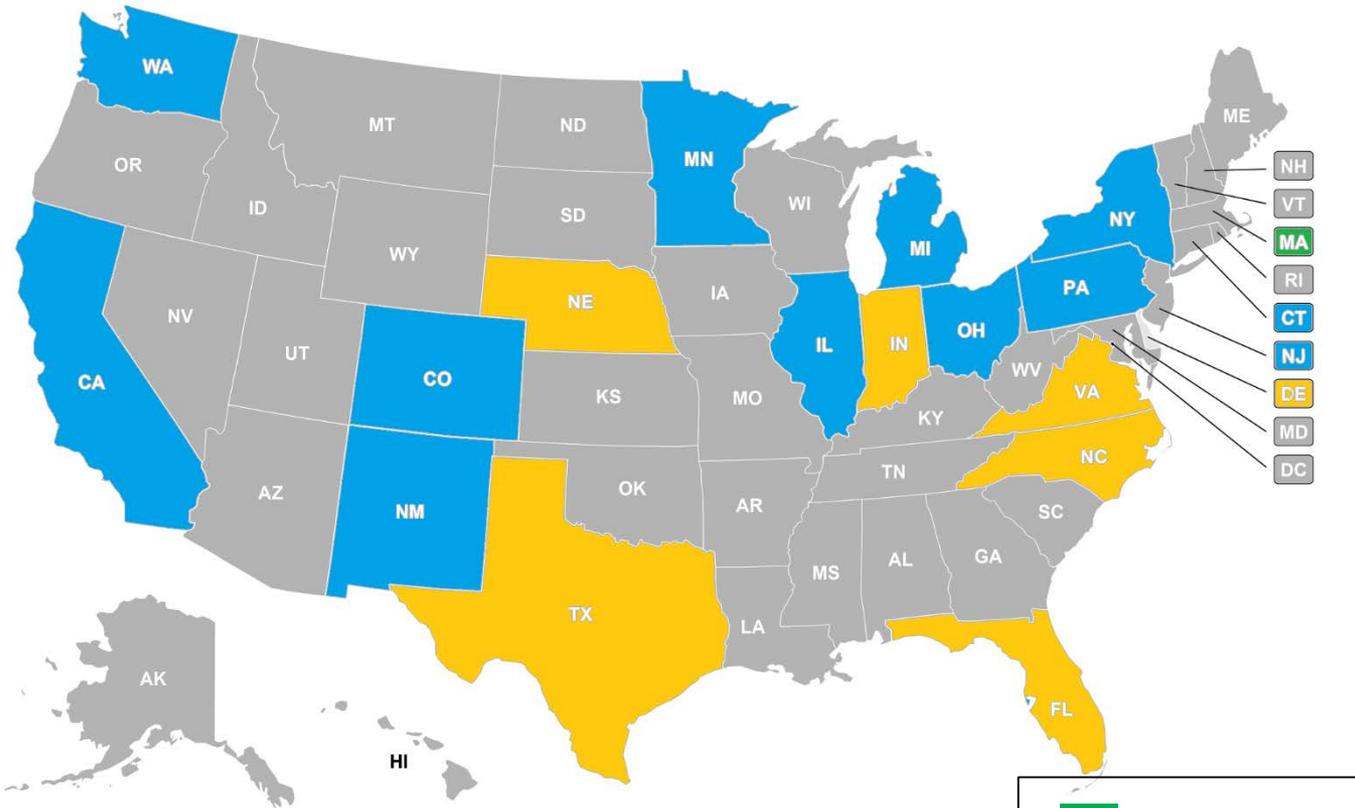
Additional Investment

More than **5X** the DOE Investment

*for selected companies

Commercial Technologies by State

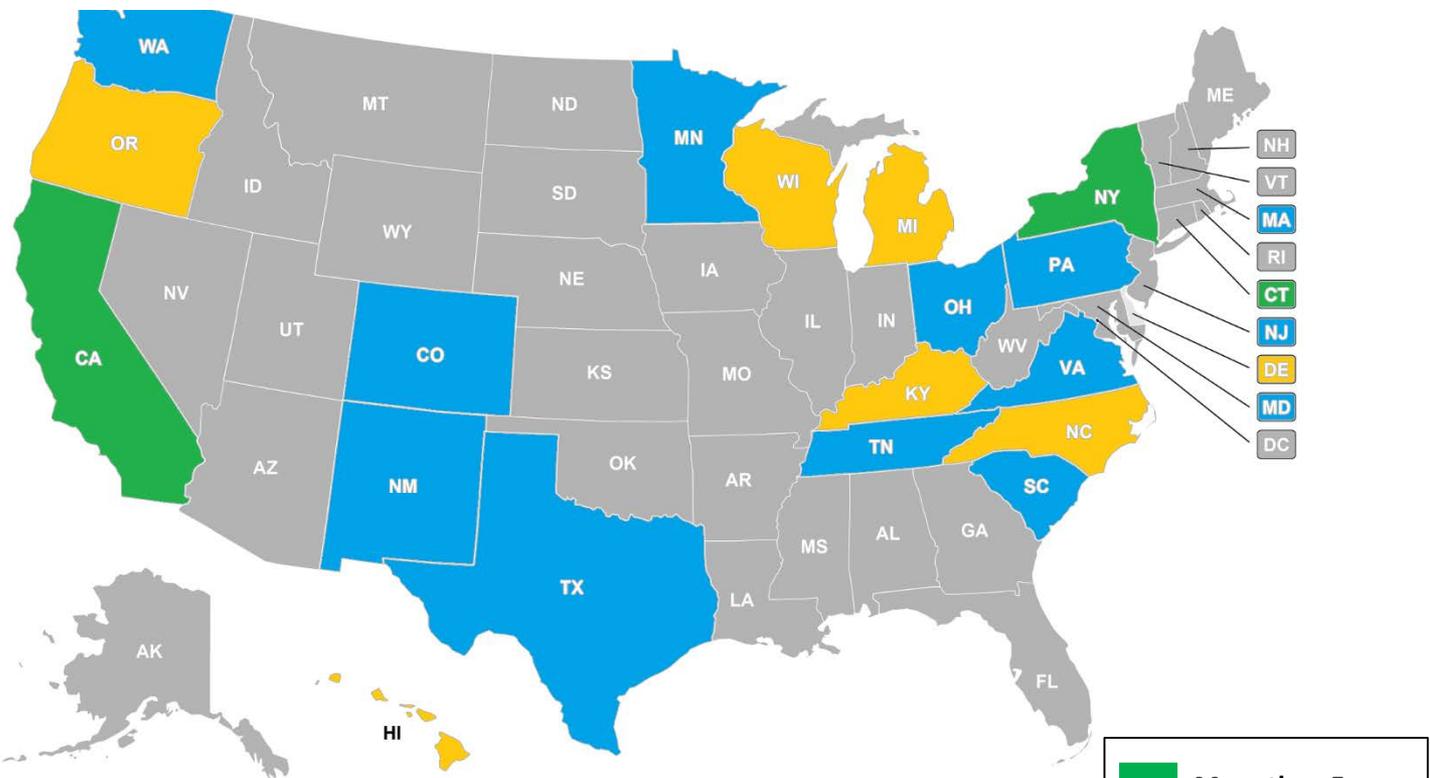
DOE-Enabled Commercial Technologies by State



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

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

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

- More than 5
- Between 2 and 5
- One

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.
Distributors

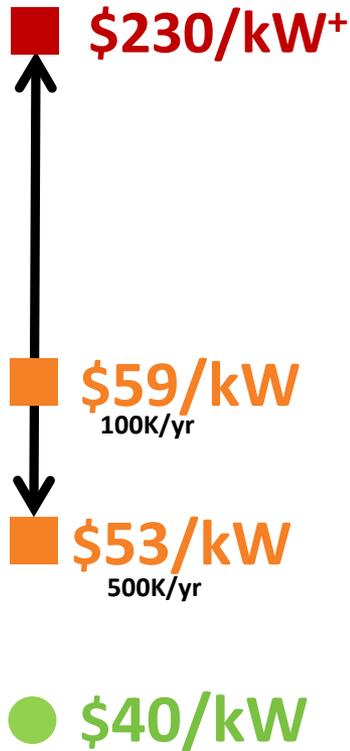
8-10 E. BIJOU STREET

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

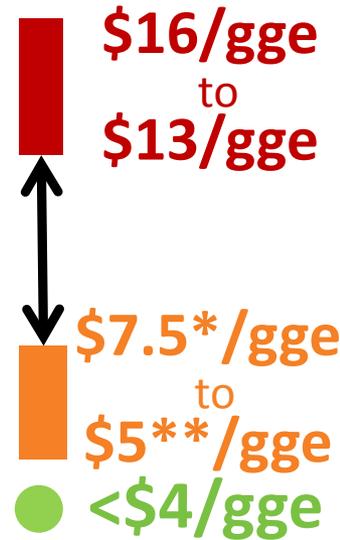


DOE Cost Targets and Status

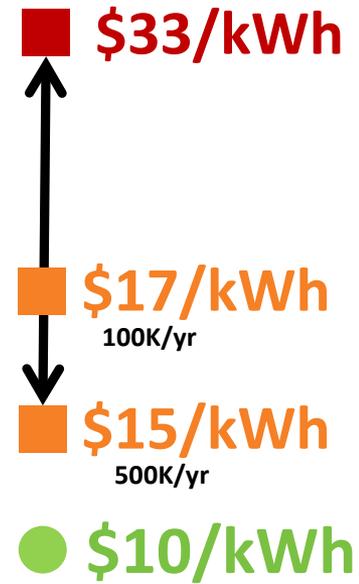
Fuel Cell System



H₂ Production, Delivery & Dispensing



Onboard H₂ Storage (700-bar compressed system)



