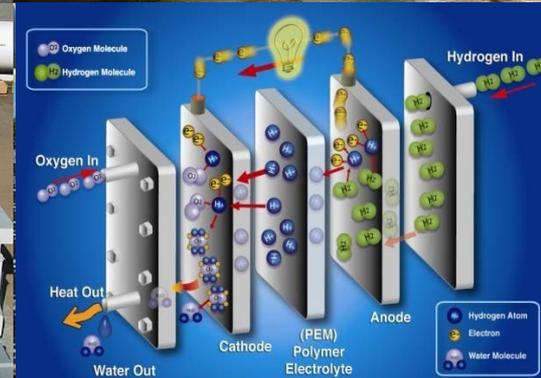


U.S. Department of Energy Fuel Cell Technologies Office

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



Hydrogen and Fuel Cell Technical Advisory Committee

Washington, D.C

October 27, 2015

Dr. Sunita Satyapal

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

- **HTAC Scope**
 - Energy Policy Act (EPACT) 2005 Title VIII
 - Key Recommendations and Program Responses
- **Program Updates**
 - Key Accomplishments
 - Recent Priorities (Lab Impact Initiative, Lab Consortia, etc.)
 - Collaborative Efforts
- **Next Steps**

Energy Policy Act of 2005 (Title VIII)

Program goals, include:

“To enable a commitment by automakers *no later than year 2015* to offer safe, affordable, and technically viable hydrogen fuel cell vehicles in the mass consumer market”

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 foreign oil & emissions** and enhance energy security
5. Create, strengthen, and protect a **sustainable national energy economy.**

FCTO Overview

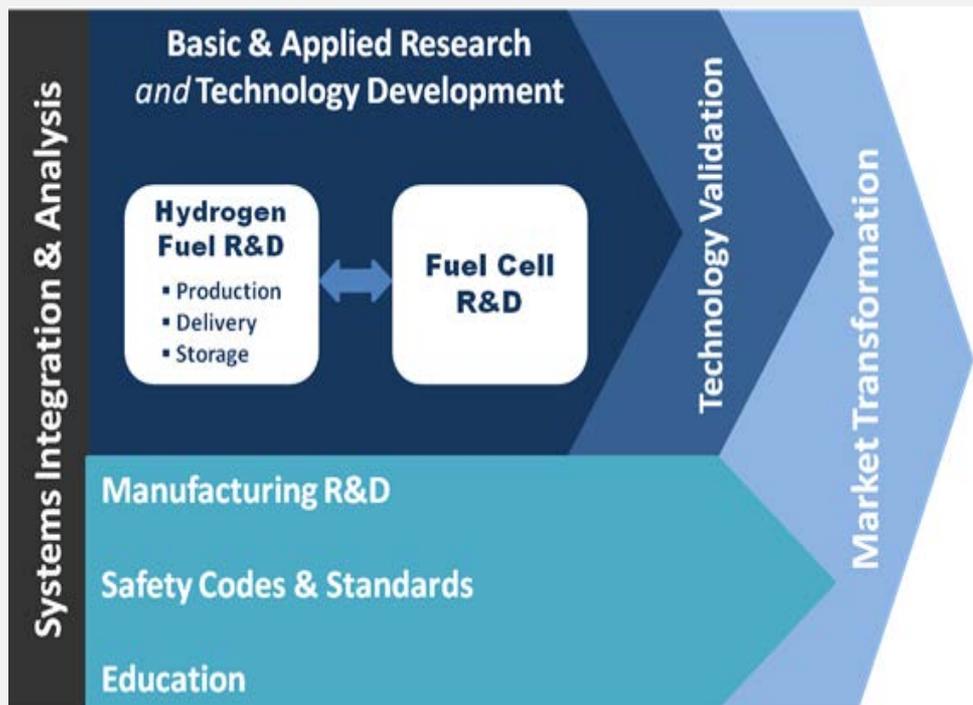
Mission

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.

Impact

2-4 million barrels per day petroleum reduction by 2050
200- 450 million metric tons/year GHG emissions reduction by 2050

Strategy and Approach



2020 Targets



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	
H ₂ Cost at Pump	<\$4/gge	

*For Natural Gas
 **For Biogas

DOE Activities Span from R&D to Deployment

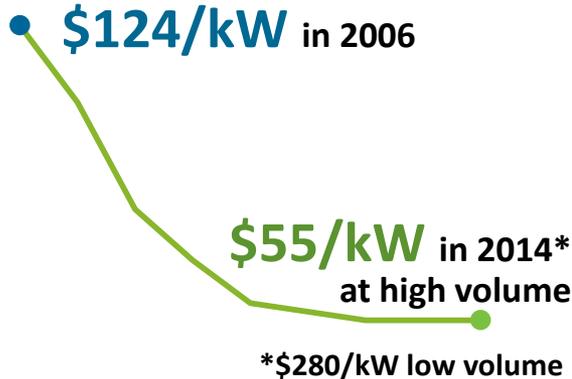


1.

Research & Development

Cost Reductions

- **50%** for fuel cell systems
- **5x less** platinum
- **> 2x** increase in durability
- **80%** for electrolyzers



2.

Demonstration

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

>215 FCEVs, **30** stations,
5.7M miles traveled

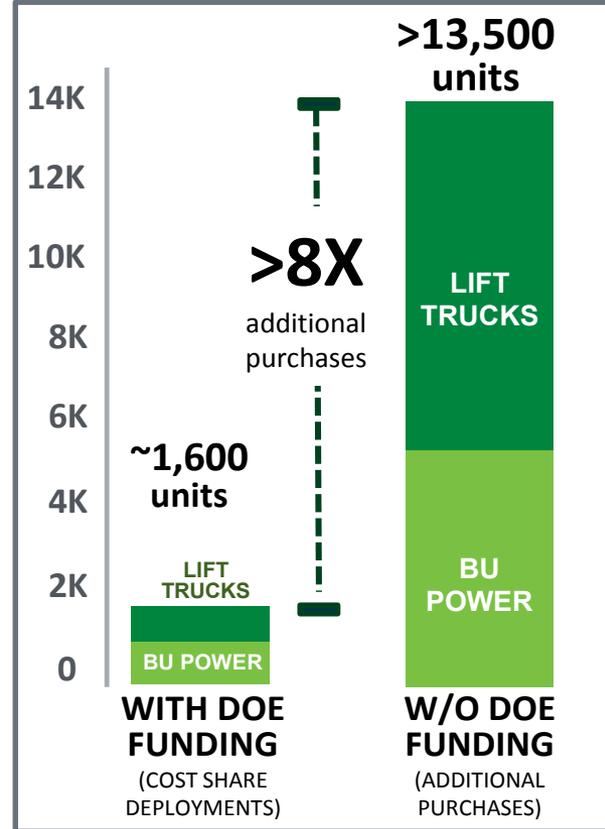
World's first tri-gen station



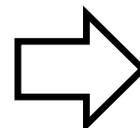
3.



Deployment



Savings from Active Project Management



More than \$35M last 5 yrs



More than \$3M last year

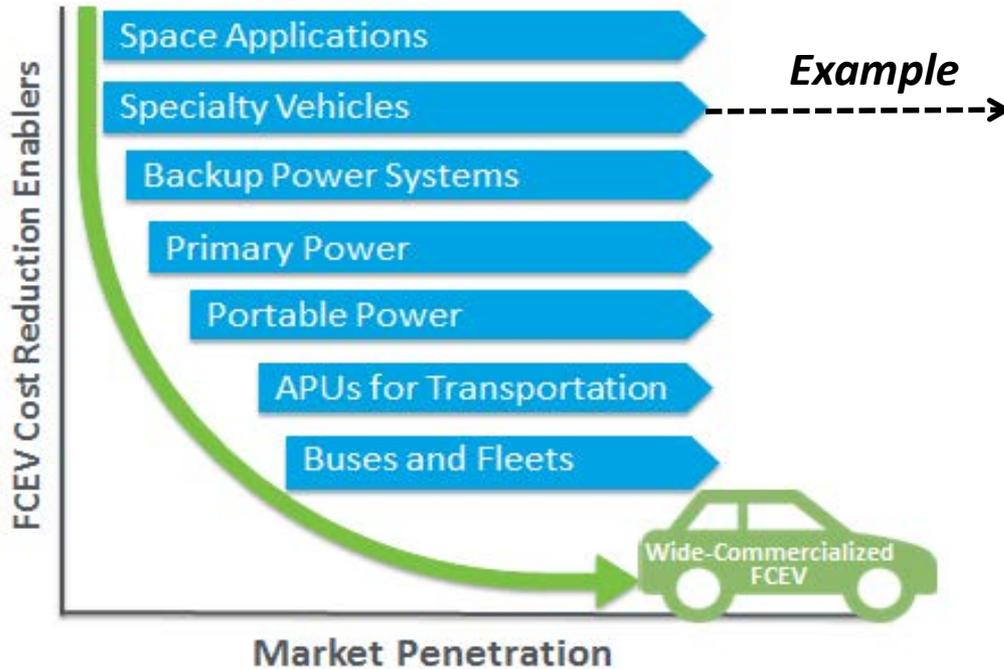
*Bar graphs not drawn to scale

Early Market Strategy

Early Markets enable:

- Fuel cell cost reduction
- Robust supply base
- Emerging Infrastructure
- Customer acceptance

Early Market
 Application
 Examples



World's First Fuel Cell Cargo Trucks at Memphis International Airport



facebook

Post Stats:

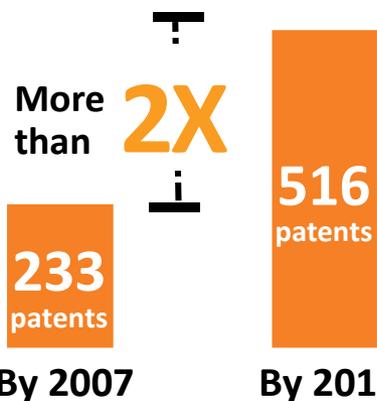
More **180 shares**
 than **240 likes**

➔ **Over 45,000**
 people reached



Innovation

Cumulative Number of Patents



Commercialization

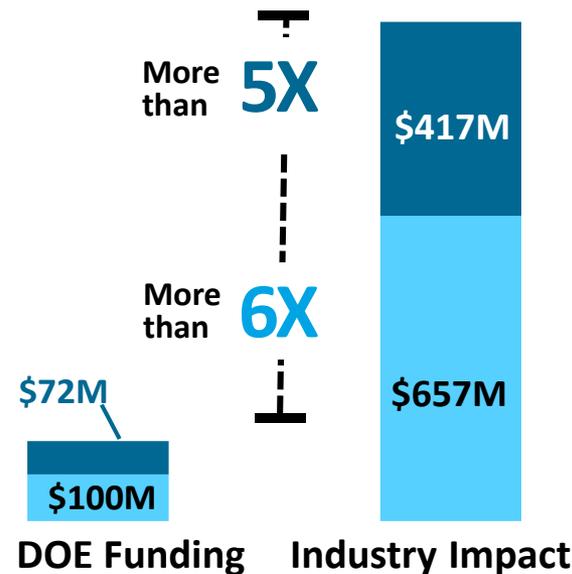
Commercial Technologies Entering the Market



Return on Investment

DOE impact on Private Investment and Industry Revenues

Preliminary Analysis



Jobs from commercial technologies and ARRA

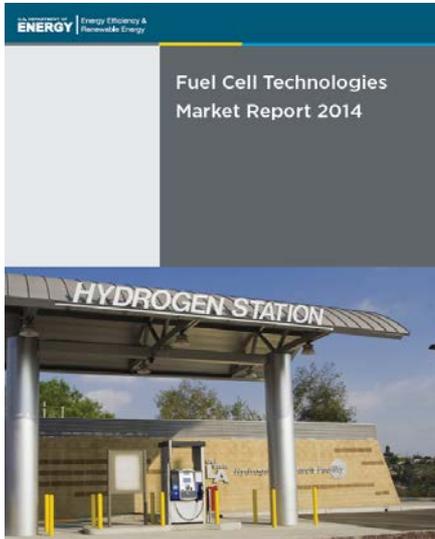


Commercial Technologies- Examples

- Catalysts
- Electrolyzers
- Tanks
- Fuel Cell System Components

Fuel Cells- Steady Market Growth

Market Report Just Published!



