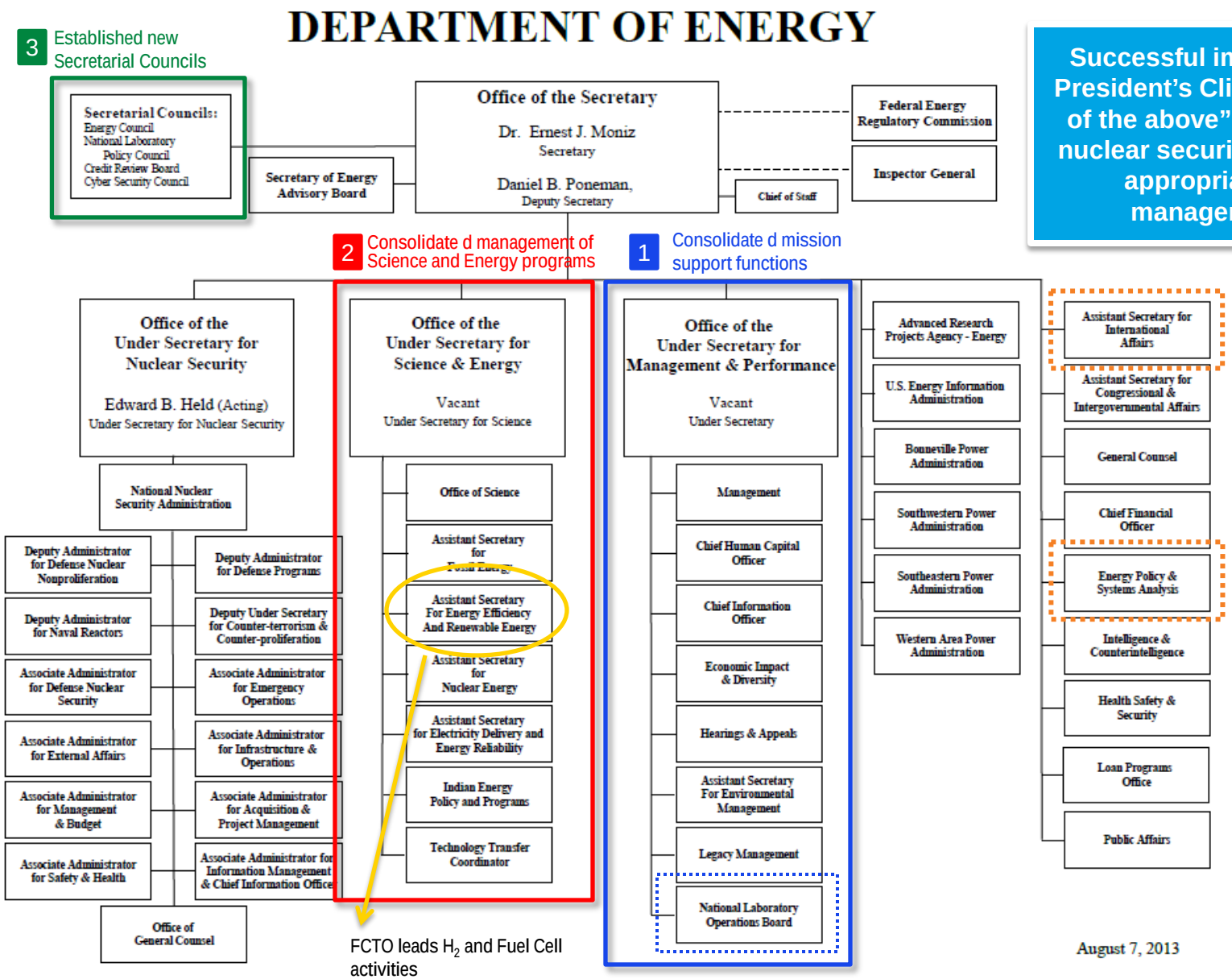
U.S. Country Update

IPHE Steering Committee Meeting

Dr. Sunita Satyapal
Director
Hydrogen and Fuel Cells Program
U.S. Department of Energy

November 20th, 2013
Fukuoka, Japan

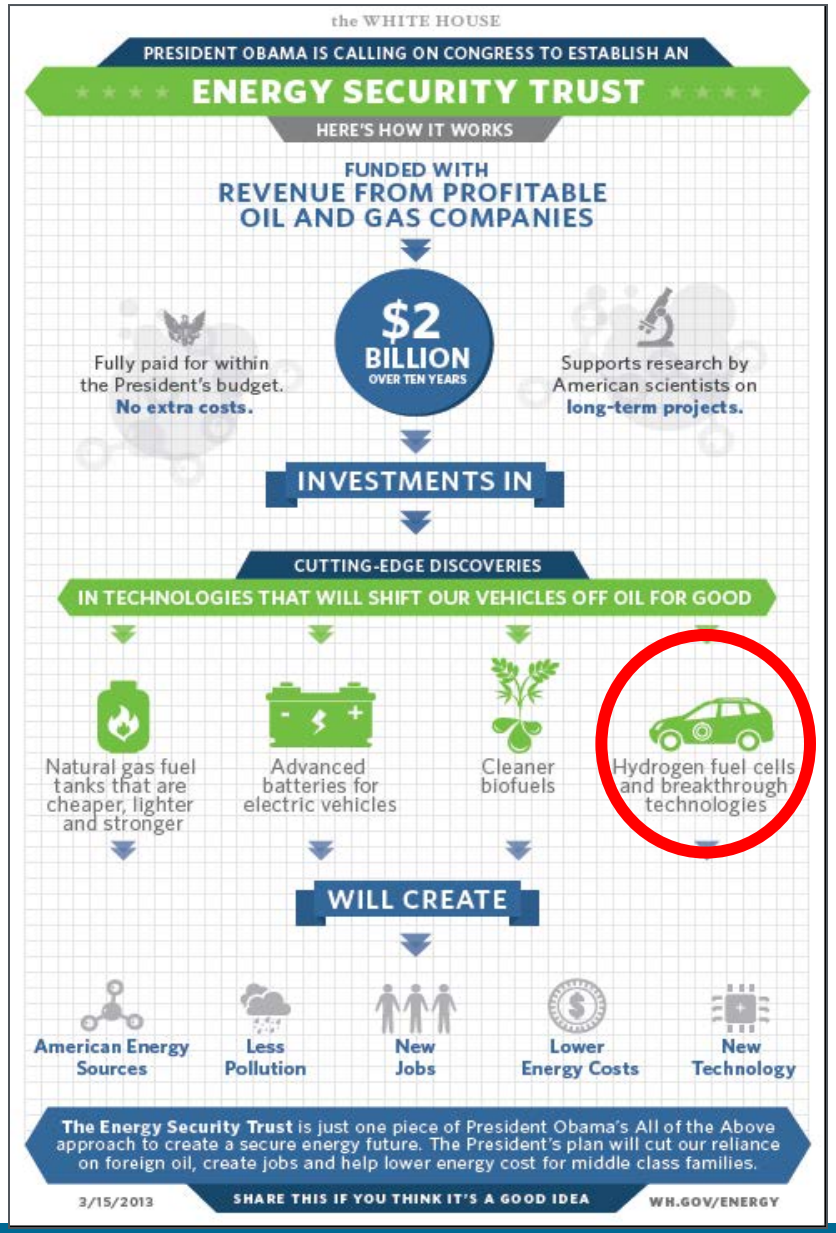
U.S. Dept. of Energy Organization



Successful implementation of the President's Climate Action Plan, "all of the above" energy strategy and nuclear security agenda require the appropriate alignment of management functions.