● 2020 Targets

■ High-Volume Projection

■ Low-Volume Estimate

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 H₂ Infrastructure Roadmap Development

Purpose

Align RD&D across sub-programs to enable H₂ 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 H₂ Infrastructure Strategy

KEY CHALLENGES

1 Station Cost

2 Station Reliability

3 Station Rollout

DOE ACTIVITIES

- ✓ Components R&D
- ✓ Systems R&D

- ✓ Contaminant Detection
- ✓ Sensors Testing

- ✓ Safety Awareness
- ✓ Codes and Standards Harmonization
- ✓ Training & Education

EXAMPLES



- HySTEP
- Reference Station Design
- Contaminant Report

SHOWCASE STATION
(HyTEST)

TOOLS
(HyRAM- Hydrogen Risk
Assessment Models)

DOE efforts support public-private partnership:

H₂USA

Gasoline History: Many diverse options

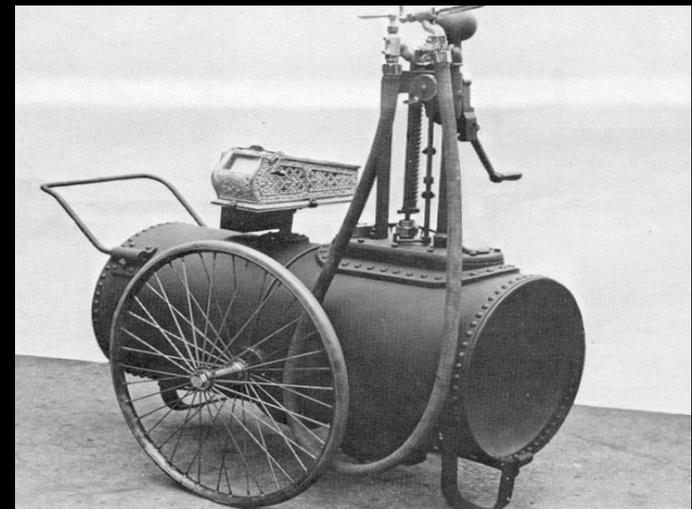
Cans, barrels, home models, mobile refuelers



Source: M. Melaina 2008.

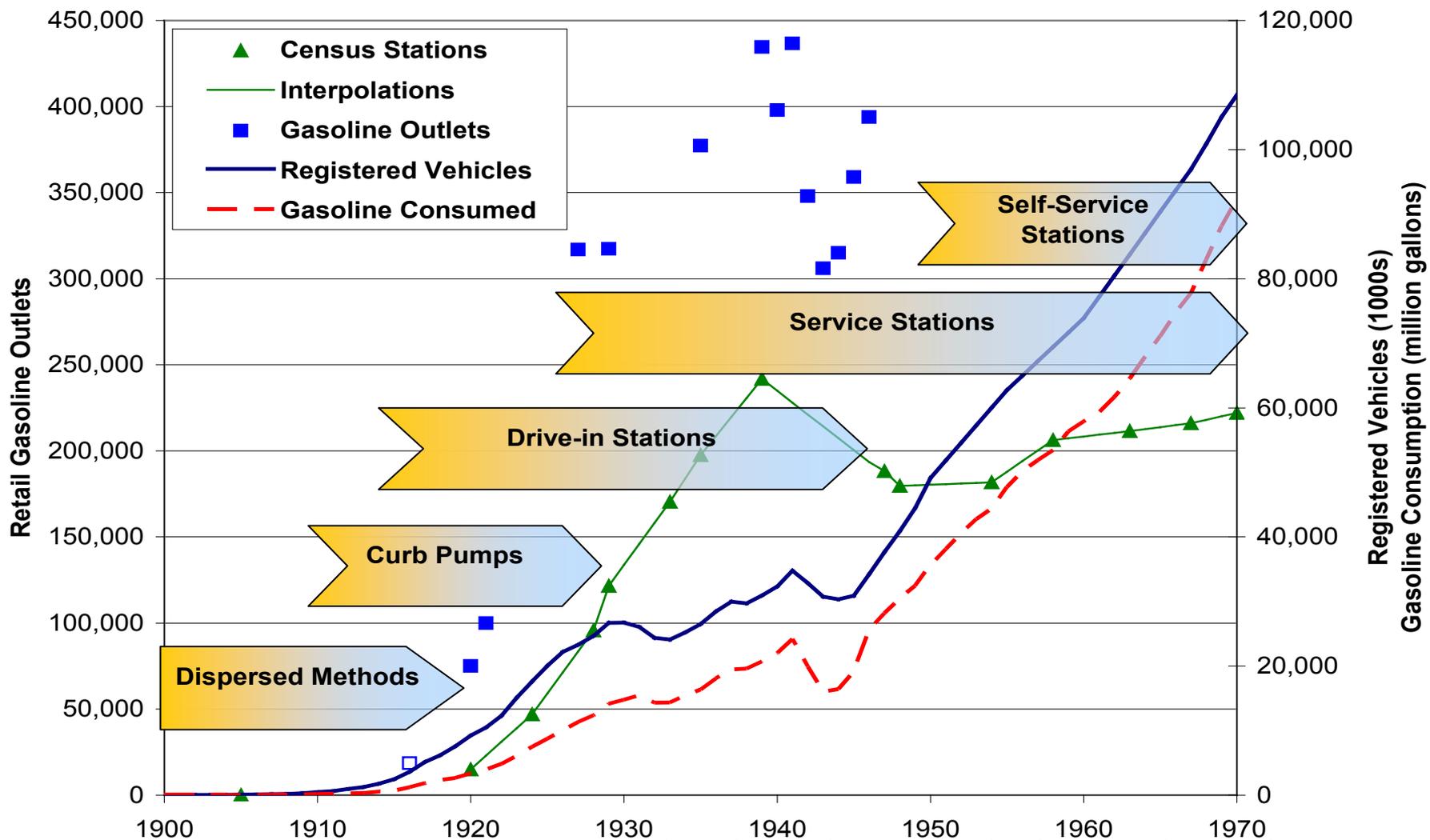


Source: Vieyra, 1979



Source: Milkues, 1978

Refueling Methods Evolved Over Time

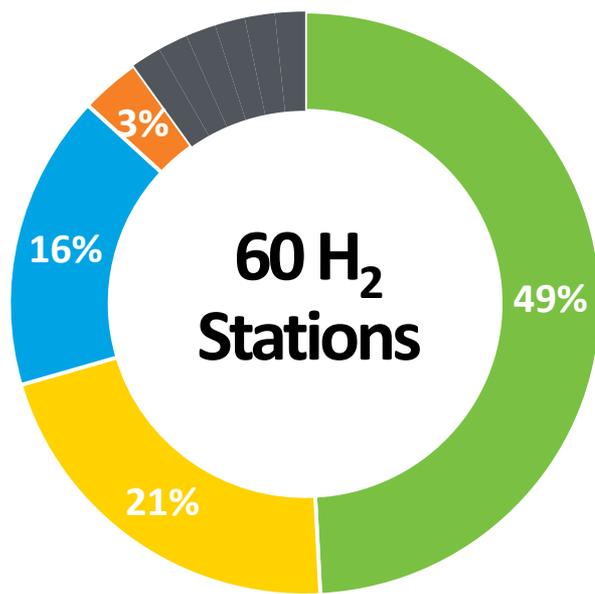


Source: Turn of the Century Refueling: A Review of Innovations in Early Gasoline Refueling Methods and Analogies for Hydrogen (Melaina 2007)

History shows phased introduction of different refueling methods

- **California** : 25 retail stations now, 100 planned
- **U.S. Northeast** : 12 to 25 stations planned
- Approx. **10M metric tons of H₂ produced** annually
- **1,600 miles of H₂ pipeline** already in place

A variety of H₂ 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





\$1M Competition: On-site H₂ 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



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

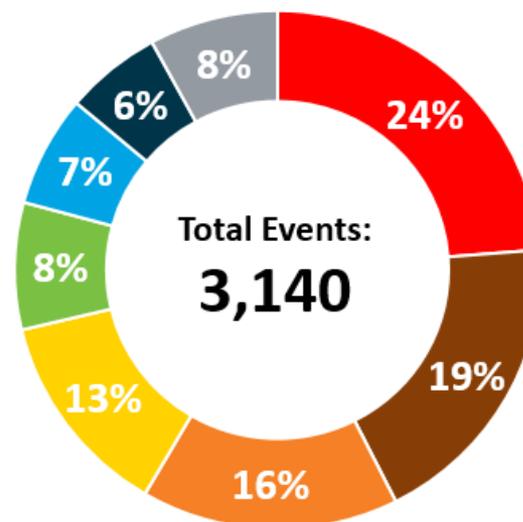
To Participate

techval@nrel.gov

Models “Toolbox” Online

- Financial, technical and economic models covering H₂ infrastructure, jobs, and more.
- Visit: energy.gov/eere/fuelcells/hydrogen-analysis-toolbox

Example: Sources of H₂ Infrastructure Maintenance



Compressor
Dispenser
Entire
Safety
Storage
Reformer
Thermal Management
Other Chiller, Feedwater

