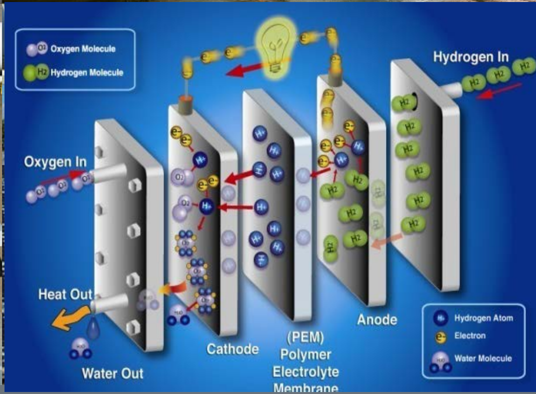
Fuel Cell Technologies Office Overview

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





Hydrogen and Fuel Cells Technical Advisory Committee (HTAC)

Golden, CO

10/29/2013

Dr. Sunita Satyapal

Director
Fuel Cell Technologies Office
Energy Efficiency and Renewable Energy
U.S. Department of Energy

Agenda

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- HTAC Scope & Membership
- DOE Organizational Updates
- Program Overview
  - Updates since prior HTAC meeting
  - DOE impact (patents, commercial products, etc.)
  - Budget
  - Analysis, IG report
- HTAC Input & DOE Responses/Activities
  - HPEP Report, H-Prize
  - Additional areas of feedback

Hydrogen and Fuel Cell Technical Advisory Committee (HTAC) Scope

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Scope of the committee (from HTAC's Charter): Review and make recommendations to the Secretary of Energy on:

(1) The implementation of programs and activities under Title VIII of EPACT (which authorizes funding for federal RD&D efforts in hydrogen and fuel cells)
(2) The safety, economical, and environmental consequences of technologies for the production, distribution, delivery, storage, or use of hydrogen energy and fuel cells
(3) The plan under section 804 of EPACT (the *DOE Hydrogen & Fuel Cells Program Plan*, formerly *Hydrogen Posture Plan*)

Academia

Dr. Mark J. Cardillo, Executive Director
Camille & Henry Dreyfus Fdn.

Dr. Timothy Lipman, Co-Director
Transportation Sustainability Research Center, UC-Berkeley

Dr. Joan Ogden, Co-director
Sustainable Transportation Pathways Program, Institute of Transportation Studies, UC-Davis

Dr. Levi Thompson
Professor of Chemical Engineering, U. of Michigan

Fuels Production

John Hofmeister, Founder and Chief Executive,
Citizens for Affordable Energy;
President & U.S. Country Chair (retired),
Shell Oil Company

David Taylor, Vice President, Energy Business
Air Products and Chemicals, Inc.

Government

Dr. Peter Bond, Senior Advisor to the Director
Brookhaven National Laboratory

Dr. Richard Carlin, Department Head,
Sea Warfare and Weapons Department
Office of Naval Research

Anthony Eggert, Executive Director,
The Policy Institute for Energy, Environment and the Economy, UC-Davis

Maurice Kaya, Project Director,
Pacific International Center for High Technology Research; Energy Program Director (retired), State of Hawaii

Industry Associations

Robert Rose, Senior Advisor
Fuel Cell and Hydrogen Energy Association

Stationary Power

Gary Flood, President and CEO,
ReliOn Inc.

Harol Koyama, President and CEO,
H2 PowerTech

Transportation

Charles Freese, Executive Director Global Fuel Cell Activities, GM

Dr. Alan Lloyd, President
International Council on Clean Transportation

Dr. Kathleen Taylor, Director of Material Processing Laboratory (retired),
General Motors Research Laboratories

Joe Triompo, Vice President & General Manager,
UTC Power-> ClearEdge

Utilities (Electricity & Natural Gas)

Frank Novachek, Director of Corporate Planning,
Xcel Energy

Venture Capital

Dr. Robert Shaw, President (retired),
Aretê Corporation

Jan van Dokkum, Operating Partner
Kleiner, Perkins, Caufield & Byers;
President (retired) UTC Power

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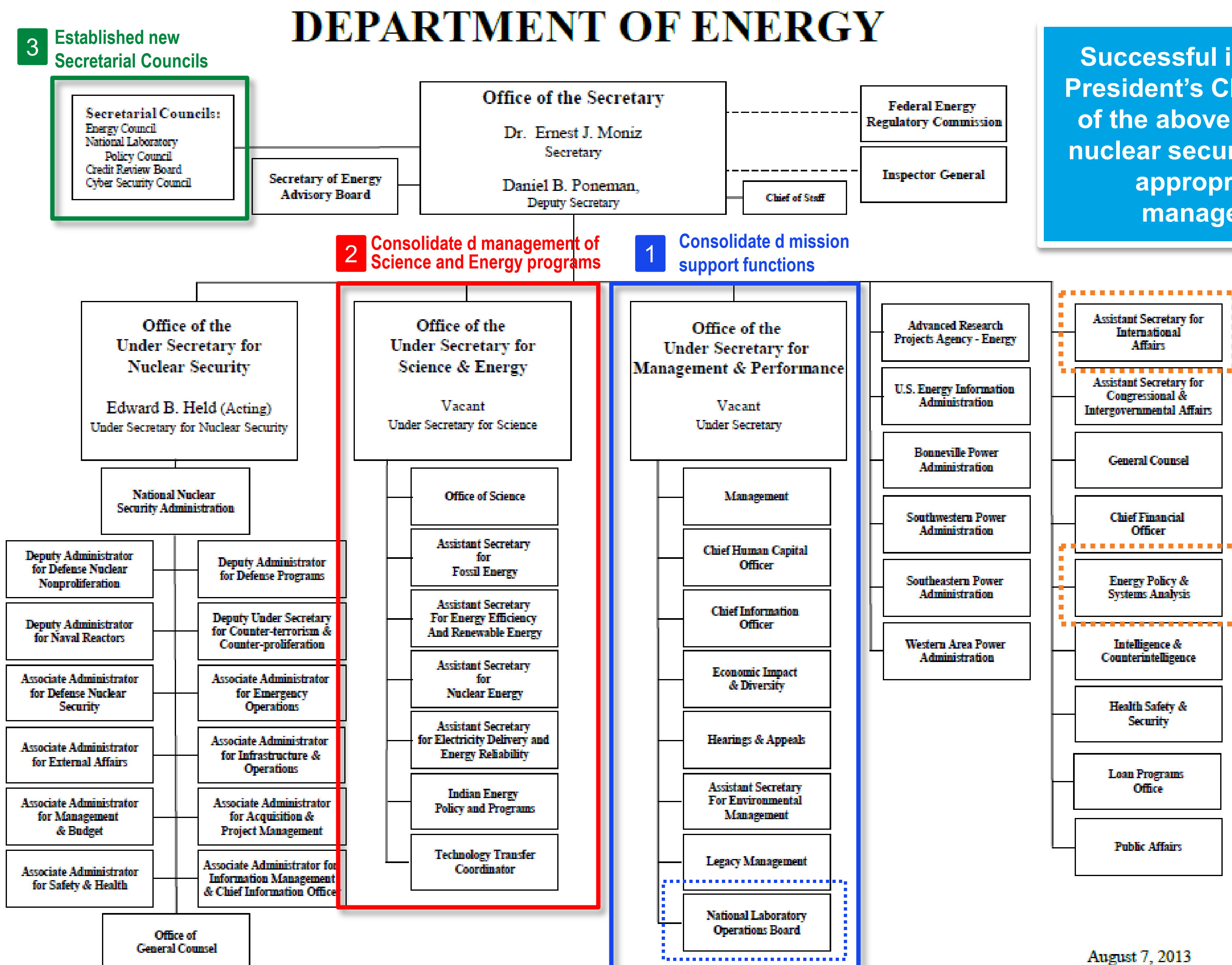

Successful implementation of the President's Climate Action Plan, "all of the above" energy strategy and nuclear security agenda require the appropriate alignment of management functions.

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

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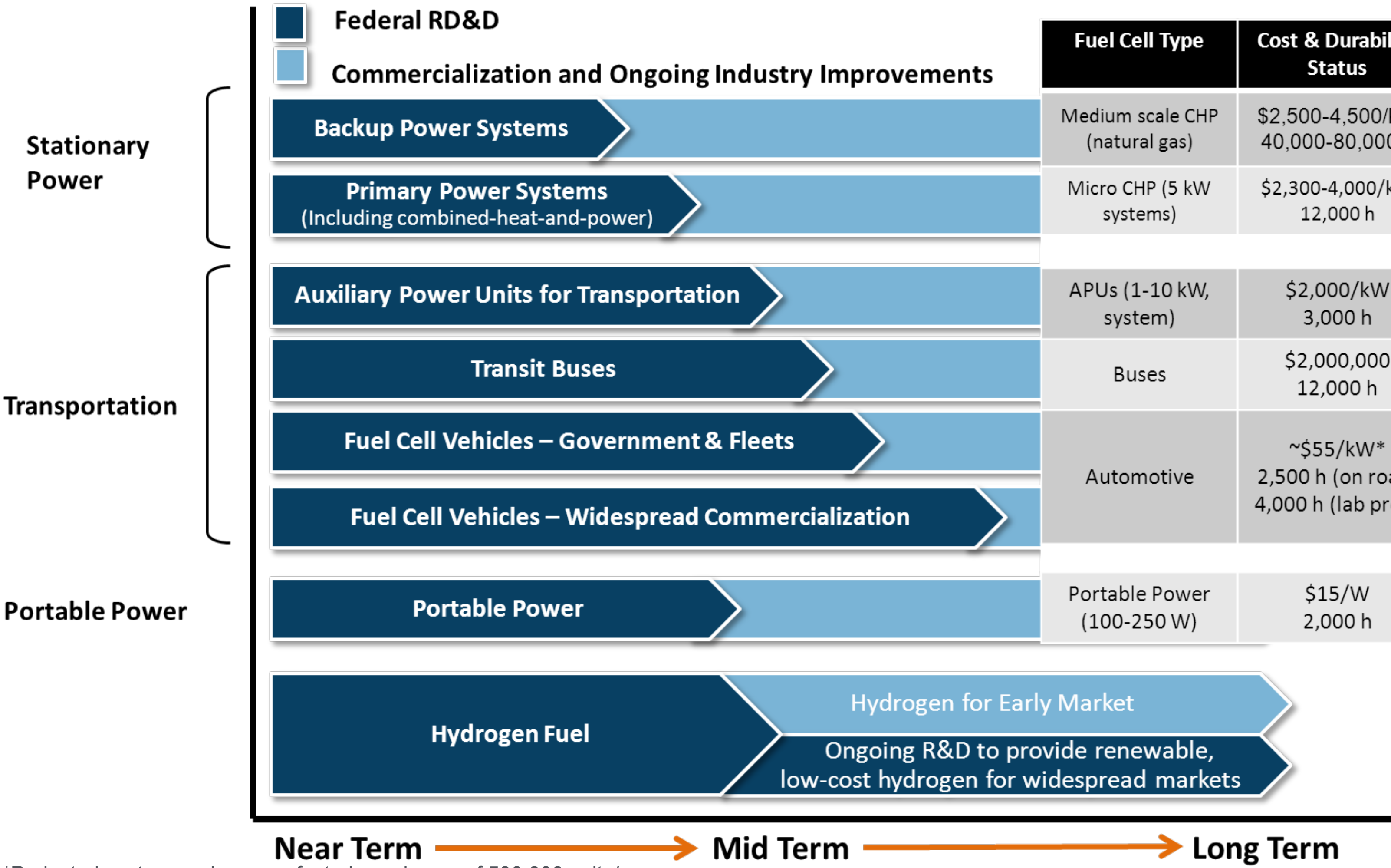
Mission: Enable widespread commercialization of a portfolio of hydrogen and fuel cell technologies through applied research, technology development and demonstration, and diverse efforts to overcome institutional and market challenges.