In 2014...

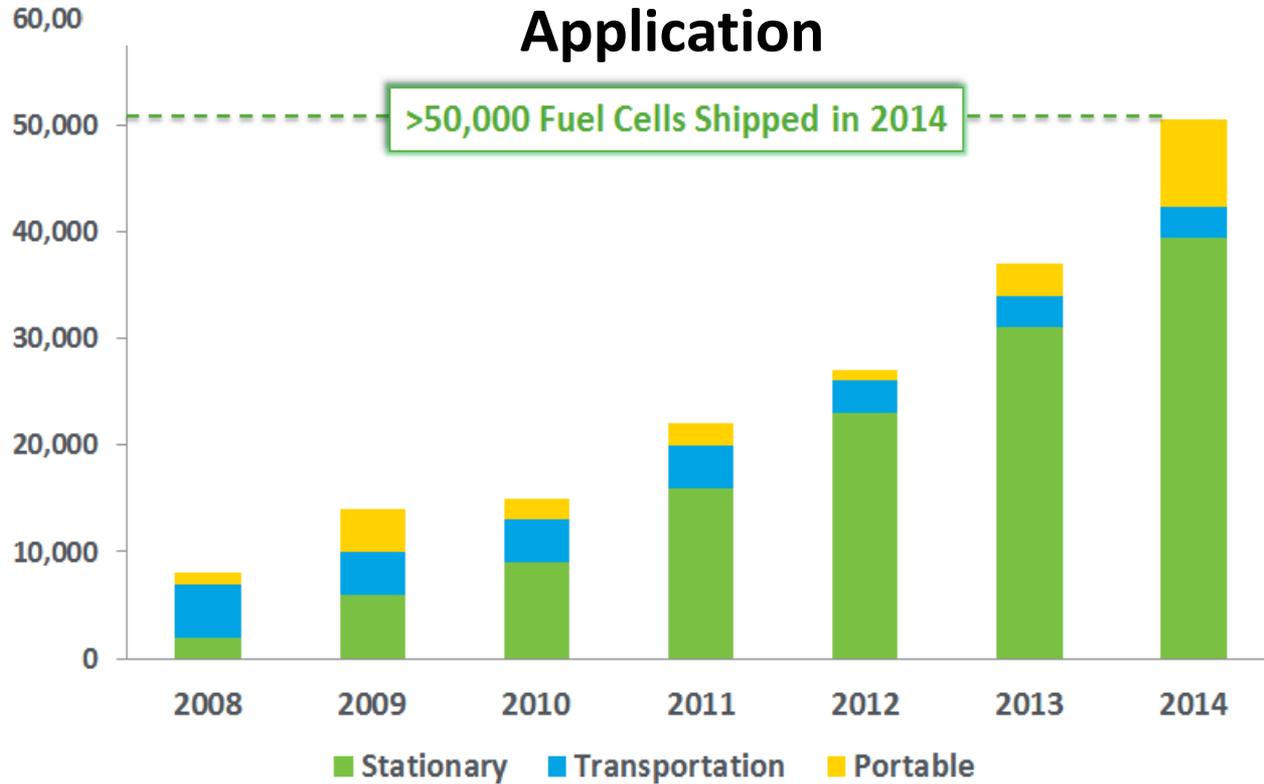
>\$2B in revenues

>180 MW fuel cells shipped

Available at:

<http://energy.gov/eere/fuelcells/downloads/2014-fuel-cell-technologies-market-report>

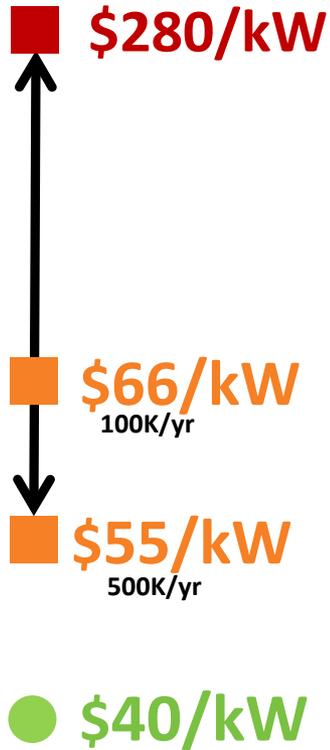
Fuel Cell Systems Shipped Worldwide by Application



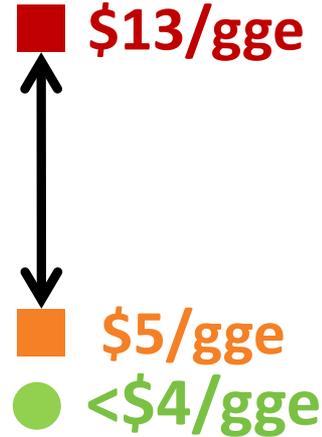
- **Consistent ~30% annual growth since 2010**
- **Global Market Potential in 10- 20 year**
 - ➔ \$14B – \$31B/yr for stationary power
 - ➔ \$11B /yr for portable power
 - ➔ \$18B – \$97B/yr for transportation

DOE Cost Targets and Status

Fuel Cell System



H₂ Production & Delivery



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

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**

H₂ Station

Storage
Cooling
Dispensing
Other



**Advanced Compression
Alternate Approaches**

H₂ Storage

BOP/Assembly
Other processing
Resin

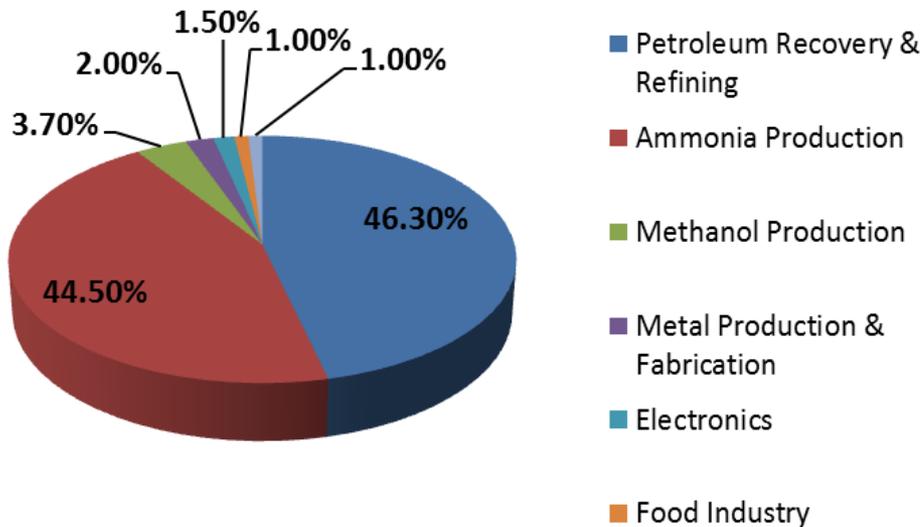


**Low Cost Carbon Fiber (CF)
Long term Materials Approaches**

U.S. H₂ Production: Current Status

~10 million metric tons of H₂ mostly:

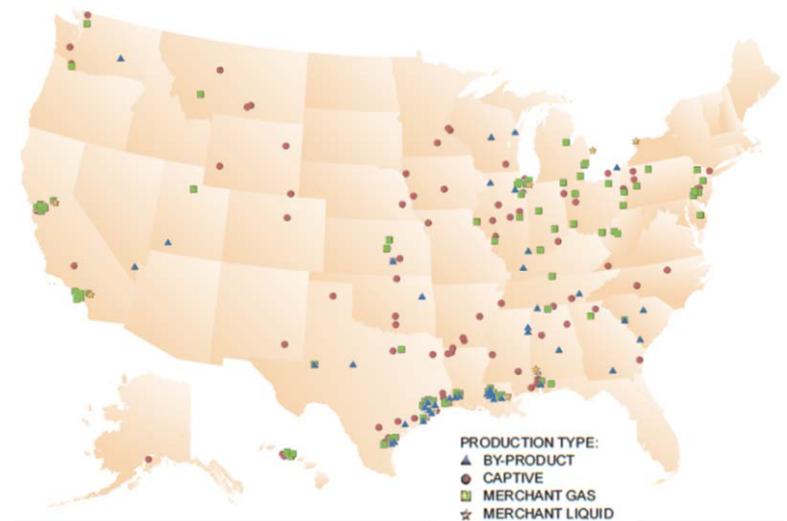
- From steam methane reforming of natural gas (SMR)
- For petroleum refining, ammonia production



H₂ consumption market share by application

Strategy for cost-competitive hydrogen fuel

- Near term from Natural Gas
- Longer term- renewables
- ~50 stations (~10 public- CA)



Centralized H₂ production facilities

Early adoption of H₂ and fuel cell technologies can leverage production and delivery infrastructure associated with low cost NG reforming

Examples of Global Infrastructure Activities



Hydrogen Supply/Utilization Technology (HySUT)

- 18 companies (including 3 auto companies), have announced plans to commercialize FCEVs and provide infrastructure by 2015.
- **100** H₂ stations and FCEVs launched in **4** urban areas by 2015



H2Mobility

- Public-private initiative for nationwide H₂ infrastructure—will develop into joint venture to install stations.
- **50** H₂ stations (public-private funds committed); and **5,000** FCEVs expected on the road by 2015



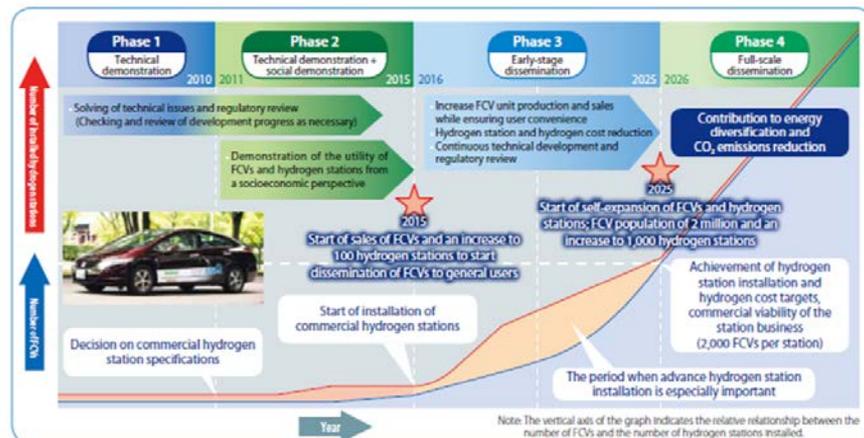
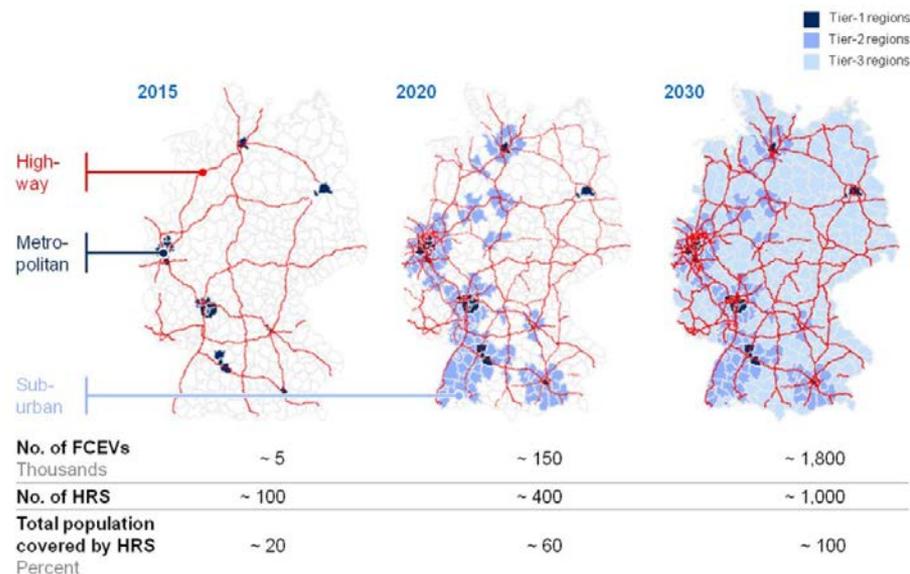
UKH2Mobility