Split Office of Policy & International Affairs into the Office of Energy Policy and Systems Analysis (EPSA) and the Office of International Affairs (IA)

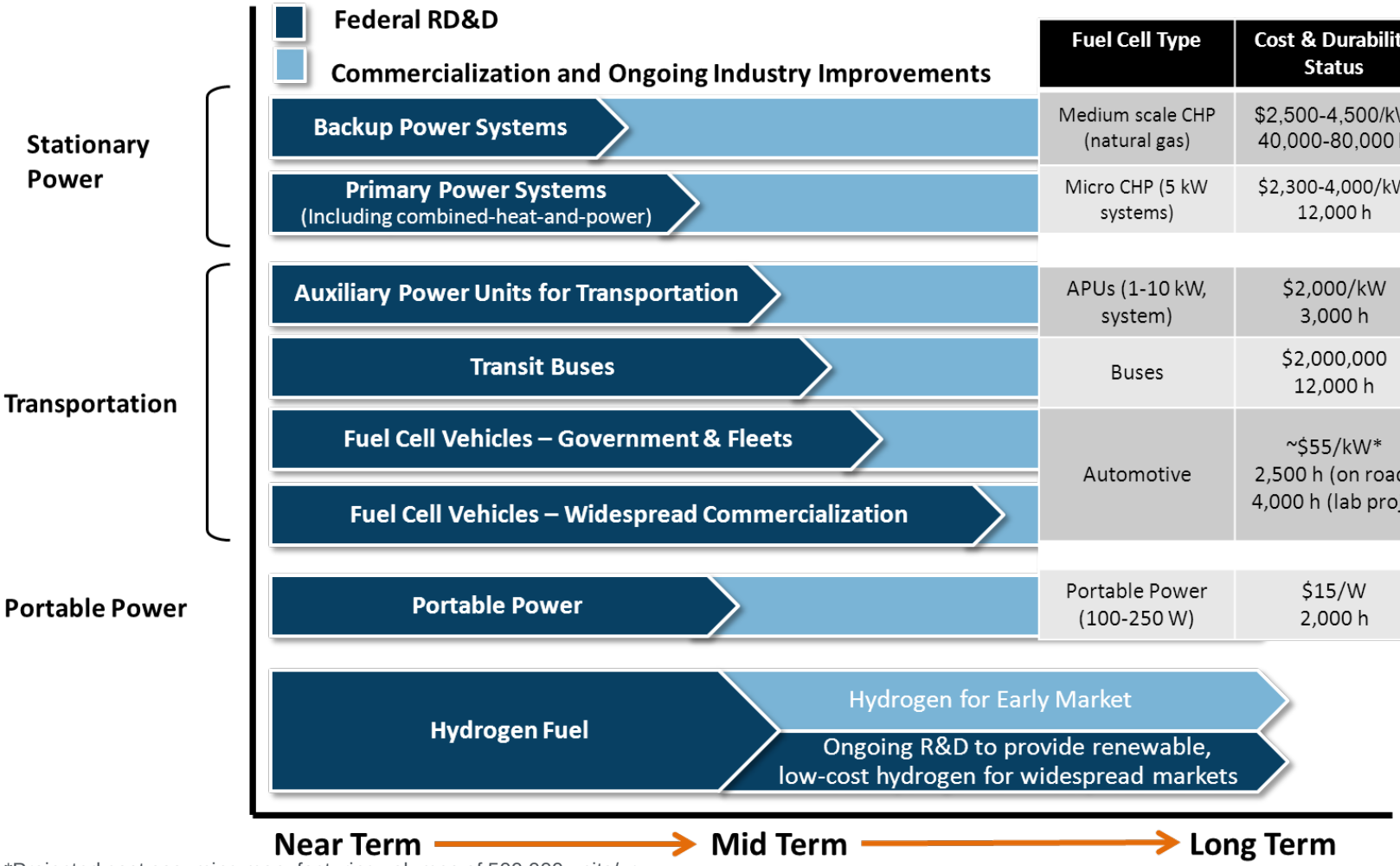
Fuel Cells are part of All-of-the-Above Energy Strategy



The President's proposal will support research into a range of cost-effective technologies – like advanced vehicles that run on electricity, homegrown biofuels, fuel cells, and domestically produced natural gas.

Overview

Mission: Enable widespread commercialization of a portfolio of hydrogen and fuel cell technologies through applied research, technology development and demonstration, and diverse efforts to overcome institutional and market challenges.



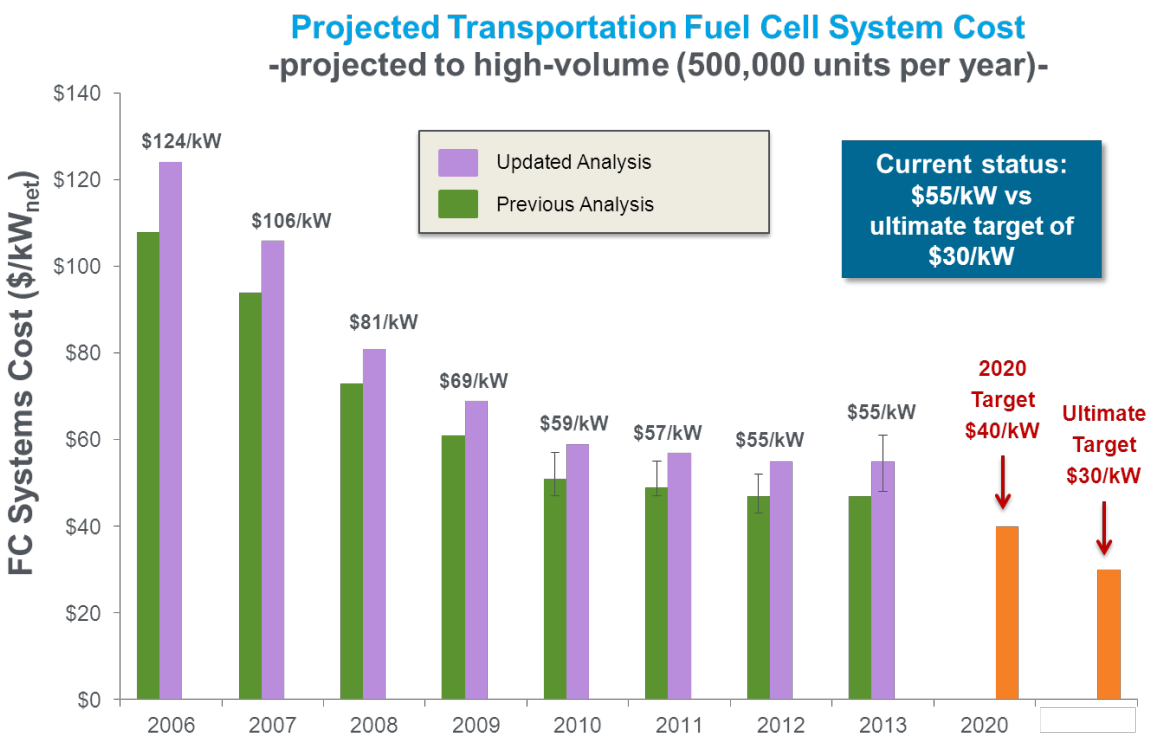
Fuel Cell Type	Cost & Durability Status	Cost & Durability Target
Medium scale CHP (natural gas)	$2,500-4,500/kW 40,000-80,000 h	$1,000/kW 80,000 h
Micro CHP (5 kW systems)	$2,300-4,000/kW 12,000 h	$1,500/kW 60,000 h
APUs (1-10 kW, system)	$2,000/kW 3,000 h	$1,000/kW 20,000 h
Buses	$2,000,000 12,000 h	$600,000 25,000 h
Automotive	~$55/kW* 2,500 h (on road) 4,000 h (lab proj.)	$30/kW* ($40/kW by 2020) 5,000 h
Portable Power (100-250 W)	$15/W 2,000 h	$5/W 5,000 h