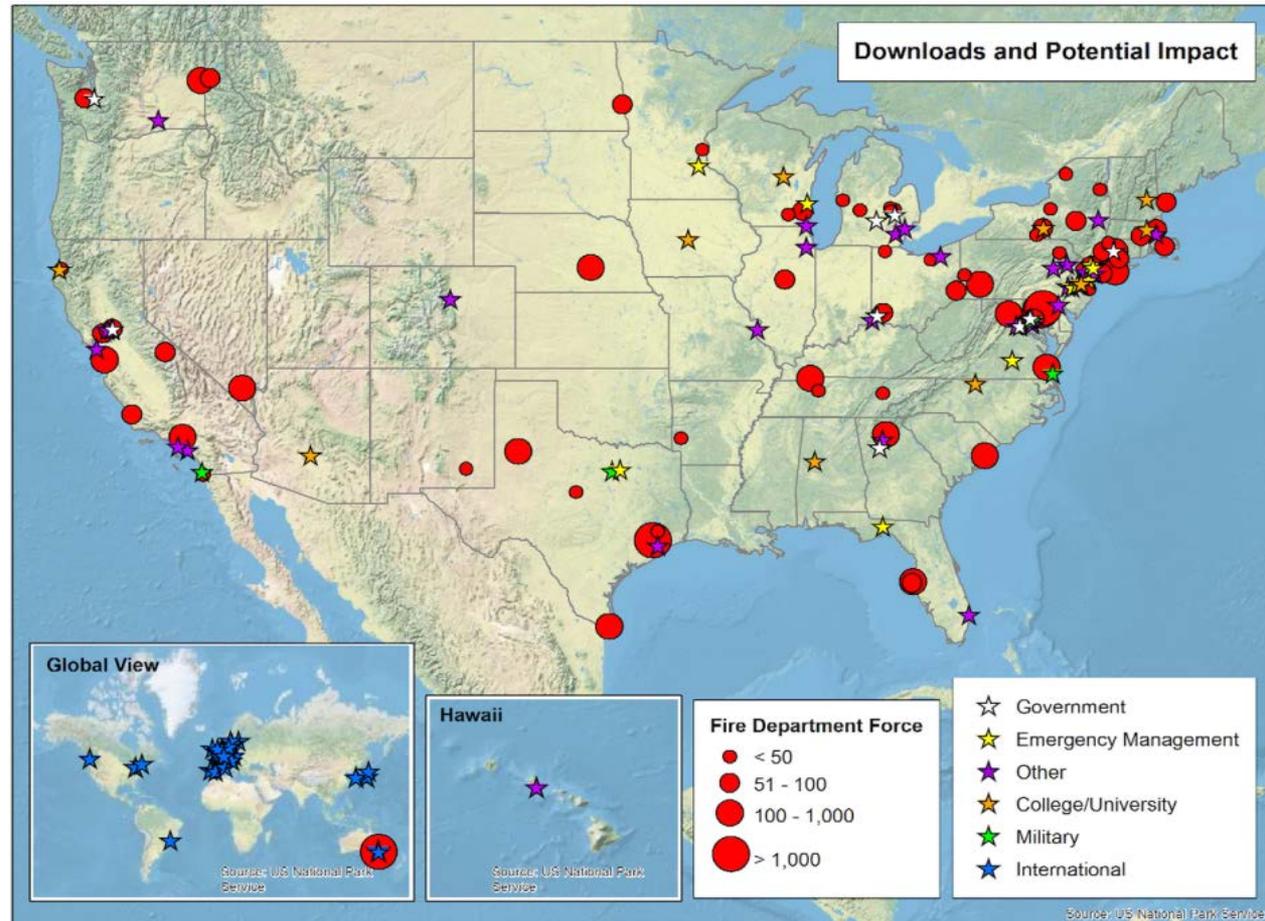
NREL logo_H2_21
 Created: April 19, 2018 11:18 | Data Range: 2017Q1-Q4

Most maintenance related to **compressors and **dispensers****



h2tools.org

- Includes resources on **safety** best practices, **first responder training**, and **H₂ 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 H₂ Opportunity Center



- 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**

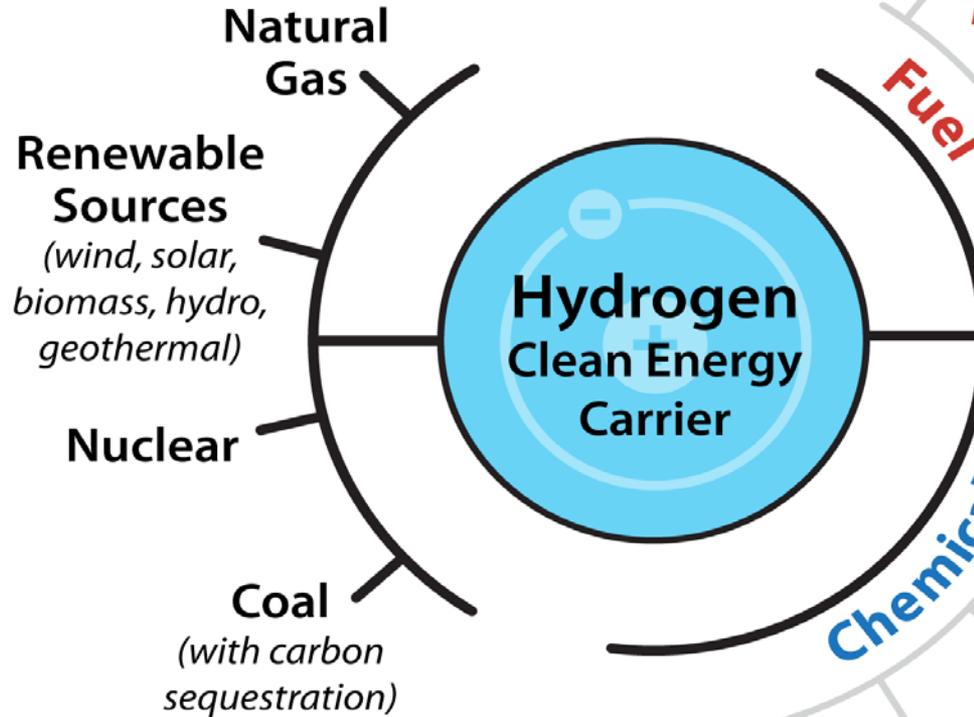


Objectives

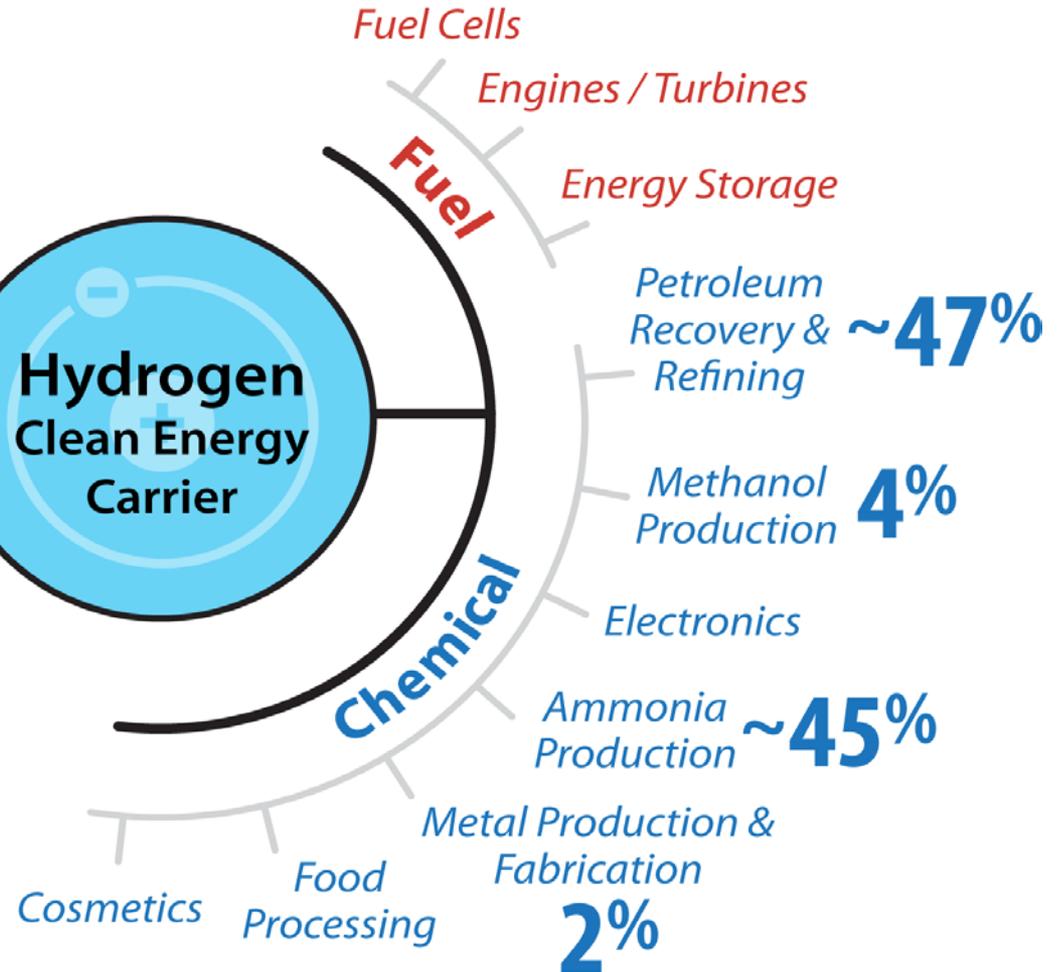
- Identify gaps, needs and opportunities
- Enhance interaction between supply chain stakeholders

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

Diverse Energy Sources



Diverse Applications

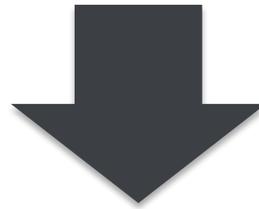


Services all energy sectors AND improves Energy Security and Domestic Economy

How much H₂ is needed?