- Evaluating anticipated FCEV rollout in 2014-2015
- Will develop action plan to make UK a leading market for FCEVs



Scandinavian H2 Highway Partnership (SHHP)

- Partnership of Hydrogen Link (Denmark), HyNor (Norway) and Hydrogen Sweden.
- 45 H₂ stations and a fleet of ~1K vehicles. Projects include H2Moves Scandinavia and Next Move
- 2012 MOU signed between auto & infrastructure companies and NGOs to introduce FCEVs and H₂ infrastructure within 2014 and 2015 timeframe.



*Assumption: FCEV user benefits (price, convenience, etc.) have been secured, and dissemination proceeds steadily.
 Source: Fuel Cell Commercialization Conference of Japan

International partnerships established to accelerate hydrogen infrastructure

H₂USA: Public-Private Partnership

H₂USA

Partners



~ 45 Partners in 2015

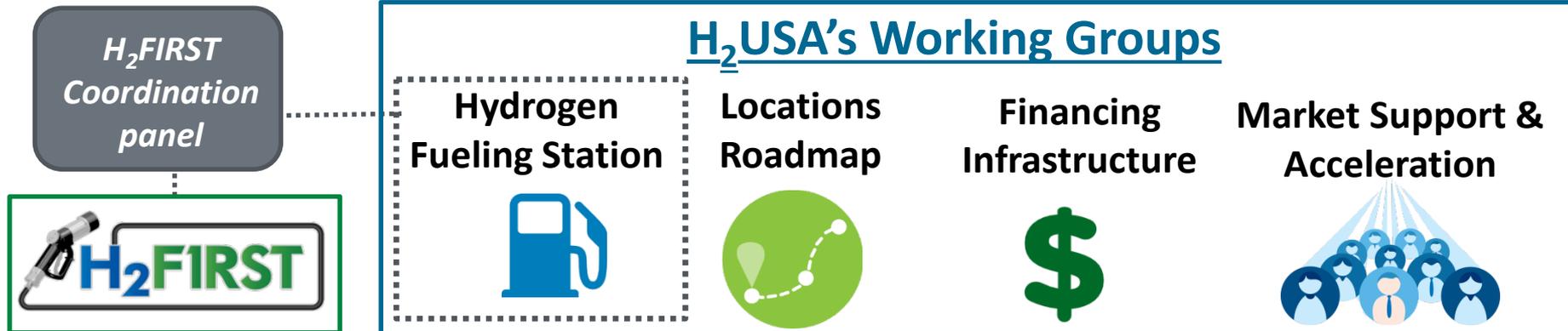
Mission

To address hurdles to establishing hydrogen fueling infrastructure, enabling the large scale adoption of fuel cell electric vehicles

Structure

4 Working Groups coordinated by the Operations Steering Committee

H₂USA's Working Groups



More than 45 partners working towards adoption of FCEVs and H₂

Key HTAC Recommendations and Responses

Recommendations

Key Responses

1

Increased visibility including support of tax incentive renewal proposal



Factsheet on proposed tax incentive proposal for advance vehicle technologies; 1st ever H₂ and Fuel Cell day; ~100 news articles/blogs and >11,800 readers; FCEV ride & drives; increased outreach

2

Best practices/lessons learned from CA on infrastructure and international coordination as well as across states



H₂ Refueling Summit; Reference Station Design; H2USA activities; CA update on stations; joint int'l workshops; int'l collaboration through IPHE and IEA

3

Support for fuel cells for grid resiliency and storage



Participation in DOE-wide crosscut effort on Grid Modernization; contribution of topics to grid modernization lab call; NREL/INL joint project related to real-time grid simulation of electrolyzers

4

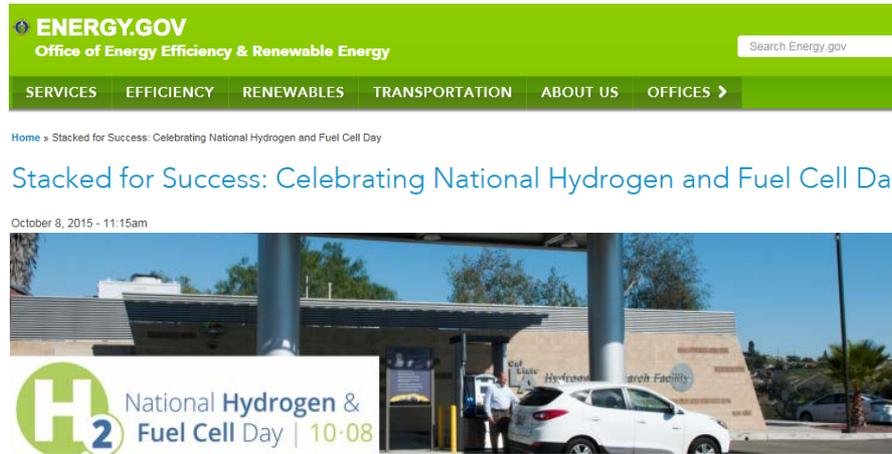
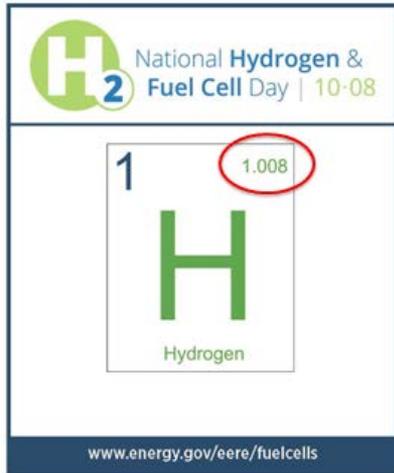
Budgetary support and higher level of funding commensurate with global leadership



FY16 request (\$103M) 10% higher than 2015 request (\$93M); >\$20M just announced to support RDD&D efforts; HyMARC, FC-PAD lab consortia; T2M activities; SOFC activities (~\$30M)

1. Increased Visibility

First Ever National Hydrogen and Fuel Cell Day



- Public outreach to thousands; Hill events (trade association)
- > \$20M in new DOE projects announced
- DOE blogs and Facebook posts; news nation-wide
- National Lab & Industry activities

Increased Support at DOE Leadership Level & Public Outreach!



Assistant Secretary Danielson meets with Hyundai President and drives FCEV



Secretary Moniz drives Toyota Mirai

- >100 publications and 15 webinars in 2015
- Newsletter with >11,800 readers
- Educated 35,000 code officials/first responders & 12,000 teachers
- ~10M people reached at Shell Ecomarathon
- EERE's Factsheets online!

2a. Lessons Learned from CA on Infrastructure

Updates on H₂ Stations to Stakeholders

On Current Status:

- **53 H₂ stations**
- **8 open**
- **15 under construction**

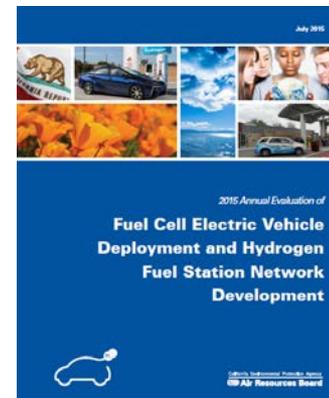
Open - Retail	2
Open - Non-Retail	6
Commissioning	6
Under Construction	15
Approval to Build	3
Planning Approval	4
Permit in Process	6
Pre-Permit Application	4
Site Acquisition	7

Available on CaFCP's website and sent to ZEV stakeholders regularly

Other mechanisms: Joint workshops with CaFCP, briefings from FCTO to stakeholders, etc.

On Future (Projected) Status:

- **CARB released 2015 AB8 report projected hydrogen demand and additional hydrogen fueling stations**
- **Post-2018, FCEV deployment is anticipated to accelerate more rapidly than previously projected**



Hydrogen Refueling Summit

- **Perspective on H₂ infrastructure challenges unique to retailers**
- **Request for feedback on H₂FAST and H₂ Infrastructure Guide**
- **Next Steps: Business case for retailers developed by industry and in collaboration with National Labs and DOE**

Reference Station Design Report Published

- **Analyzed 120 station permutations**
- **Four high-priority, near-term station concepts selected based on economics, technical feasibility, and market need**
- **Shows ~\$6-13/gge for H₂ and ~\$1-2M for stations (~100-300 kg/day)**

Available at:

<http://www.nrel.gov/docs/fy15osti/64107.pdf>

2b. International and State Coordination

Joint Workshops with International Stakeholders



3rd International Infrastructure Workshop in Tokyo, Japan



6th Int'l Conference on Hydrogen Safety in Kawasaki/Yokohama, Japan



Japan-US Collaboration on Technical Areas:

- Hydrogen Storage Vessels
- Hydrogen Materials Compatibility
- Fuel Quality

More activities through H₂USA



- Tools recently developed through DOE supporting H₂USA
 - Hydrogen Refueling Stations Analysis Model (HRSAM)
 - Hydrogen Financial Analysis Tool (H2FAST)

State Collaboration and Activities

- 8 State MOU- 3.3M ZEVs by 2025
- 9 states (4 ZEV states) offer incentives for FCEVs and H₂ station deployment
- Integrated Network of Regional Technical Centers for Manufacturing

IPHE and other International Collaboration



- 17 partners + EU
- Dec 1st- Next Meeting at Grenoble, France

- 2015 Technology Roadmap Released  International Energy Agency
- Includes H₂ and fuel cells input from international stakeholders

3. Grid Resiliency

Focusing on areas related to grid resiliency and energy storage

Dynamic Modeling and Validation of Electrolyzers in Real-time Grid Simulation

- ❑ Real time digital simulator (RTDS) to RTDS communications network established between NREL and INL
- ❑ Hardware-in-the-loop simulations with electrolyzer hardware at NREL and grid simulation at INL
- ❑ Also will identify high-value locations to implement demand response and ancillary services using hydrogen stations

GRID MODERNIZATION

- **Provide feedback and content to Grid Multi-Year Plan**
- **Contribute to Grid lab call:**
 - ❑ Topic 1a: Building Manager Dispatch Tool for Integrated Fuel Cell/ Building/ Energy Storage
 - ❑ Topic 1b: Optimal Planning of Integrated Fuel Cell/ Building/ Energy Storage
 - ❑ Topic 2: Capacity for Hydrogen Infrastructure and Fuel Cell Vehicles to Support the Grid

Consistent budgetary support

- **\$5.8M allocated in FY15**
- **\$5.1M allocated in FY16**

FY16 PLANS

- **Hi-temp & Low-temp Electrolyzer R&D for Energy Storage and Grid Services**
- **Grid Modernization Lab Call**
- **Hydrogen Energy Storage Working Group**

Quadrennial Technology Review (QTR)



Available at:
<http://energy.gov/qtr>

- **Ch. 3 - hydrogen energy storage systems**
- **Ch. 7 - H₂ infrastructure for FCEVs**
- **Ch. 4 - stationary fuel cells for distributed generation, grid integration, etc.**

4. Budgetary Support

Increased FY16 Budget Request

For FCTO

- **10 % higher budget request for FY16**
- **FY15 Request: \$92.3M**
- **FY15 Appropriation: \$97M**
- **FY16 Request: \$103M**

SOFC: \$30M for FY15, \$9M for FY16 Request

Total FY16 DOE request: \$30B

- **9% higher than FY15 enacted level**

\$20M Funding Awards Announced!