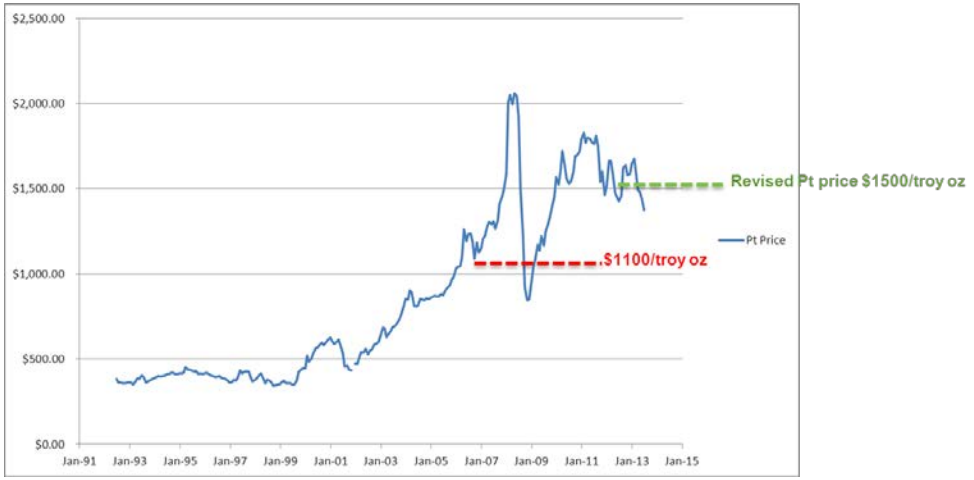
*Projected cost assuming manufacturing volumes of 500,000 units/yr

Fuel Cell Cost Reduction

Projected high-volume cost of fuel cells has been reduced to $55/kW (2013)*

- ***More than 30% reduction since 2008***
- ***More than 50% reduction since 2006***





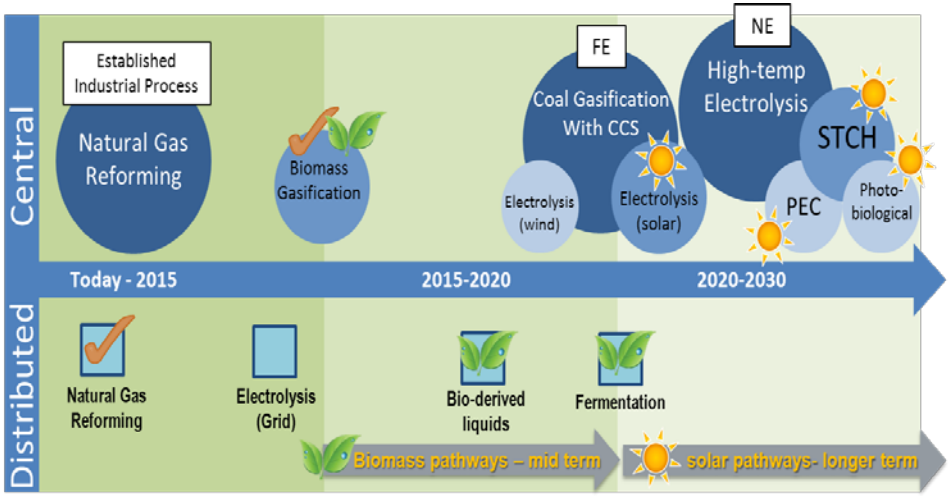
Based on projection to high-volume manufacturing (500,000 units/year). *The projected cost status is based on an analysis of state-of-the-art components that have been developed and demonstrated through the DOE Program at the laboratory scale. Additional efforts would be needed for integration of components into a complete automotive system that meets durability requirements in real-world conditions.*

Hydrogen Production Strategies

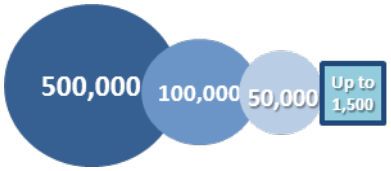
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Goal: Develop technologies to produce hydrogen from clean, domestic resources at a delivered and dispensed cost of $2-$4/gge H_2

H_2 Production Strategy



Estimated Plant Capacity (kg/day)