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

DOE Program: RD&D to Deployments

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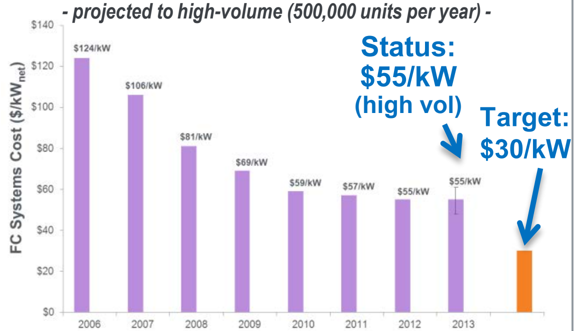
DOE R&D

- *Reduces cost and improves performance*

Examples of progress:

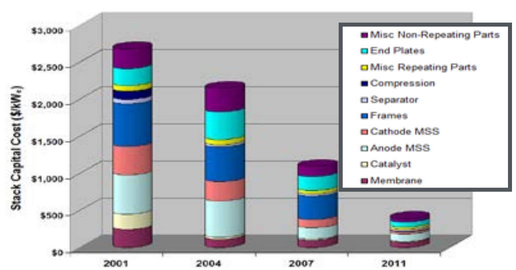
Transportation Fuel Cell System Cost

- projected to high-volume (500,000 units per year) -



→ *Reduced cost of fuel cells 50% since 2006*

→ *2020 target $40/kW, ultimate target $30/kW*



→ *Reduced cost of electrolyzer stacks 60% since 2007*

DOE Demonstrations & Technology Validation

- *Validate advanced technologies under real-world conditions*
- *Feedback guides R&D*

Demonstrated >180 FCEVs, 25 stations, 3.6 million miles traveled

Examples—validated:

- *59% efficiency*
- *254 mile range (independently validated 430-mile range)*
- *75,000-mi durability*

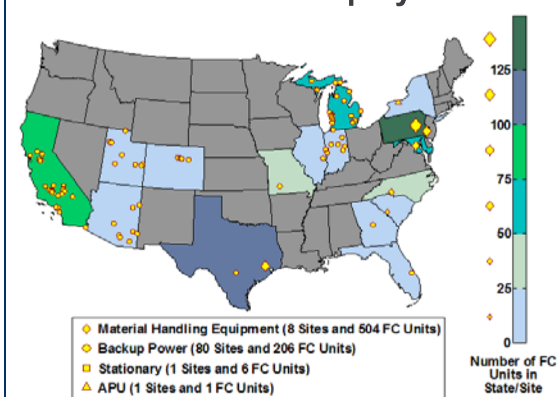
Demonstrated **world's first tri-gen** station (250 kW on biogas, 100 kg/d)

Program also includes enabling activities such as codes & standards, analysis, and education.

Deployments

- *DOE Recovery Act and Market Transformation Projects*
- *Government Early Adoption (DoD, FAA, California, etc.)*
- *Tax Credits: 1603, 48C*

Recovery Act & Market Transformation Deployments



Nearly 1,600 fuel cells deployed

Hydrogen Production Strategies

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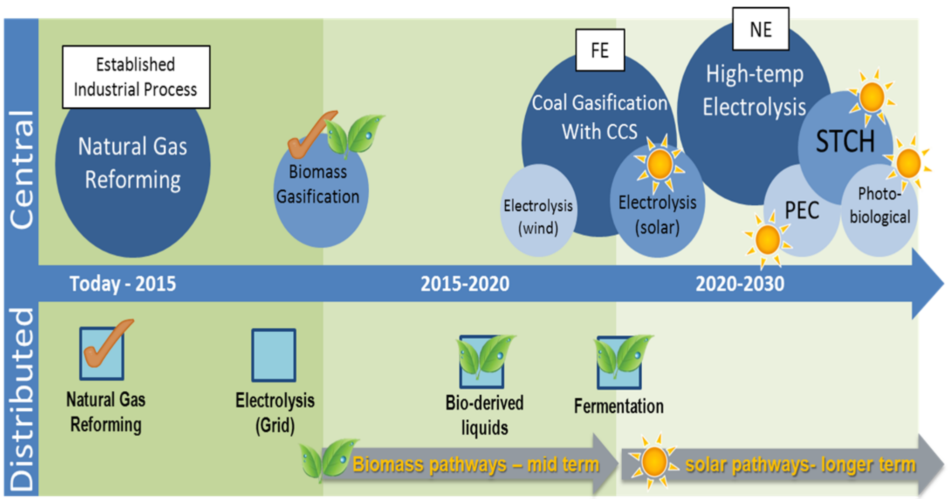
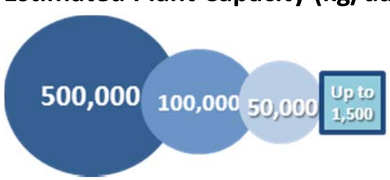
Goal: Develop technologies to produce hydrogen from clean, domestic resources at a delivered and dispensed cost of \$2-\$4/gge H_2



Estimated Plant Capacity (kg/day)

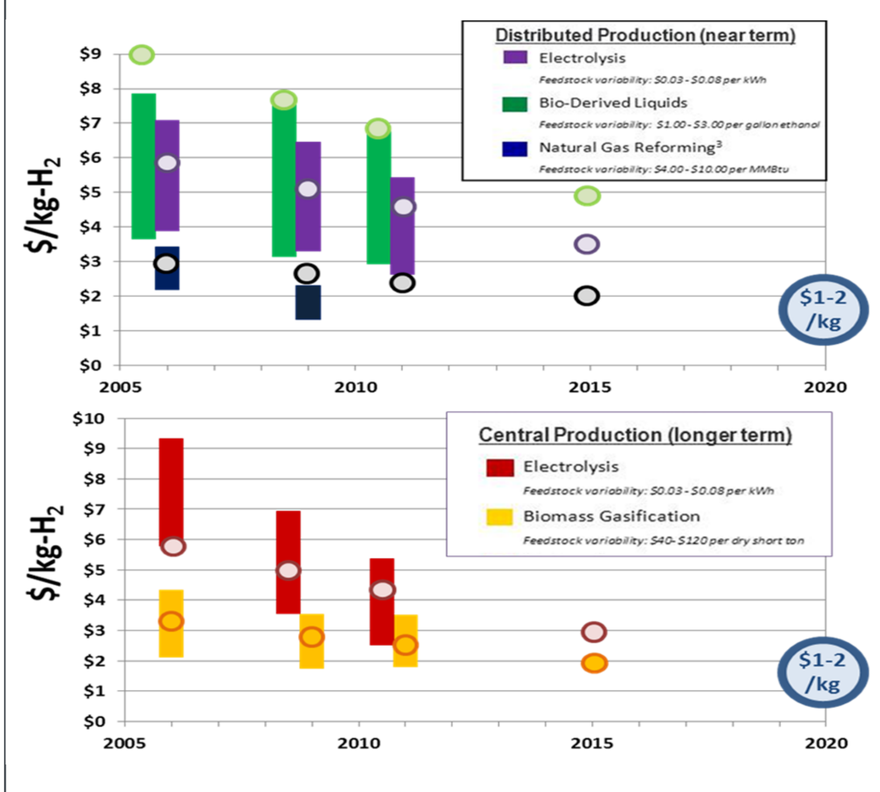


✓ P&D Subprogram R&D efforts successfully concluded

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.

Assessing the Impact of DOE Funding

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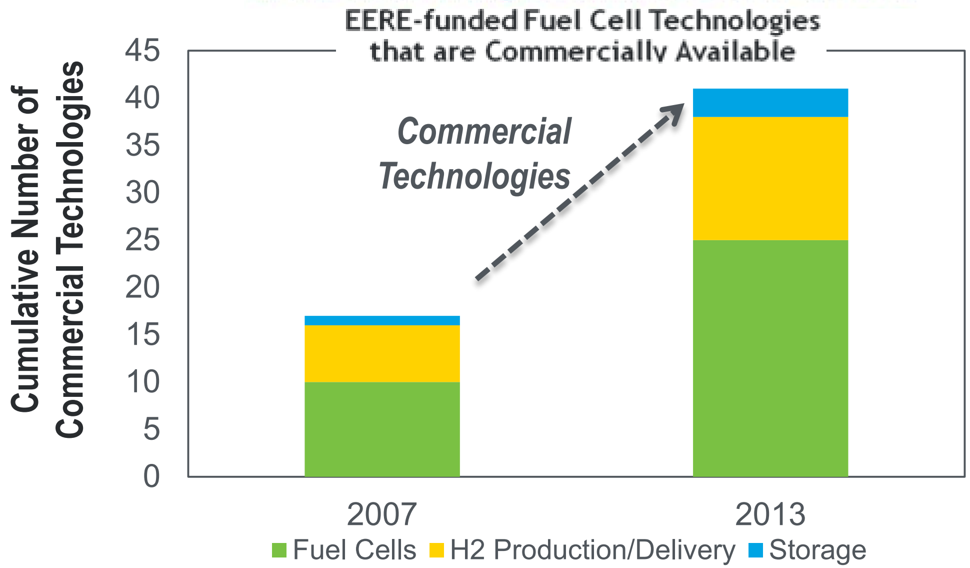
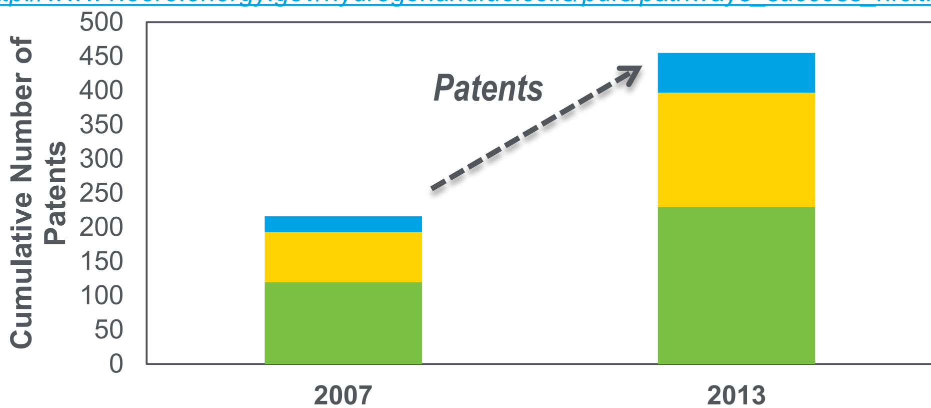
DOE funding has led to 40 commercial hydrogen and fuel cell technologies and 65 emerging technologies.

Accelerating Commercialization

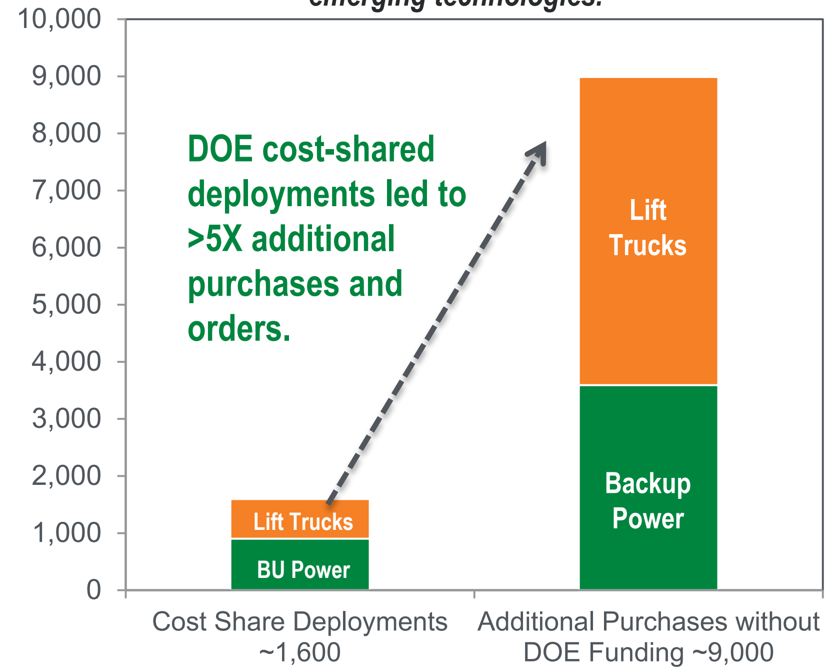


Source: Pacific Northwest National Laboratory
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_success_hfcit.pdf



Leveraging DOE Funds:

Government as "catalyst" for market success of emerging technologies.