- **More than \$20M for 10 new projects**
- **7 R&D projects** covering hydrogen, low PGM catalysts, dispensers and pipeline manufacturing.
- **3 Demonstration and Deployment projects** including mobile refuelers and range extenders.

Lab Consortia Established

- **Fuel Cells: FC-PAD** (Fuel Cell Performance and Durability)
- **Storage: Hy-MARC**(Hydrogen Storage Materials Advanced Research Consortium)
- **Projects will be added through FOAs**

Increased Tech-To-Market Activities

- **Sessions to engage National Labs**
- **Poster sessions to highlight National Labs' unique capabilities**
- **Collaboration Corner (CC) for networking between industry, labs and DOE**

Hydrogen & Fuel Cells Budget

Key Activity	FY 15	FY 15	FY 16
	(\$ in thousands)		
	Request	Approp.	Request
Fuel Cell R&D	33,000	33,000	36,000
Hydrogen Fuel R&D ¹	36,283	35,200	41,200
Manufacturing R&D	3,000	3,000	4,000
Systems Analysis	3,000	3,000	3,000
Technology Validation	6,000	11,000	7,000
Safety, Codes and Standards	7,000	7,000	7,000
Market Transformation	3,000	3,000	3,000
NREL Site-wide Facilities Support	1,700	1,800	1,800
Total	\$92,283	\$97,000	103,000

Office	FY 2015
EERE	\$97M
Basic Science ²	~\$20M
Fossil Energy, SOFC	\$30M

Total FY 2015 DOE: **~\$150M**

ARPA-E (FY14): ~\$33M

Number of Recipients funded from 2008-2015	
Industry	>110
Universities	>100
Laboratories	12

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

²Estimated from FY14 appropriation

*More stable R&D funding requests and appropriations in recent years
 > 20 new projects including 11 new Incubator projects (2014-2015)*

- **Continue to strengthen R&D activities and accelerate Tech to Market (Lab impact)**
 - H₂, fuel cells, safety, manufacturing, etc.
 - Cost, performance, durability need to be addressed
- **Conduct strategic, selective demonstrations**
 - Industry cost share and potential to accelerate market transformation
- **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)
- **Leverage activities to maximize impact**
 - U.S. and global partnerships, H2USA, States

- Annual Report
- Prior input on Program Requests
 - H₂ cost target revision ✓
 - H₂ Production Expert Panel ✓
 - Feedback on H-Prize ✓
 - Manufacturing subcommittee ✓

Request to HTAC for Future Areas of Input:

- Program Plan revision (previous update 2011)
- Increasing outreach/awareness and State collaboration
- H₂ Energy Storage (Enabling Renewables) Subcommittee

Thank You

Dr. Sunita Satyapal

Director

Fuel Cell Technologies Office

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hydrogenandfuelcells.energy.gov

Additional Information

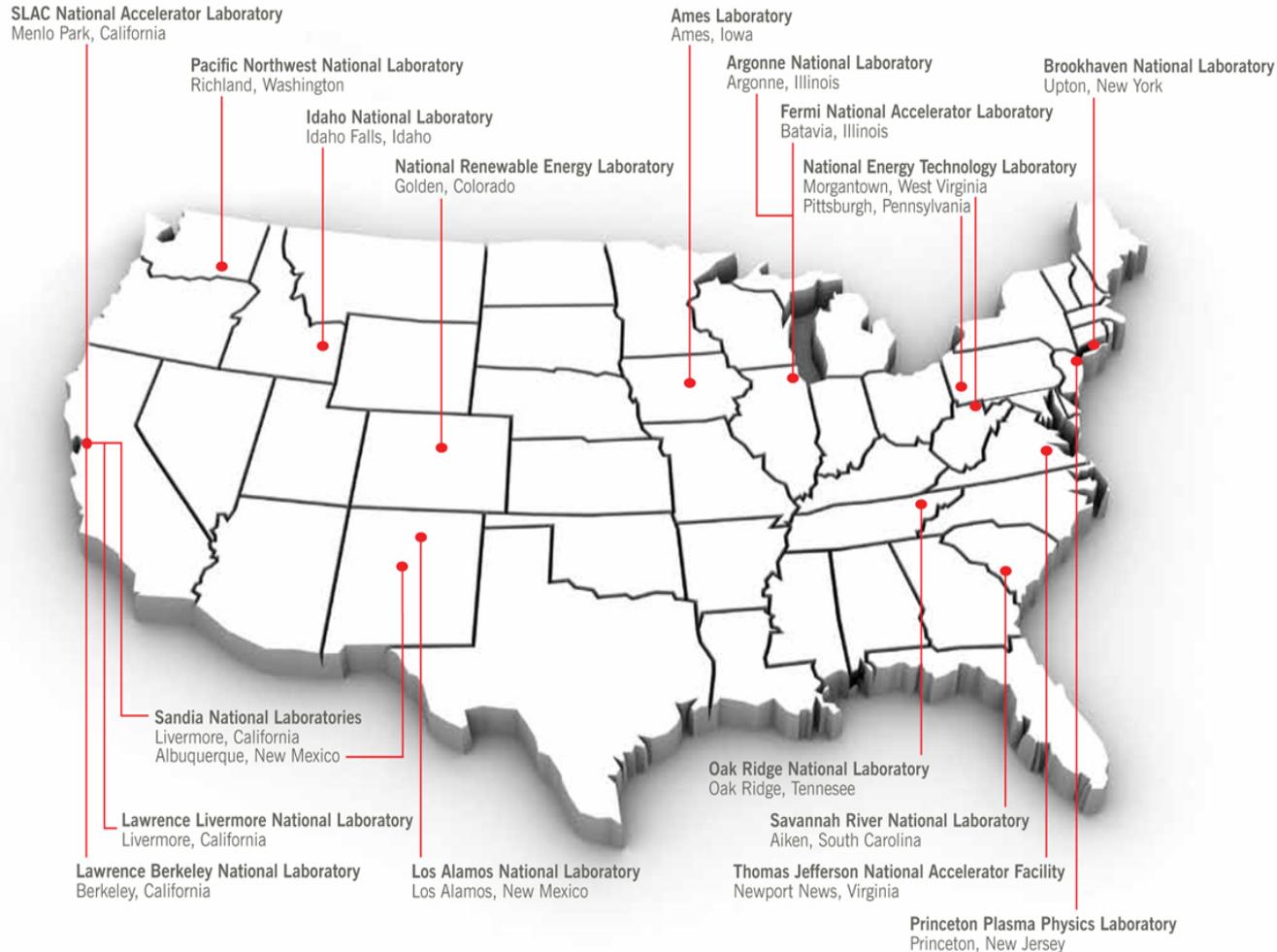


EERE Lab Impact Initiative

Mission: significantly increase the industrial impact of DOE national labs on the U.S. clean energy sector!

- Increase and **enhance lab-private sector relationships**
- Increase and **streamline access to national lab** capabilities
- **Demonstrate** the **value** of lab-developed **science and technology**

Where in the US?



How Many?

17 Facilities

- 10 Office of Science
- 3 NNSA
- 1 Nuclear Energy
- 1 Fossil Energy
- 1 Energy Efficiency and Renewable Energy
- 1 Environmental Management

~ **66,000 Total Employees**

Over 50 Nobel laureates affiliated with DOE Labs

T2M Strategy

Increase Industry Contact

- Business-to-Business Product Theater at conferences
- Manufacturing Road Show
- Small Business Vouchers

Listen to the Voice of the Customer

- Key Staff Exchange with industry and national labs
- Site visits, Feedback sessions at ECS

Develop Technology Transfer Skills

- Business Plan Development Training
- Lab Corps

Activities

Goals

Increase Market Understanding

Improve Private Sector and National Lab Relationships

Improving technology transfer and targeted impact from lab to market

Lab Consortia Approach

Activities

Consortia Core

- **Fuel Cells: FC-PAD**
Fuel Cell Performance and Durability
- **Storage: Hy-MARC**
Hydrogen Storage Materials
Advanced Research Consortium

Projects added through FOAs

- Companies, universities, labs
- 2-4 yrs/project
- May include seedling projects

* Subject to appropriations

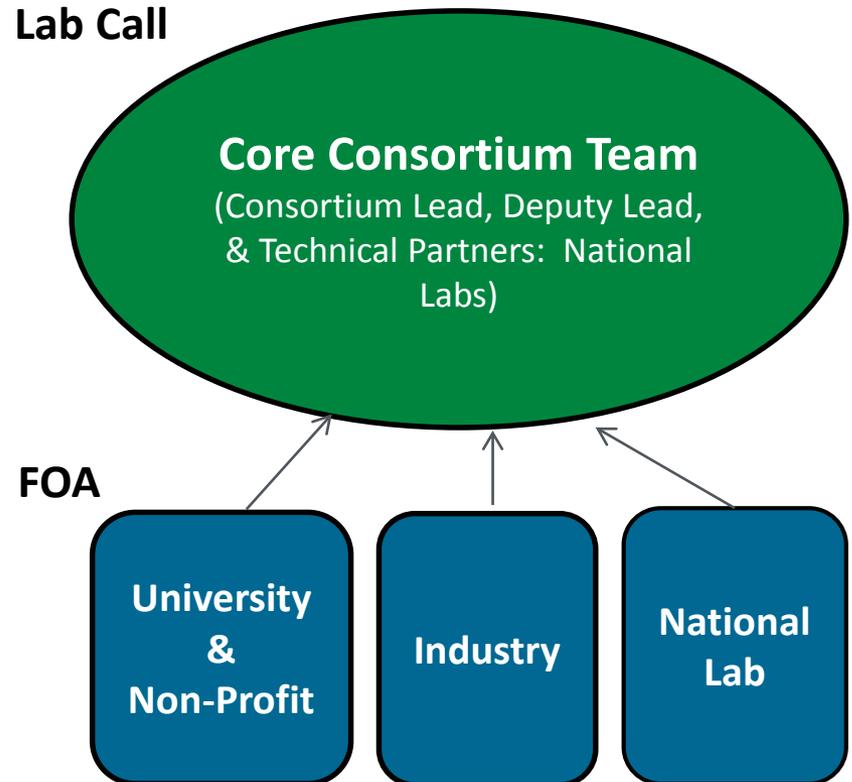
Potential Future Collaborations

Relevant Offices and other Agencies (e.g. Office of Science , Advanced Manufacturing Office, etc)