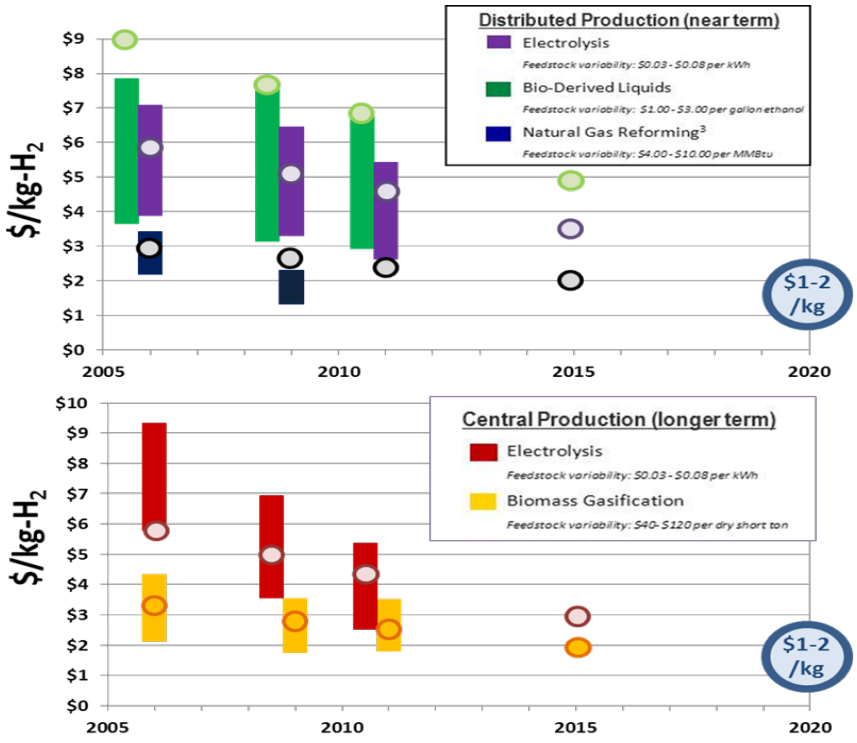


P&D Subprogram R&D efforts successfully concluded

FE = *R&D efforts in DOE Office of Fossil Energy*

NE = *R&D efforts in DOE Office of Nuclear Energy*

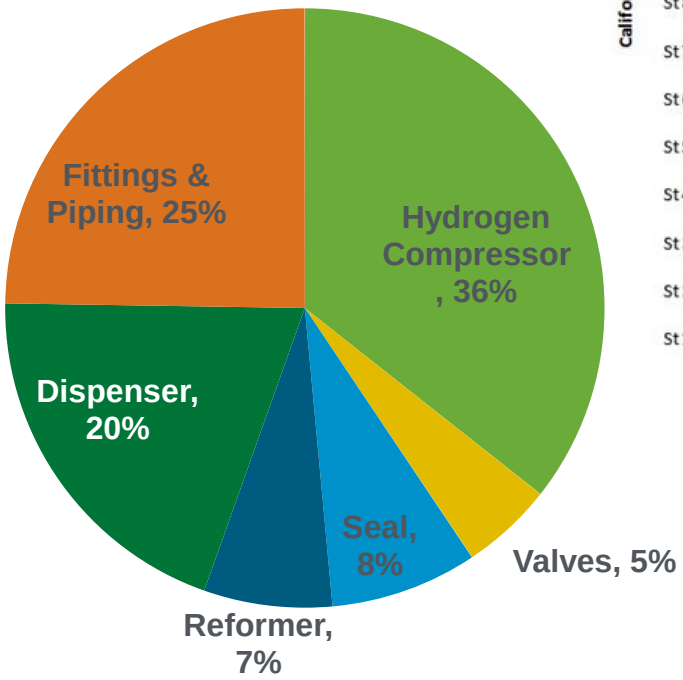
Projected High-Volume Cost of Hydrogen Production for Different Pathways

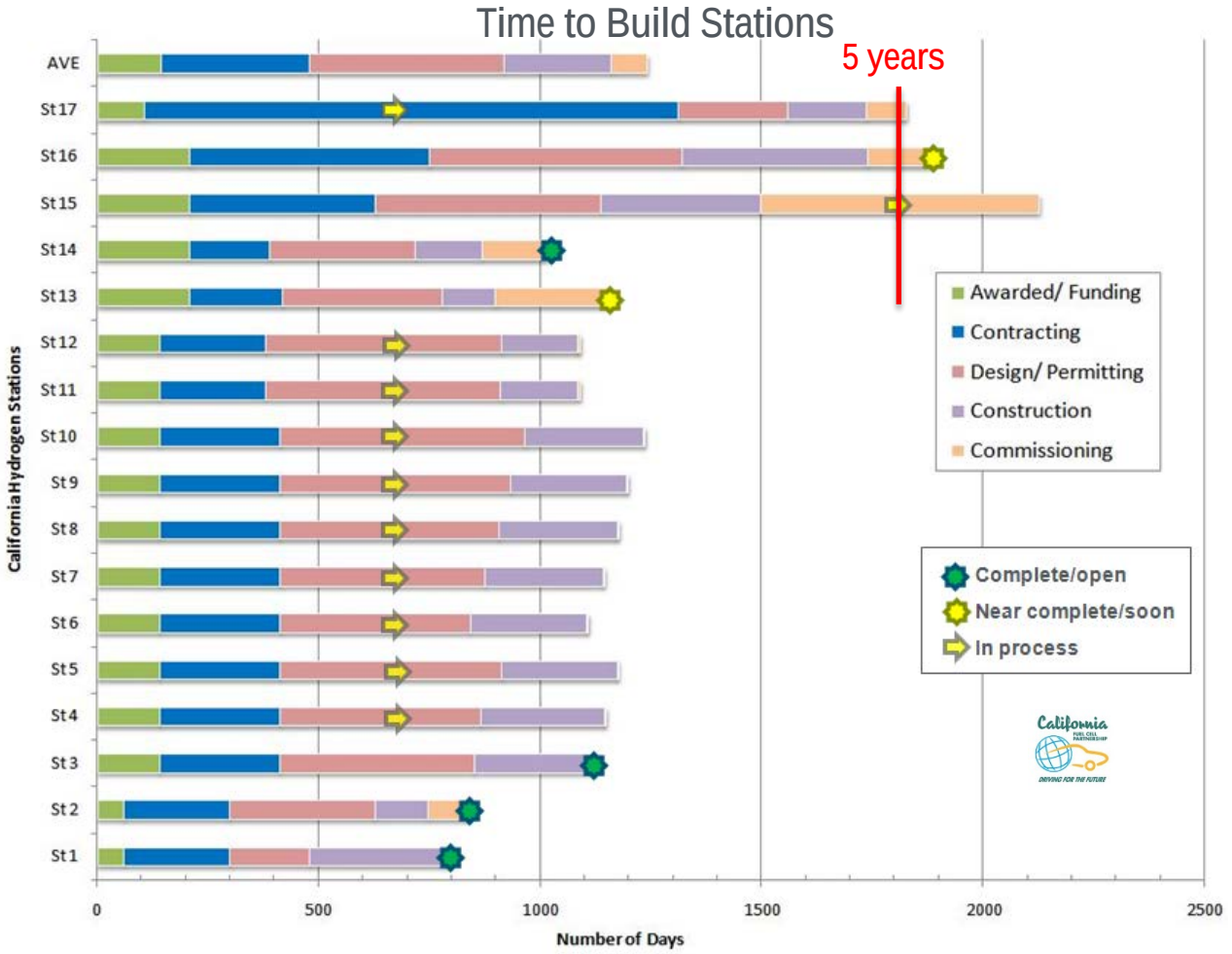


- Cost ranges are shown in 2007 dollars, based on projections from H2A analyses, and reflect variability in major feedstock pricing and a bounded range for capital cost estimates.
- Projections of costs assume Nth-plant construction, distributed station capacities of 1,500 kg/day, and centralized station capacities of ≥50,000 kg/day.

Infrastructure: Current Barriers

Despite progress in infrastructure development, more work is needed to address permitting times, contract issues, and equipment reliability.