More than 450 PATENTS resulting from EERE-funded R&D:

- ***Includes technologies for hydrogen production and delivery, hydrogen storage, and fuel cells***

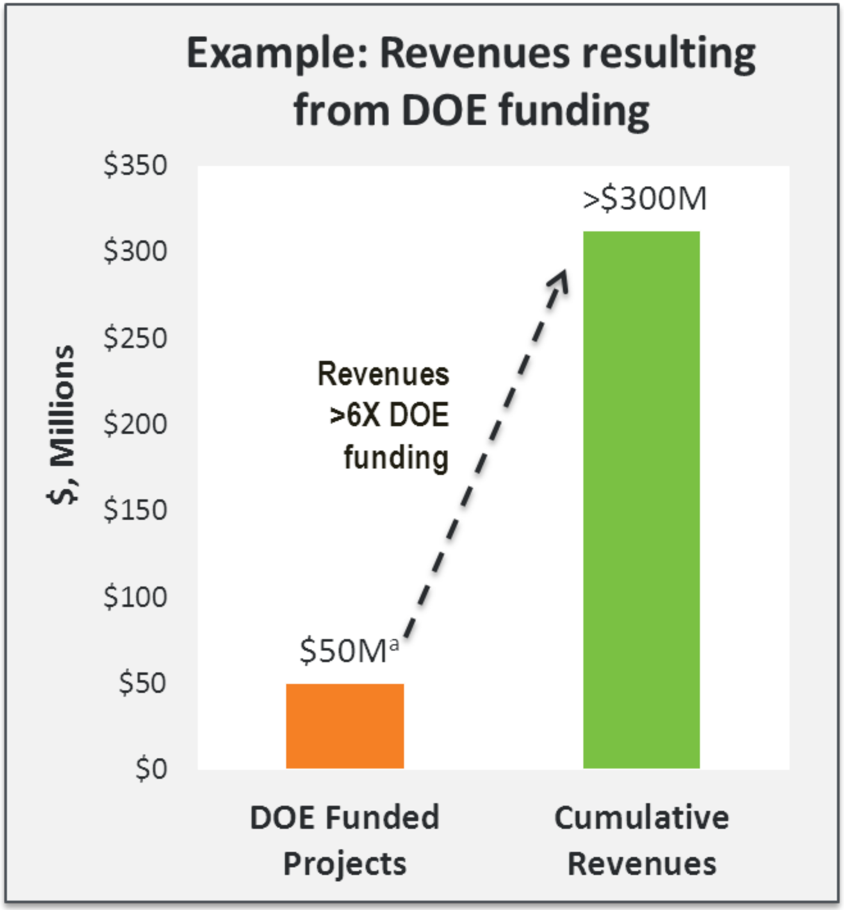
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2013.pdf

Assessing the Impact of DOE Funding

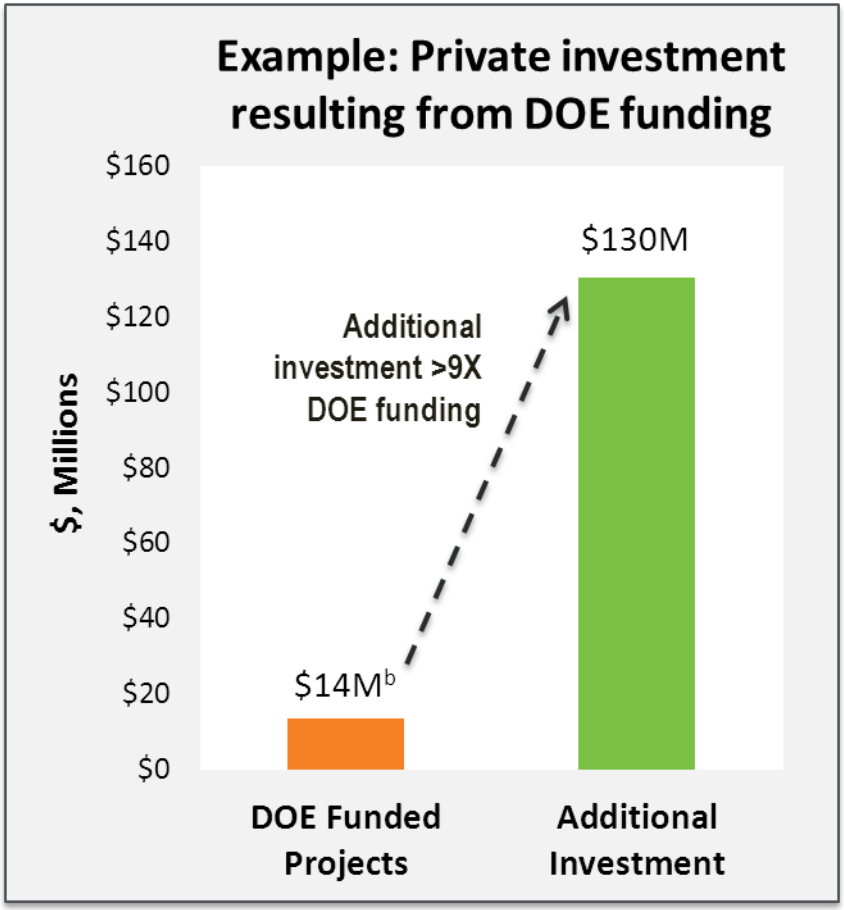
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

For selected projects tracked, DOE EERE funding has led to:

- **Revenues valued at >6 times the DOE investment**
- **Additional private investment valued at >9 times the DOE investment**



[a]DOE's $50M is linked to selected projects with ~$310M in revenues..



[b]DOE's $14M is linked to selected projects w/$130M additional industry investment

Kick-off meeting with Assistant Secretary & working groups established (see H2USA briefing)

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
- Global Automakers
- EDTA – Electric Drive Transportation Association
- Nissan
- Hyundai
- Honda – The Power of Dreams
- ITM Power – Energy Storage | Clean Fuel
- AGA – American Gas Association
- California Fuel Cell Partnership – Driving for the Future
- GM
- Mercedes-Benz
- Proton – The Leader in On Site Gas Generation.
- NREL – National Renewable Energy Laboratory
- Massachusetts Hydrogen Coalition
- Plug Power
- Toyota

Infrastructure: Examples of Barriers

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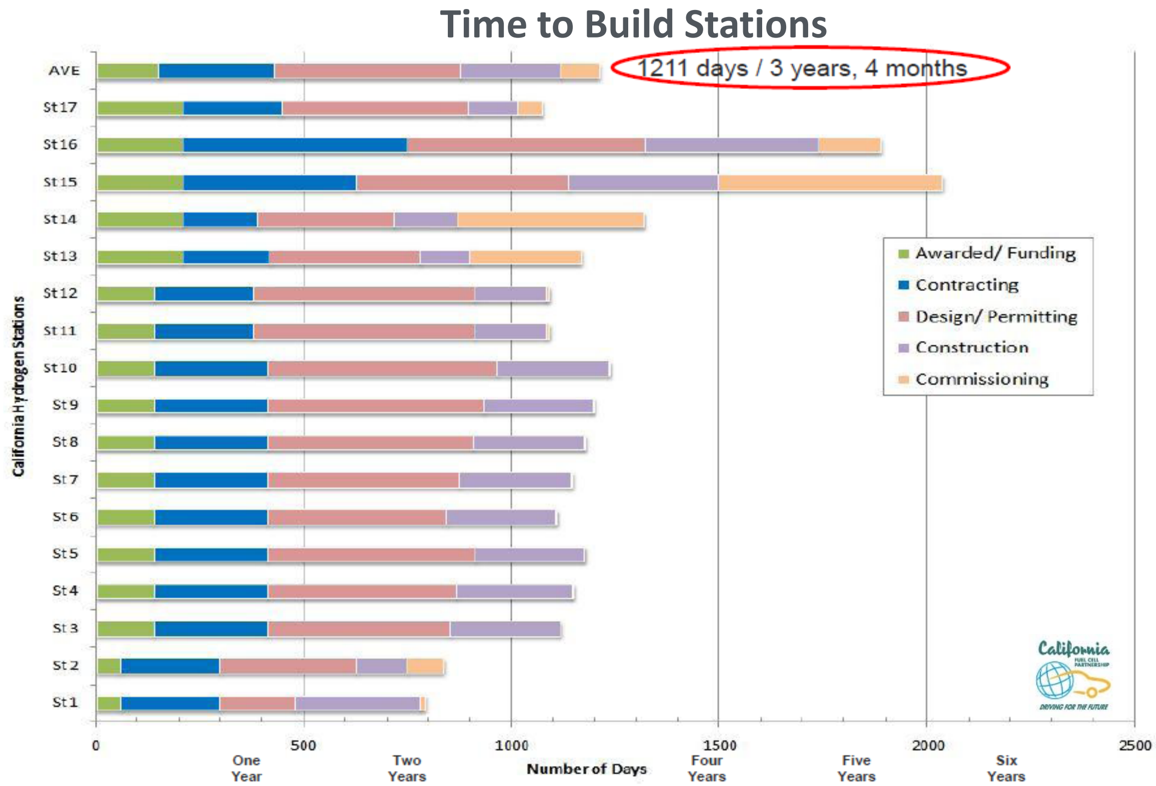
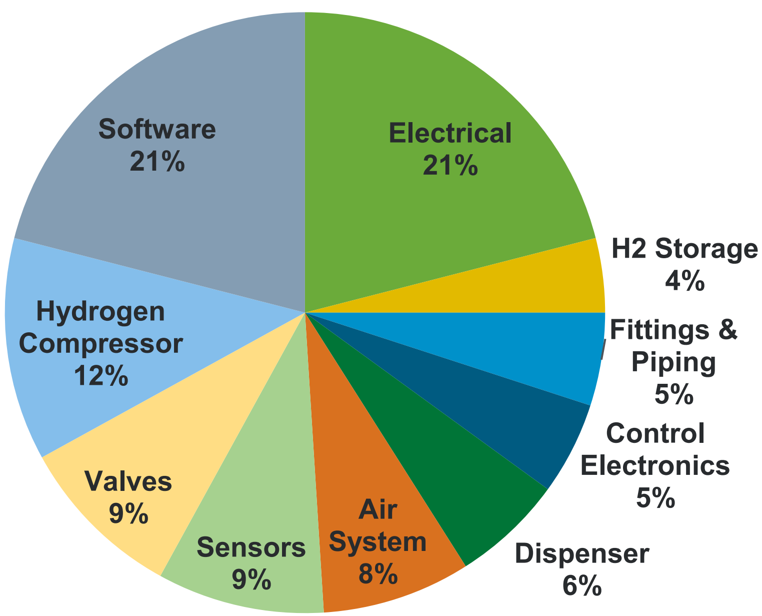
Despite progress in infrastructure development, more work is needed to address permitting times, contract issues, and equipment reliability.





Infrastructure Maintenance by Equipment Type

Over 50% of maintenance is associated with the compressor, electrical, and software systems.

Source: NREL http://www.nrel.gov/hydrogen/docs/cdp/cdp_94.jpg

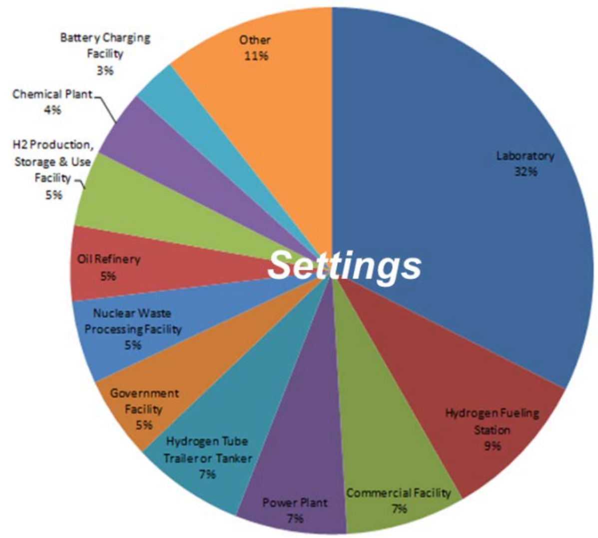
Hydrogen Safety

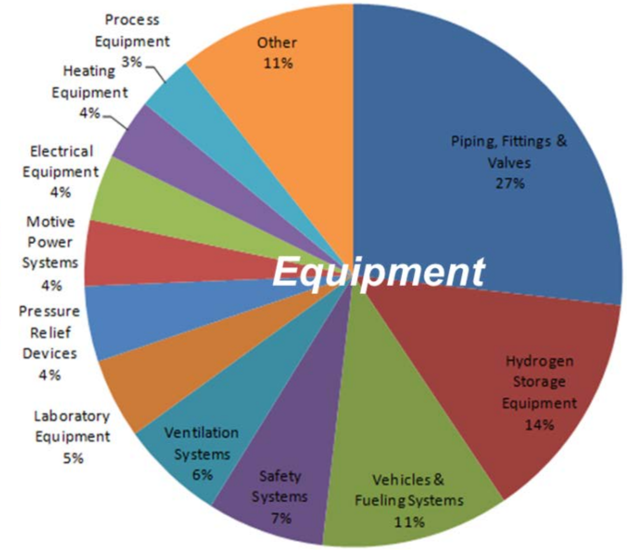
- **Safety Information helps guide R&D.**
- **It is critical to collect and disseminate relevant information.**

Database web address – www.h2incidents.org

Examples:
Piping (36)
Valve (36)
Flexible Tubing (8)
Gasket (6)
Bolts (6)

Two Looks at H2Incidents.org
210 Lessons Learned Events in "H2Incidents.org"





- **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

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

Budget: FCT Program Key Activities

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Funding ($ in thousands)						
	FY 2012	FY 2013		FY 2014		
Key Activity	Approp.	Request	Enacted (C.R.)	Request	Senate	House
Fuel Cell R&D	43,634	36,899	41,266	37,500	TBD	TBD
Hydrogen Fuel R&D[1]	33,824	26,177	31,682	38,500	42,000	TBD
Manufacturing R&D	1,944	1,939	1,899	4,000	TBD	TBD
Systems Analysis	3,000	2,922	2,838	3,000	TBD	TBD
Technology Validation	8,986	4,992	8,514	6,000	10,000	TBD
Safety, Codes and Standards	6,938	4,921	6,808	7,000	TBD	TBD
Market Transformation	3,000	0	2,838	3,000	10,000	TBD
Education	0	0	0	0	0	0
SBIR/STTR	2,298	2,150	2,139	TBD	TBD	TBD
Total	**$103,624**	**$80,000**	**$97,984**	**$100,000**	**$100,000**	**$65,000**

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.

