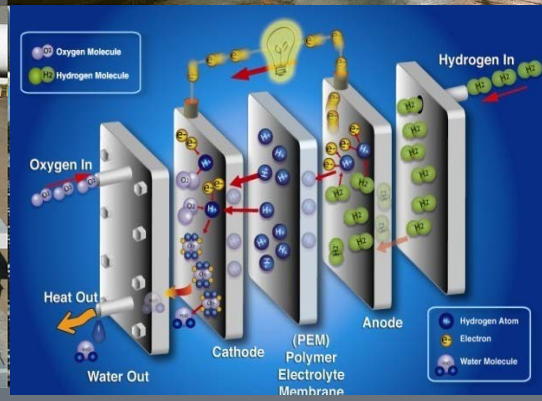
U.S. Department of Energy
Fuel Cell Technologies Office

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

Agenda

- 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"

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 foreign oil & emissions** and enhance energy security

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

FCTO Overview

Mission

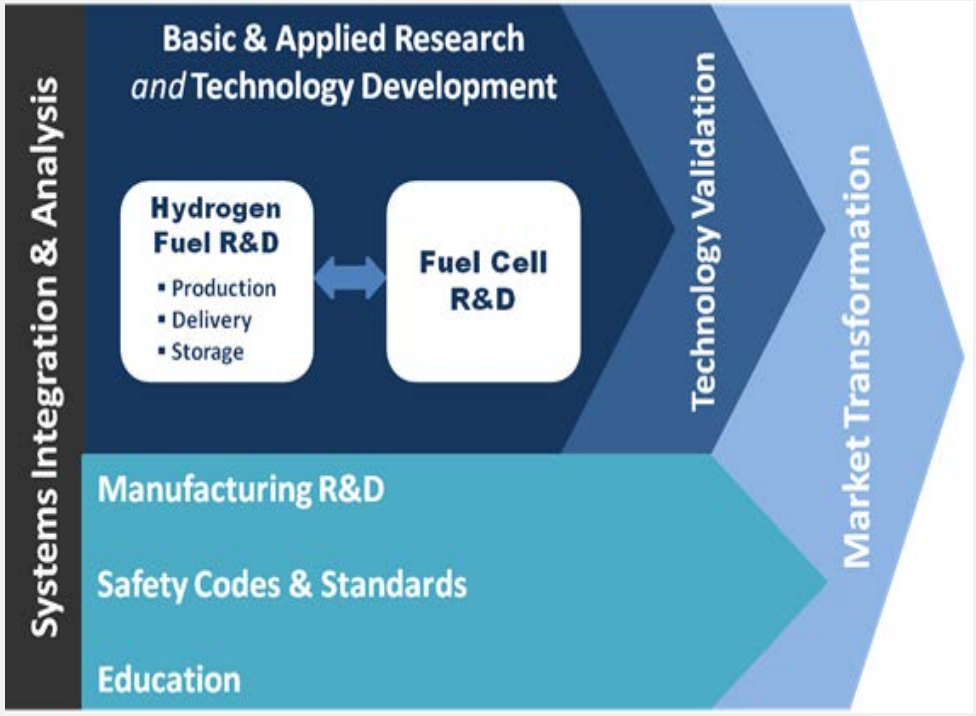
To enable the **widespread commercialization** of hydrogen and fuel cell technologies, which will reduce petroleum use, greenhouse gas (GHG) emissions, and criteria air pollutants, and will contribute to a more diverse energy supply and more efficient use of energy.

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

$124/kW in 2006

$55/kW in 2014* at high volume

*$280/kW low volume

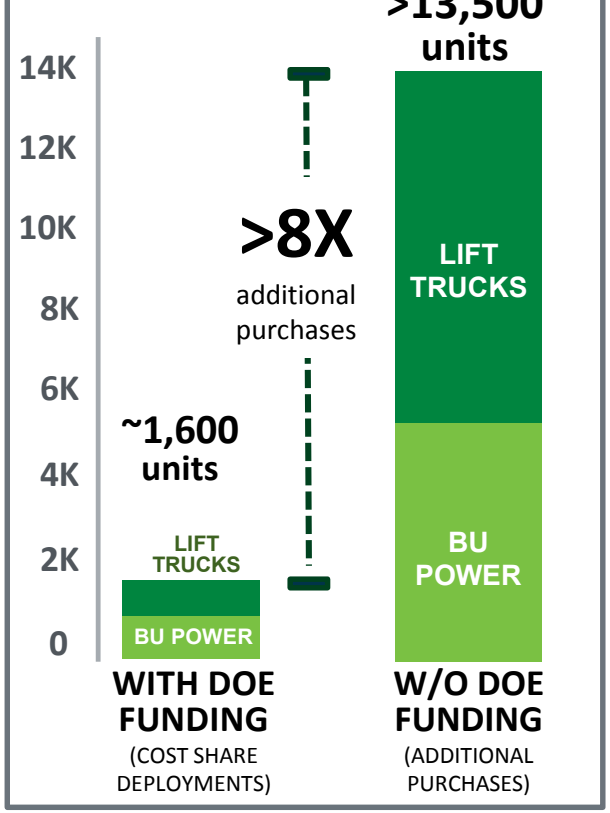
2. Demonstration

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

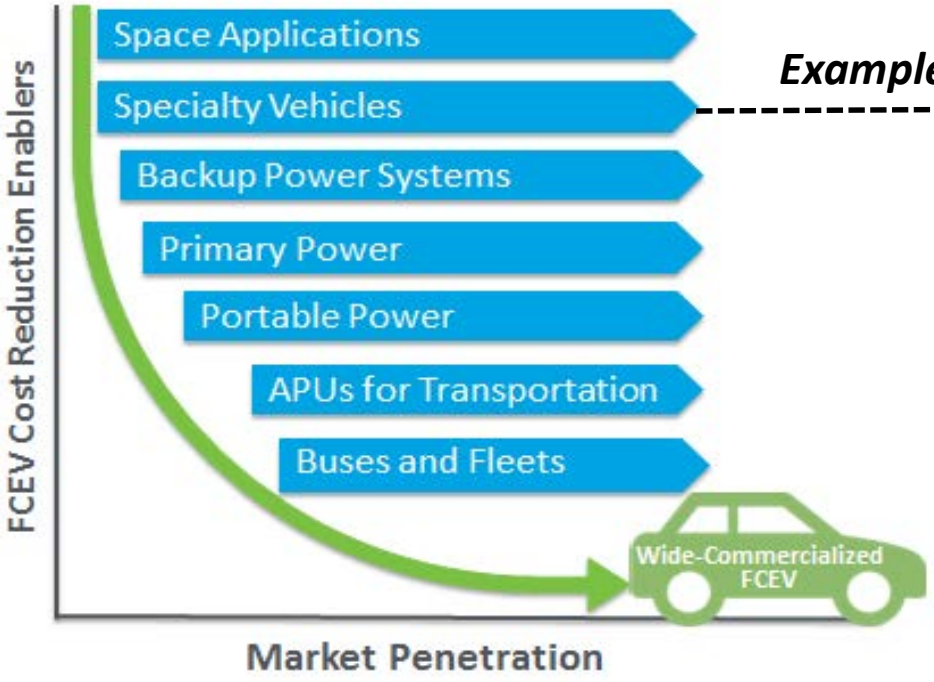
*Bar graphs not drawn to scale

Early Market Strategy

Early Markets enable:

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

Early Market Application Examples



Example

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

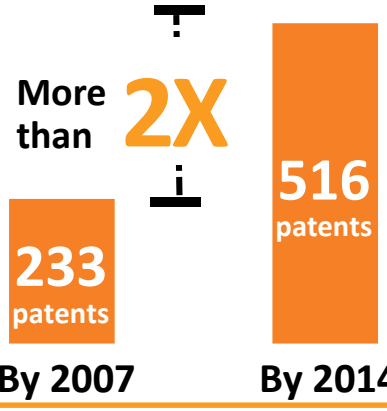
facebook Post Stats:

More than **180 shares** **240 likes** → **Over 45,000** people reached

DOE Impact- H_2 and Fuel Cells

Innovation

Cumulative Number of Patents



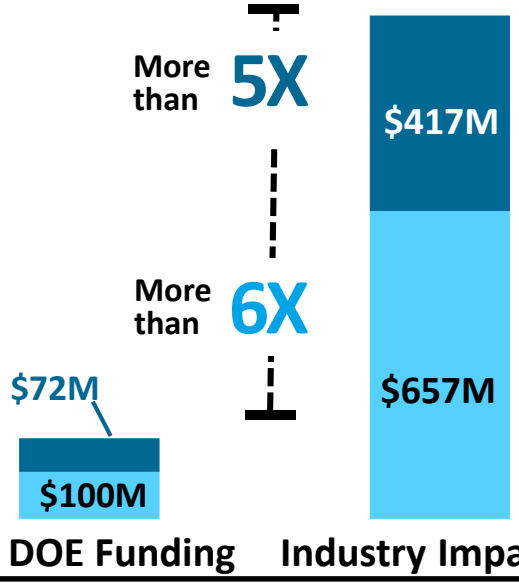
Commercialization

Commercial Technologies Entering the Market

Return on Investment

DOE impact on Private Investment and Industry Revenues

Preliminary Analysis



Jobs from commercial technologies and ARRA

More than **450 jobs** tracked per year

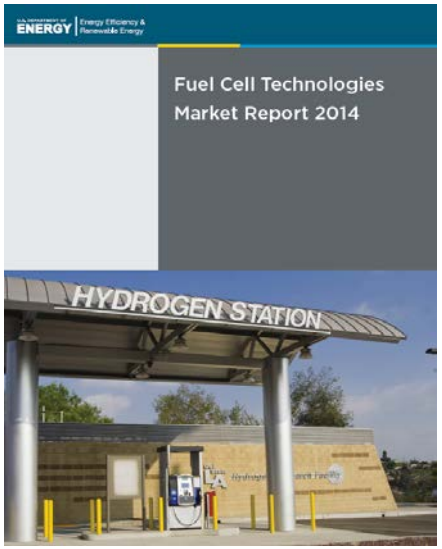
1,400 jobs created or sustained

Commercial Technologies- Examples

- Catalysts
- Electrolyzers
- Tanks
- Fuel Cell System Components

Fuel Cells- Steady Market Growth

Market Report Just Published!