Source: NREL http://www.nrel.gov/hydrogen/cfm/images/cdp_mhe_51_infhydrogenleaksbyequipmenttype.jpg

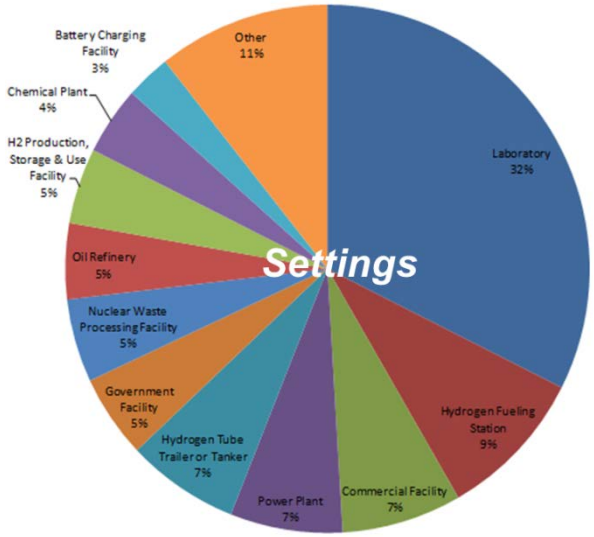
Hydrogen Safety, Codes & Standards

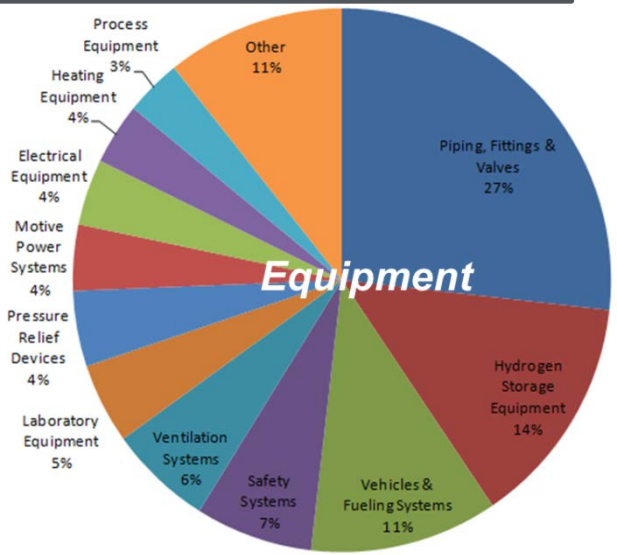
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- Safety Information helps guide R&D.
- It is critical to collect and disseminate relevant information.

Database web address – www.h2incidents.org

Two Looks at H2Incidents.org
210 Lessons Learned Events





Examples:

- Piping (36)
- Valve (36)
- Flexible Tubing (8)
- Gasket (6)
- Bolts (6)

- Trained > 26,000 first-responders and code officials on hydrogen safety and permitting through on-line and in-classroom courses

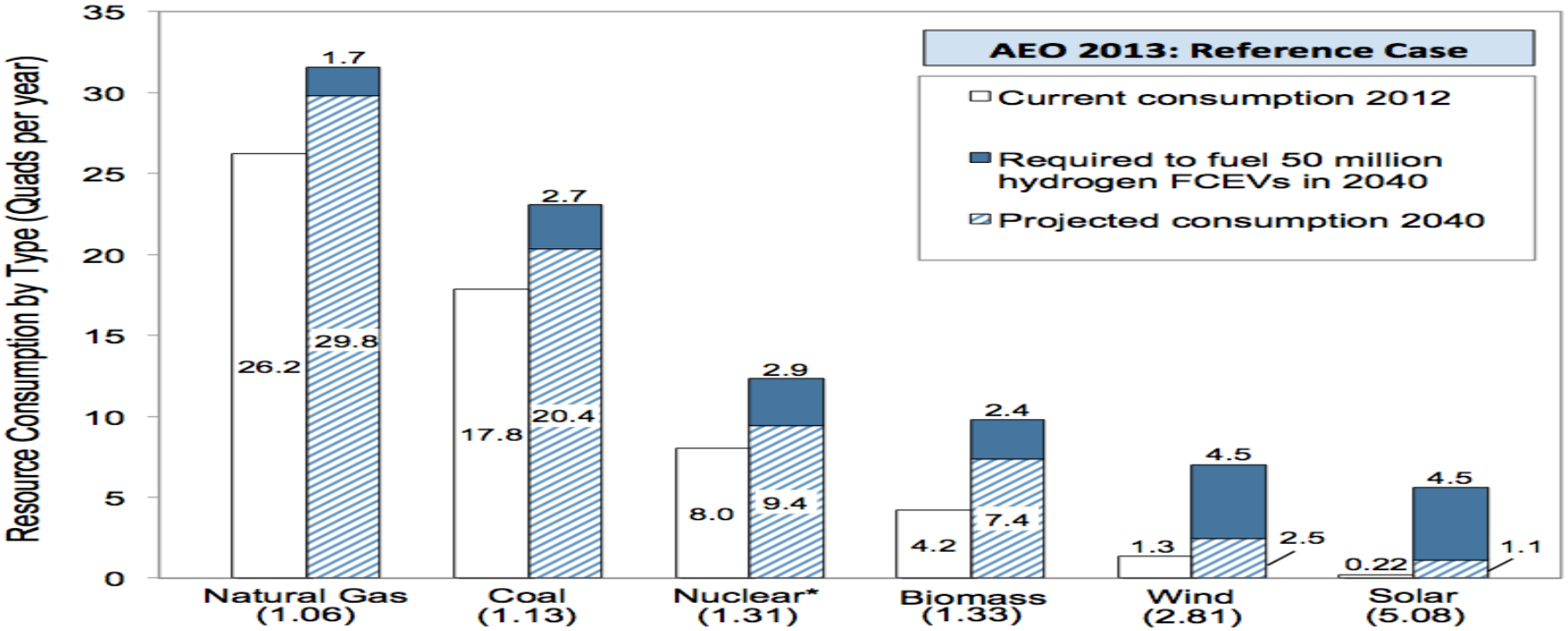
Announced by the U.S. Department of Energy September 2013

Resource Requirements Analysis

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

Hydrogen demand from future market success with FCEVs would not place excessive strain on resources or production capacity for natural gas or coal, would comprise a significant portion of total demand for nuclear and biomass, and would significantly exceed expected demand for wind and solar.

Current and projected scenarios for energy consumption by resource type, with requirements for 50 million FCEVs



NREL report to be published (Q1 FY2014)

Report identifies percent increase in resources required for 20-50M FCEVs.

Budget: DOE H_2 & Fuel Cells Program

Funding *($ in thousands)*			
Key Activity	FY 2012 Approp.	FY 2013 Enacted *(C.R.)*	FY 2014 Request
Fuel Cell R&D	43,634	41,266	37,500
Hydrogen Fuel R&D[1]	33,824	31,682	38,500
Manufacturing R&D	1,944	1,899	4,000
Systems Analysis	3,000	2,838	3,000
Technology Validation	8,986	8,514	6,000
Safety, Codes and Standards	6,938	6,808	7,000
Market Transformation	3,000	2,838	3,000
NREL Site-Wide Facilities Support	0	0	1,000
SBIR/STTR	2,298	2,139	TBD
Total	$103,624	$97,984	$100,000

Funding *($ in thousands)*		
Key Activity	FY 2012 Approp.	FY 2013 Enacted *(C.R.)*
Science (Basic Energy Science)	27,466	25,769
Fossil Energy (SECA)	25,000	~23,750
ARPA-E (FC related)	0	2,114
Total	$52,466	$51,633

Funding Opportunity Announcements (FOAs) planned

- Production & Delivery (FY14)
- Hydrogen Storage (FY14)
- Technology Validation and Market Transformation (FY13 & FY14)
- Manufacturing R&D (FY14)

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

Note: The FY 2012 and FY 2013 numbers shown on page 384 of the White House's FY 2014 Budget Request (www.whitehouse.gov/sites/default/files/omb/budget/fy2014/assets/doe.pdf) reflect $9.7 million that was carried over from FY 2012 to FY 2013 for obligation in FY 2013.