Strategy and Structure

Multi-Lab team with Lab Call to competitively select core team

Lab Call

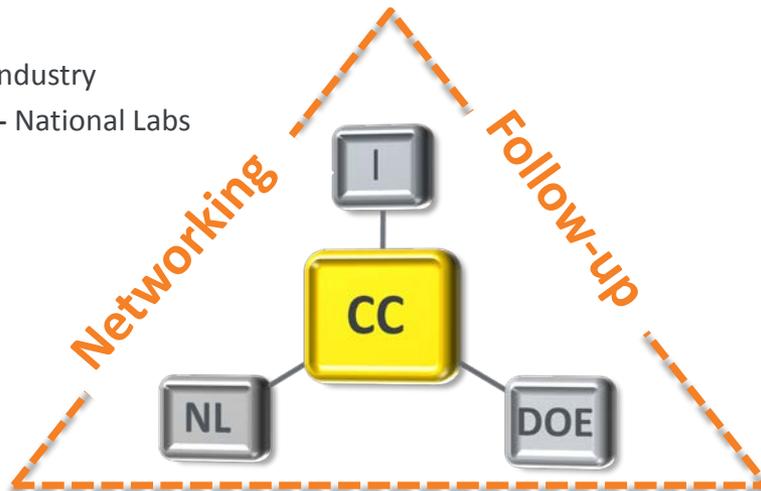


T2M Activities at the Electrochemical Energy Summit

- Seminar to **demystify the process of working with National Labs**
- Poster Session to highlight **National Labs' unique capabilities and opportunities** in fuel cells and electrochemical systems
- **Collaboration Corner (CC)** for networking and follow up

I- Industry

NL- National Labs



ElectroChemical Energy Summit 2015

Featuring Hydrogen Fuel Cells and Electrochemical Systems

Sponsored by the Fuel Cell Technologies Office
Phoenix Convention Center, Phoenix, Arizona

PLENARY SPEAKER

Monday, October 12, 2015 at 8:00 am
Lynn Orr
Under Secretary for Science and Energy
U.S. Department of Energy



DOE EERE LAB TECH TO MARKET SHOWCASE

LEVERAGING NATIONAL LAB CAPABILITIES TO SOLVE INDUSTRY PROBLEMS

TUESDAY, OCTOBER 13

On Tuesday, October 13, join us at these two **one-day-only** events to increase collaboration between national labs and industry:

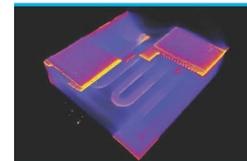
LEVERAGING THE LABS | 12:45-1:45 PM

The first session will demystify the process of working with national labs and discuss the mechanisms from the first (oral) session on industry problems.

LAB SHOWCASE | 5:30-6:30 PM

The second (poster) session will highlight technologies developed at the national labs, their unique capabilities, and opportunities for collaboration.

Following presentations from each lab, representatives will be available in the room to further discuss their industrial solutions.



3-D X-ray Tomography of a mixed-potential hydrogen sensor at LANL. Sensor response is controlled by the kinetics of the electrode reactions occurring at the gas-electrode-electrolyte interface.



NREL has received four Fuel Cell Hybrid Vehicles—Advanced (FCHV-adv) on loan from Toyota, enhancing their research capabilities related to hydrogen fueling infrastructure.



Xiaoping Wang of Argonne National Laboratory prepares a cell for testing the activity of fuel cell catalysts.

U.S. DEPARTMENT OF
ENERGY

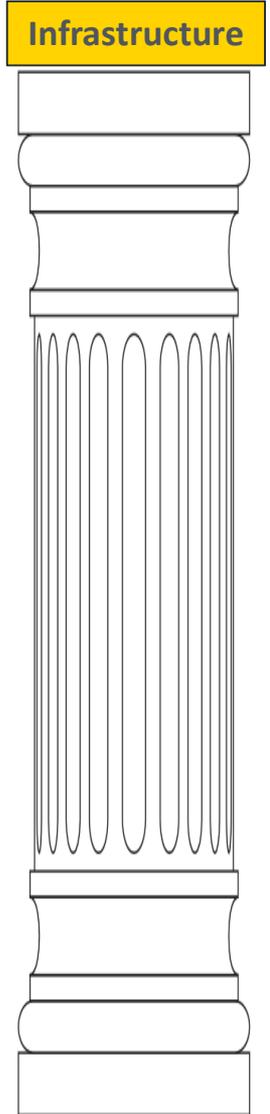
Energy Efficiency & Renewable Energy

EERE-funded research has:

- Reduced cost of fuel cells by more than 50% since 2006 and 30% since 2008
- Achieved a more than five-fold reduction in the platinum content of fuel cells
- Led to more than 500 patents, 45 commercial technologies, and 65 emerging technologies that will be commercialized in the next 3-5 years
- <http://energy.gov/eere/fuelcells/downloads/2014-pathways-commercial-success-technologies-and-products-supported-fuel>

www.energy.gov/eere/fuelcells

Small Business Vouchers (SBV): Unleashing Infrastructure

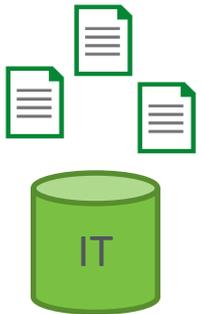


GOAL: Provide clean energy small businesses with easy and affordable access to laboratory capabilities to solve critical technology challenges

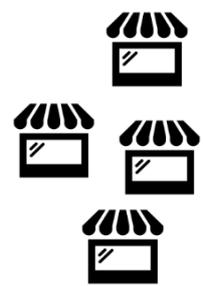
Labs
Conduct
Outreach



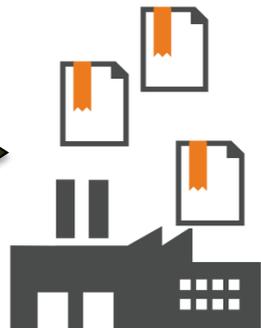
Labs Issue
Voucher
Competition



High Impact
Small
Businesses
Chosen



Voucher
Credit
Spent at
Labs



Major Components:

- Lab Call
- *IT Platform*

- *Outreach*
- *Lab Infrastructure*
- Voucher Work

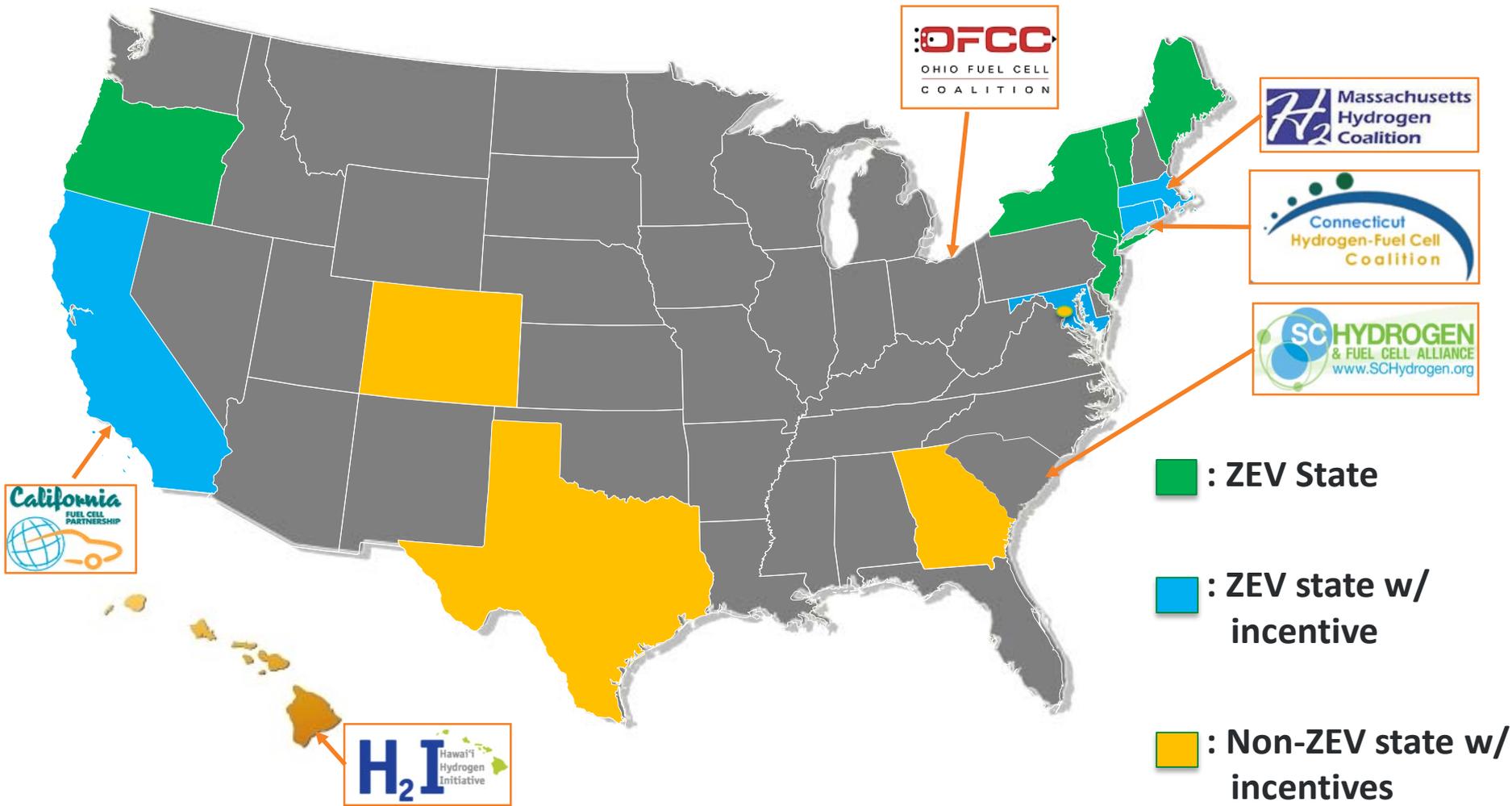
- *Standard IP terms*
- *Third Party Evaluation*

FY15 Funding = \$20M

www.sbv.org **DEADLINE OCT. 23**

State-related information

State FCEV/H2 Incentives and Partnerships



Source: NCSL <http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx>

9 states (4 ZEV state) offer incentives for FCEVs and H₂ station deployment

Examples of Activities Supporting ZEV Action Plan

ACTION

RESEARCH

PARTNERSHIPS

M-S ZEV Action Plan

1. Vehicle Markets
2. Incentives
3. Lead-by-Example
4. Fleets
5. Workplace Charging
6. Infrastructure
7. Signage
8. Local Barriers
9. Interoperability
10. Fuel Markets
11. Data
- Research
- Partnerships

“Collaboration for Success”

DOE/EERE/FCO

- Fuel Cell Cost
- H₂ Production
- H₂ Delivery
- Tanks and Storage
- Safety Codes and Standards
- Tech Validation (NFCTEC)
- Market Transformation
- H2FIRST
- H2USA
- CaFCP
- IPHE

- Example of State Activities

Preliminary Analysis- Economic Impact Summary

	CT	NY	MA	ME	NH	RI	VT	NJ	Regional
Total Employment	2,529	1,728	964	18	45	32	16	111	5,443
Total Revenue / Investment in 2010 (\$ million)	\$496	\$292	\$171	\$2.9	\$8.7	\$6.9	\$3.3	\$26.5	\$1,009
Total Supply Chain Companies	599	183	322	28	25	19	5	8	1189

International Collaboration



International Partnership for Hydrogen and Fuel Cells in the Economy

- Representatives from 17 member countries & the European Commission
- Facilitates international collaboration and a forum for advancing policies education
- Recent Activities (thru RCS WG):
 - International Maintenance and Reliability Data Sharing Initiative (U.S., Japan, and EC)