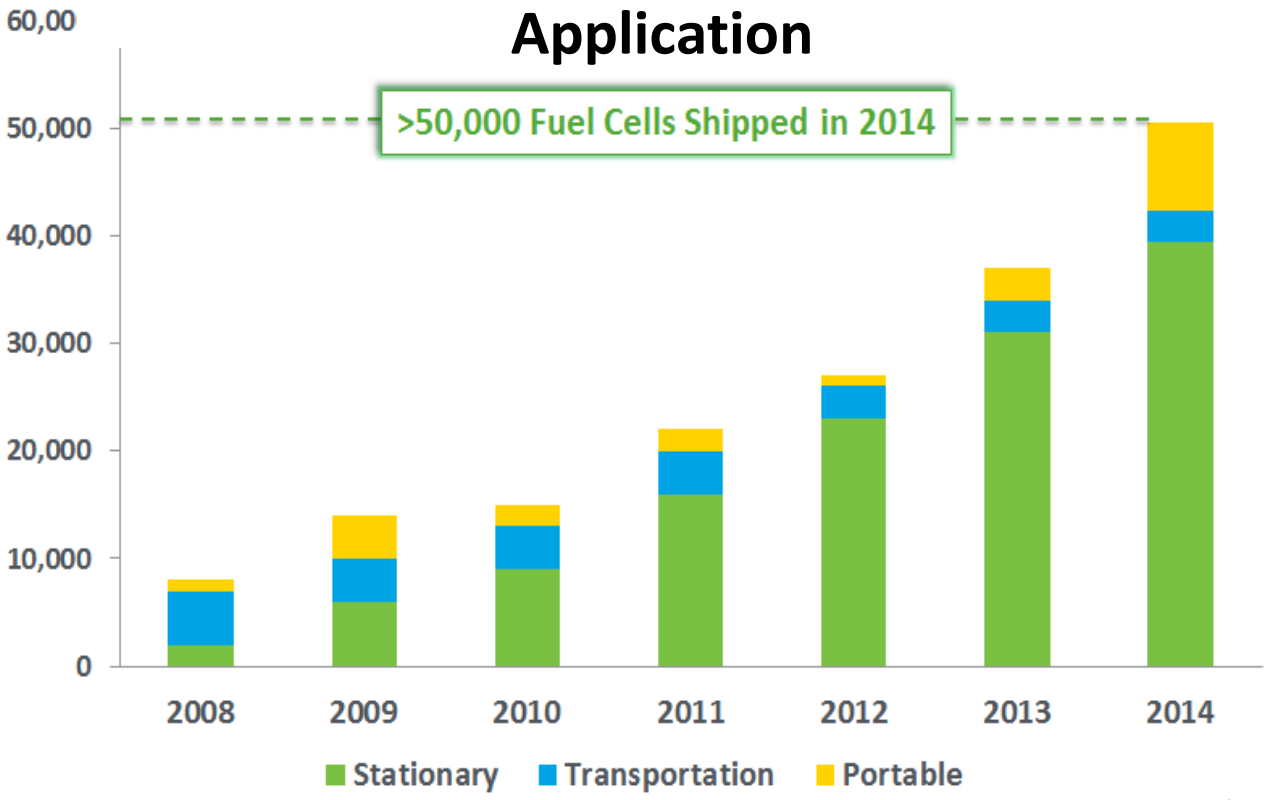
In 2014…

>$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

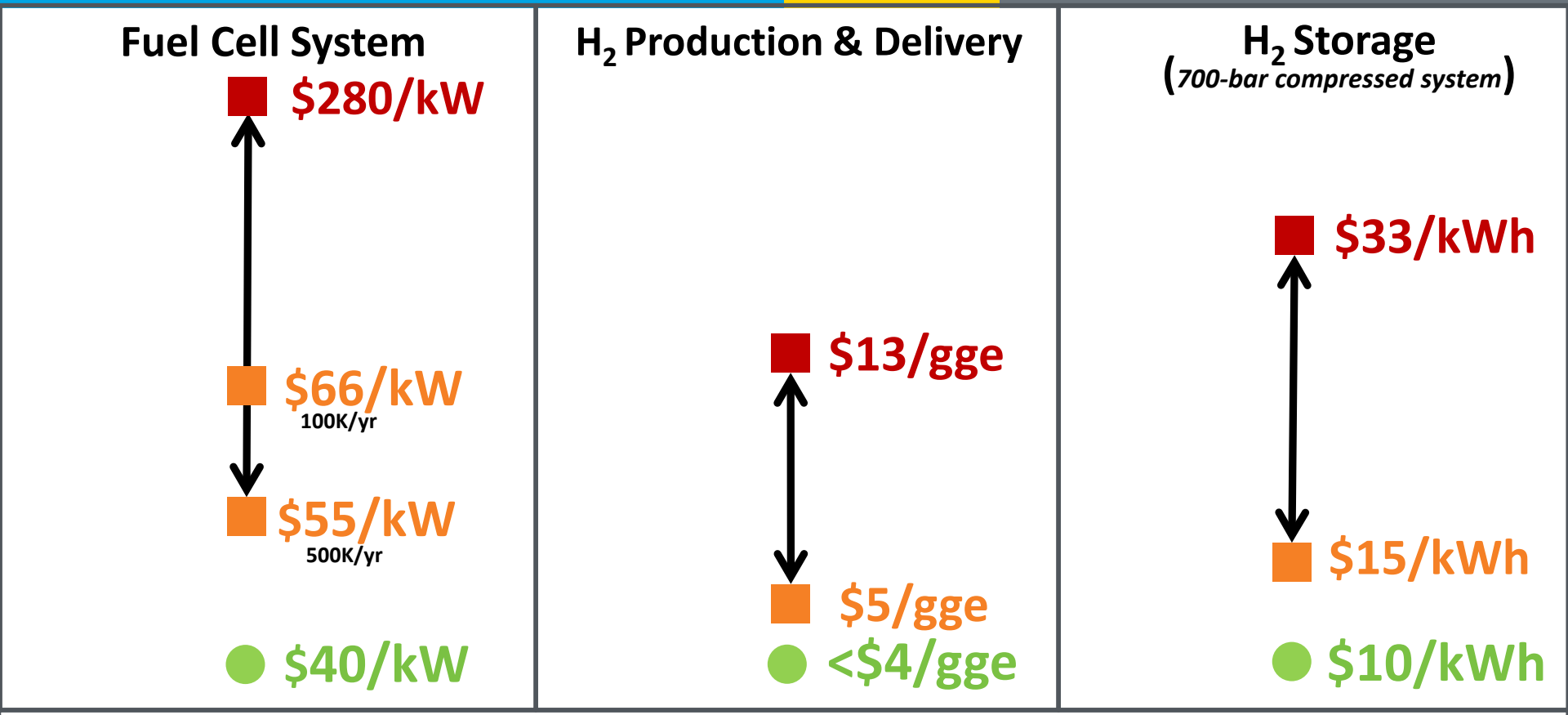


Source: Navigant & E4tech

- 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



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

H_2 Station

Storage
Cooling
Dispensing
Other

Advanced Compression

Alternate Approaches

H_2 Storage

BOP/Assembly
Other processing
Resin

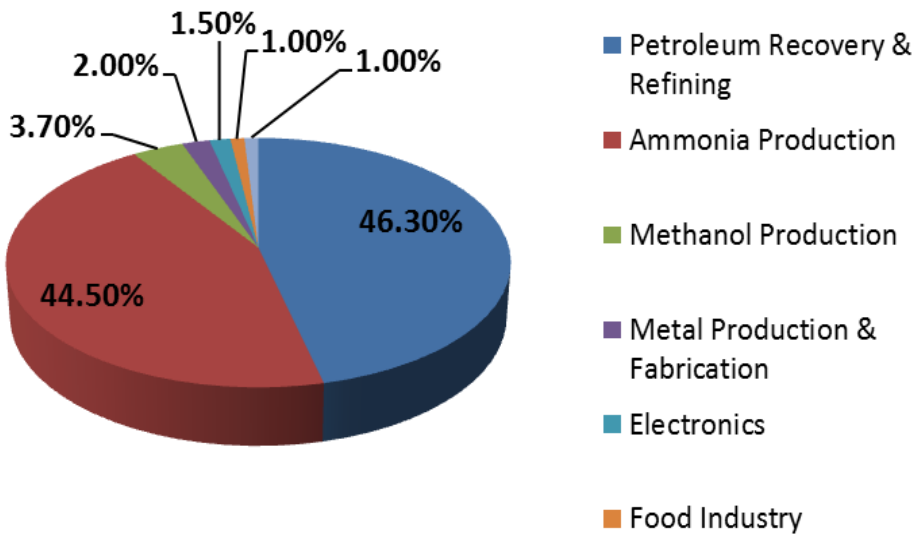
Low Cost Carbon Fiber (CF)