Co-Launched Public-Private Partnership

H_2USA

Mission: To promote the commercial introduction and widespread adoption of FCEVs across America through creation of a public-private partnership to overcome the hurdle of establishing hydrogen infrastructure.

Current partners include (additional in process):

U.S. DEPARTMENT OF ENERGY

Fuel Cell & Hydrogen Energy Association

GlobalAutomakers

EDTA Electric Drive Transportation Association

DAIMLER

HYDROGENICS Advanced Hydrogen Solutions

HONDA The Power of Dreams

NISSAN

HYUNDAI

GM

Mercedes-Benz

OAK RIDGE National Laboratory

ITM POWER Energy Storage | Clean Fuel

AGA American Gas Association

California Fuel Cell Partnership

DRIVING FOR THE FUTURE

SCRA

Sandia National Laboratories

PROTON THE LEADER IN ON SITE GAS GENERATION.

NREL NATIONAL RENEWABLE ENERGY LABORATORY

AIR LIQUIDE

arc:HYDROGEN

plug power

NUVERA Making hydrogen make sense.

Massachusetts Hydrogen Coalition

TOYOTA

Argonne NATIONAL LABORATORY

H_2USA Organization Chart

H-Prize: Hydrogen Refueler (Draft)

- The Hydrogen Refueler H-Prize will work to incentivize the development of small-scale systems for non-commercial fueling to supplement the larger infrastructure development

Previous H-Prize RFIs and discussions at HTAC meetings

May 2012: H-Prize topic RFI (issued March, deadline extended through May)
August-September 2012: Meter topic RFI
September 2012: Briefing and consultation on the Meters topic
November 2012: Update on meter prize (put on hold)
February 2013: Update on reasons for dropping the meter topic and ideas about the home refueler topic
April 2013: Update on newly released RFI on the Home Refueler topic

- Refueler entries would:
  - produce hydrogen from resources available to most residential locations – electricity or natural gas
  - dispense at least 1 kg during a fueling period, roughly the amount needed for an average day's drive
  - be designed for non-commercial use in either homes (1-5 kg/day) or community centers/retail fleets (5-50 kg/day)
- Guidelines will be posted for open public comment before the competition begins; competition is expected to last 2 years after the official launch
- Approximately 18 months into the competition teams will submit data to show the entry meets the minimum criteria; the top 5 entries will proceed to the testing phase, where tested criteria will be scored to determine the team rankings

Hydrogen and Fuel Cell Initiatives at the State Level

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

Several states—including California, Connecticut, Hawaii, Ohio, New York, and South Carolina—have major hydrogen and fuel cell programs underway.

8 states sign MoU to put 3.3M zero-emission vehicles on roads by 2025

States include California, Connecticut, Massachusetts, Maryland, New York, Oregon, Rhode Island, & Vermont

- **Represents a new vehicle market penetration of ~15%**

California

FCEVs and Fuel Cell Buses

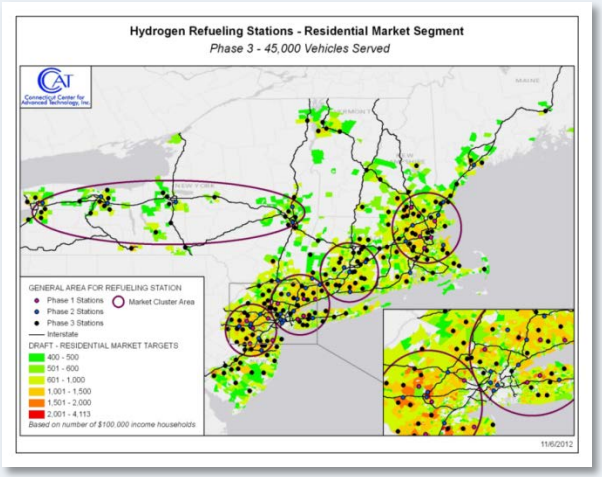
- **> 560 vehicles** in operation since 1999 — ~230 currently operating
- **> 6 million miles** driven
- **> 1 million passengers** on fuel cell buses

H_2 Station Investment

- **~$34M invested** *(CARB and CEC)*
- **$5.5M invested** by SCAQMD
- **~$29.9M available** (CEC solicitation coming)
- **$20M for 2014/15** (CEC)
- **$20M annually** thru 2023 for at least 100 stations (AB8)

Northeast (e.g. MA, NY, CT)

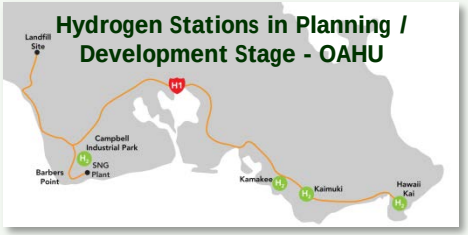
Preliminary: ***3 phase plan for the development of hydrogen infrastructure and deployment of fuel cell electric vehicles (FCEVs) in the north eastern coastal metro centers.***



Hawaii

Agreement signed by 12 stakeholders—including GM, utilities, hydrogen providers, DOD, DOE—to establish hydrogen as a major part of the solution to Hawaii's energy challenges.

- 15 GM FCEVs **currently in demonstrations with military**
- Renewable hydrogen **(from geothermal and wind energy) will be used for buses**
- **Goals include a nascent refueling infrastructure on Oahu by 2015 to support initial deployments of government and industry FCEV fleets**



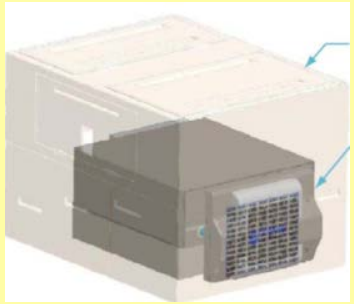
Fuel Cell Buses in the U.S.

Multiple platforms and technologies developed under NFCBP

$90 Million Federal investment
Matched by over $90 million in industry investment

- American Fuel Cell (AFCB) bus operating in SunLine Transit in California since late 2011
- Additional AFCB deliveries planned for SunLine Transit, Connecticut, Chicago, Ithica, NY, and Cleveland, Ohio

Next generation fuel cell for transit development project, with improved power, durability, lower cost, transitioned to new partner



- Proterra bus operated in Austin, Texas and South Carolina
- Next Generation bus planned for Austin and Washington, DC
- FCB deliveries to other operators in CA and WA

Follow-on program could bring 50-100 additional fuel cell buses to U.S.