How much hydrogen for 1 car?

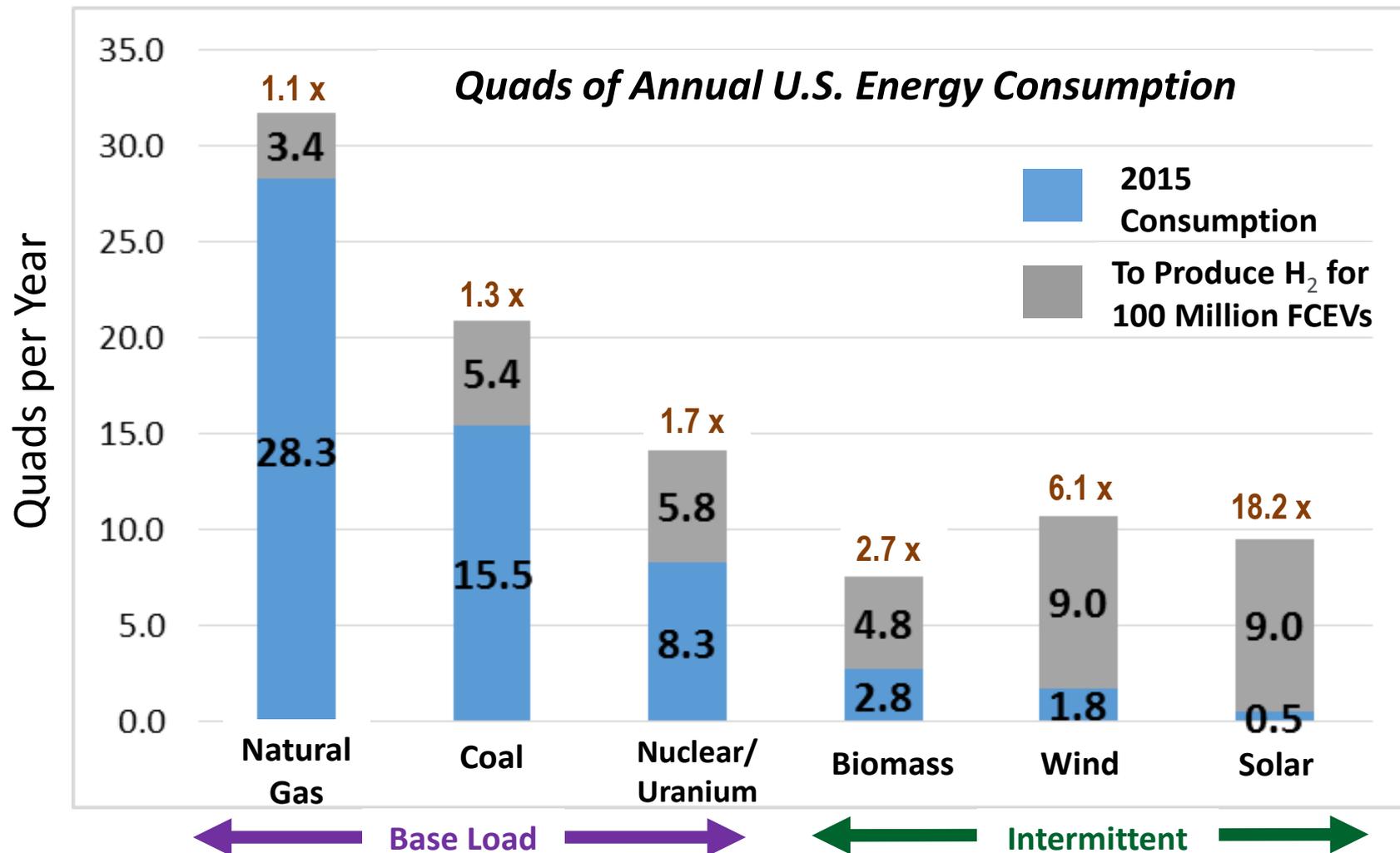
$$\frac{12,000 \text{ miles per year}}{60 \text{ miles per kilogram}} = 200 \text{ kg per year} \text{ or } 0.2 \text{ tonnes per year}$$



How much hydrogen for many cars?

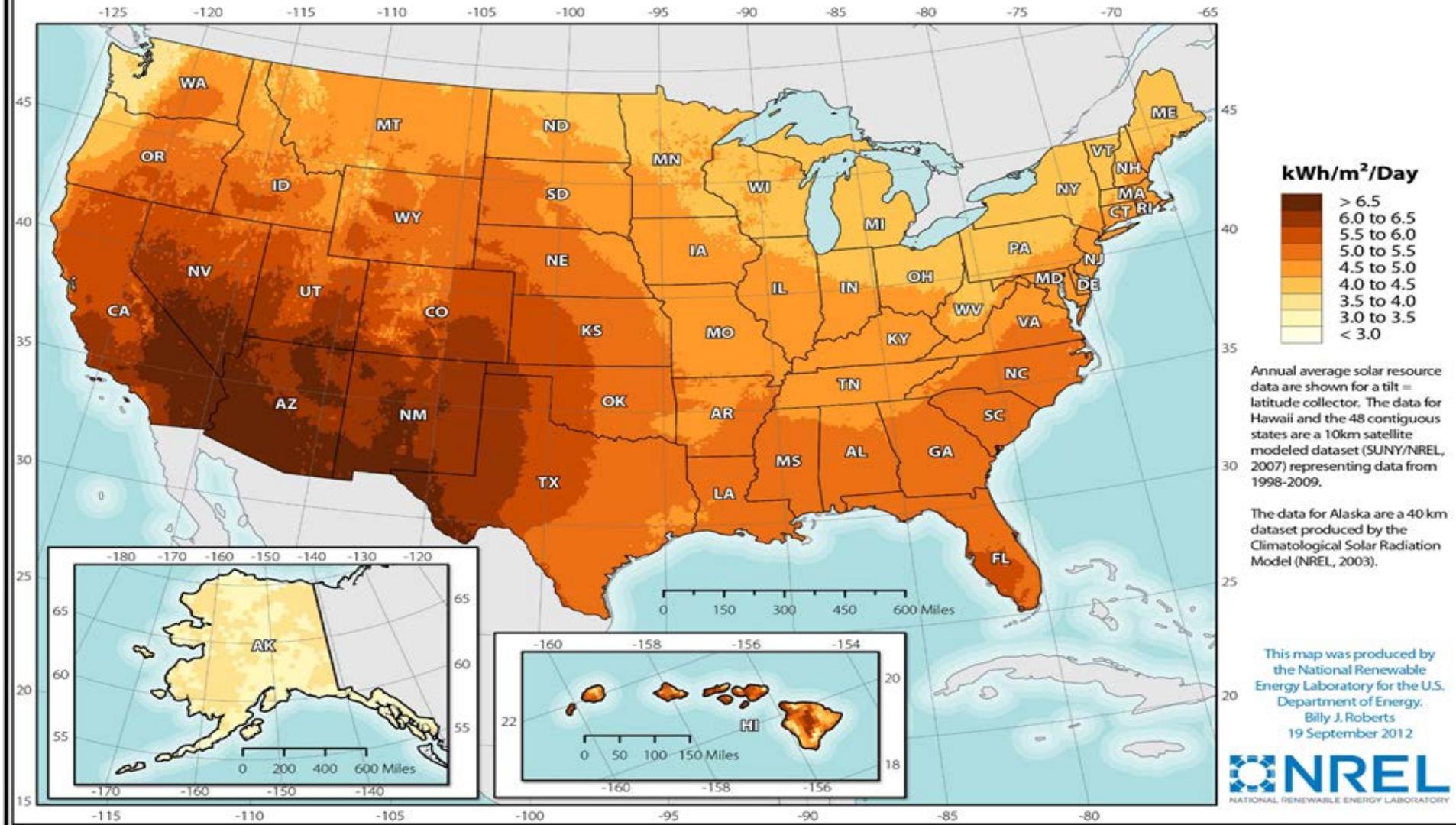
<p>1 M cars</p>  <p><small>1 car icon = 100,000 cars</small></p>	<p>0.2 M tonnes H₂ per year</p> <p>200 M kg H₂ per year</p>	<p>100 M cars</p>  <p><small>1 car icon = 10M cars</small></p>	<p>20M tons H₂ per year</p> <p>20 B kg H₂ per year</p>
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How to get hydrogen for 100M FCEVs?