Long term Materials Approaches

U.S. H_2 Production: Current Status

~10 million metric tons of H_2 mostly:

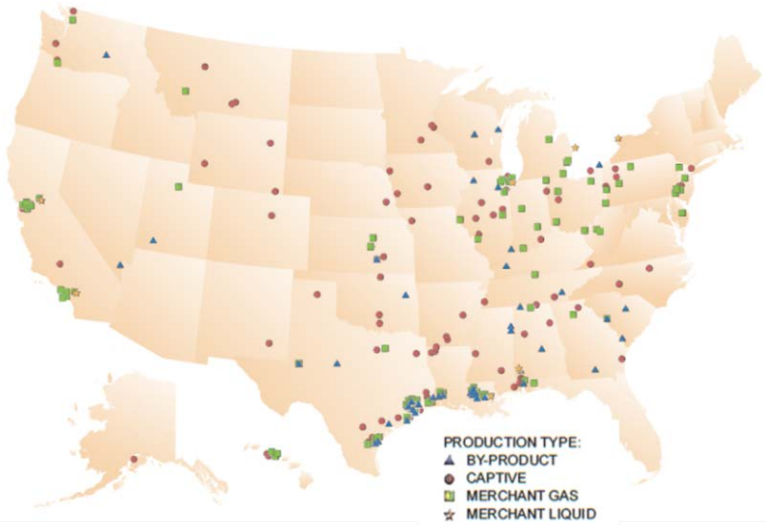
- From **steam methane reforming of natural gas (SMR)**
- For **petroleum refining**, ammonia production



H_2 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 H_2 production facilities

Early adoption of H_2 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** H_2 stations and FCEVs launched in **4** urban areas by 2015

H2Mobility

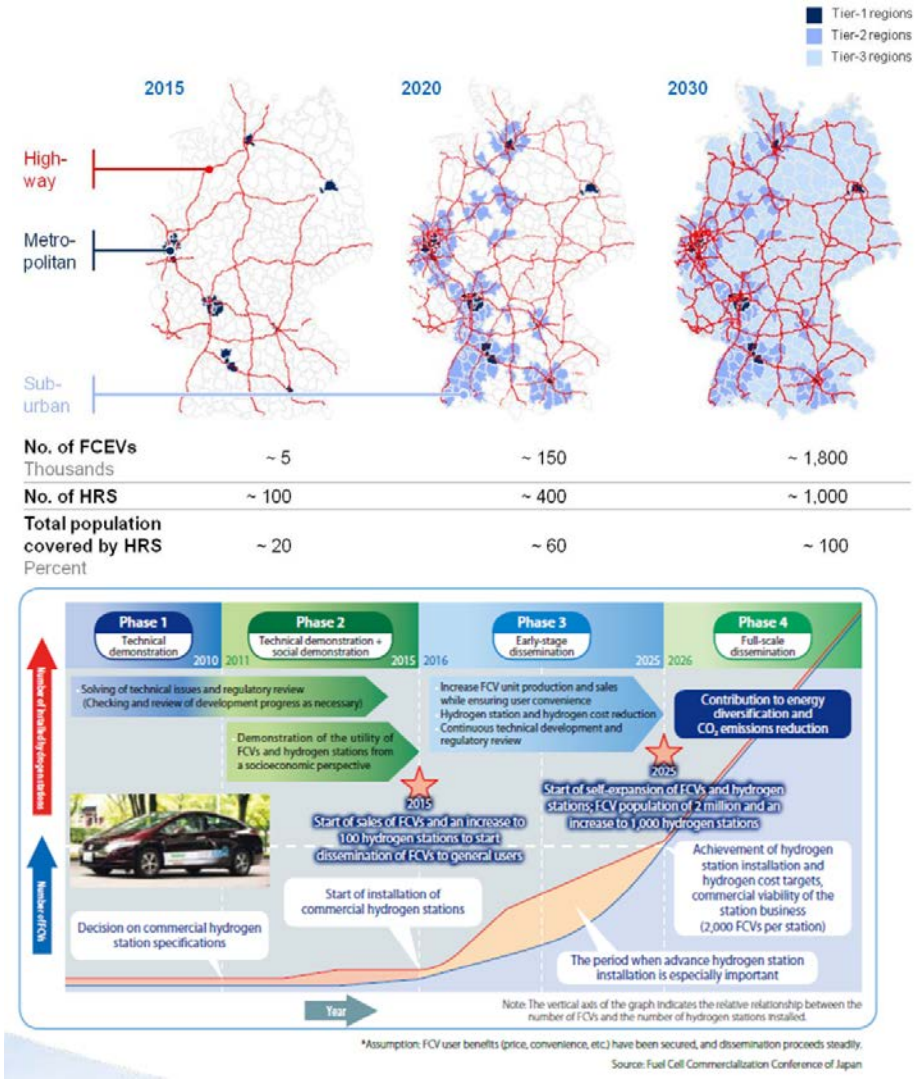
- Public-private initiative for nationwide H_2 infrastructure—will develop into joint venture to install stations.
- **50** H_2 stations (public-private funds committed); and **5,000** FCEVs expected on the road by 2015

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 H_2 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 H_2 infrastructure within 2014 and 2015 timeframe.



International partnerships established to accelerate hydrogen infrastructure

H_2USA: Public-Private Partnership

H_2USA

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

H_2FIRST Coordination panel

H_2FIRST

H_2USA's Working Groups

- **Hydrogen Fueling Station**
- **Locations Roadmap**
- **Financing Infrastructure**
- **Market Support & Acceleration**

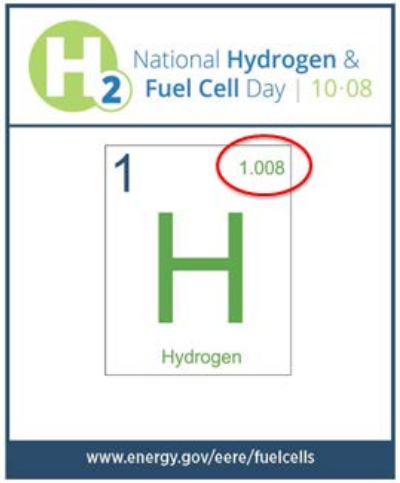
More than 45 partners working towards adoption of FCEVs and H_2

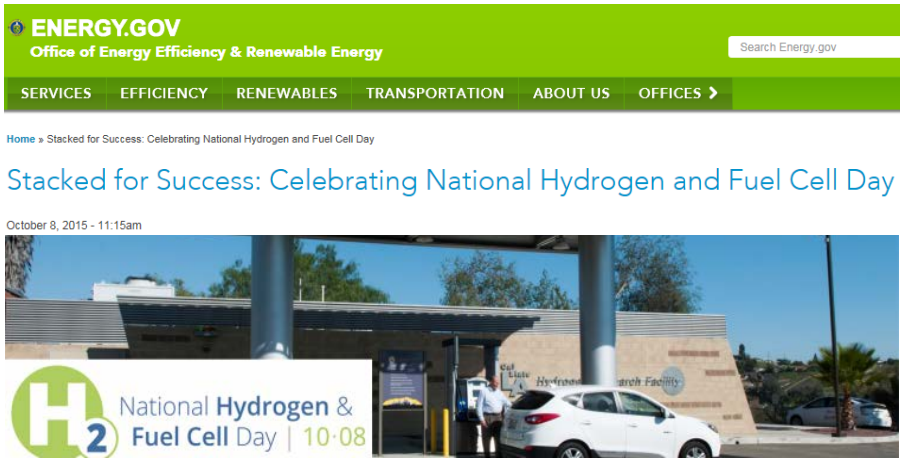
Key HTAC Recommendations and Responses

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 H_2 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	H_2 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 H_2 Stations to Stakeholders

On Current Status:

- **53 H_2 stations**
- **8 open**
- **15 under construction**

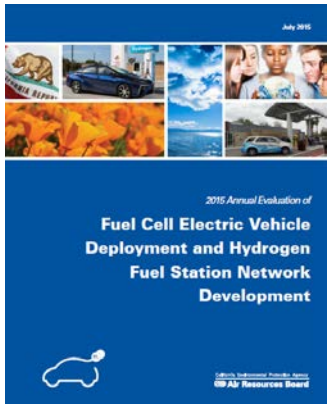
Open - Retail	2
Open - Non-Retail	6
Commissioning	6
Under Construction	15
Approval to Build	3
Planning Approval	4
Permit in Process	6
Pre-Permit Application	4
Site Acquisition	7

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 H_2 infrastructure challenges unique to retailers**
- **Request for feedback on H_2FAST and H_2 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 H_2 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 H_2USA

H_2USA

- **Tools recently developed through DOE supporting H_2USA**
  - **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 H_2 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**
- **Includes H_2 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 - H_2 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 Request ($ in thousands)	FY 15 Approp. ($ in thousands)	FY 16 Request ($ in thousands)
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

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

[2]Estimated from FY14 appropriation

More stable R&D funding requests and appropriations in recent years

> 20 new projects including 11 new Incubator projects (2014-2015)