6th International Conference on Hydrogen Safety
 October 19-21, 2015 in
 Kawasaki/Yokohama, Japan
 (Hosted by Technova)



3rd International Infrastructure Workshop (June 2015 in Tokyo, Japan)

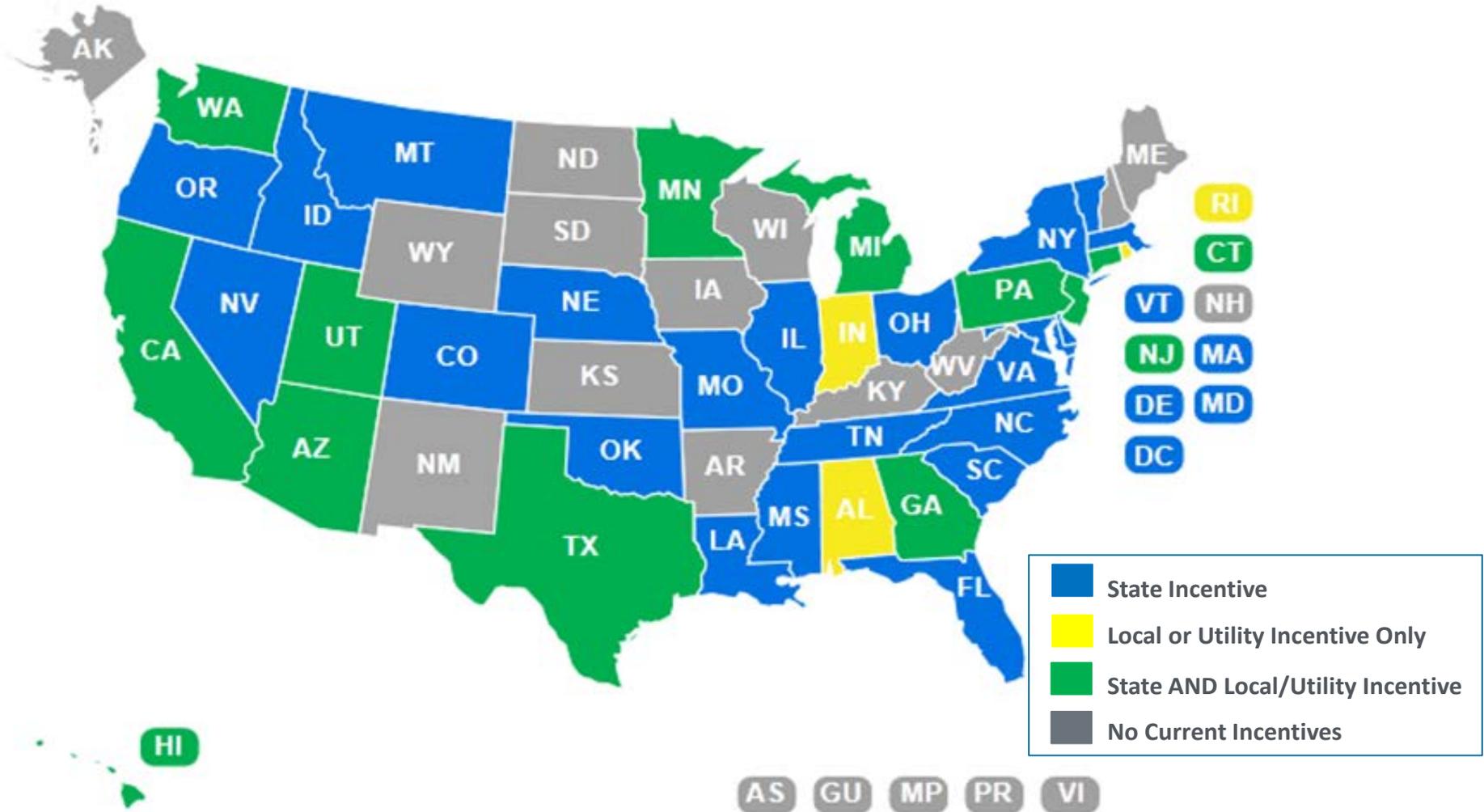
- Organized by NOW, DOE and NEDO
 - Included ~60 participants from Germany, the EU, Scandinavia, Japan and the U.S.
 - The FCHJU has offered to host the 4th in June 2016 in the Netherlands
- Objective: To enable international information exchange on hydrogen infrastructure challenges in four key areas:
 - Refueling,
 - Hydrogen Quality,
 - Metering, and
 - Hardware Reliability & Performance

National Laboratory-Level Collaboration

- MOU between Sandia National Laboratories (SNL) and AIST
 - Hydrogen Storage Vessels
- Technical cooperation of SNL with I2CNER
 - Hydrogen Materials Compatibility
- LANL collaboration with JARI
 - Fuel Quality



Hybrid and Electric Vehicle Incentives



Source: NCSL (<http://www.ncsl.org/research/energy/state-electric-vehicle-incentives-state-chart.aspx>)

37 states + DC offer incentives: Financial, HOV lanes, parking, reduced utility rates, etc.

DOE H2 NESCAUM Survey Results

	California	Connecticut	Maryland	Massachusetts	New York	Oregon	Rhode Island	Vermont
Top 3 Questions or concerns on H2 or FCEV	Path to higher capacity stations	Revise options to incent fleets	Cost (stations, vehicles and fuel)	Proof of H2 generation benefits	How will OEM's create demand for FCEV	Reasons for states to invest in H2	H2 location and access choice	Station funding and metrics for same
	Safety for non-OEM product refueling	DOE tech and financial station assistance	Safety of stations	H2 station funding path	How do we fund instructure	What are H2 storage tech breakthrough	What is car and station timing to market	Will there be a variety of FCEV types
	Station verification	DOE role in Café standards to help FCEV	Gaurantee sufficient vehicles available	Location, location, location	What are best FCEV market segments	Why not just wait for CA to show success		Has cold weather use been addressed
		DOE coordination of all clean tech						No H2 from NG
Top 3 EV or CNG Learnings or Advice to H2 Group	Incentivized charging works	Convenience is key to consumers	Station sites must be proven locations	Tunnel travel exemptions	Vehicle type matters to launch	Consider flexible transporation funding	Consumer law changes and tax generation	Confidence refueling site #s are enough
	DC fast charging is growing	Value proposition must compete	Installation costs always exceed estimates	Fire Marshall permit guidance to locals	Location of infrastructure IS important			Need OEM help marketing the cars
		Must have range and station redundancy	Local zoning can be a hurdle		Right market segment / base load helps			Limited # of qualified dealers is an issue
		Assure fed programs reduce GHG						Some EV lessons not relavent to FCEV's
Top 3 Priorities from your state for DOE	Support for H2FIRST	Use fed rules & SEPS to leverage \$'s	Funding / Incentives	Finance / Funding	Do not know	Look at H2 storage beyond compressed	Way to share lessons learned	How to pick where to go first with H2
	MD/HD FCEV market development	Coordinate DOE \$ opps with states	H2 Education	Regional station location map		Guidance for state for H2 station design	Home fueling option	Station permitting facilitation
	Support for large volume H2 station work	Assure CCC alignment with ZEV plans	Well defined standards			Describe variable H2 station business model	Way to pass along progress	Support and funding on incentives
		Standardize stations to lower H\$ pricing						Fund consumer education & awareness

Examples of Identified **Current** and **Future** Activities

- Promoting public-private partnerships to overcome H₂ infrastructure challenges (e.g., H2USA), including outreach for code officials and first responders.
- Providing State of the States annual reports with emphasis on FCEV progress in ZEV states.
- Coordinating public "ride-and-drives" in ZEV states. (e.g. Alternative Wheels event - Boston, Fuel Cell Seminar)

- Collaborating with other agencies and industry to identify opportunities for stations.
- Identifying and promoting a successful model of partnering with station owners/operators to provide access to clean fuels.
- Developing infrastructure cost analysis in key ZEV states such as MA, RI, CT with H2USA coordination.

Preview of Supporting Actions Matrix			ACTION # 1: Sales		ACTION # 2: Incentives		ACTION # 3: Leading by Example			
			Access	Education	Non-Cost	Partnerships	Forum	Data	Purchase	
			<i>Reduce effective price</i>	<i>Outreach and education</i>	<i>Non-monetary incentives (including common decal)</i>	<i>Local public and private partnerships</i>	<i>Multi-state Fleets Users Forum</i>	<i>Common data collection and information sharing</i>	<i>Pooled purchases</i>	
DOE Activities	Market Support and Acceleration Working Group	Public & Stakeholder Education		X		X		X		
		H2USA Website, FAQs		X				X		
		Joint Codes & Standards Task Force								
	Investment and Finance Working Group	Station Siting								
		Financial Incentives & Scenario Analysis	X			X		X		
	H2USA	Hydrogen Fueling Station Working Group	Investor Outreach & Coordination		X				X	
			Station Cost & Utilization Research						X	
			Station Equipment & Component R&D							
			Regulations, Codes & Standards; Addressing Market Barriers							
			Regional Station Metrics Coordination						X	

} ZEV Actions

DOE is helping to develop a H2USA Infrastructure Guide and a Cost Estimating Model aimed to help relevant stakeholders address challenges related to H₂ and FCVs.

Infrastructure Guide

Guidance Best Practices Information



Cost Estimation Tool

- Used on Feasibility Study for Hawaii
- Demonstrated profitability of hydrogen fueling station

INL/EXT-14-31624
Revision 0

Hydrogen Fueling Station in Honolulu, Hawaii Feasibility Analysis

Porter Hill – INL
Michael Penev – NREL

August 2014



The INL is a U.S. Department of Energy National Laboratory operated by Battelle Energy Alliance

Examples of relevant areas from QTR

- **Major challenges:**

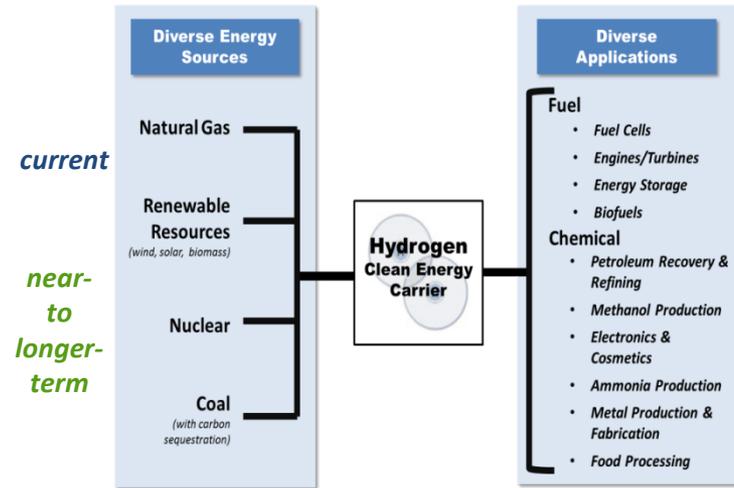
Reduce the cost of producing and delivering H₂ from renewable/low-carbon sources for FCEV and other uses (capex, O&M, feedstock, infrastructure, safety, permitting, codes/standards)