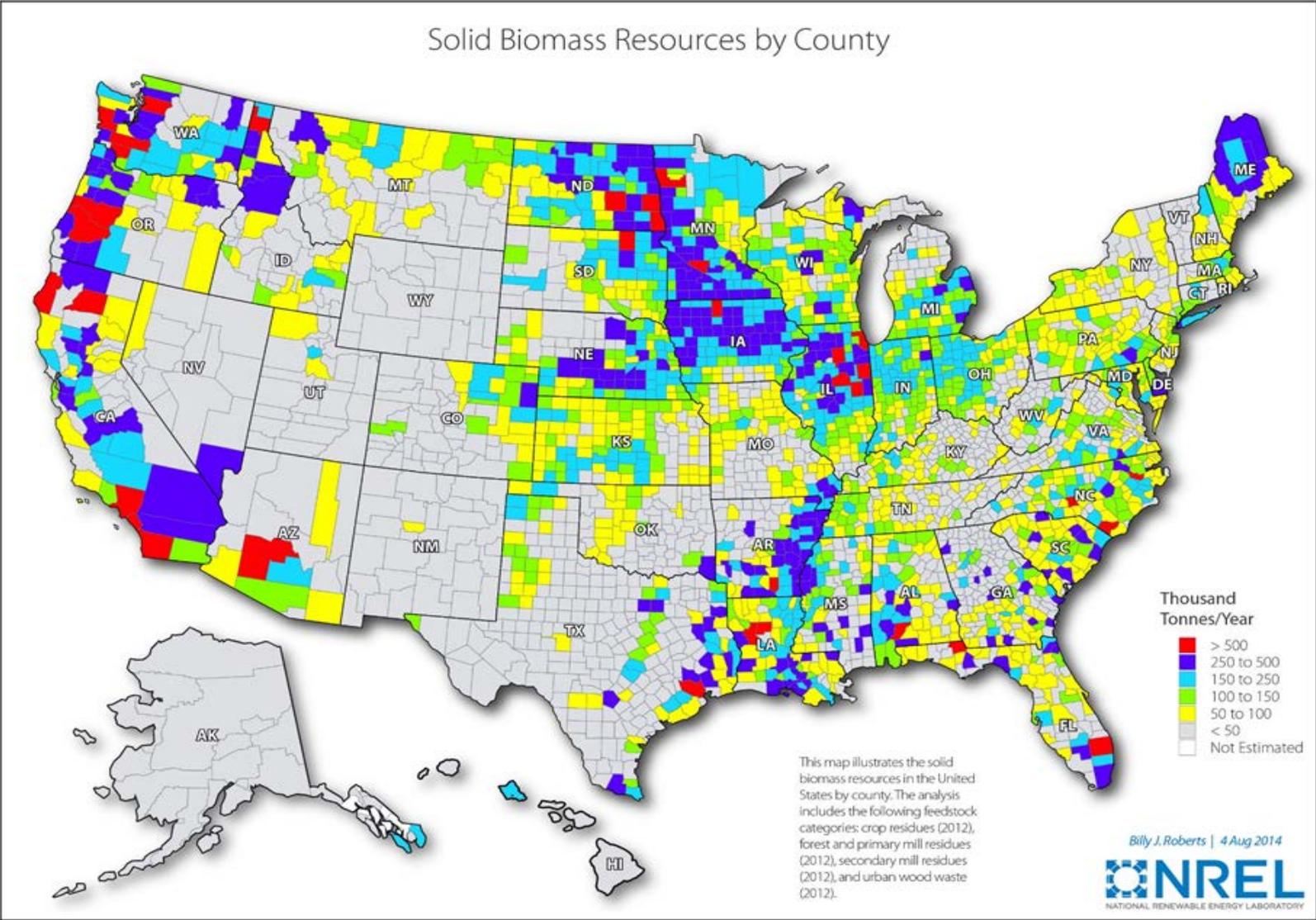
Solar Sources: Opportunity for Renewable H₂

Photovoltaic Solar Resource of the United States



Resource analysis underway

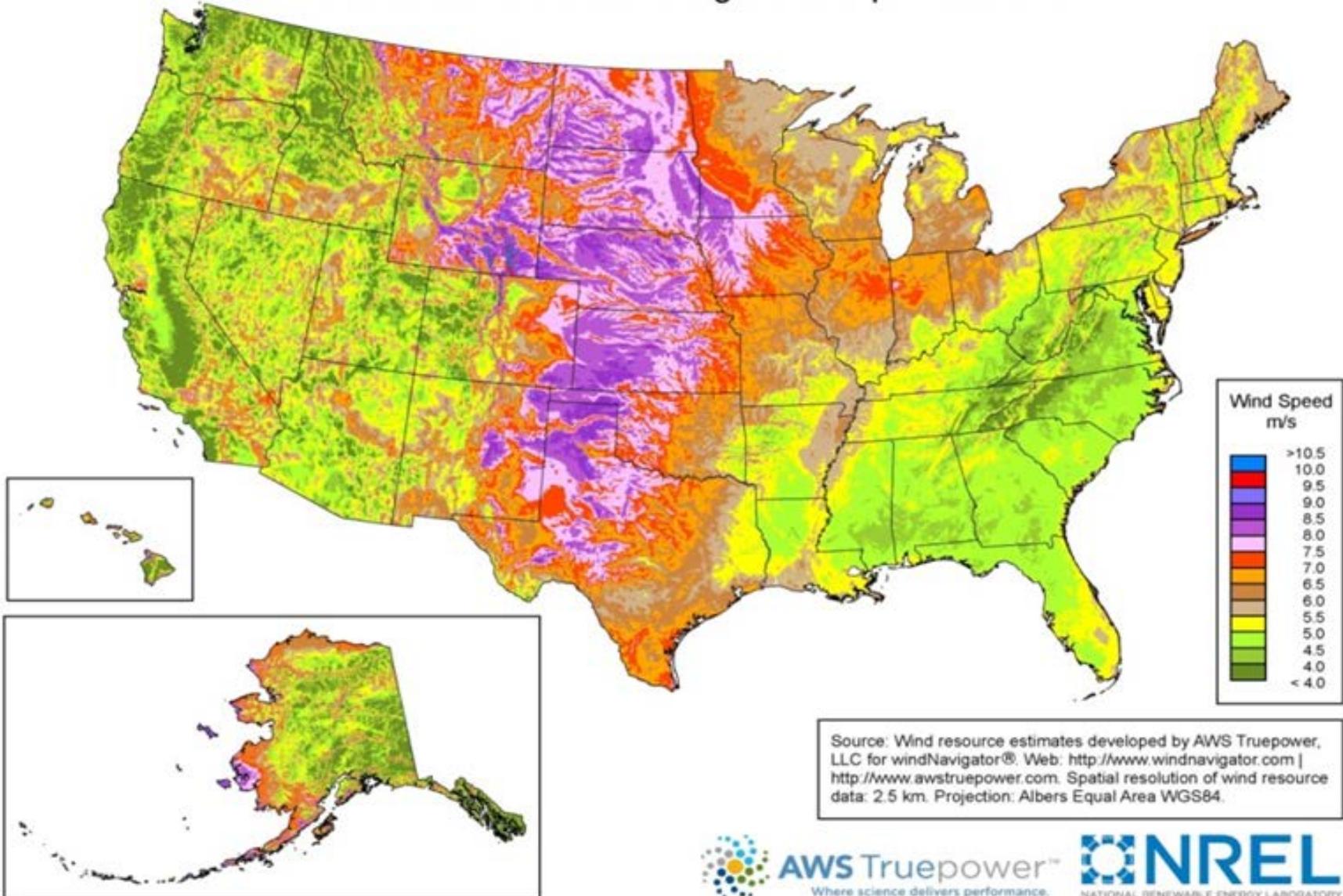
Biomass Resources: Opportunity for Renewable H₂



Bio-feedstock reforming is a near term option

Wind Resources: Opportunity for Renewable H₂

United States - Annual Average Wind Speed at 80 m



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

1



Hydrogen

1.008



**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

- **Continue to strengthen R&D activities**
 - H₂, 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

Dr. Sunita Satyapal

Director

Fuel Cell Technologies Office

Sunita.Satyapal@ee.doe.gov

hydrogenandfuelcells.energy.gov

Additional Information

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.

BARRIERS

NEAR TO MID-TERM

LONG-TERM

R&D

- Fuel Cell Cost and Durability
- Hydrogen Storage
- Hydrogen Production and Delivery



Low PGM catalysts, MEAs, durability, components	PGM-free catalysts, advanced membranes, AEMs, MEAs
700 bar tanks, composites	Materials R&D for low P storage, cold/cryo-compressed
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
- Manufacturing and Supply Chain
- Safety, Codes and Standards (SCS)
- Public Acceptance and Awareness



Enablers: H2FIRST-station validation, metering, sensors, etc.	Materials compatibility, station innovation, cost reduction- H-Prize
Catalyst, MEA and tank manufacturing; QC; cost & reliability; supply chain	Mfg. processes and scale up; strong supply base- H ₂ and fuel cells
Set back distances, fueling protocols; safety dissemination	Risk mitigation; National and International harmonization of SCS
H ₂ Tools, code officials, responders; early markets; H ₂ USA	Widespread Outreach, Education & Social Acceptance

Level of Difficulty

- High
- Medium
- Low to Medium

\$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 H₂ storage (Topic 3)
- **Develop precursors for low cost, high strength carbon fiber** for high pressure H₂ storage vessels (Topic 4)