Going Forward

- **Continue to strengthen R&D activities and accelerate Tech to Market (Lab impact)**
  - **H_2, 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**

Examples of Key Activities: HTAC and Program Impact

- Annual Report
- Prior input on Program Requests
  - H_2 cost target revision ✓
  - H_2 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
- H_2 Energy Storage (Enabling Renewables) Subcommittee

Thank You

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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**

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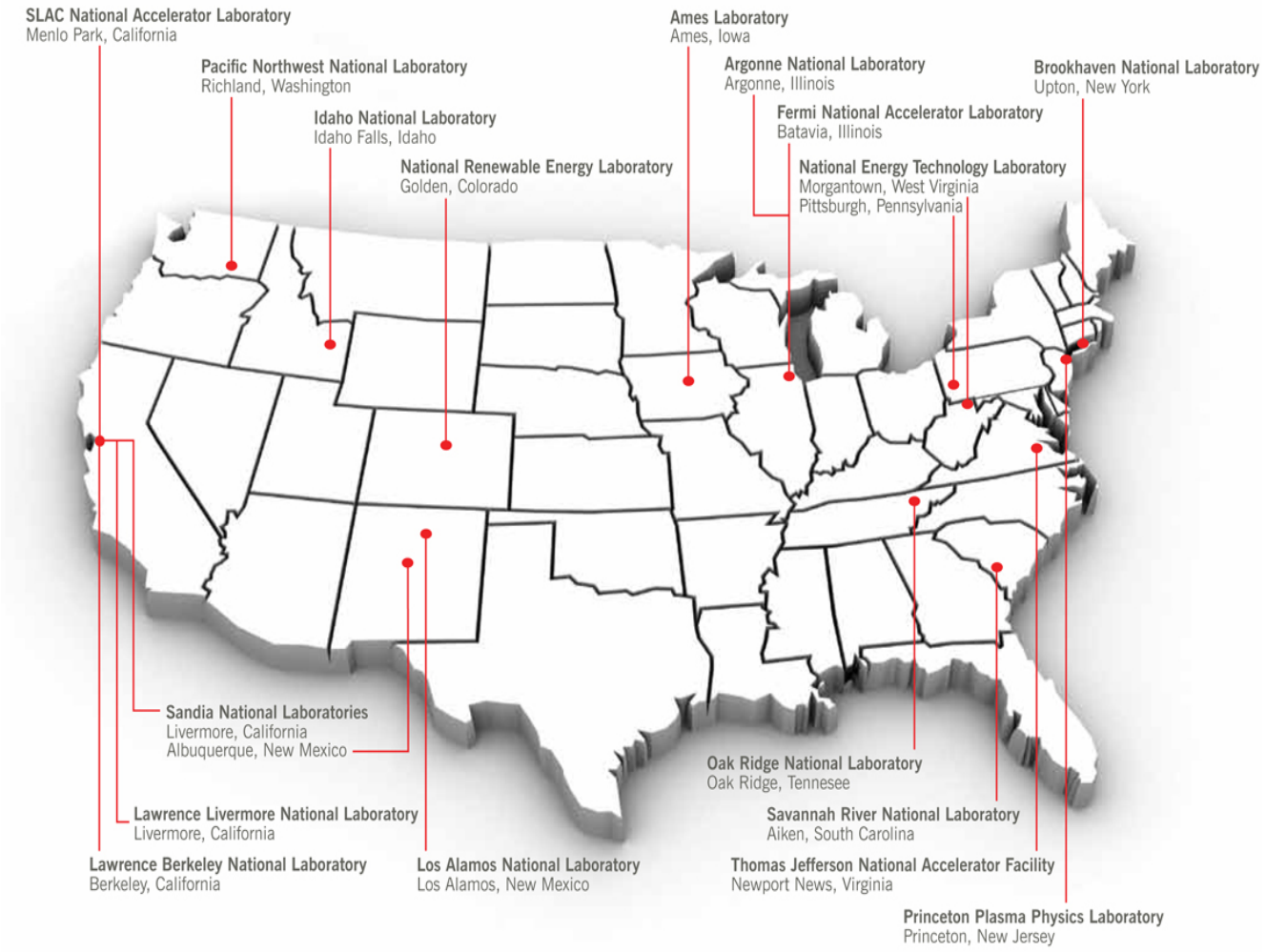
DOE Labs: A Reservoir of Talent for Science and Technology

Where in the US?



Graphic taken from "A Decade of Discovery" DOE. 2008

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

Tech-to-Market (T2M) Strategy for National Labs

T2M Strategy

	Activities	Goals
Increase Industry Contact	• Business-to-Business Product Theater at conferences • Manufacturing Road Show • Small Business Vouchers	**Increase Market Understanding**
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	**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

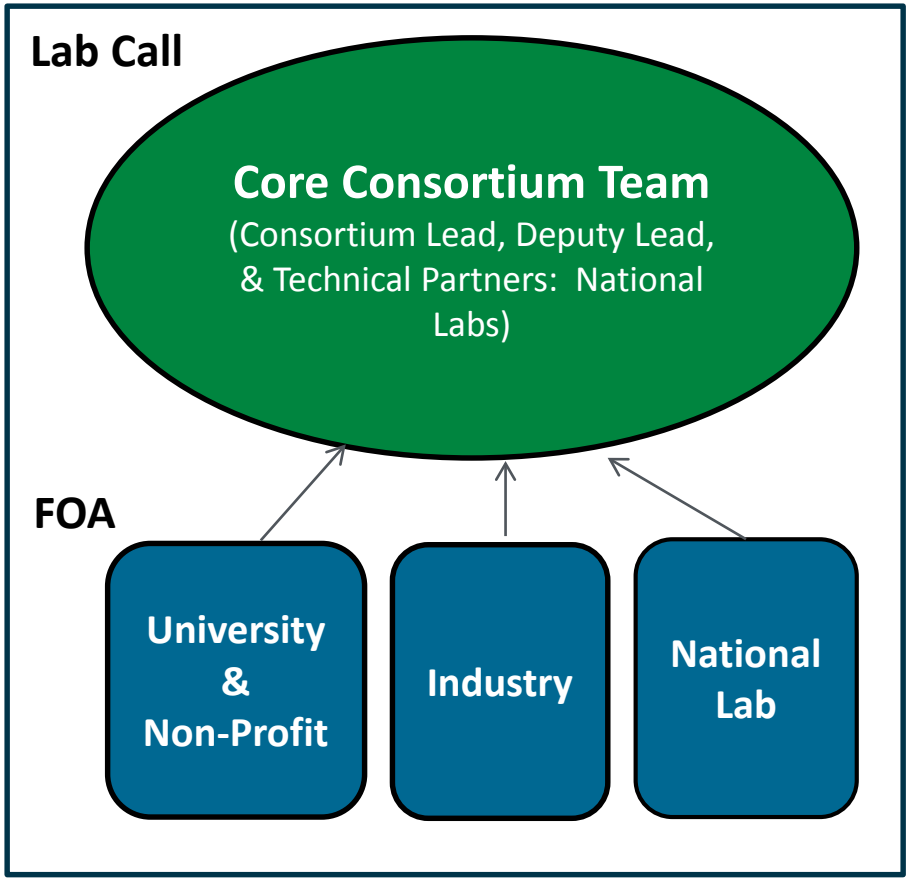
* Subject to appropriations

Potential Future Collaborations

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

Strategy and Structure

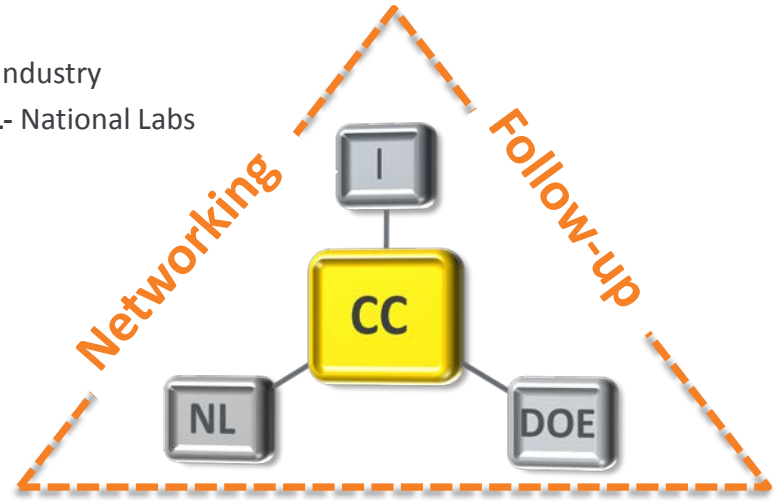
Multi-Lab team with Lab Call to competitively select core team



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
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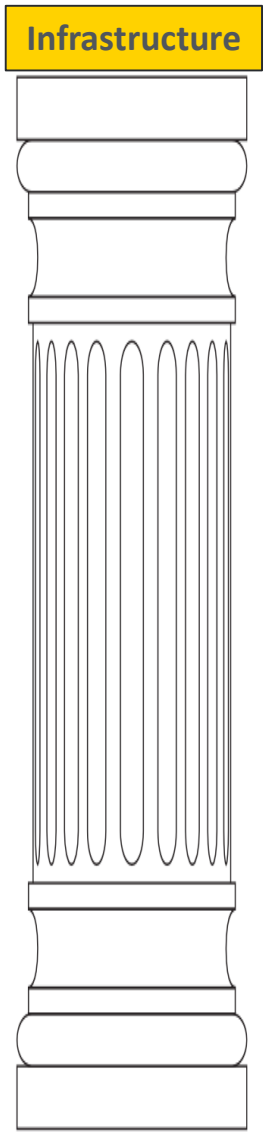
EERE-funded research has:

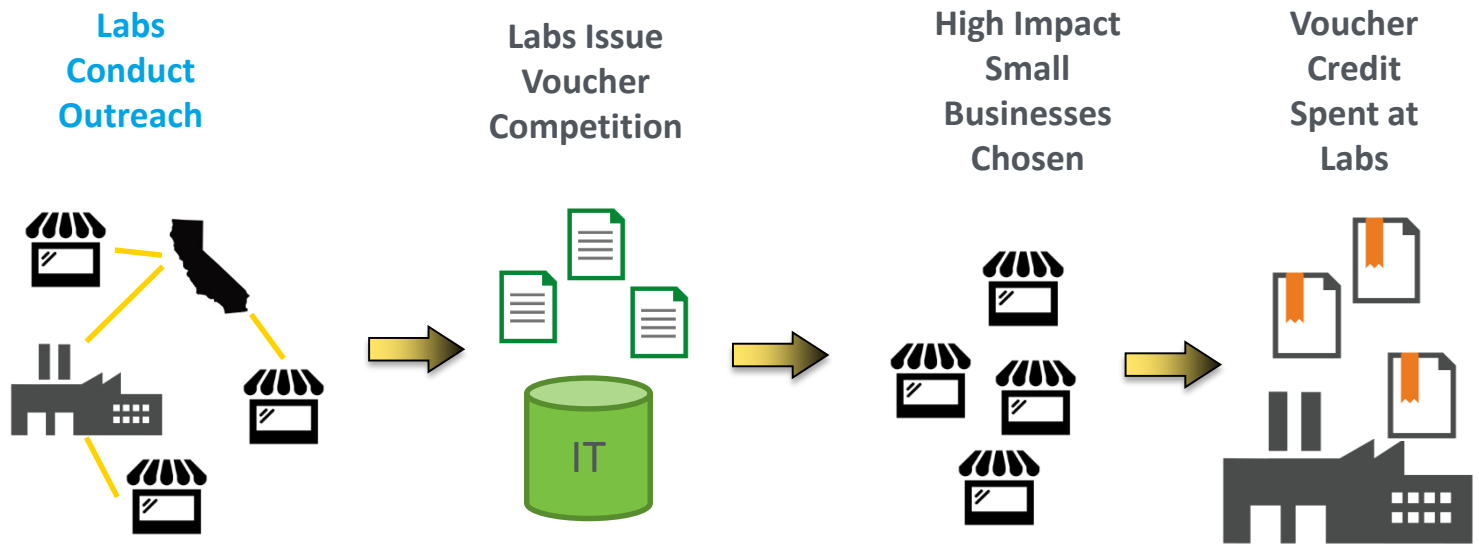
- Reduced cost of fuel cells by more than 50% since 2006 and 30% since 2008
- Achieved a more than five-fold reduction in the platinum content of fuel cells
- Led to more than 500 patents, 45 commercial technologies, and 65 emerging technologies that will be commercialized in the next 3-5 years
- http://energy.gov/eere/fuelcells/downloads/2014-pathways-commercia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



Major Components:

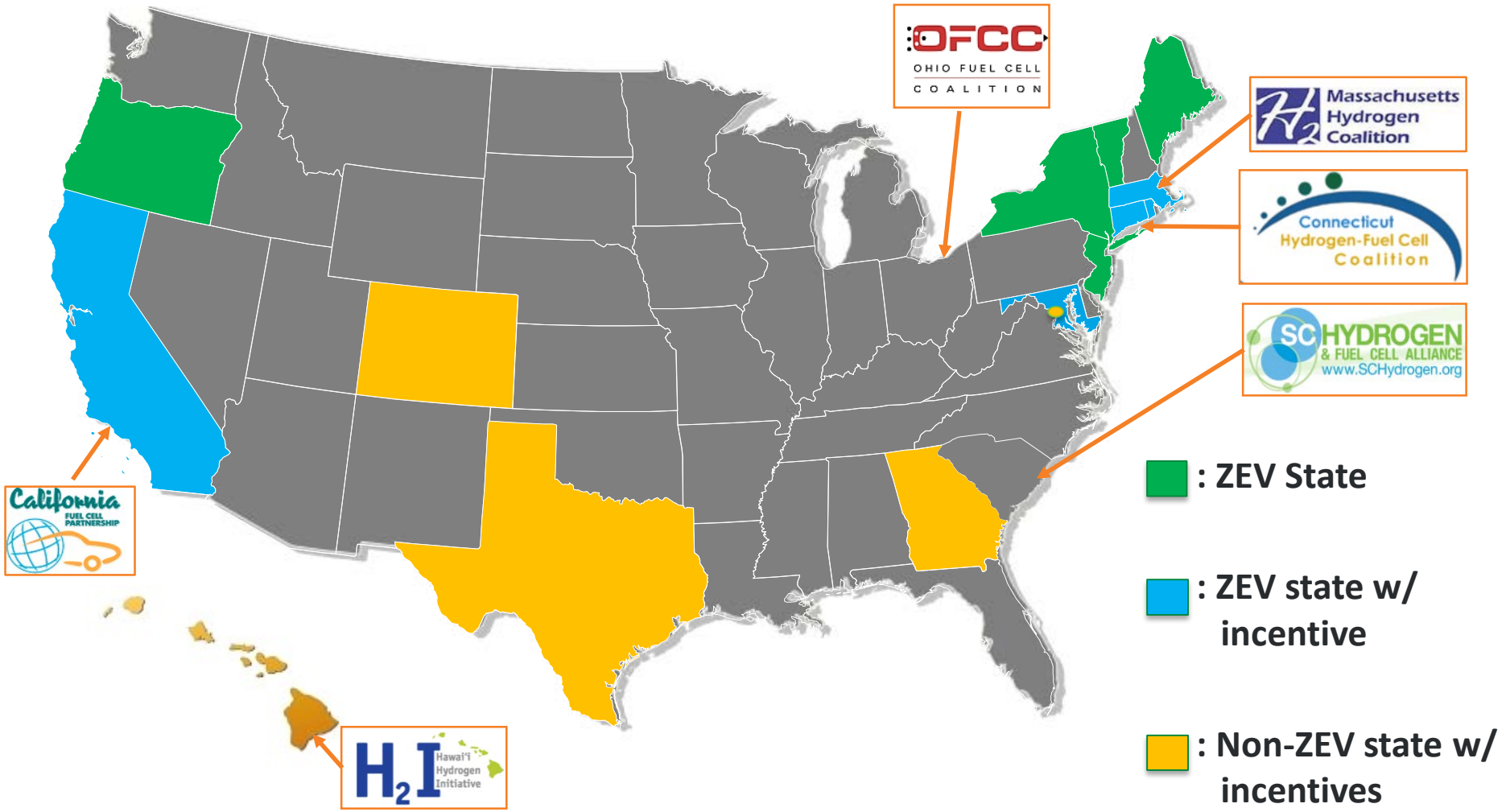
- Lab Call
- *IT Platform*
- *Outreach*
- *Lab Infrastructure*
- Voucher Work
- *Standard IP terms*
- *Third Party Evaluation*