Southern CA Public Hydrogen Stations

Open

Burbank
Torrance
Newport Beach
Irvine
Fountain Valley
West LA
Thousand Palms
Harbor City

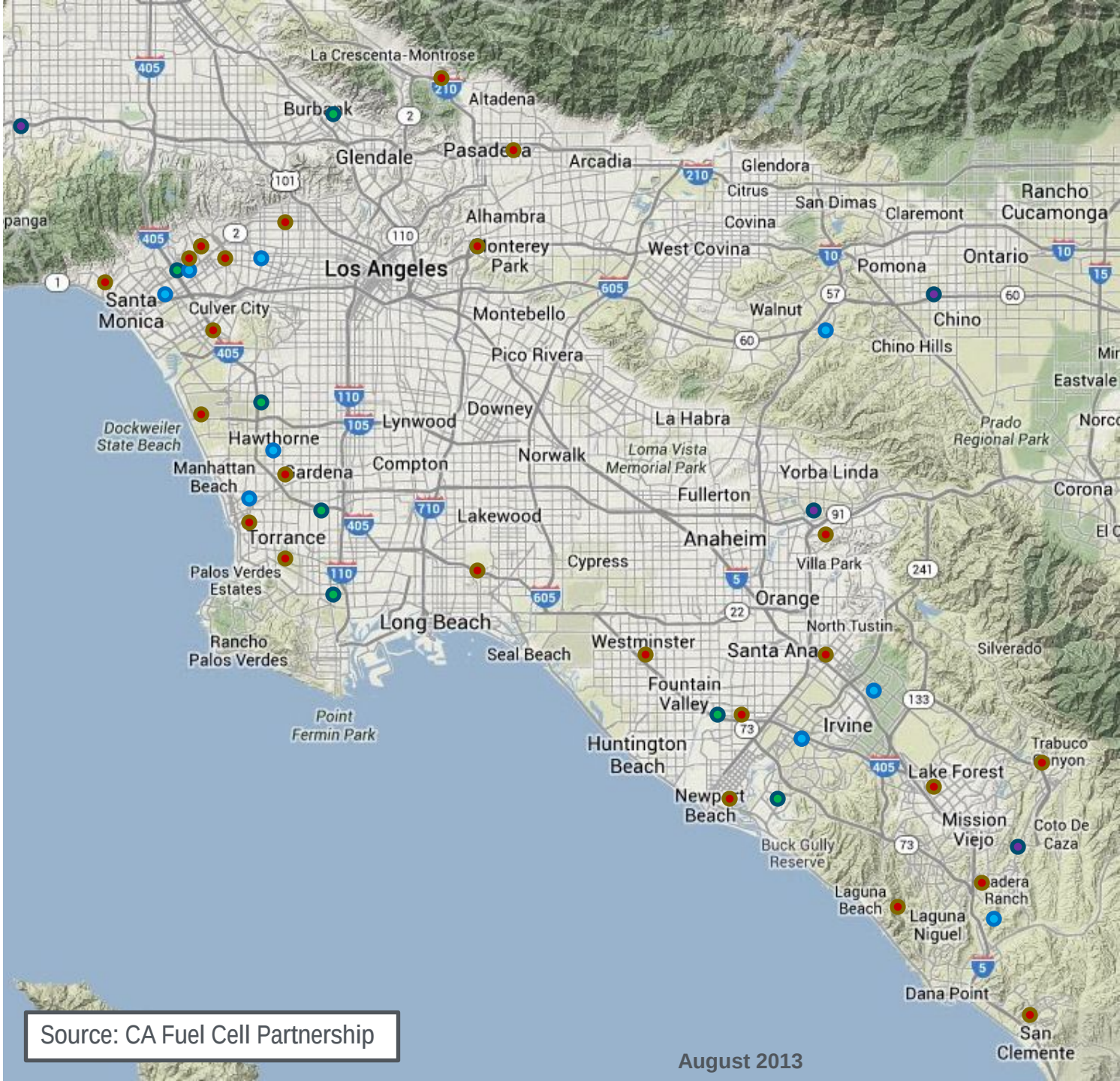
In Development

Beverly Hills
Diamond Bar (upgrade)
Hawthorne
Hermosa Beach
Irvine (upgrade)
Irvine North
San Juan Capistrano
Los Angeles
Santa Monica
West LA
Westwood

Funded in 2013

Anaheim
Chino
Mission Viejo
Woodland Hills

Targets areas for future funding



Source: CA Fuel Cell Partnership

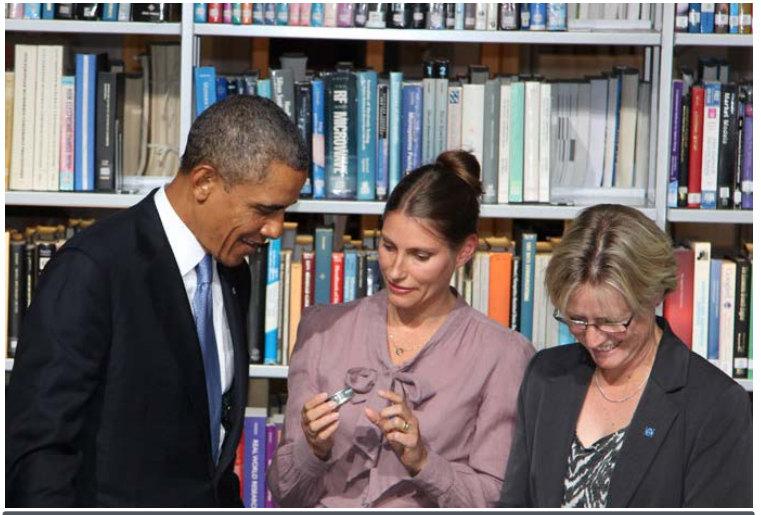
August 2013

Communication & Outreach

Published more than 80 news articles this year (including blogs, progress alerts, DOE news alerts)

- ***Monthly Webinar Series – held 15 webinars***
  - Register at - http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html
- ***Announcements***
  - Launched NFCTEC (secure data center)
  - Launched Hydrogen Safety Tools App for iPhone and iPad
  - Launched Alternative Fueling Station Locator App
- ***Training and Workforce Development***
  - Trained more than 10,000 teachers and more than 26,000 code officials and first responders in person and online
- ***Monthly Newsletter***
  - Visit the web site to register or to see archives - (http://www1.eere.energy.gov/hydrogenandfuelcells/newsletter.html)

Kyushu University was the Grand Prize Winner of the 2013 H_2 Student Design Contest!



President Obama inspects a fuel cartridge while at the Swedish Royal Institute of Technology.

Hydrogen fuel cell powers lights at entertainment industry events.

Hydrogen fuel cell powered light tower at Space Shuttle launch

Thank You

Sunita.Satyapal@ee.doe.gov

hydrogenandfuelcells.energy.gov

Global Safety Collaboration

International Partnership for Hydrogen and Fuel Cells in the Economy Regulations, Codes and Standards Working Group

RCSWG provides a forum to exchange information, attain consensus, and develop recommendations to IPHE member countries to facilitate harmonization of key RCS.

Activities:

- Harmonized test measurement protocol for hydraulic and pneumatic testing of Type IV tanks. Hydraulic testing is complete.
- Fuel quality stack testing round robin to develop a harmonized testing protocol
- International "Safety Portal" on Lessons Learned (e.g.-H2incidents.org or HIAD databases) in deployment of hydrogen technologies

Images provided by IPHE member countries.