Deadlines

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

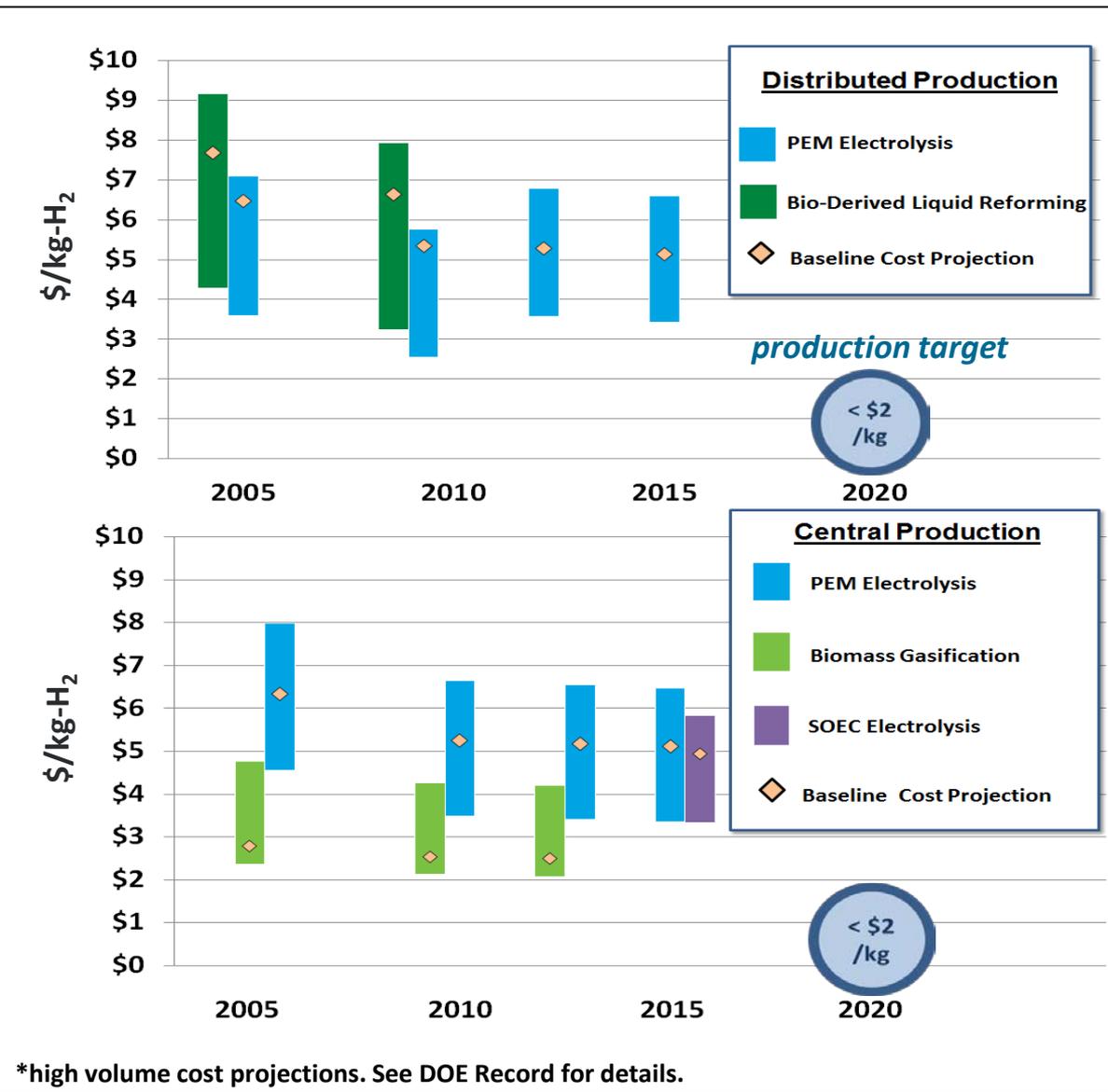
More Information

Visit EERE Exchange website at
eere-exchange.energy.gov

[DE-FOA-0001647](https://www.fda.gov/oc/foia/2017-0001647)

Highlights: Renewable H₂ Production

Cost* Renewable H₂ Production Pathways



World Record

Solar-to-hydrogen Efficiency

16.4%

Benchmarked under outdoor sunlight at NREL

Source: NREL

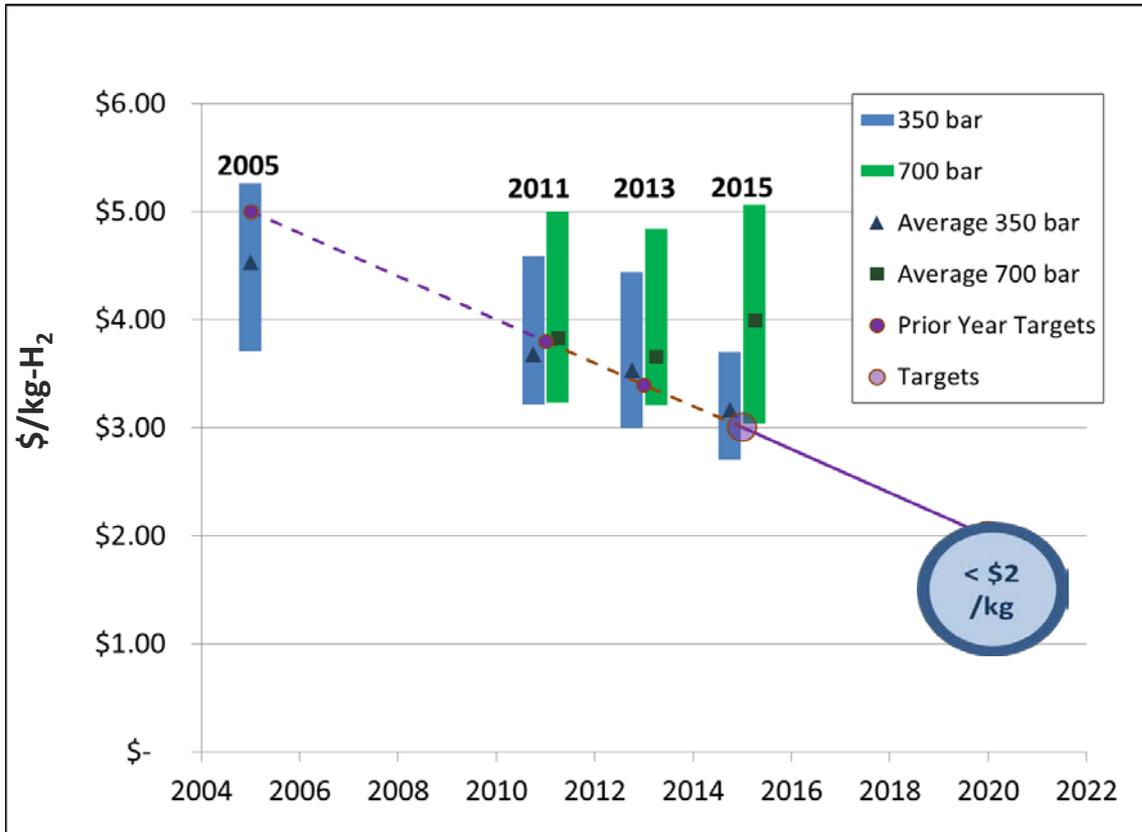
H₂ Cost* Targets

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

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

*at the pump

Cost of Delivering and Dispensing H₂ from Central Production



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

World Record

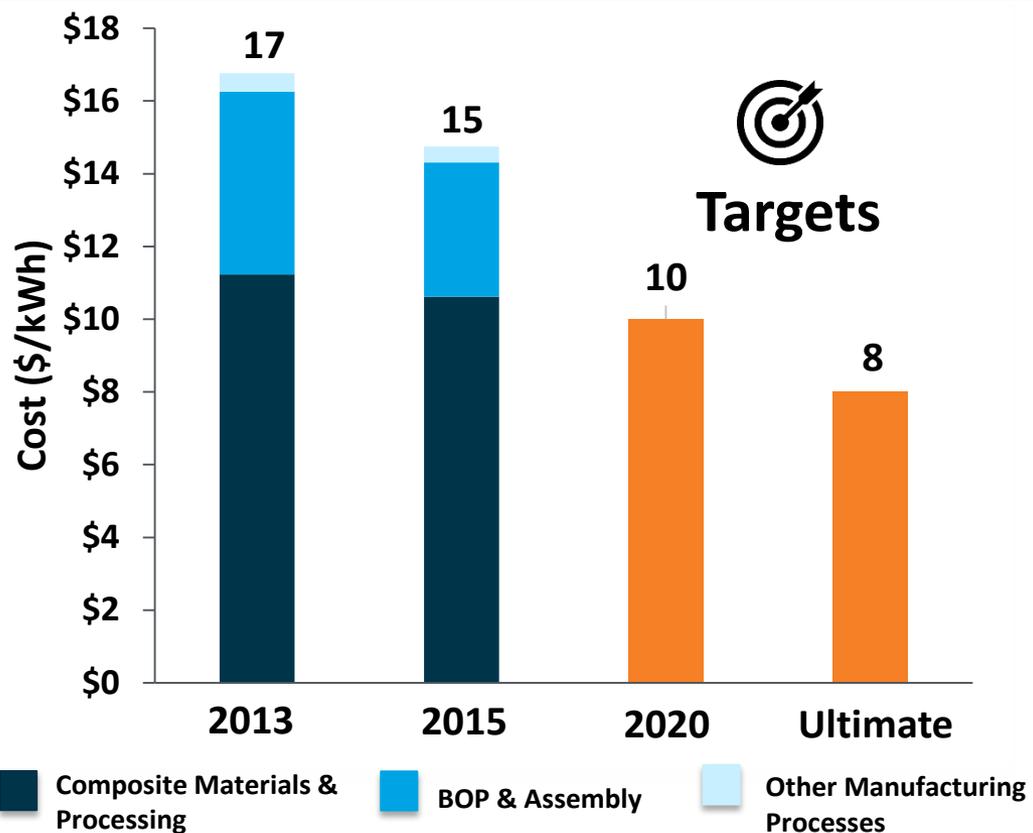
- **First ever liquefaction of a gas from room temperature with magnetocaloric cooling**
- **Record breaking 100°C temperature span**