FY15 Funding = $20M

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

State-related information

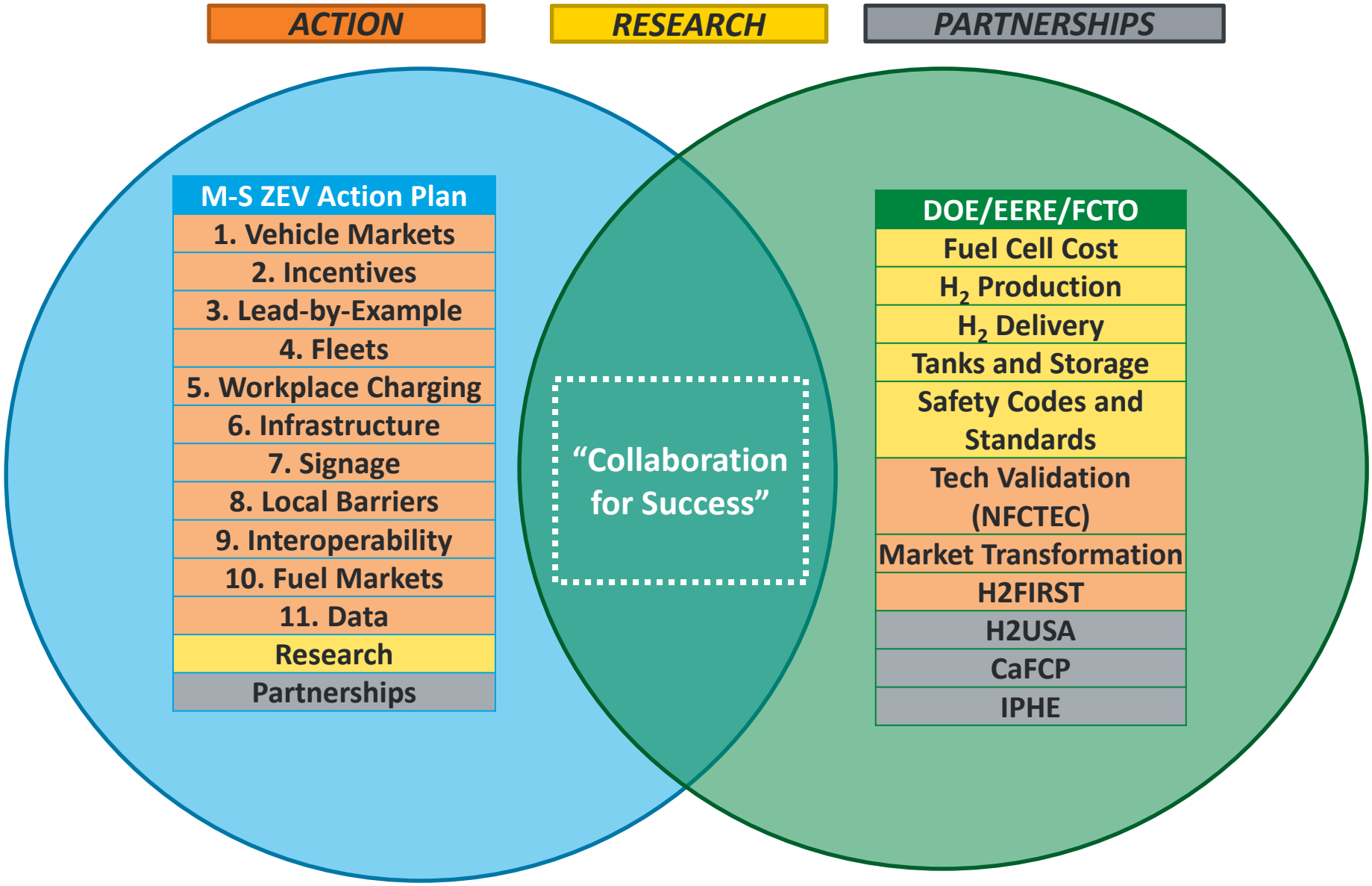
State FCEV/H2 Incentives and Partnerships



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 H_2 station deployment

Examples of Activities Supporting ZEV Action Plan



Northeast Hydrogen Fuel Cell Cluster Economic Impact

- **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**

The Connecticut Center for Advance Technology, Inc.

www.ccat.us

DOE Jobs Tool developed by ANL to estimate H2 and FC jobs potential

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)

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

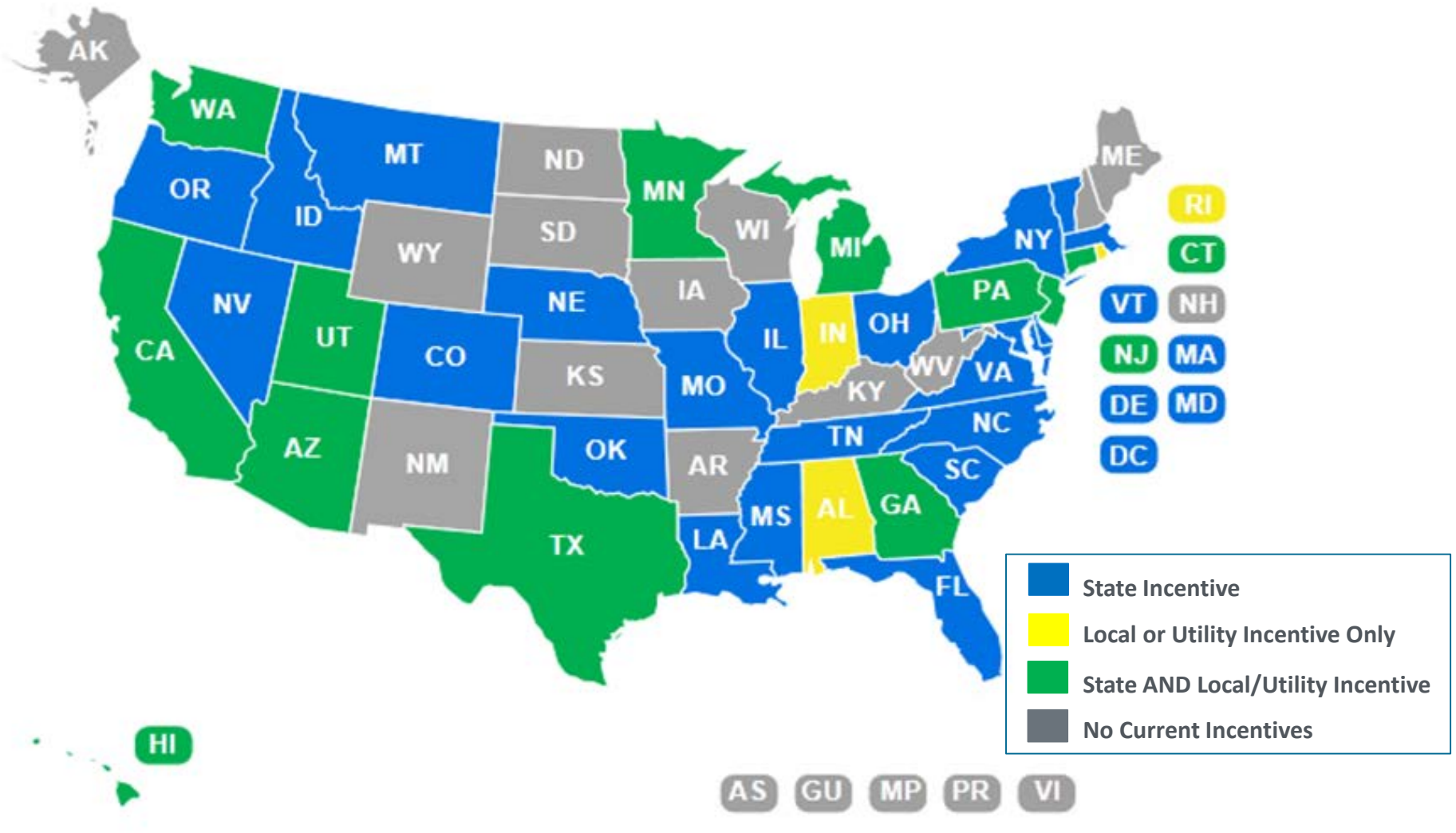
6th International Conference on Hydrogen Safety

October 19-21, 2015 in Kawasaki/Yokohama, Japan (Hosted by Technova)

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 redundency	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 H_2 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
			Reduce effective price	*Outreach and education*	*Non-monetary incentives (including common decal)*	*Local public and private partnerships*	*Multi-state Fleets Users Forum*	*Common data collection and information sharing*	*Pooled purchases*
H2USA	Market Support and Acceleration Working Group	Public & Stakeholder Education		x		x		x	
		H2USA Website, FAQs		x				x	
		Joint Codes & Standards Task Force							
		Station Siting							
	Investment and Finance Working Group	Financial Incentives & Scenario Analysis	x			x		x	
		Investor Outreach & Coordination		x				x	
	Hydrogen Fueling Station Working Group	Station Cost & Utilization Research						x	
		Station Equipment & Component R&D							
		Regulations, Codes & Standards; Addressing Market Barriers							
		Regional Station Metrics Coordination						x	

DOE Activities

ZEV Actions

Infrastructure Guide and Cost Estimation Tool in Development

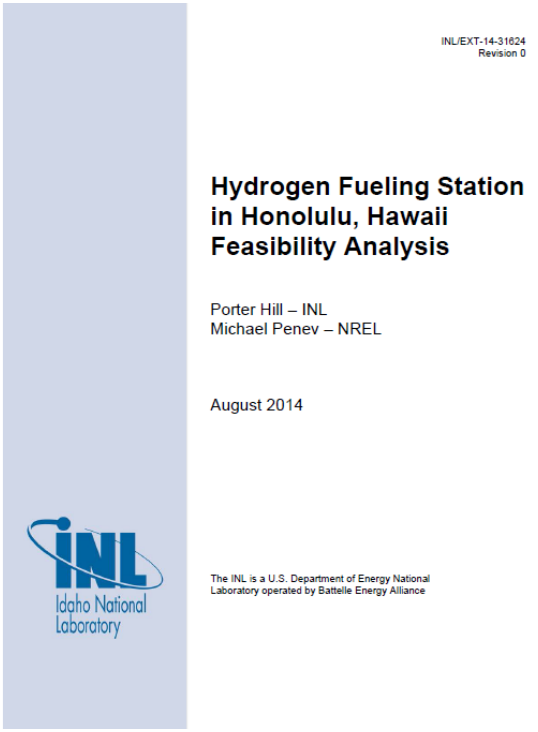
DOE is helping to develop a H2USA Infrastructure Guide and a Cost Estimating Model aimed to help relevant stakeholders address challenges related to H_2 and FCVs.