DOE Funding in Hydrogen and Fuel Cells

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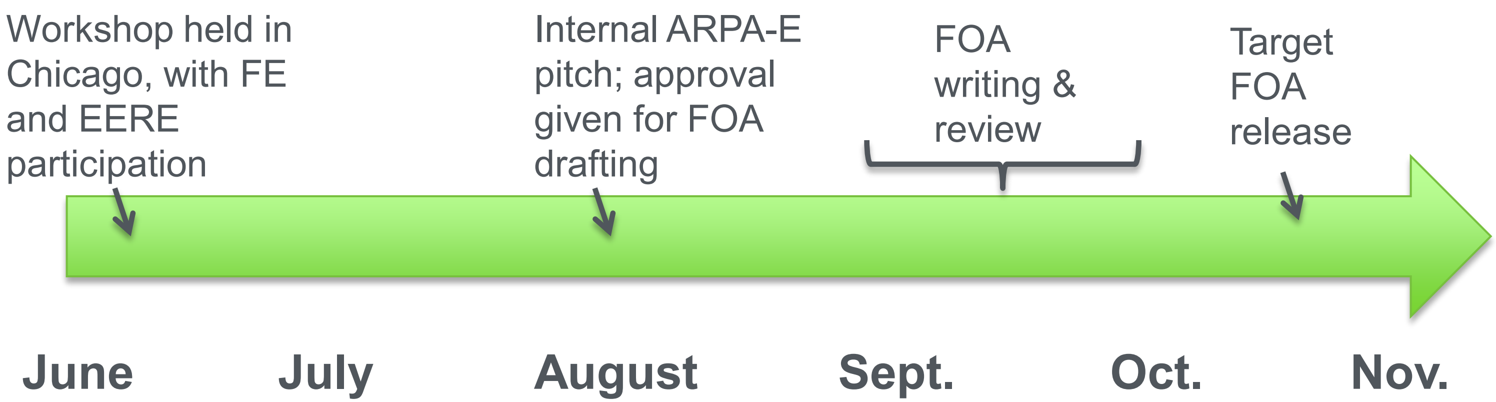
		Funding (*$ in thousands*)						
		FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Approp.	FY 2011 Allocation	FY 2012 Approp.	FY 2013 Approp
EERE Hydrogen & Fuel Cells	**H2**	133,878	145,822	115,797	95,228	53,931	57,692	54,579
	FC	55,633	60,419	80,068	75,069	41,916	43,634	41,266
Fossil Energy (FE-H2 related)		21,513	14,891	20,151	13,970	11,394	0	0
Nuclear Energy (NE)		18,855	9,668	7,340	5,000	2,800	0	0
Science (SC) (Basic Energy Sciences)	**H2**	~20,006	20,058	21,186	19,734	17,640	13,664	~13,720
	FC	~16,382	16,425	17,098	18,318	16,971	13,802	~12,595
Fossil Energy (SECA)		63,400	56,000	58,000	50,000	49,500	25,000	~23,750
ARPA-E (FC related)		0	0	1,248	0	0	0	2,114
DOE FC SUBTOTAL		**135,415**	**132,844**	**156,414**	**143,387**	**108,387**	**82,436**	**79,725**
DOE TOTAL		**329,667**	**323,283**	**320,888**	**277,320**	**194,152**	**153,792**	**~148,024**

ARPA-E Fuel Cell Activities

- Two projects to-date
  - University of Delaware: new alkaline membranes for vehicles
  - Ceramatec: Anhydrous intermediate temperature proton conductors for vehicles
- New program area: intermediate temperature fuel cells (ITFCs) that operate between 200 – 500 °C



- Areas of interest

Category 1: ITFCs with high performance, reliability, and pathways to low cost; deliverable will be short stack

Category 2: ITFCs with additional functionality, such as battery-like response times and fuel production capability; deliverable will be cell

Hydrogen Pathways Report

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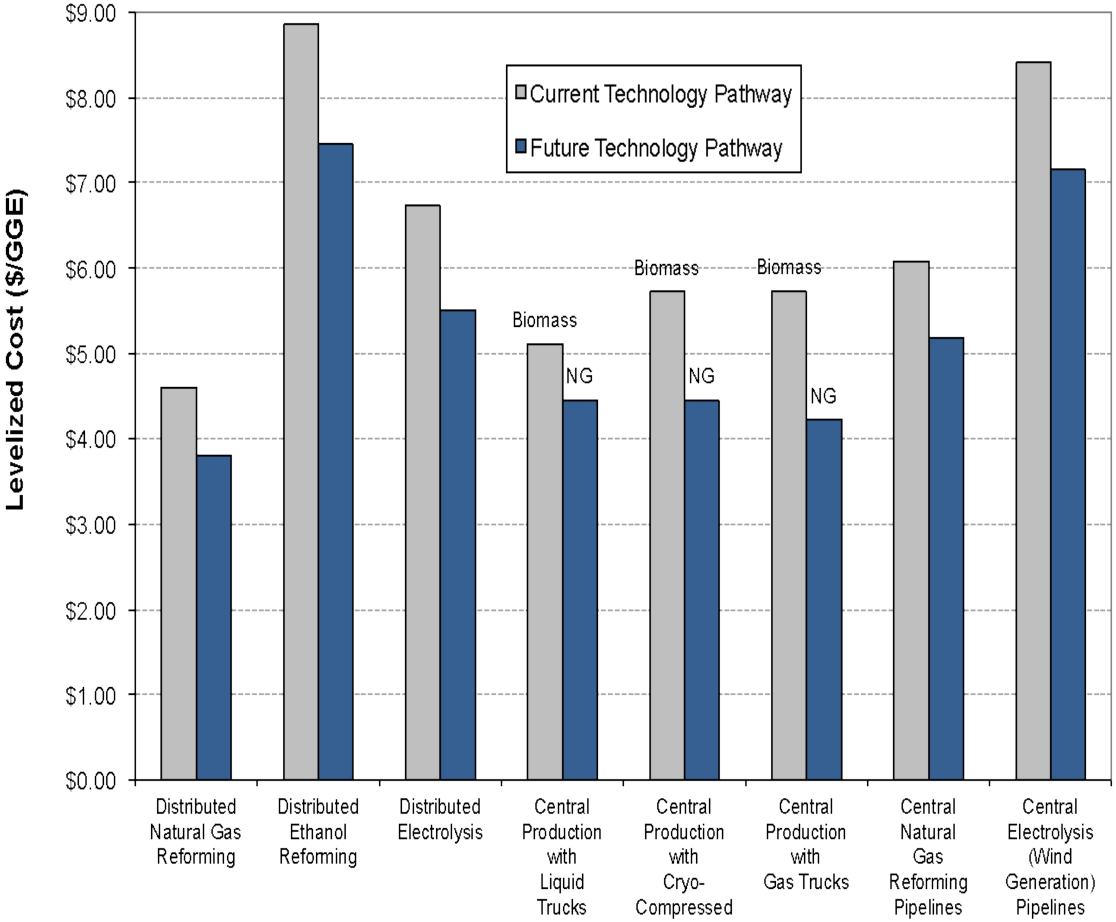

Report Published by NREL

- Life-cycle assessment conducted by NREL of 10 hydrogen production, delivery, dispensing, and use pathways.
- Evaluated for cost, energy use, and GHG emissions. Updates and expands on a previous assessment of seven pathways conducted in 2009.
- Takes a life-cycle approach, addressing both the “well-to-wheels” transportation fuel cycle and also the portion of the vehicle cycle that considers the manufacturing of FCEVs and decommissioning and disposal/recycling of FCEVs.

- Hydrogen production, delivery, and dispensing costs range from $4.60/kg H_2 to almost $9.00/kg H_2.
- Hydrogen production costs are at or near DOE’s $2.00/kg target for four of the production pathways (representing 7 of the total 10 overall pathways evaluated).
- Station CSD costs range from about $1.00/kg to $2.50/kg, showing the need for R&D advancements to lower the cost of dispensed hydrogen.

Resource Requirements Analysis

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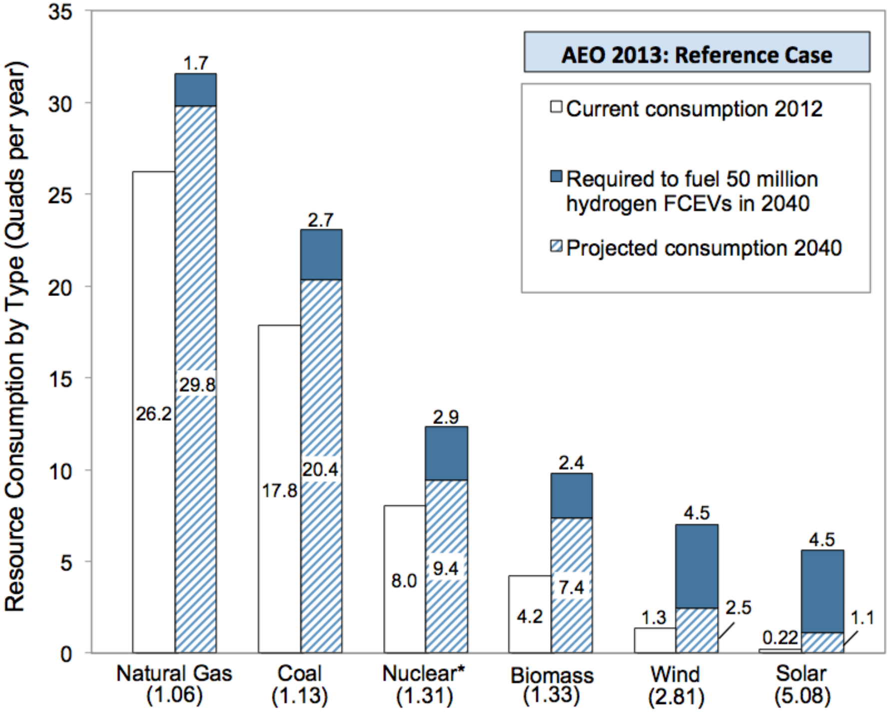
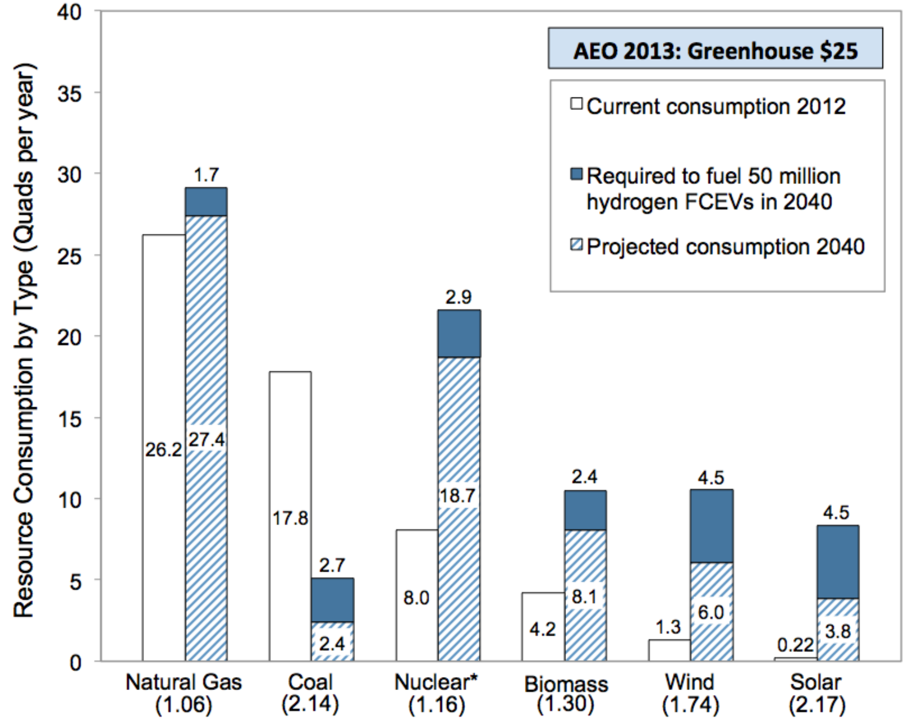
Hydrogen demand from future market success with FCEVs would not place excessive strain on resources or production capacity for natural gas or coal, would comprise a significant portion of total demand for nuclear and biomass, and would significantly exceed expected demand for wind and solar.