Source: PNNL, Emerald Energy, Ames Laboratory

Highlights: H₂ Storage

Cost* of High Pressure H₂ Storage System



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

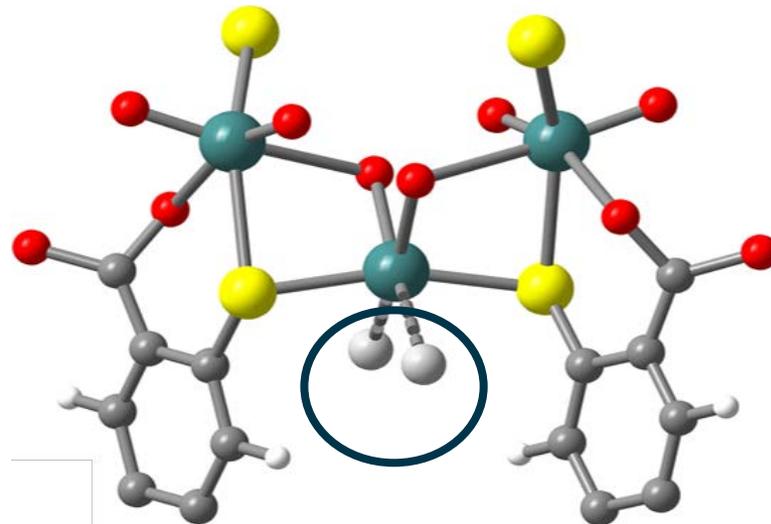
12%

Net Cost Reduction

since 2013 for H₂ storage systems

World's First

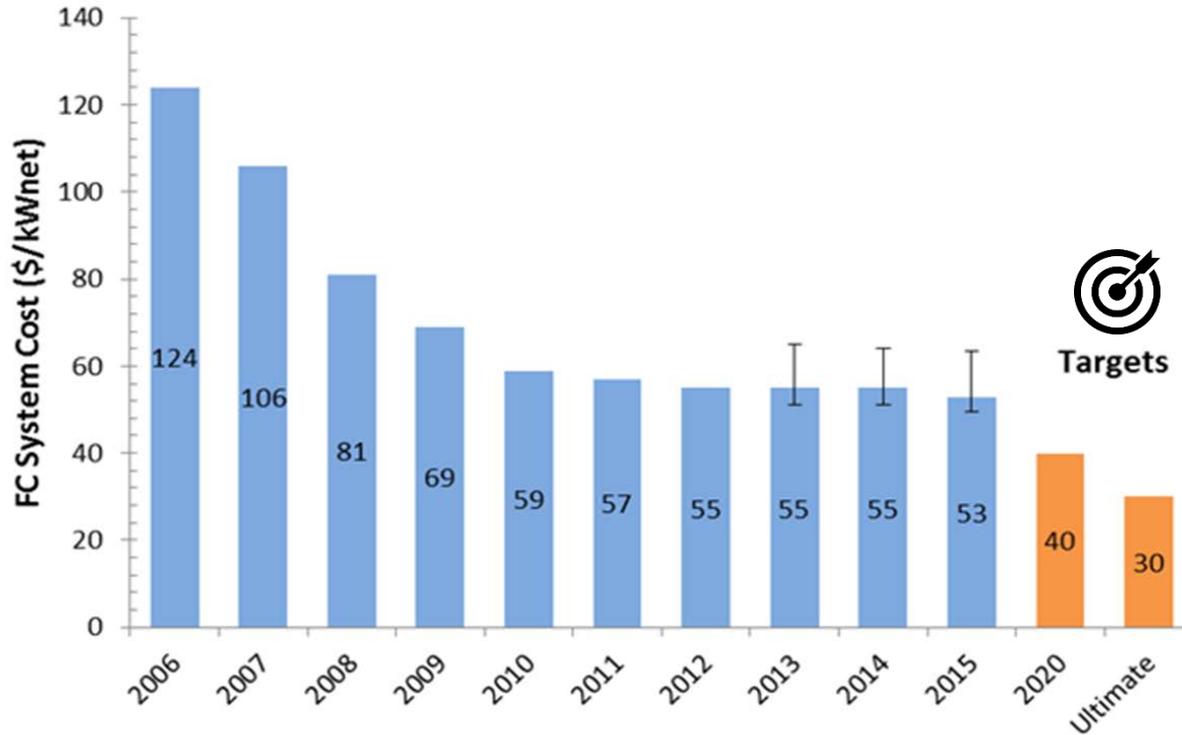
- Two H₂ molecules adsorbed at a single metal site
- Synthetic path to materials with higher densities of adsorbed H₂



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

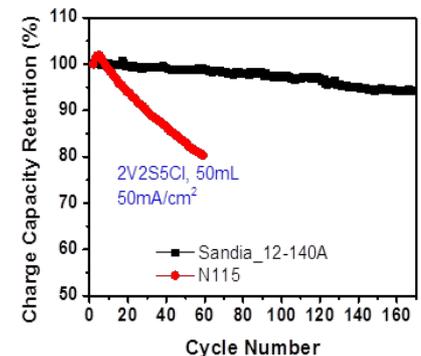
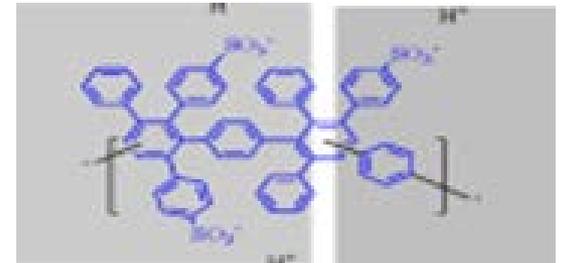
Modeled Cost* of Fuel Cell System Over Time



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

World Record

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



Source: SNL

 **8,000 Hrs.**

**Ultimate Durability
 Target Established**

Resources

“Toolbox” online:



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

Available now at:

<http://energy.gov/eere/fuelcells/hydrogen-analysis-toolbox>



H2Tools.org

HYDROGEN FUEL CELL NEXUS
Hydrogen and Fuel Cell Supply Chain Database

COMPANY TYPES | PRODUCTS | MATCHMAKER | EDUCATION | RESOURCES

Fuel Cell | **Vehicle**

Catalyst
Compressor/Expander
Electrodes
Electrolyzer
Gauges
High Pressure Plumbing
Hydrogen Pump/Ejector
MEAs
Power Electronics
Reactant Management
Sensors
Testing

membrane electrode assembly (MEA)

Dispensing | Storage | Compression | Generation

vessels & vessel liners | compressor expander | battery

power electronics

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



Supporting veterans and their families in 3 areas:



Wellness



Employment



Education

**Strong Commitment by the
H₂ 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.**

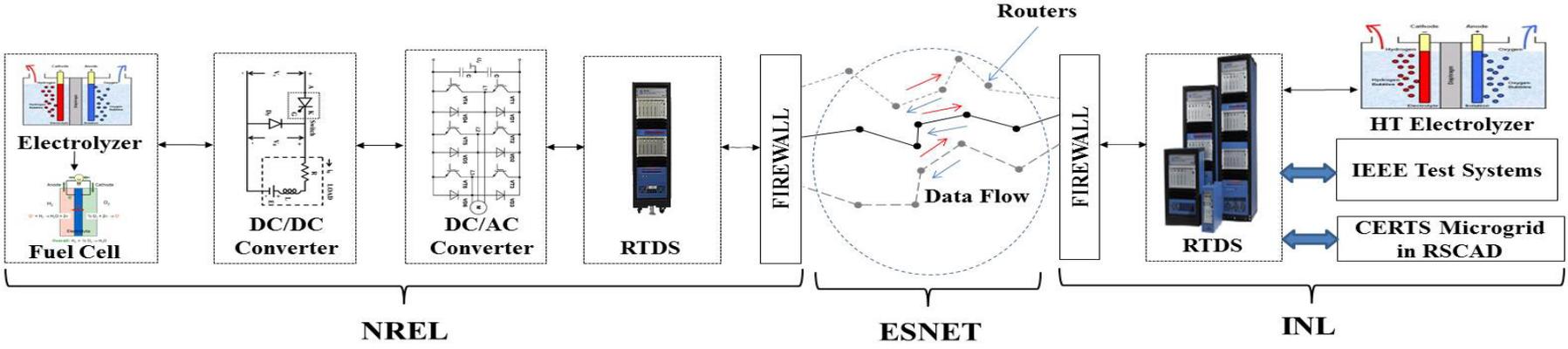
Techno-economic analysis will forecast the resource requirements and impact of H2@Scale

Demonstration of Electrolyzer Grid Integration

NREL



INL



FCTO is validating electrolyzer potential in energy storage.