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

INL Idaho National Laboratory

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

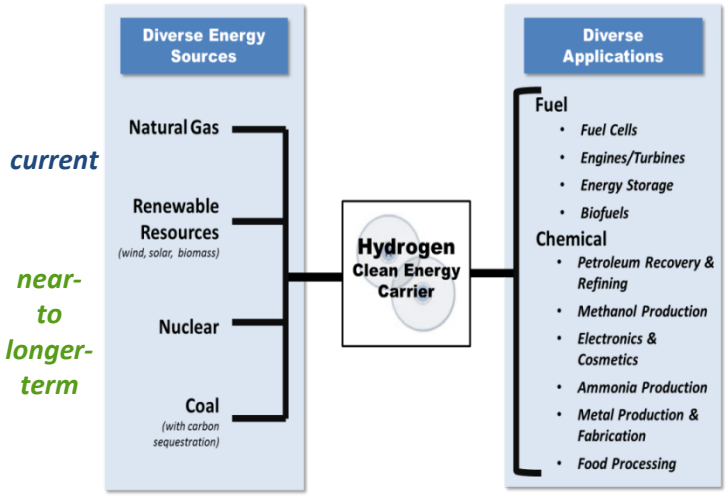
Examples of relevant areas from QTR

QTR Feedback

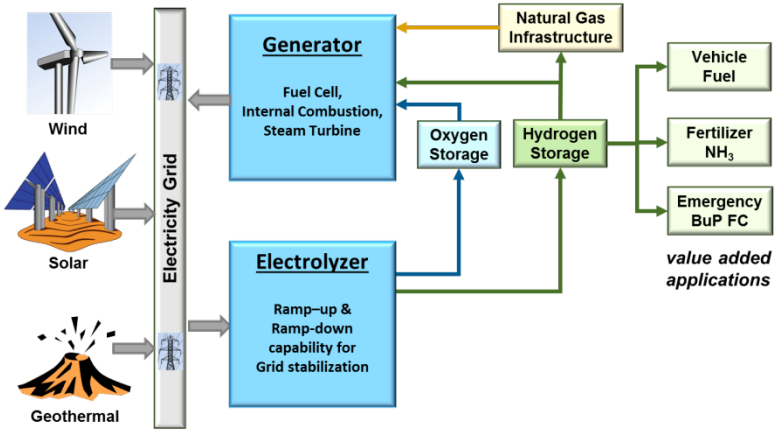
- **Major challenges:**
  Reduce the cost of producing and delivering H_2 from renewable/low-carbon sources for FCEV and other uses (capex, O&M, feedstock, infrastructure, safety, permitting, codes/standards)

- **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 H_2), energy storage balance-of-plant improvements, etc.
  - Cost reductions in H_2 compression, storage and dispensing components
  - Continued resource assessments to identify regional solutions to cost-competitive H_2



H_2 offers important long-term value as a clean energy carrier



Renewable energy integration options with hydrogen

Note: H2 storage on-board FCEVs is addressed in Ch. 8

QTR - Hydrogen Analysis and Research Goals

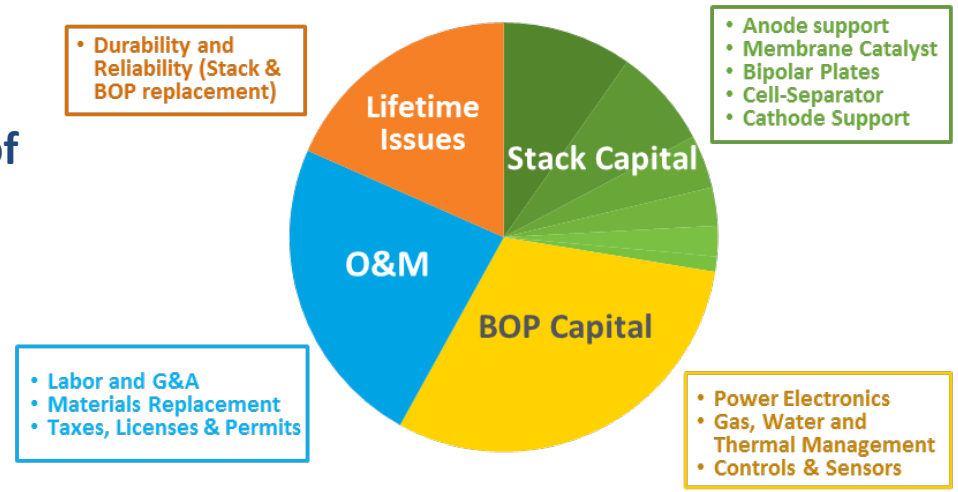
- **Reduce the cost of H_2 from renewable and low-carbon domestic resources to achieve a delivered & dispensed cost of <$4/gge** (Note: 1 kg H_2 ~ 1 gge)

  Pathways:
  - Electrolysis, high temperature thermochemical (solar/nuclear), biomass gasification/bio-derived liquids, coal gasification with CCS, biological & photoelectrochemical

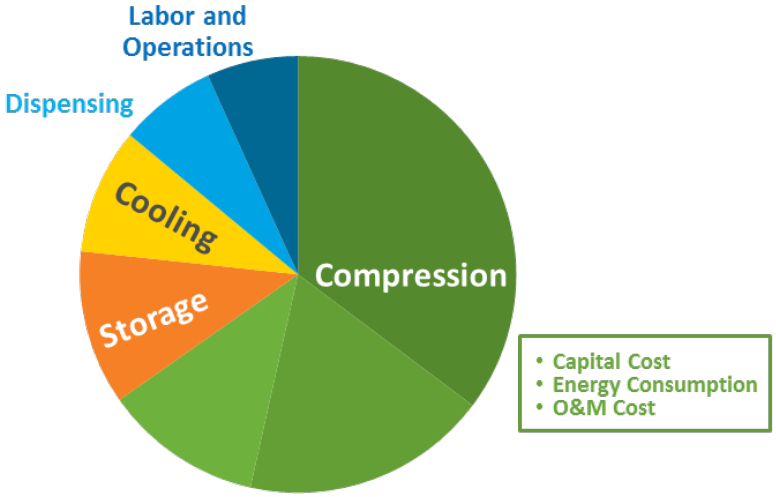
- **Need R&D in materials and components to improve efficiency, performance, durability, and reduce capital and operating costs for all pathways**
  - For many pathways, feedstock cost is a key driver of H_2 cost

- **Need strong techno-economic and regional resource analysis**

- **Opportunities for energy storage (e.g. curtailed wind for electrolyzing water)**



H_2 Production Example- Cost Breakdowns for PEM electrolysis, (excluding electricity feedstock costs)

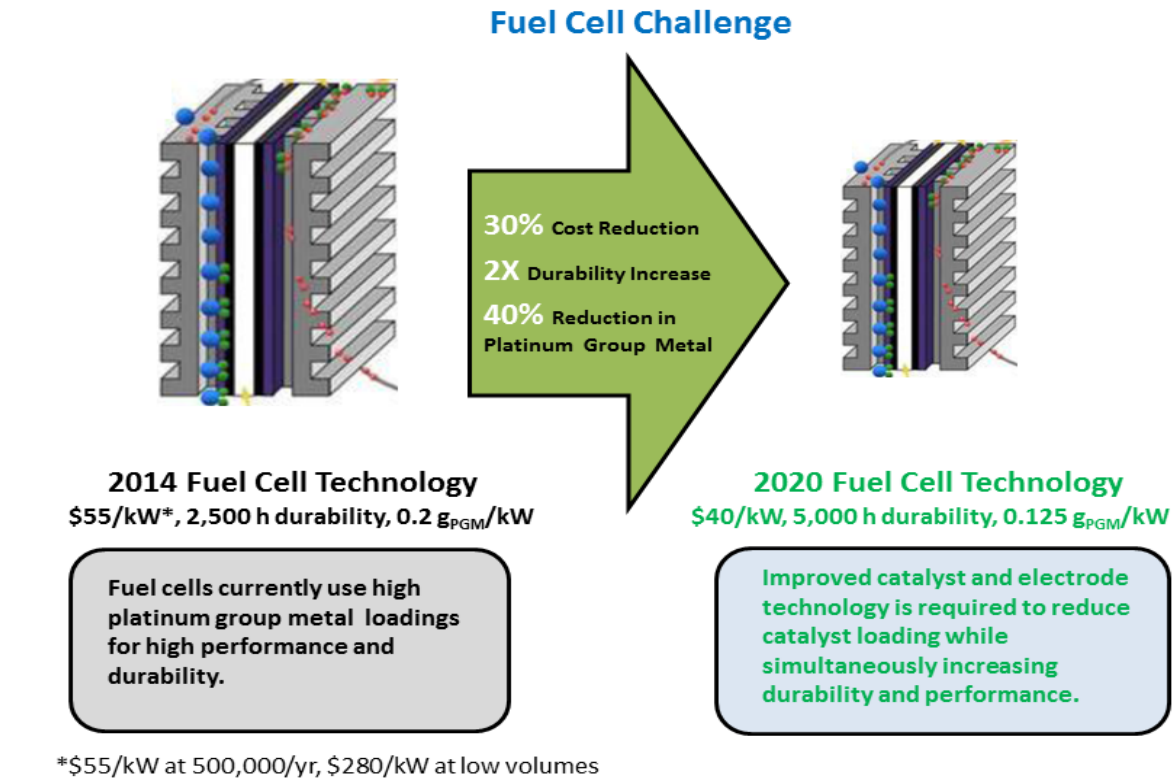


H_2 Delivery Example- Compression, Storage and Dispensing (CSD) Cost Breakdown for the Pipeline Delivery Scenario

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



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

Key HTAC Recommendations and Responses (April 2015 Meeting)

Recommendations	Key Responses
Emphatic public support for FCEV deployment to inspire confidence and increase public awareness.	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.
Stronger commitment to R&D to ensure U.S. technology leadership.	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.
Collaboration with infrastructure initiatives in Germany, Japan, Korea, and the UK on technical and regulatory issues to reduce cost and accelerate deployment.	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.
Direct investment in H2 infrastructure as part of a integrated strategy or comprehensive National Energy Policy to accelerate deployment and attract private investment.	Committed to H_2USA, 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)