Current and projected *Reference Case* and Greenhouse Gas $25 Scenario energy consumption across all energy sectors by resource type, with requirements for 50 million FCEVs





NREL report to be published (Q1 FY2014)

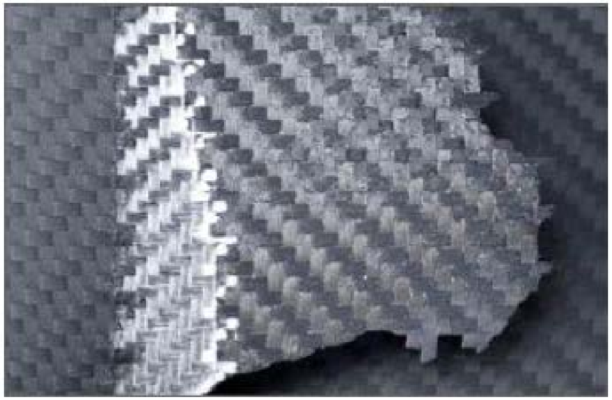
Report identifies percent increase in resources required for 20-50M FCEVs.

IG Audit of DOE's Hydrogen and Fuel Cells Program

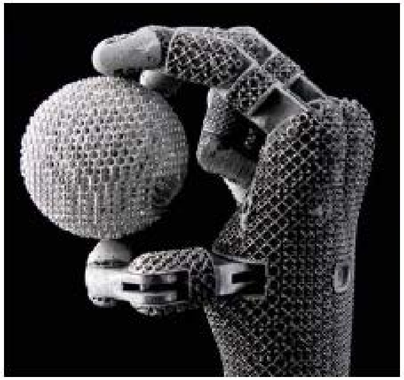
- The IG's report made 4 recommendations:
  - Enhance financial monitoring activities, to include identifying and mitigating potential conflicts of interest, enforcing requirements pertaining to documentation of procurement decisions, and reviewing recipient reimbursement requests for unallowable costs; and
  - Ensure recipients are aware of Federal award requirements related to cost and procurement standards, including allowability of costs claimed for reimbursement, annual indirect cost proposals and ensuring that internal control audits are performed as required.
  - Contracting Officers in EERE and the Office of Fossil Energy conduct reviews of questioned costs identified in our report and determine whether the costs were allowable, allocable and reasonable; and
  - Contracting Officers in EERE conduct a review of the indirect cost rates of the recipient that included potentially unallowable costs associated with legal and professional expenses, meals and entertainment expenses, and bad debt expenses and collect any resulting overpayments identified
- Management concurred with all 4 recommendations and outlined steps that had been or would be taken to improve financial oversight

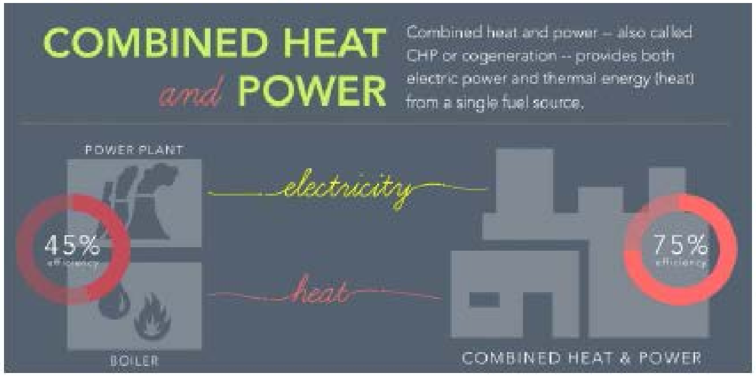
Note: 10 recipients & 20 projects funded by EERE and FE were audited. Out of ~$68M reviewed, ~10%($6.6M) in costs were questioned. Review is underway to determine if questioned costs were unallowable.

1. Increase U.S. competiveness in the production of clean energy products

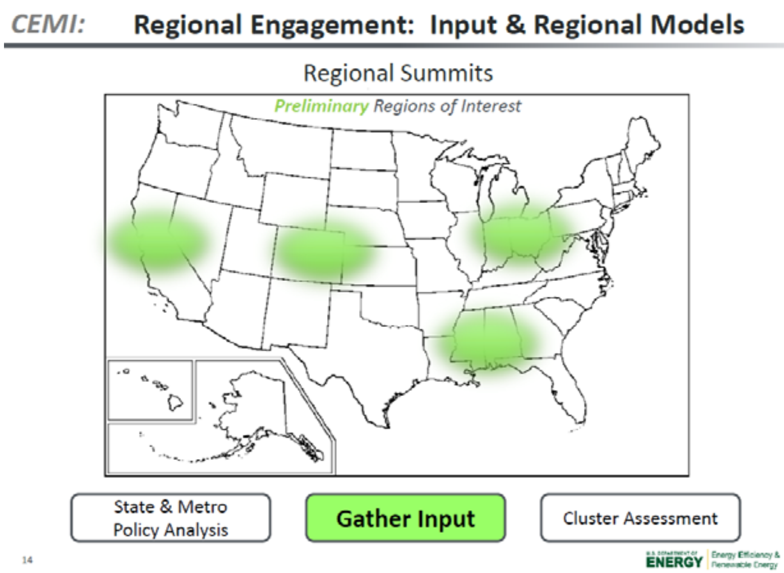


2. Increase U.S. manufacturing competitiveness across the board by increasing energy productivity





CEMI Regional Summits



First Regional Summit – Toledo, OH

Purpose of Regional Summits

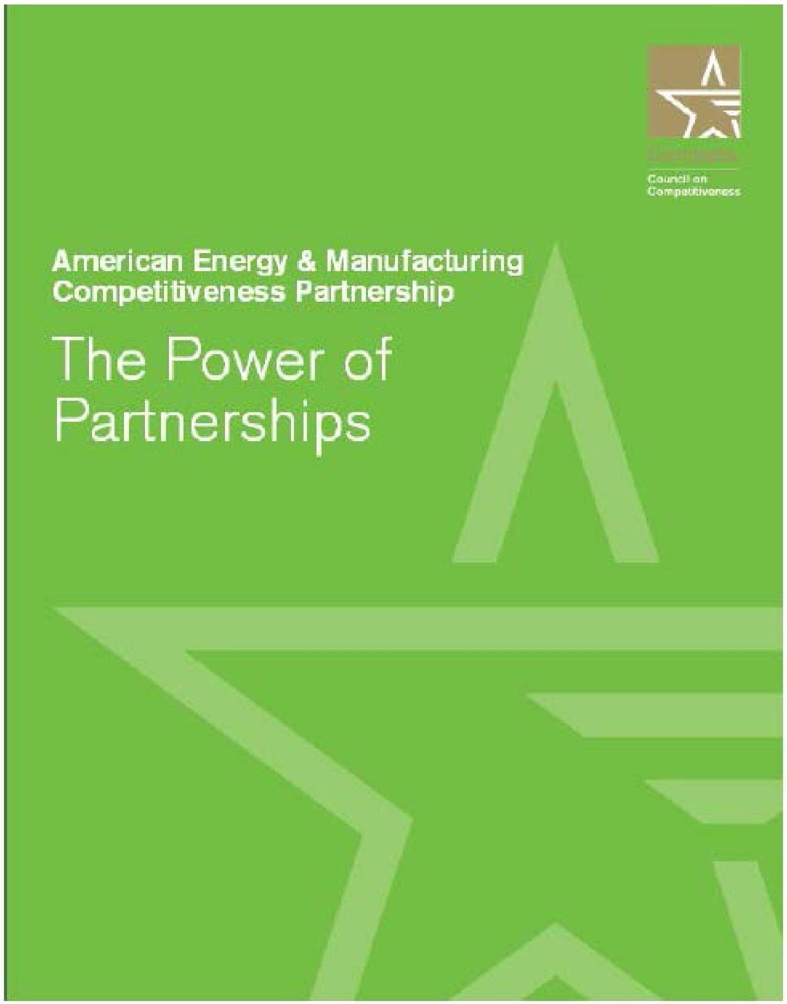
- Showcase regional Clean Energy Manufacturing activities,
- opportunities, priorities, and success stories
- Highlight EERE and Federal Clean Energy Manufacturing
- resources
- Seek input on how the Initiative can strengthen national and
- regional manufacturing competitiveness
- Foster regional stakeholder networking and partnerships

Hydrogen and Fuel Cells Breakout Session

Industry or Industries involved or targeted	**Fuel cell & hydrogen industry and existing supply chain plus suppliers that produce similar items for other industries, e.g., automotive.**
Key problem identified	Volumes are too low for H_2/FC OEMs to provide supply chain leverage, thus component costs are high and/or OEMs use components that are COTS that don't meet operational requirements.
Solution proposed	Better communication on needs, volumes, and standardization, as well as the ability to pool demand for common items would enable lower costs now, while volumes are still low.
Potential impact & Scalability	Enable lower near term system costs to increase market volume; establishes strong relationship and communication between OEMs and supply chain.
How the idea is different from existing efforts	Similar DOE/Fed similar activities are characterized as too formal or too broad to provide specific benefits – State-supported activities are seen as better platforms/methods to facilitate this interaction.
Who would be involved in implementing the idea	DOE would provide overall support and gather knowledge at national level, State and non-profits to enable and run forums, OEMs, and supply chain
Why it is important for DOE to be involved / why this is a good role for DOE	DOE wants to support the commercialization of H_2 & FC technologies to enable national goals for energy and environment, and DOE needs to understand the results and impacts of these activities. DOE, in its 'convening' function, can provide national support to these more regional efforts.
What new resources would be required	Resources need to facilitate, organize and integrate the regional groups
New funding or authorization would be required	Possibly, but probably not extensive.

AEMCP and the Council on Competitiveness

CEMI:



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The American Energy and Manufacturing Competitiveness (AEMC) Partnership between the Council on Competitiveness (CoC) and EERE is a 3-year effort to bring together national leaders to address a rapidly shifting energy landscape and uncover actions that can be taken now to enable America to bolster dramatically its energy, manufacturing, and economic competitiveness.

The focus of the Partnership will be to:

- Increase U.S. competeveness in the production of clean energy products
- Increase U.S. manufacturing competitiveness across the board by increasing energy productivity

Cross-EERE Workshop on QC/Metrology planned

Objective:

- Convene industry and other stakeholders to discuss current status/state-of-the-art for quality control/quality assurance and metrology in manufacturing processes relevant to EERE Offices (Fuel Cells, Solar, Buildings, Vehicles, Advanced Manufacturing).

Discussion points:

- **Critical process and material inspection and metrology needs** for the manufacturing technologies relevant to each EERE Office
- Identify **key challenges to the development, validation, and deployment of technique**s to address those needs
- Identify materials and processes inspection and metrology needs
- Identify **opportunities for collaboration** across EERE Offices to address shared challenges

Outcomes:

- Plans and strategies to address synergistic opportunities and to accelerate collaboration with and transfer of these technologies to industry
- The results of the workshop will inform EERE of opportunities to address synergistic and cross-cutting measurement and inspection needs for EERE technologies.