- **Factors driving change in the technologies:**

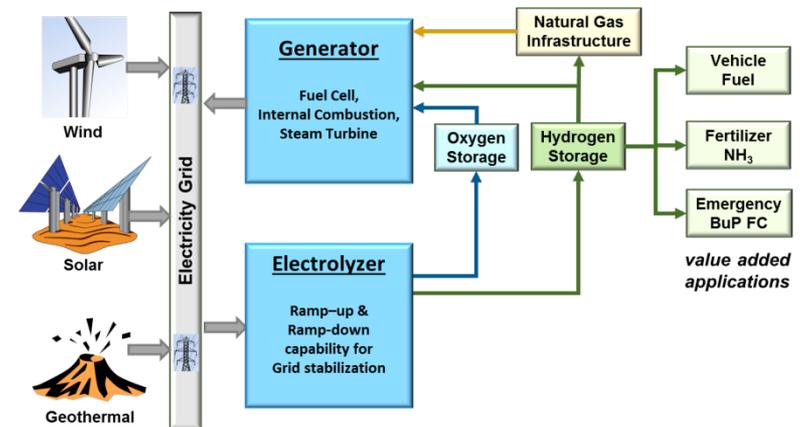
- FCEVs are driving requirements (e.g. high P tanks)
- Need to reduce cost of 700 bar refueling stations for near-term FCEV roll-out

- **Where the technology R&D needs to go:**

- Materials innovations to improve efficiencies, performance, durability and cost, and address safety (e.g. embrittlement, high pressure issues)
- System-level innovations including renewable integration schemes, tri-generation (co-produce power, heat and H₂), energy storage balance-of-plant improvements, etc.
- Cost reductions in H₂ compression, storage and dispensing components
- Continued resource assessments to identify regional solutions to cost-competitive H₂



H₂ offers important long-term value as a clean energy carrier

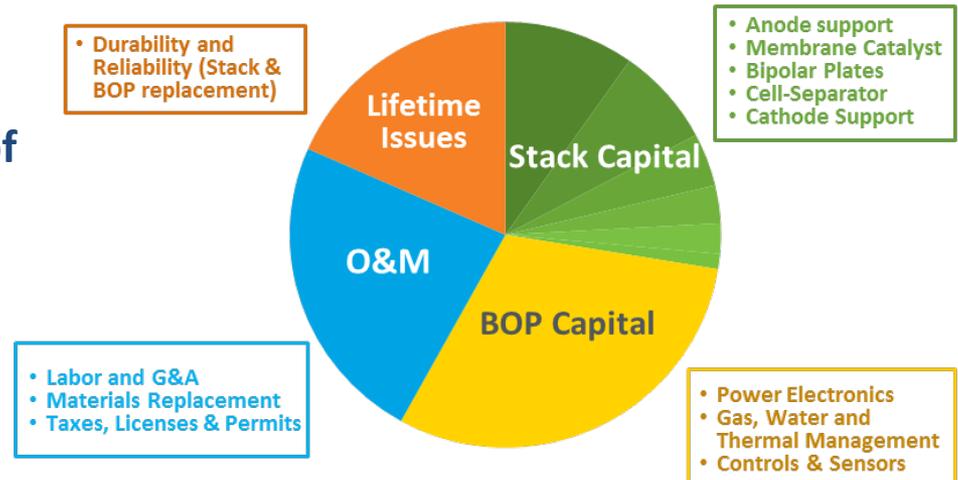


Renewable energy integration options with hydrogen

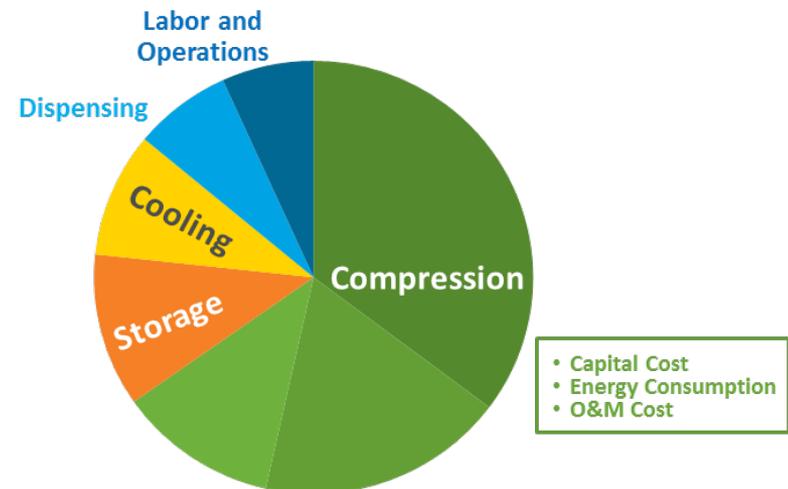
- Reduce the cost of H₂ from renewable and low-carbon domestic resources to achieve a delivered & dispensed cost of <math>< \\$4/\text{gge}</math> (Note: 1 kg H₂ ~ 1 gge)

Pathways:

- Electrolysis, high temperature thermochemical (solar/nuclear), biomass gasification/bio-derived liquids, coal gasification with CCS, biological & photoelectrochemical
- Need R&D in materials and components to improve efficiency, performance, durability, and reduce capital and operating costs for all pathways
 - For many pathways, feedstock cost is a key driver of H₂ cost
- Need strong techno-economic and regional resource analysis
- Opportunities for energy storage (e.g. curtailed wind for electrolyzing water)



H₂ Production Example- Cost Breakdowns for PEM electrolysis, (excluding electricity feedstock costs)



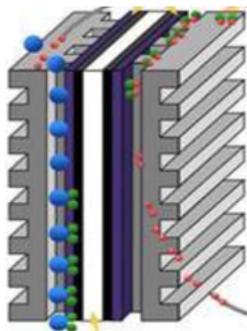
H₂ Delivery Example- Compression, Storage and Dispensing (CSD) Cost Breakdown for the Pipeline Delivery Scenario

QTR - Fuel-Cell Electric Vehicles

- FCEVs refuel in a few minutes, have a wide range of vehicle sizes and performance requirements, achieve a >300-mile driving range, and have zero emissions from tailpipe
- Key issues are: fuel cell cost and durability and on-board hydrogen storage (hydrogen production, delivery, and infrastructure covered in Ch. 4)

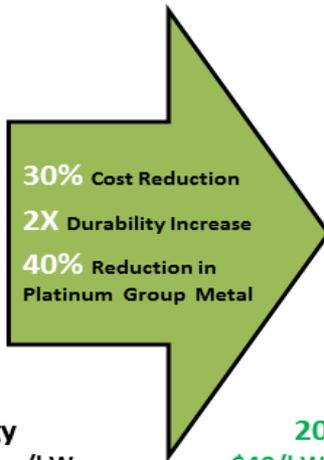
Fig 8.15 in QTR Chapter 8 of 2015 QTR

Fuel Cell Challenge

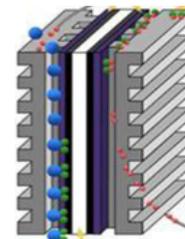


2014 Fuel Cell Technology
 \$55/kW*, 2,500 h durability, 0.2 g_{PGM}/kW

Fuel cells currently use high platinum group metal loadings for high performance and durability.



30% Cost Reduction
 2X Durability Increase
 40% Reduction in
 Platinum Group Metal



2020 Fuel Cell Technology
 \$40/kW, 5,000 h durability, 0.125 g_{PGM}/kW

Improved catalyst and electrode technology is required to reduce catalyst loading while simultaneously increasing durability and performance.

*\$55/kW at 500,000/yr, \$280/kW at low volumes

Key Areas of R&D

Stack:

- Catalysts, membranes, gas diffusion layers, bipolar plates

Balance of plant components:

- Air management, humidification systems

Hydrogen storage:

- Tanks (carbon fiber)
- Materials R&D for long term low pressure storage

Vehicle-delivery interface & safety (materials compatibility see Ch. 4)

Previous HTAC recommendations and additional program/strategic information

Recommendations

Emphatic public support for FCEV deployment to inspire confidence and increase public awareness.



Stronger commitment to R&D to ensure U.S. technology leadership.



Collaboration with infrastructure initiatives in Germany, Japan, Korea, and the UK on technical and regulatory issues to reduce cost and accelerate deployment.



Direct investment in H2 infrastructure as part of a integrated strategy or comprehensive National Energy Policy to accelerate deployment and attract private investment.



Key Responses

Published ~ 80 news articles/blogs, etc. /yr; trained 30,000 code officials/first responders, 12,000 teachers. Secretary driving FCEV video; Remarks at DC autoshow, Secretary tweet ; FedEx Memphis event, Investor days; House/Senate Caucus events.

H2 & fuel cells are part of President's all-of-the-above strategy. >500 patents; 40 commercial technologies. FY16 budget request (\$103M) for FCTO 10% higher than FY15 request. SOFC FY16 request (\$9M) vs. \$3M in FY15. Moving towards funding stability.

DOE serves as Vice Chair of IPHE (17 countries); Co-organized int'l workshops and webinars; multi-country round robin, safety/reliability database sharing, data collection.

Committed to H₂USA, public-private partnership. Focusing on enablers (station design, cost reduction, validation, metering, reliability) and leveraging state funds for stations . Strong state collaborations (e.g., CEC, CARB, CAFCP, NESCAUM)

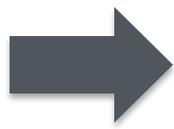
BARRIERS

NEAR TO MID-TERM

LONG-TERM

R&D

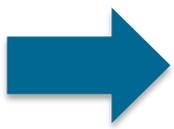
- Fuel Cell Cost and Durability
- Hydrogen Storage
- Hydrogen Production and Delivery



Low PGM catalysts, MEAs, performance durability, components	Non PGM Catalysts AEMs
700 bar tanks, composites, cryo-compressed	Materials R&D for low P storage
H ₂ from NG/electrolysis; delivered H ₂ , compression	H ₂ from renewables (PEC, biological, etc.), pipelines, low P option

NON-R&D

- Infrastructure Development
- Manufacturing and Supply Chain
- Safety Codes and Standards (SCS)
- Public Acceptance and Awareness