5th International Conference on Hydrogen Safety

September 9-11, 2013 Brussels, Belgium

Purpose is to improve public awareness and trust in hydrogen technologies by communicating a better understanding of both hazards and risks associated with hydrogen

- Approximately 200 participants, 28 countries
- Topics included H2 Release and dispersion, Risk Management, Safety H2 infrastructure, Education, and RCS

- **1st Bilateral Webinar between U.S. and European Commission (~210 participants)**

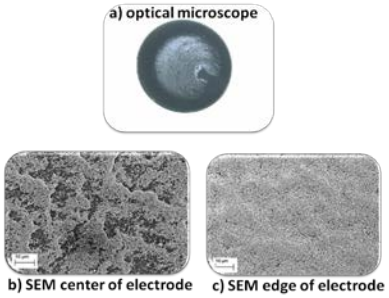
  What Can We Learn from Hydrogen Safety Event Databases?

  https://www1.eere.energy.gov/hydrogenandfuelcells/webinar_archives_2013.html

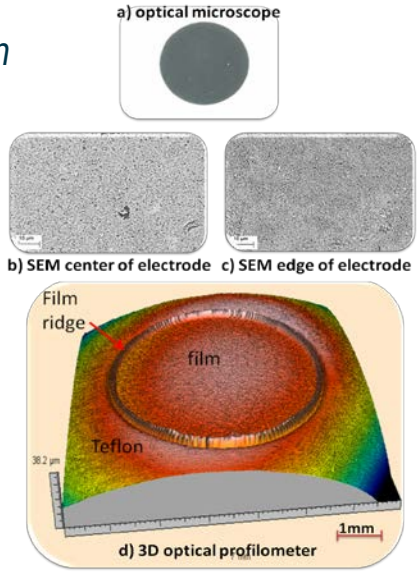
Tech Team Output: A standard test protocol and best practices would enable consistency in procedures and less variability in results from different labs

- *Trends in catalyst activity and durability in RDE can be used to predict trends in PEMFCs.*
- *RDE is less challenging and less costly than membrane electrode assembly (MEA) preparation and testing.*
- *Variability in reported testing protocols introduces performance variability from different labs. Reported catalyst activity varies for the same materials by a factor of 2.*

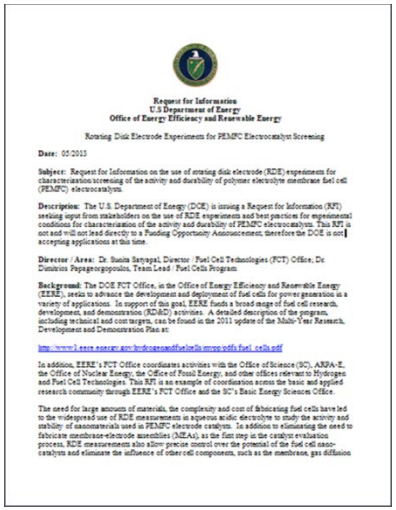
Example:



Rotational ink drying, based on spin coating technology, could be universally used as a reliable solution for drying electrocatalyst films



DOE solicited input for Stakeholders and the research community on a standard RDE test protocol



Request for Information
U.S Department of Energy
Office of Energy Efficiency and Renewable Energy

Rotating Disk Electrode Experiments for PEMFC Electrocatalyst Screening

Date: 05/2013

Subject: Request for Information on the use of rotating disk electrode (RDE) experiments for characterization/screening of the activity and durability of polymer electrolyte membrane fuel cell (PEMFC) electrocatalysts.

Description: The U.S. Department of Energy (DOE) is issuing a Request for Information (RFI) seeking input from stakeholders on the use of RDE experiments and best practices for experimental conditions for characterization of the activity and durability of PEMFC electrocatalysts. This RFI is not and will not lead directly to a Funding Opportunity Announcement; therefore the DOE is not accepting applications at this time.

Director / Area: Dr. Sunita Satyapal, Director / Fuel Cell Technologies (FCT) Office; Dr. Dimitrios Papageorgopoulos, Team Lead / Fuel Cells Program

Background: The DOE FCT Office, in the Office of Energy Efficiency and Renewable Energy (EERE), seeks to advance the development and deployment of fuel cells for power generation in a variety of applications. In support of this goal, EERE funds a broad range of fuel cell research, development, and demonstration (RD&D) activities. A detailed description of the program, including technical and cost targets, can be found in the 2011 update of the Multi-Year Research, Development and Demonstration Plan at:

http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/fuel_cells.pdf

In addition, EERE's FCT Office coordinates activities with the Office of Science (SC), ARPA-E, the Office of Nuclear Energy, the Office of Fossil Energy, and other offices relevant to Hydrogen and Fuel Cell Technologies. This RFI is an example of coordination across the basic and applied research community through EERE's FCT Office and the SC's Basic Energy Sciences Office.

The need for large amounts of materials, the complexity and cost of fabricating fuel cells have led to the widespread use of RDE measurements in aqueous acidic electrolyte to study the activity and stability of nanomaterials used in PEMFC electrode catalysts. In addition to eliminating the need to fabricate membrane-electrode assemblies (MEAs), as the first step in the catalyst evaluation process, RDE measurements also allow precise control over the potential of the fuel cell nanocatalysts and eliminate the influence of other cell components, such as the membrane, gas diffusion

Test protocol and best practices to be validated and communicated in the near future

Proposed H-Prize Criteria- Draft

Minimum criteria

Criteria	Home	Community
Min. dispensing pressure	350 bar	
Max. 1 kg dispensing time	10 hours	30 minutes
Dispensable hydrogen	1 kg/day	4 kg/day
Hydrogen purity	Meets SAE J2719	
Fill method	Meets appropriate standards for vehicle type	
Safety	Meets relevant safety standards; designs to be examined by safety experts	
Usability	Can be installed at intended locations (footprint, noise, etc.), usable with minimum training and time – determined by judges	

Cost criteria

	System Install Cost		Cost per kg	
Score	Home	Community	Home	Community
1	$25k/kg or less	$15k/kg or less	$8 or less	
2	20k/kg or less	$12.5K/kg or less	$7 or less	
3	$15k/kg or less	$10K/kg or less	$6 or less	
4	$10k/kg or less	$7.5K/kg or less	$5 or less	
5	$5k/kg or less	$5K/kg or less	$4 or less	

Technical criteria

	Dispensed pressure		1 kg dispensing time		1-kg fills per day		Tested Availability	
Score	Home	Community	Home	Community	Home	Community	Home	Community
1	350 bar or higher		10 hours or less	60 minutes or less	1 or more	4 or more	85% or higher	
2	430 bar or higher		8 hours or less	30 minutes or less	2 or more	10 or more	88 % or higher	
3	510 bar or higher		5 hours or less	15 minutes or less	3 or more	20 or more	91% or higher	
4	590 bar or higher		2 hours or less	10 minutes or less	4 or more	40 or more	94% or higher	
5	700 bar or higher		30 minutes or less	3 minutes or less	5 or more	50 or more	97% and above	

Northern CA Public Hydrogen Stations

- **Open**
  - Emeryville
- **In Development**
  - West Sacramento
- **Funded in 2013**
  - Cupertino
  - Foster City
  - Mountain View
- **Target areas for future funding**

Source: CA Fuel Cell Partnership