International Partnerships

International Partnership for Hydrogen and Fuel Cells in the Economy

- ***Representatives from 17 member countries & the European Commission***
- **Facilitates international collaboration on RD&D and education**
- **Provides a forum for advancing policies and common codes and standards**
- **Guided by four priorities:**
  1. Accelerating market penetration and early adoption of hydrogen and fuel cell technologies and their supporting infrastructure
  2. Policy and regulatory actions to support widespread deployment
  3. Raising the profile with policy-makers and public
  4. Monitoring technology developments

Japan - Chair
US and Germany - Vice Chairs
Next meeting Nov 2013- Japan

5^{th} International Conference on H_2 Safety
Progress in Safety of H_2 Technology & Infrastructure: Enabling the Transition to Zero Carbon Energy
September 9-11, 2013 Brussels, Belgium

Recent Activities:

- Launched international round robin testing of Type IV tanks
- Published Demonstration and Deployment Map
- Published Communiqué on the opportunities associated with using hydrogen and fuel cell technologies
- Fuel Cell Cost Analysis Comparison Published

Website: http:www.iphe.net

International Energy Agency – Implementing Agreements

Advanced Fuel Cells Implementing Agreement: 13 member countries currently implementing seven annexes

Hydrogen Implementing Agreement: 18 member countries, plus the European Commission currently implementing nine tasks

Other Collaboration examples

Joint Technology Initiative (JTI); **MOUs** (NEDO-AIST-LANL, Hiroshima U-LANL); **Bi-lateral agreements, strong international collaboration on safety**

HTAC Hydrogen Production Expert Panel Workshop

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

Held 10-12th May 2012 in Arlington VA:
Event kick-off featured opening remarks from U.S. Secretary of Energy (2012- Steven Chu)

EXPERT PANEL GOALS

- **EVALUATE the status and prospects for hydrogen production, quantifying supply and demand in current markets and in possible future scenarios (energy, transportation, chemicals and fuels, etc.)**
- **IDENTIFY the key technologies and critical challenges in producing hydrogen for today's markets, and for large-scale central and distributed renewable production**
- **PRIORITIZE research and development needs to advance promising hydrogen production technologies**
- **STRATEGIZE on how to best leverage R&D efforts in hydrogen production among DOE Offices and Programs (including EERE-FCT, SC, ARPA-E and the Innovation Hubs), and with other agencies**

WORKSHOP PROCESS

Panel Steering Committee with broad spectrum of expertise oversees workshop flow and report generation

↓

Panel Technical Experts present on opportunities and challenges in near-term to long-term H_2 production technologies

↓

Breakout sessions of Panelists and invited stakeholders identify key challenges and research priorities in near- and long-term technologies

↓

WORKSHOP PRODUCT: Recommendations Report Submitted to DOE

The report with the DOE response can be found at: http://www.hydrogen.energy.gov/advisory_htac.html

Expert Panel Participants

Steering Committee	
Panel Chair: Dr. Levi Thompson, University of Michigan	
Near Term Technologies	***Longer Term Technologies***
Proton OnSite	*Air Liquide*
Air Products & Chemicals, Inc.	*The Earth Institute - Columbia University*
Aretê Corporation	*University of Colorado Boulder*
Hydrogenics Corporation	*University of Oregon*

Technical Expert Presenters	
Near Term Technologies	***Longer Term Technologies***
Proton Onsite	*Sun Catalytix*
Air Products & Chemicals, Inc.	*California Institute of Technology*
Hydrogenics Corporation	*Pennsylvania State University*
Air Liquide	*National Renewable Energy Laboratory*
FuelCell Energy	*Pacific Northwest National Laboratory*
Nuvera Fuel Cells	*University of Colorado Boulder*

More then 20 additional stakeholders from government, industry and academia attended the workshop as observers, and as active participants in the breakout sessions

Expert Panel Report*

Examples of Recommendations and Activities/Responses (see url for detailed responses)

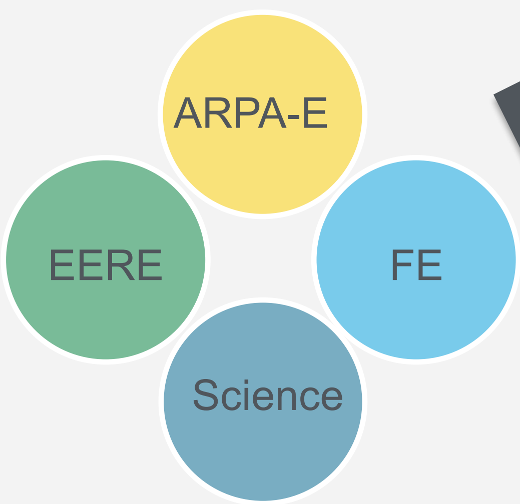
- **Public-Private Partnerships- to focus on infrastructure**
  - Aligned with DOE efforts to co-launch H2USA (>25 partners)- see H2USA briefing
- **Hydrogen for Energy Storage**
  - Additional analysis underway (e.g. discussions with EPRI) to identify specific next steps & strategy
  - International workshop on energy storage (IPHE) conducted
  - NREL Energy Systems Integration Facility (ESIF) established – next steps involve identifying opportunities through ESIF
- **Coordination & Collaboration (within DOE & other agencies)**
  - DOE-wide Tech Team formed on fuel cells (EERE, FE, BES, ARPA-E, EPSA, etc)
  - Interagency Working Group (Interagency Action Plan)
  - Example- joint FOA planned with NSF (longer term hydrogen production technologies)

****http://www.hydrogen.energy.gov/advisory_htac.html***

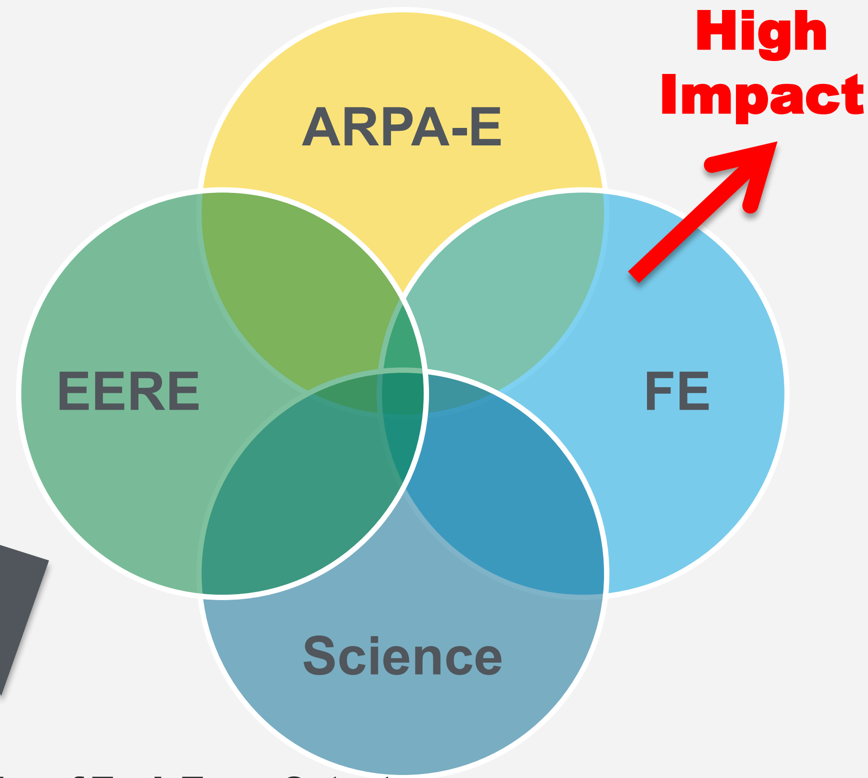
DOE-wide Tech Team established

Examples of Information Sharing

- Best practices/protocols on diagnostics
- Biweekly meetings- presentations/updates
- Cross-tech team/office coordination
- Workshop planning (e.g., NG for fuel cells)



High-impact Interactions - DOE Fuel Cells Tech Team



Examples of Tech Team Outputs

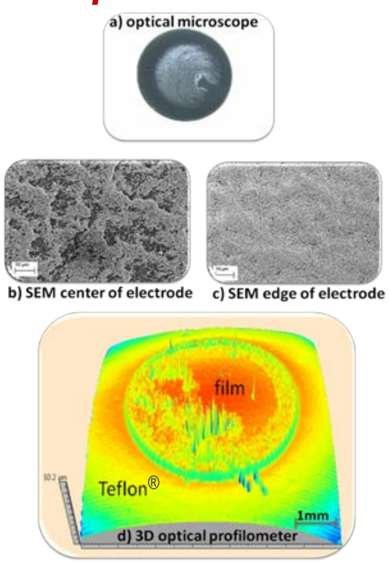
Annual Merit Review coordination (joint poster session)
CFO White paper on big ideas
Portfolio optimization
Specific example to impact scientific R&D community planned: Develop best practices in diagnostics, disseminate to basic science and applied R&D community
Future: Joint workshops planned to identify overarching goals and strategy

Example: Rotating Disk Electrode (RDE) technique used by basic/applied science community for PEMFC electrocatalyst screening

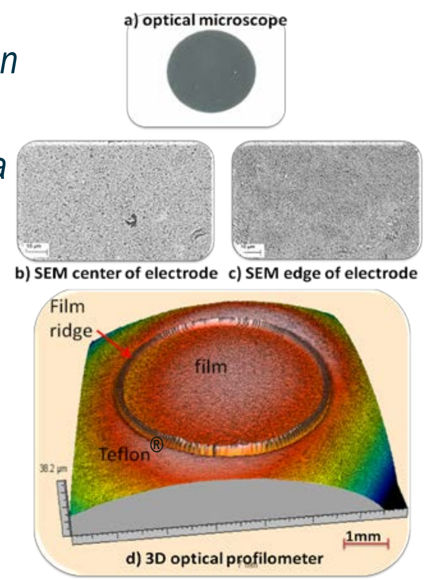
Tech Team Output: A standard test protocol and best practices would enable consistency in procedures and less variability in results from different labs

- *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.*

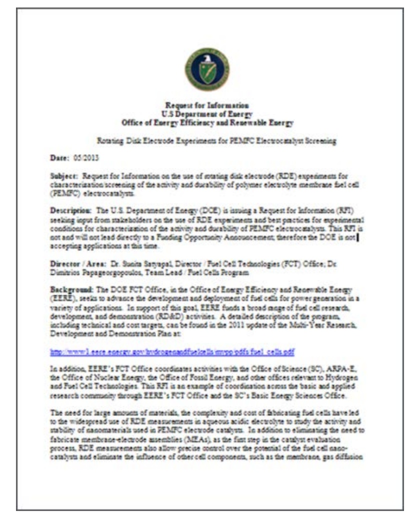
Example:



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 nano-catalysts 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

H-Prize: Home 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
- Input from HTAC would be welcomed – email sarah.studer@ee.doe.gov or reginald.tyler@go.doe.gov.

Proposed H-Prize Criteria- Draft

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

Key questions for HTAC: usability criteria and relative weight of different criteria

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	

Examples of Key Activities: HTAC and Program Impact

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

- Annual Report
- Prior input on Program Requests
  - H_2 threshold cost revision
  - H_2 Enabling Renewables Working Group (subcommittee)
  - H_2 Production Expert Panel
  - Feedback on H-Prize
  - Manufacturing Working Group (subcommittee)

Additional Areas of Interest:

- Feedback on interim hydrogen cost target
- Assessment of e-gallon (and feedback on H-gallon concept)
- RFIs planned
- Other?

Interim H_2 Cost Target

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

Objective: Establish an interim hydrogen cost target to evaluate and measure cost of hydrogen for early market applications for transportation fuel.

Methodology: The interim hydrogen cost target analysis is a "top-down" analysis of the cost at which hydrogen in the early market (2015-2017) would be competitive with gasoline in the light-duty vehicle (LDV) market. Because it is market-driven, it is pathway independent and provides a measure for assessing technology performance against market requirements in regions where early fuel cell electric vehicle penetration will occur (California, New York and Hawaii). The FCEV is referenced to the gasoline ICE in the early market since it will be the predominate vehicle platform in the early market phases of the FCEV rollout.