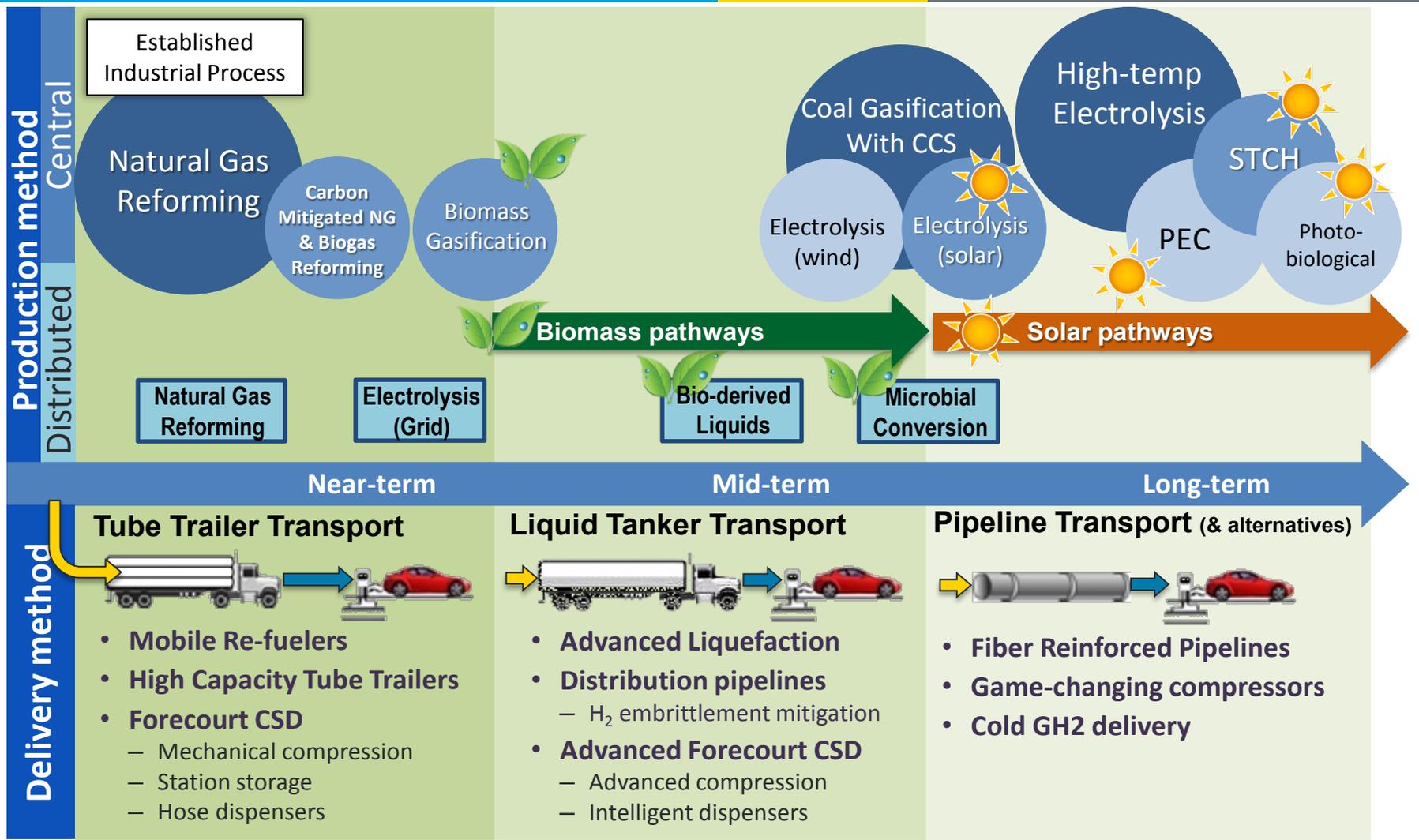


Enablers: H2FIRST-Station validation, metering, sensors, etc.	Materials compatibility, sensors, station innovation- H-Prize
Catalyst, MEA and tank manufacturing and QC; cost & reliability; supply chain	Mfg. processes and scale up; strong supply base
Set back distances, fueling protocols, Safety Dissemination	Risk mitigation; National and International harmonization of SCS
H2Tools Education, Outreach; Early markets; H2USA	Widespread Outreach, Education & Social Acceptance

Level of Difficulty

- High
- Medium
- Low to Medium

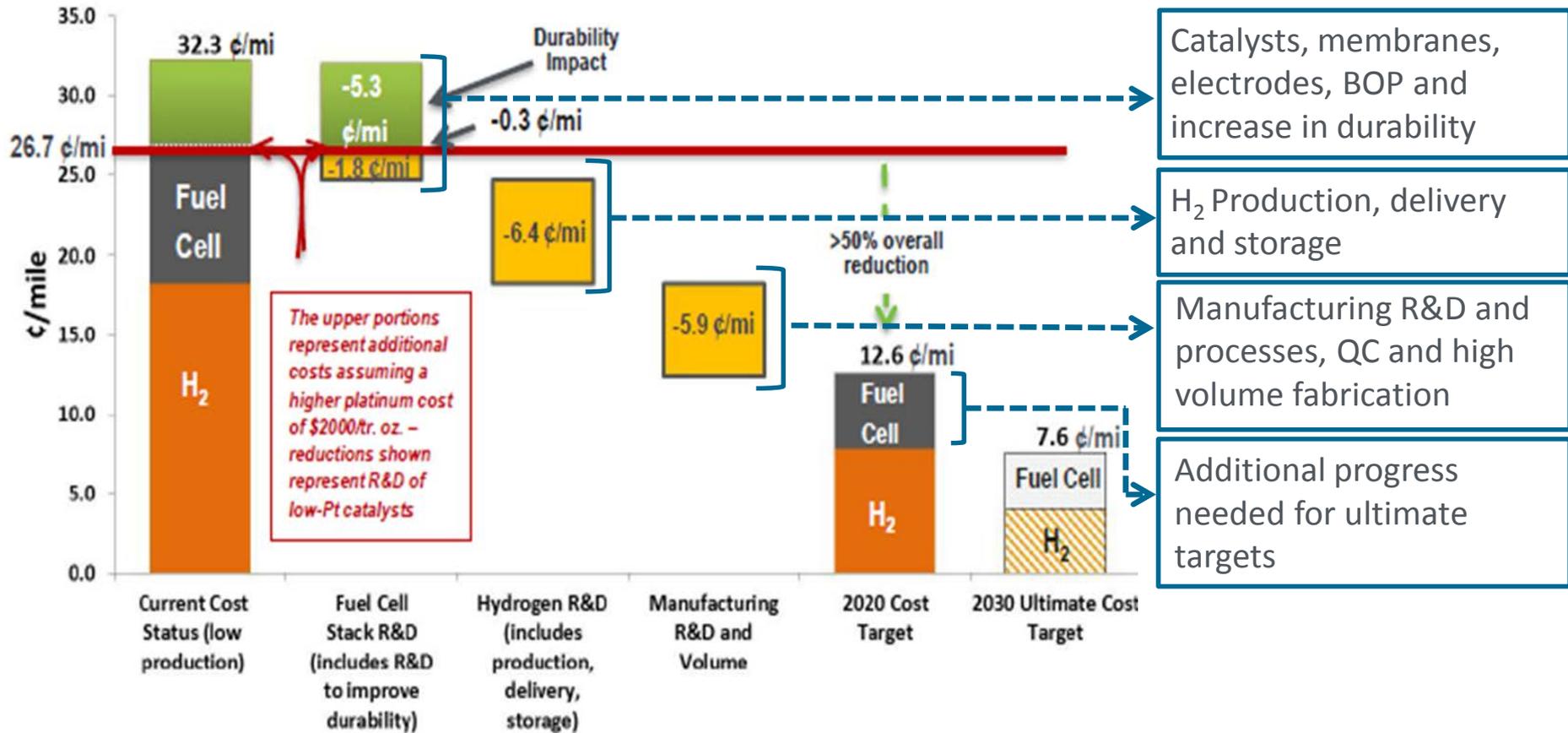
H₂ Production & Delivery Technology Strategies



The portfolio must consider near-term infrastructure rollout needs as well as the longer-term transition to large-scale renewable hydrogen

FCEV Cost Reduction Pathways @ 100,000 units

R&D Needs



Total cost of ownership analysis identifies key R&D needs to be competitive with incumbent and other advanced technologies

Workshops

- **Early Market Fuel Cell Showcase and Project Review-** 2013
- **Clean Energy Technology Showcase Review-** 2014
- **Hydrogen Transmission and Distribution Workshop held-** 2014
- **Electrolytic Hydrogen Production Workshop-** 2014
- RD&D needs identified include: materials development at the cell component level; improved electrolyzer stack and system efficiency with high temperature electrolyzers highlighted as having potential advantages in this area
- **DOE Materials-Based Hydrogen Storage Summit: Defining pathways for onboard automotive applications-** 2015
- Take-aways: (1) Need for higher-risk projects with potential to significantly change the current state-of-the-art. (2) Leverage/combine efforts across material storage pathways; emphasis on computational analysis; work with fundamental hydrogen storage studies (e.g. BES)

RFIs

- **Strategies for a robust market introduction of hydrogen supply, infrastructure, and FCEVs-** 2014
- **Existing and potential hydrogen contamination detectors-** 2014
- **Technical and economic feasibility of commercializing fuel cell range extenders as onboard power generators for electric vehicles-** 2014
- **Advanced Thermal Insulation of Composite Materials for Long-term Cold and Cryogenic H₂ Storage On-Board FCEVs-** (Planned release date September 15, 2015)

Ongoing

- USDRIVE Tech Teams
- HTAC
- H₂USA/H₂FIRST
- CaFCP and State Agencies

More than \$20M in new projects

Recipient	DOE Award	Location	Project
Oregon State University	\$1.5M	Corvallis, OR	Novel Hybrid Microbial Electrochemical System for Efficient Hydrogen Generation from Biomass
3M Company	\$3.0M	St. Paul, MN	Highly Active, Durable, and Ultra-low PGM NSTF Thin Film ORR Catalysts and Supports
General Motors LLC	\$3.0M	Pontiac, MI	Highly-Accessible Catalysts for Durable High-Power Performance
NREL	\$3.0M	Golden, CO	Extended Surface Electrocatalyst Development
Illinois Institute of Technology	\$3.0M	Chicago, IL	Corrosion-resistant non-carbon electrocatalyst supports for PEFCs
Ivys, Inc.	\$2.0M	Waltham, MA	Advancing Hydrogen Dispenser Technology by Using Innovative Intelligent Networks
Automated Dynamics	\$1.5M	Schenectady, NY	Continuous Fiber Composite Electrofusion Couplers
Electricore, Inc.	\$1.3M	Valencia, CA	Innovative Advanced Hydrogen Mobile Fueler
US Hybrid Corporation	\$3.0M	Torrance, CA	Northeast Demonstration and Deployment of fuel cell battery hybrid medium duty truck
City of Ithaca	\$0.3M	Ithaca, NY	Ithaca, NY— an Exemplary Climate Community of Excellence for the Northeastern US

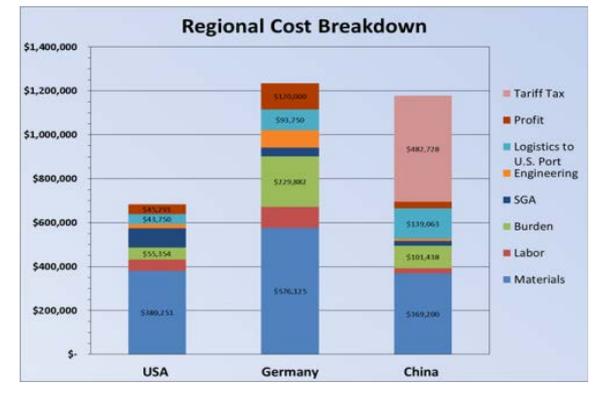
Total Award: ~\$22 Million

Global Competitiveness Analysis

including:

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

GLWN.org



Integrated Network of Regional Technical Centers



Located at

1. East Coast (CCAT)
2. Midwest at the OFCC
3. Central States at NREL's National Fuel Cell Technology Evaluation Center
4. West Coast (UC Irvine)

Activities (Examples)

- Hold supply chain exchanges
- Promote cooperation between suppliers & standardization of component specs



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.)



Collaborations and Partnerships

R&D

Demonstration & Deployment

Accelerated Commercialization



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



- Implementing Agreements
- 25 countries



- State Partnership and Collaboration



- International Government Coordination
- 17 countries and European Commission



- Public-Private Partnership
- >45 partners

Industry, academia and state & federal stakeholders working together

Proposed Advance Vehicle Tax Credit for FY16

What's being proposed?

- **Extend the current plug-in electric vehicle (PEV) tax credit to FCEVs** (and other advanced vehicle technologies).
- **Remove the cap placed on number of vehicles per manufacturer** that can receive the credit
- **Make credit up to \$10,000**
- **Increase flexibility on how the credit is passed on to the consumers** (i.e. rebates)

Vehicle Requirements

1. Operates on alternative to petroleum;
2. Few vehicles on the road using the technology;
3. Technology exceeds the footprint based target miles per gallon by at least 25 percent.



**President's Proposed
Changes to
Advanced Vehicle
Tax Credits for FY16**

General Explanations
of the
Administration's Fiscal Year 2016
Revenue Proposals



Department of the Treasury
February 2015

Available at:

<http://www.treasury.gov/resource-center/tax-policy/Documents/General-Explanations-FY2016.pdf>