1. Innovative H₂ production technologies

- Electrolyzer cost reduction
- Alternative feedstocks (e.g. solid and liquid waste, process gases)
- Integrate H₂ production with waste heat (e.g. from nuclear or steelmaking)

2. Integrated H₂ systems (e.g., reversible fuel cells,)

3. Innovative H₂ storage and delivery technologies

- Liquid organic carriers, metal organic frameworks; bulk storage

4. Use of H₂ 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 H₂ 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



Internal Combustion Engine



Hybrid Electric



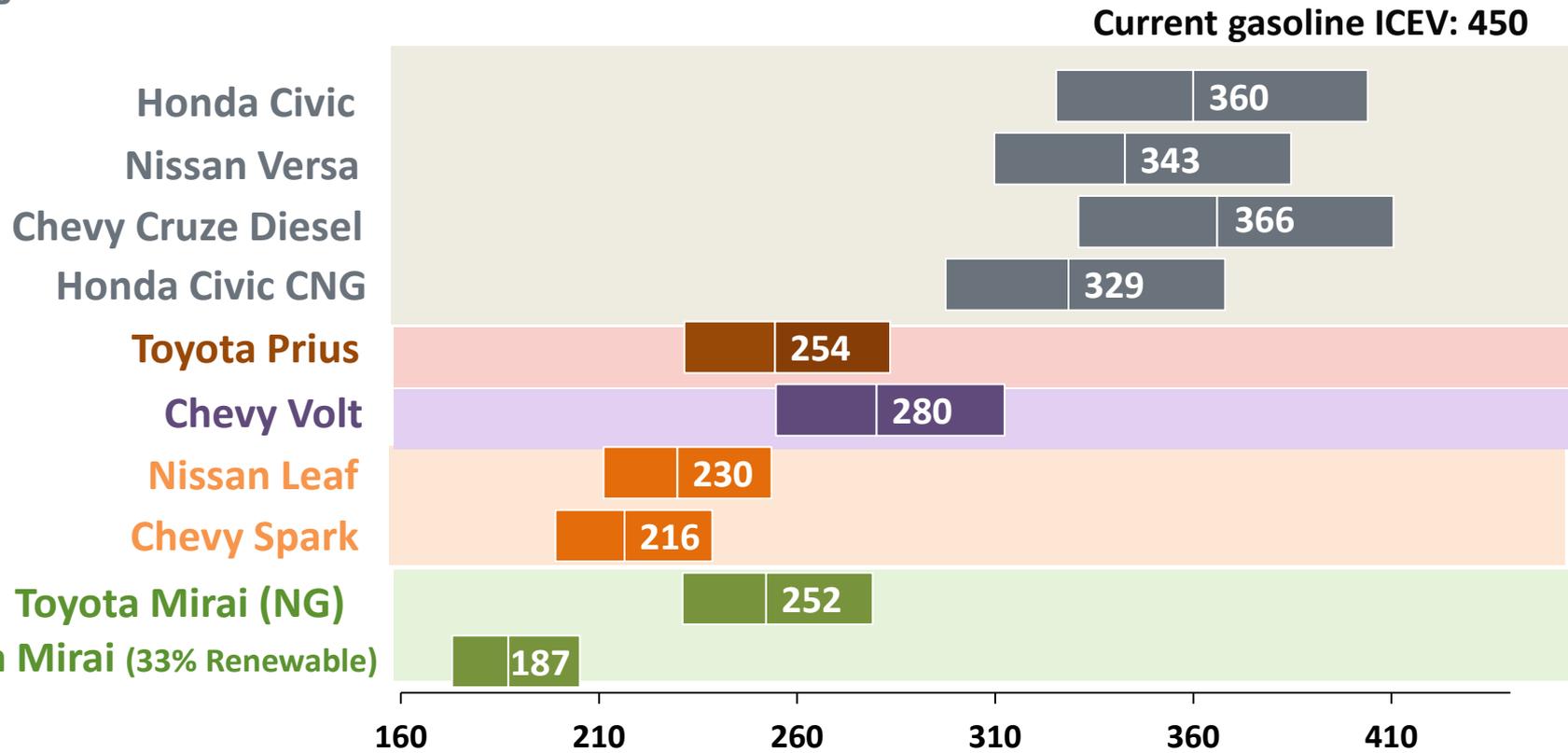
Extended-Range Electric



Battery Electric



Fuel Cell Electric



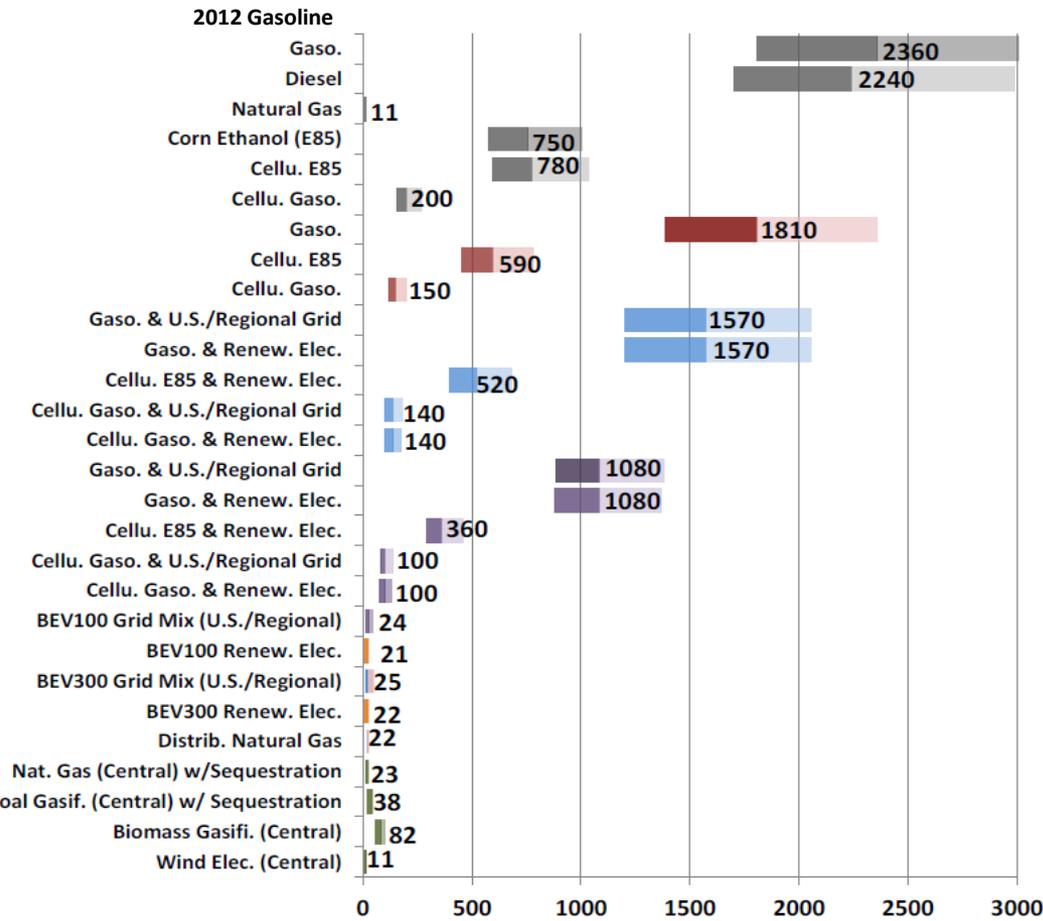
Source: Program Record 16004
 (https://www.hydrogen.energy.gov/pdfs/16004_life-cycle_ghg_oil_use_cars.pdf)

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

Well to Wheels Emissions and Petroleum Use*

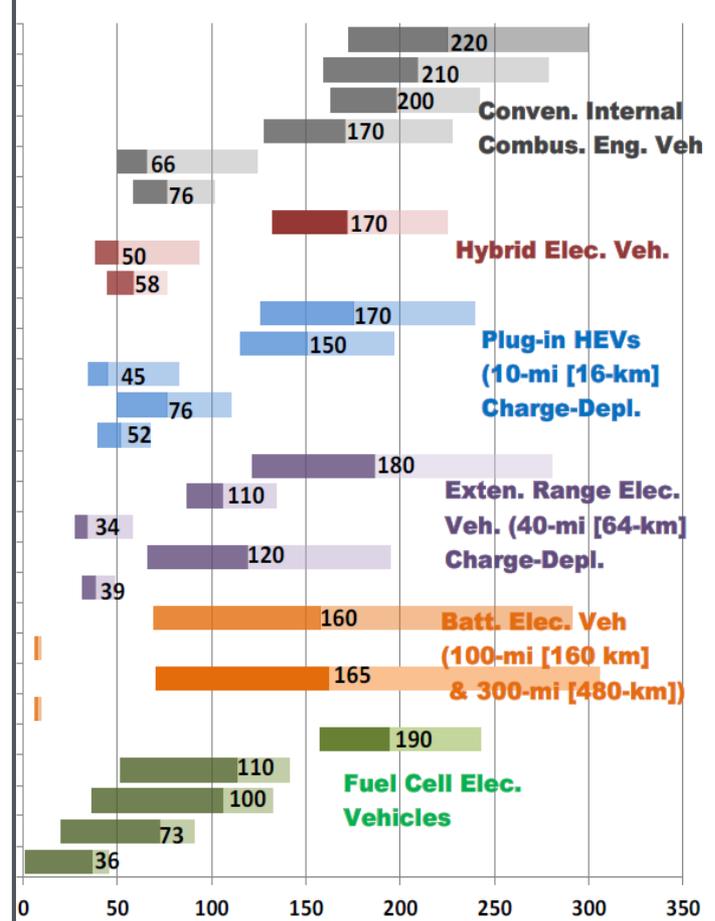
Petroleum Use, BTUs/Mile

4510



GHG Emissions, gCO₂/Mile

430



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



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



- Implementing Agreements
- 25 countries



- State Partnerships and Collaborations



- International Government Coordination
- 18 countries and European Commission



- 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