Interim H2 Cost Target ($/gge) = (GP/ICE FE) * (FCEV FE)

where

GP = the regional gasoline price, $/gge, untaxed

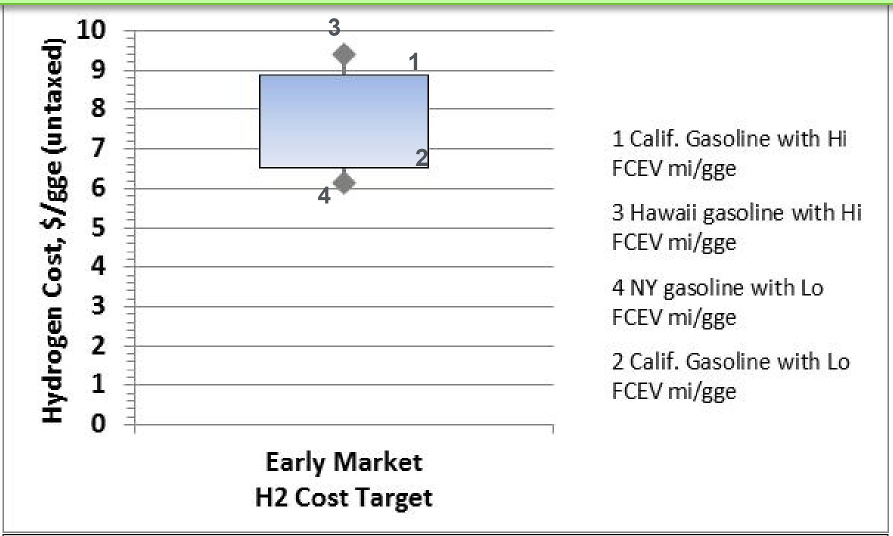
ICE FE = the average comparable passenger car adjusted combined fuel economy of a gasoline internal combustion engine, miles/gge

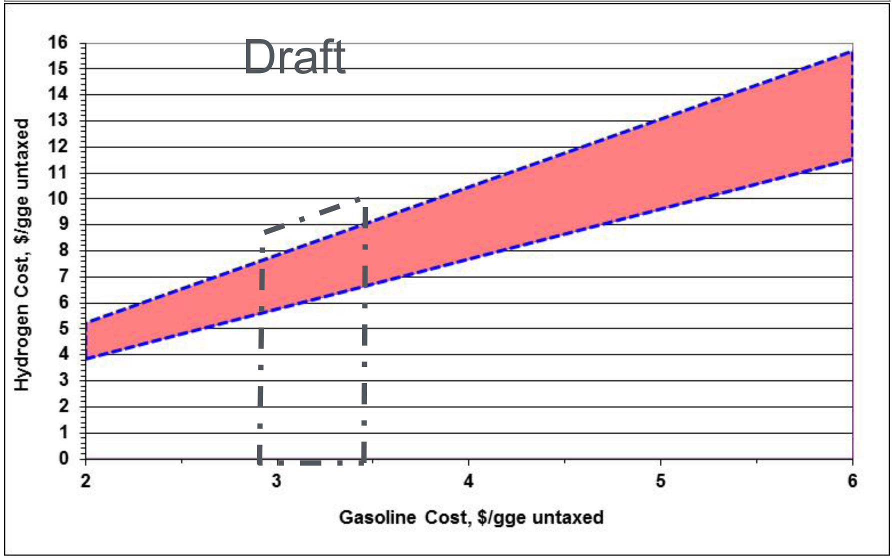
FCEV FE = the adjusted fuel economy of a comparable fuel cell electric vehicle, miles/gge

Assumptions:

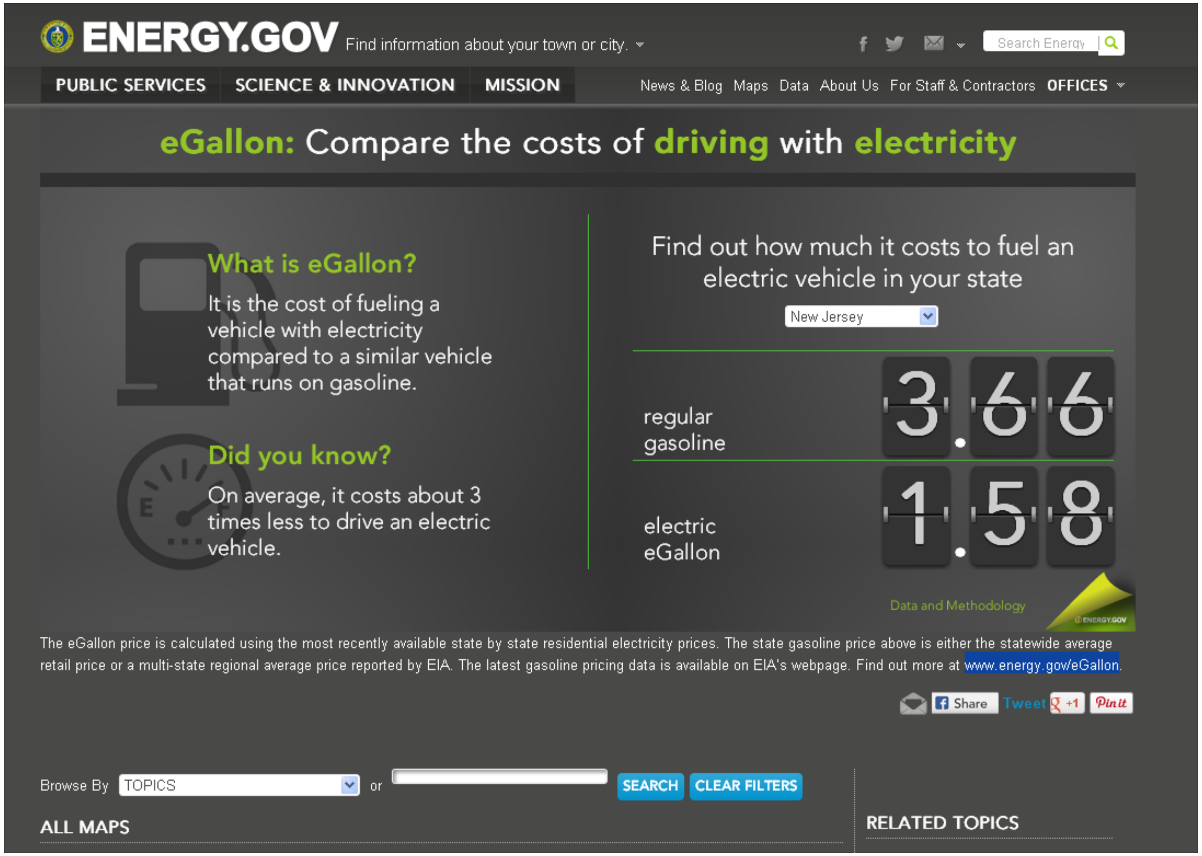
Gaso. Prices, untaxed [1]	Hawaii	California	New York
	$3.60/gge	$3.40/gge	$3.20/gge
Fuel Economies [2]	Gaso. ICE	FCEV Low	FCEV High
	26 mi./gge	50 mi/gge	68 mi/gge

H_2 would be competitive with gasoline at a cost of $6 - $9/gge in the early markets.





[1] http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_w.htm



EGALLON METHODOLOGY

The average American measures the day-to-day cost of driving by the price of a gallon of gasoline. As the price of gasoline rises and falls, it tells consumers how much it costs to drive. If you drive past a gas station you'll see the price of a gallon of gas posted. But for electric vehicle (EV) owners -- who generally fuel at home -- it's hard to measure just how much it costs to drive.

- To help current and potential EV drivers better understand the cost of driving an EV, the Energy Department created a metric called the "electric gallon" -- or "eGallon."
- The eGallon represents the cost of driving an electric vehicle (EV) the same distance a gasoline-powered vehicle could travel on one (1) gallon of gasoline.

Key Links

http://energy.gov/maps/egallon

http://energy.gov/downloads/egallon-methodology

http://energy.gov/sites/prod/files/2013/06/f1/eGallon-methodology-final.pdf

hGallon – To communicate the competitive price of hydrogen relative to gasoline for the consumer

Objective: To help potential fuel cell electric vehicle (FCEV) drivers better understand the cost of driving a FCEV, the "hydrogen gallon" or "hGallon" is created to represent the comparison of the cost of hydrogen fuel for a FCEV to the cost of gasoline for an internal combustion engine vehicle on a gasoline gallon equivalent (gge*) basis.

Methodology:
The hGallon is measured as an "implicit" cost of a gallon of gasoline. It is calculated by multiplying the hydrogen cost (HC) by the average comparable passenger car adjusted combined fuel economy (FE) and the average fuel consumption of available fuel cell electric vehicles (FCHC), as follows:

*hGallon ($/gge) = FE * HC * FCHC*

where.
FE = the average comparable passenger car adjusted combined fuel economy [2],
miles/gallon

FCHC = the average hydrogen consumption 0.017 gge/mile (1/59 miles/gge) of representative FCEVs in the U.S.[1],

And

HP = the hydrogen cost $4.50/gge[4].

Example:
The price of a hgallon would be:

*28 mi/gal * $4.50/gge * 0.017=* ***$2.14/gge***

*gge – one kg of hydrogen is equal to one gallon of gasoline on a Btu basis.

Assumptions:

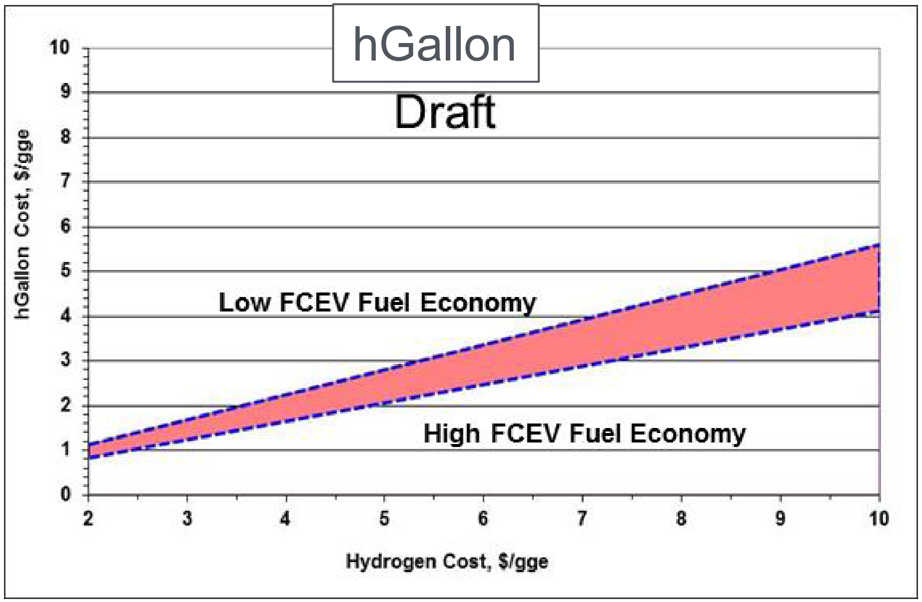
Hydrogen cost:

[4] The "hydrogen cost" is the current cost of hydrogen at high volume production and includes the cost of infrastructure.
http://www.hydrogen.energy.gov/pdfs/12024_h2_production_cost_natural_gas.pdf

FCEV fuel economies:

[1] The fuel economy is an average of the mid size fuel cell vehicle of the FCTO record (50 mpgge) and the Toyota Highlander FCEV (68 mpgge) on-road fuel economies.
http://hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

Gasoline ICE fuel economy (28 mi/gge): [2] "Comparable" is defined as those vehicles in the size classes in which FCEVs are available. For model year 2012, the harmonic mean fuel economy of small (28.8 mpg, 25.1% of cars sold) and midsize (27.5 mpg, 21.7% of cars sold) cars is 28.2 mpg.