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, performance durability, components	Non PGM Catalysts AEMs
	Hydrogen Storage	700 bar tanks, composites, cryo-compressed	Materials R&D for low P storage
	Hydrogen Production and Delivery	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	Enablers: H2FIRST-Station validation, metering, sensors, etc.	Materials compatibility, sensors, station innovation- H-Prize
	Manufacturing and Supply Chain	Catalyst, MEA and tank manufacturing and QC; cost & reliability; supply chain	Mfg. processes and scale up; strong supply base
	Safety Codes and Standards (SCS)	Set back distances, fueling protocols, Safety Dissemination	Risk mitigation; National and International harmonization of SCS
	Public Acceptance and Awareness	H2Tools Education, Outreach; Early markets; H2USA	Widespread Outreach, Education & Social Acceptance

Level of Difficulty

- High
- Medium
- Low to Medium

H_2 Production & Delivery Technology Strategies

Production method

Central

Established Industrial Process

Natural Gas Reforming

Carbon Mitigated NG & Biogas Reforming

Biomass Gasification

Coal Gasification With CCS

High-temp Electrolysis

STCH

Electrolysis (wind)

Electrolysis (solar)

PEC

Photo-biological

Distributed

Biomass pathways

Solar pathways

Natural Gas Reforming

Electrolysis (Grid)

Bio-derived Liquids

Microbial Conversion

Near-term | Mid-term | Long-term

Delivery method

Tube Trailer Transport

- Mobile Re-fuelers
- High Capacity Tube Trailers
- Forecourt CSD
  - Mechanical compression
  - Station storage
  - Hose dispensers

Liquid Tanker Transport

- Advanced Liquefaction
- Distribution pipelines
  - H_2 embrittlement mitigation
- Advanced Forecourt CSD
  - Advanced compression
  - Intelligent dispensers

Pipeline Transport (& alternatives)

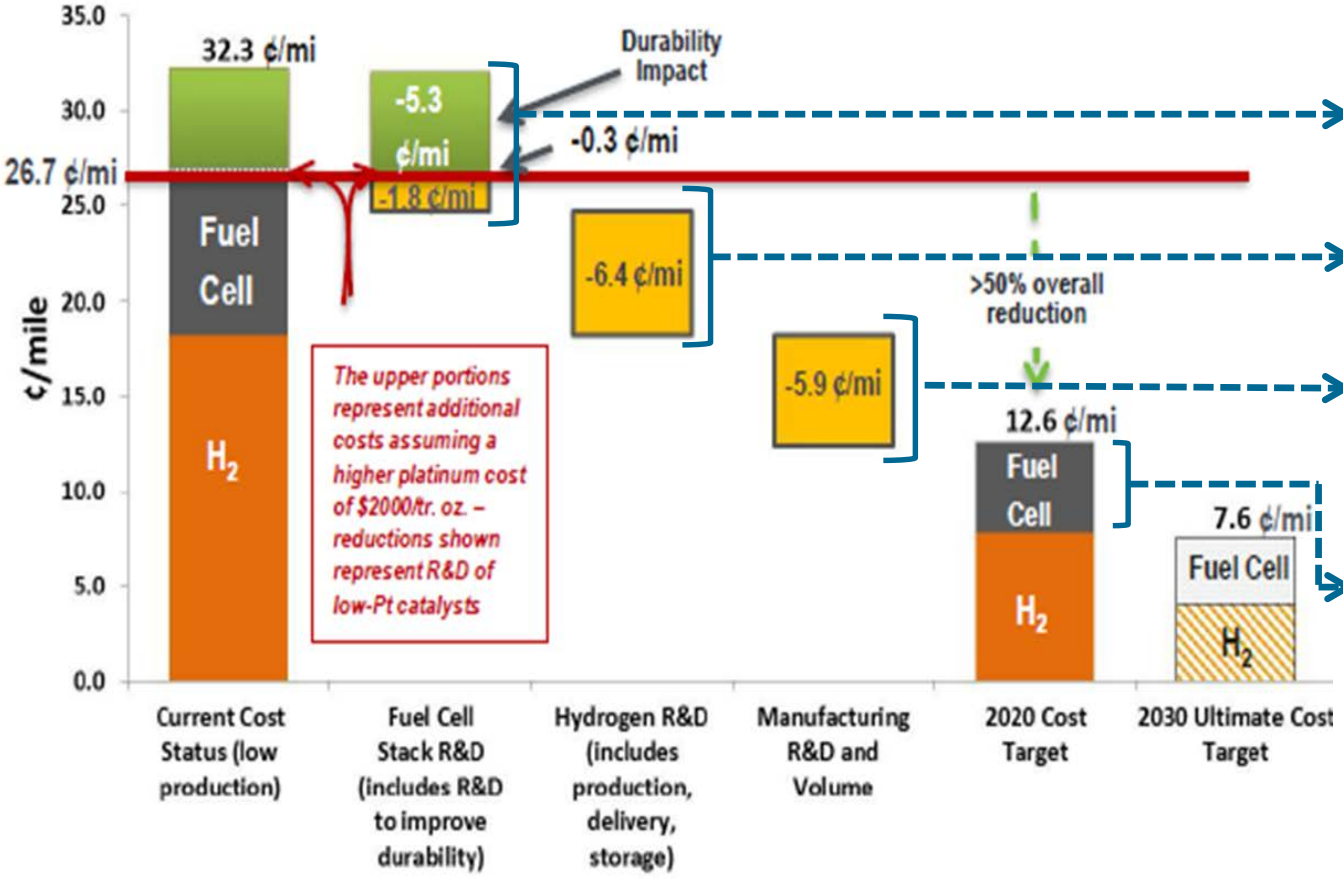
- Fiber Reinforced Pipelines
- Game-changing compressors
- Cold GH2 delivery

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

Cost Analysis and Performance Requirements Drive R&D Strategy

FCEV Cost Reduction Pathways

@ 100,000 units



R&D Needs

- Catalysts, membranes, electrodes, BOP and increase in durability
- H_2 Production, delivery and storage
- Manufacturing R&D and processes, QC and high volume fabrication
- Additional progress needed for ultimate targets

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

Stakeholder Engagement prior to FOA Topics

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 H_2 Storage On-Board FCEVs- (***Planned release date September 15, 2015)

Ongoing

- USDRIVE Tech Teams
- HTAC
- H_2USA/H_2FIRST
- 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			

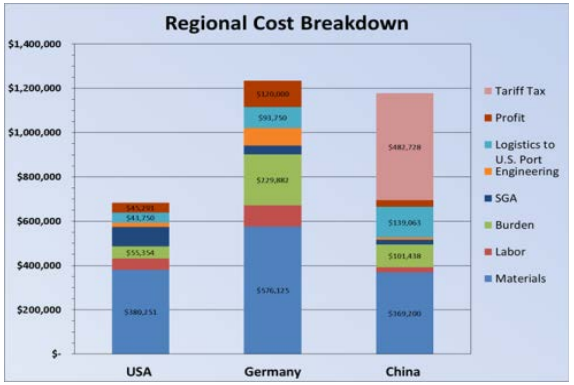
Manufacturing Highlights: 3 New Analysis Projects

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

OFCC OHIO FUEL CELL COALITION

Fuel Cell and H_2 Opportunity Center

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

JAMES MADISON UNIVERSITY

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

International Energy Agency

- Implementing Agreements
- 25 countries

California Fuel Cell Partnership

Connecticut Hydrogen-Fuel Cell Coalition

Massachusetts Hydrogen Coalition

OFCC Ohio Fuel Cell Coalition

SC Hydrogen & Fuel Cell Alliance www.SCHydrogen.org

NESCAUM

H_2I Hawai'i Hydrogen Initiative

- State Partnership and Collaboration

IPHE

- International Government Coordination
- 17 countries and European Commission

H_2 USA

- Public-Private Partnership
- >45 partners

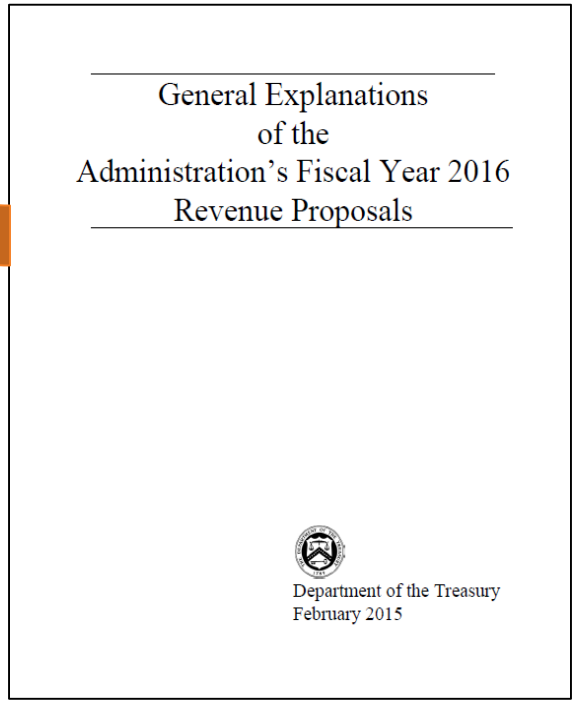
Industry, academia and state & federal stakeholders working together

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)

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

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.