Thank you

Additional Information

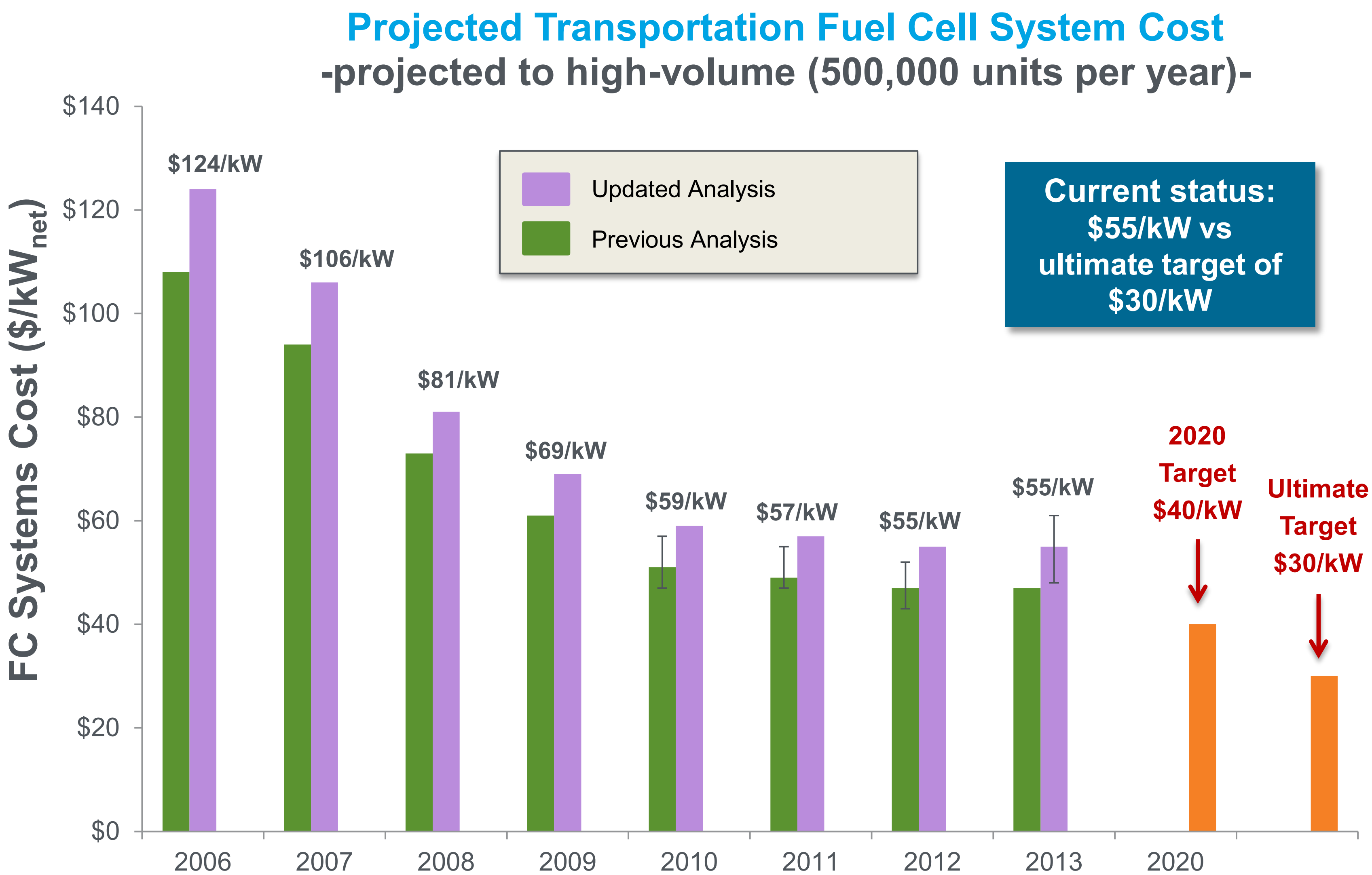
Pt price revision

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

Pt price revised to \$1500 / troy oz., from \$1100 / troy oz. used since 2007

- Fuel cell cost analysis updated with revised Pt price and with additional updates to revisions (heat rejection requirement, compressor-expander efficiencies, etc…)

Fuel Cells High Volume Cost Analysis Results



Well-to-Wheels GHG Emissions

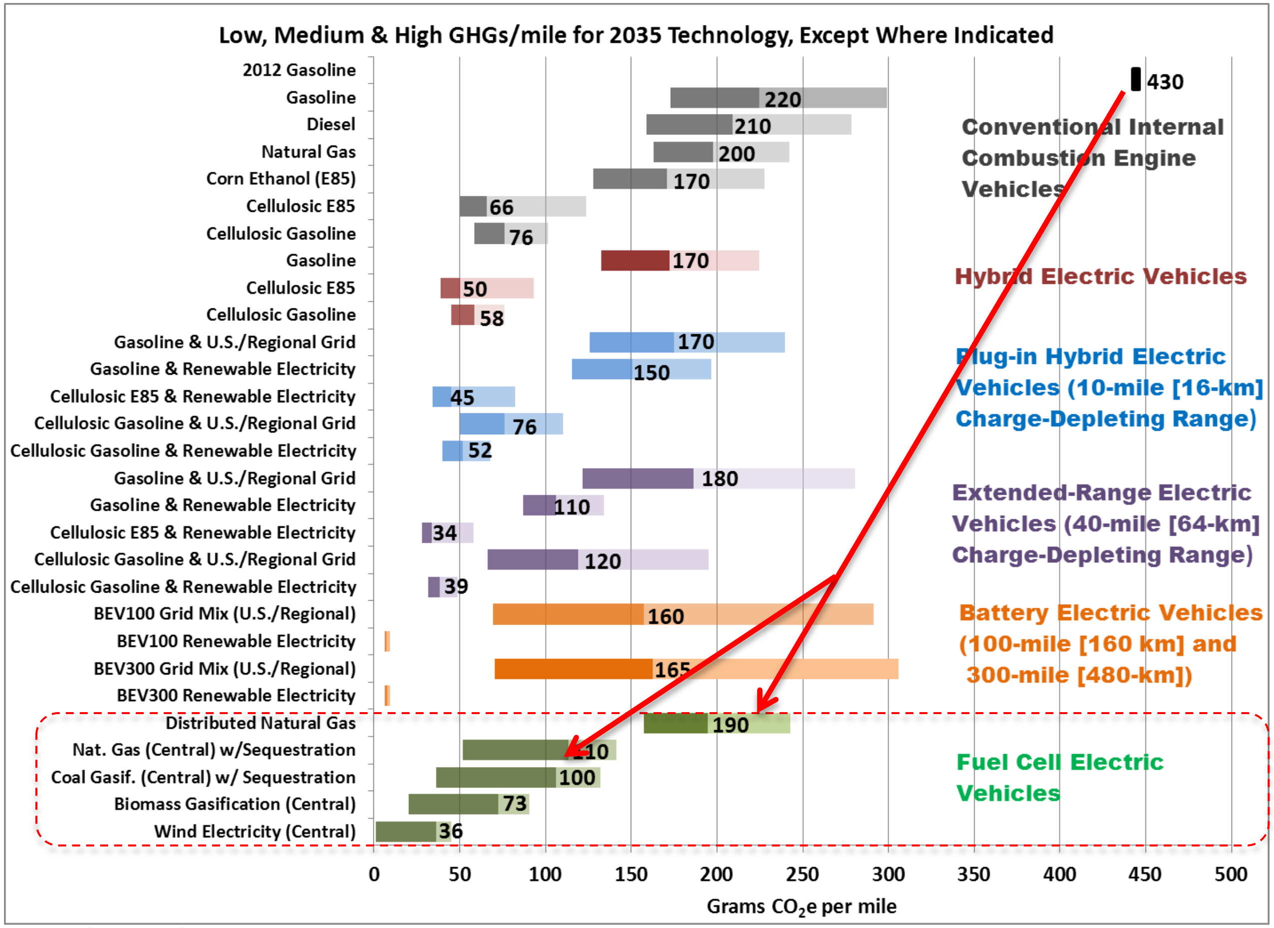
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Analysis by Argonne National Lab, National Renewable Energy Lab and EERE (Vehicles, Fuel Cells, & Bioenergy Technologies Offices) shows benefits from a portfolio of options

- Updated, peer-reviewed analysis (EERE multi-Office coordination)
- Hydrogen from natural gas can reduce GHG emissions by >50% (significantly more if centrally produced and with carbon capture)

Well-to-Wheels Greenhouse Gas Emissions for 2035 Mid-Size Car

(Grams of CO2-equivalent per mile)



Low/medium/high: sensitivity to uncertainties associated with projected fuel economy of vehicles and selected attributes of fuels pathways, e.g., electricity credit for biofuels, electric generation mix, etc.

See reference for details: http://hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

Well-to-Wheels Petroleum Use

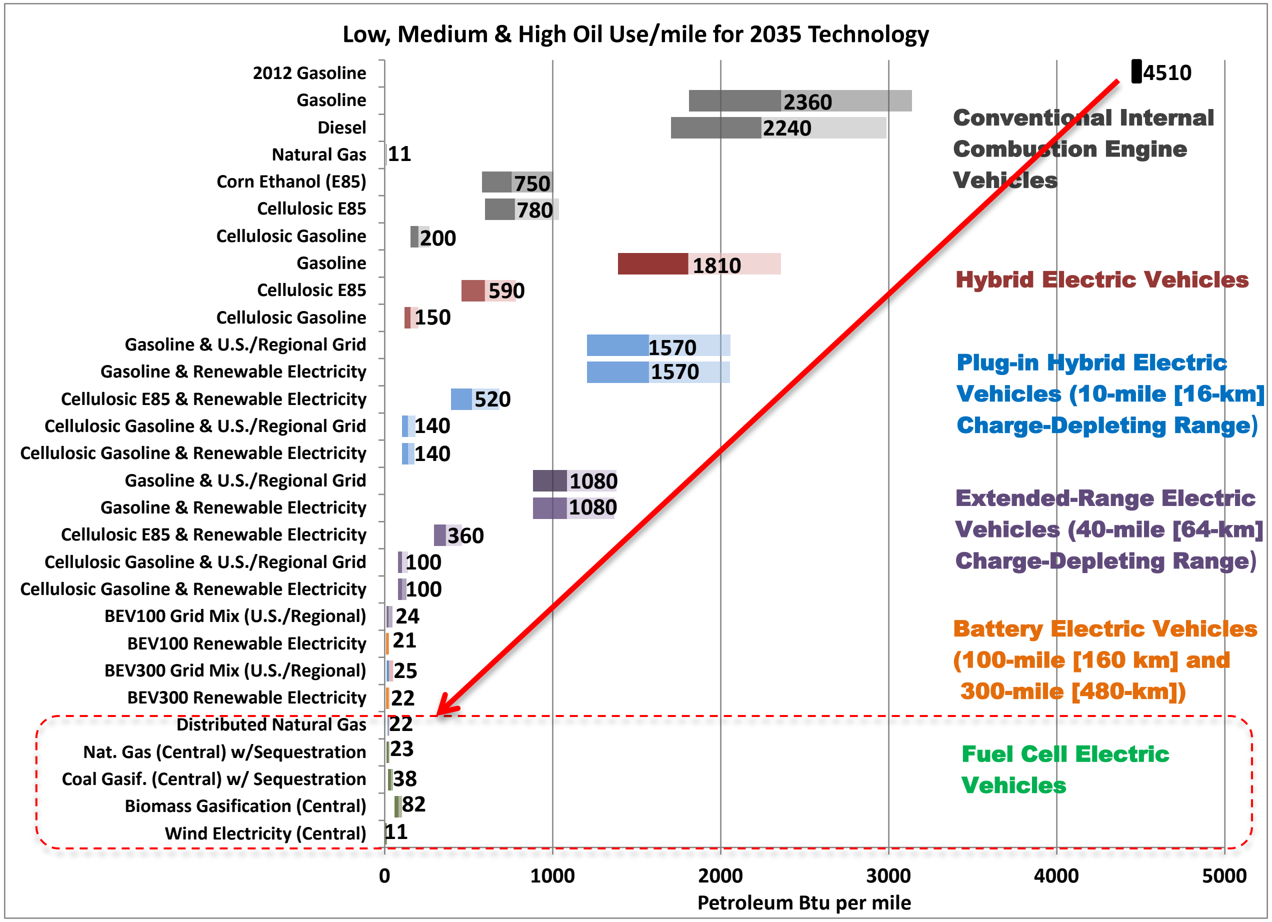
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Analysis by Argonne National Lab, National Renewable Energy Lab and EERE (Vehicles, Fuel Cells, & Bioenergy Technologies Offices) shows benefits from a portfolio of options

- Updated, peer-reviewed analysis (EERE multi-Office coordination)
- Hydrogen from natural gas can reduce petroleum use nearly 100%

Well-to-Wheels Petroleum Energy Use for 2035 Mid-Size Car

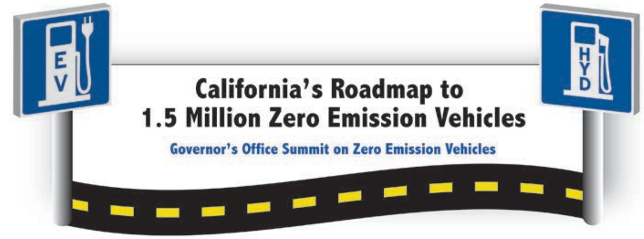
(Btu per mile)



See reference for details: http://hydrogen.energy.gov/pdfs/13005_well_to_wheels_ghg_oil_ldvs.pdf

Low/medium/high: sensitivity to uncertainties associated with projected fuel economy of vehicles and selected attributes of fuels pathways, e.g., electricity credit for biofuels, electric generation mix, etc.

California AB 8



- Extends existing fees on motor vehicles, boat registrations, and new tires to fund the AB 118, Carl Moyer, and AB 923 programs through January 1, 2024
- Extends authority of local air districts to impose vehicle registration surcharges to achieve emission reductions from vehicles and off-road engines.
- Dedicates funding for at least 100 publicly available hydrogen stations, with a commitment of $20 million a year (or 20% of available funds) until January 1, 2024.

Source: CA Fuel Cell Partnership

Hydrogen funding

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

- CEC to allocate $20 million or 20% of available funds annually until 2024 to fund at least 100 publicly available hydrogen stations.
- ARB to collect and make available the number of hydrogen-fueled vehicles that OEMs project to sell or lease over the next three years, and the number of HFVs registered with the Department of Motor Vehicles.
  - ARB will evaluate the need for, identify good locations for, and define operating standards required of hydrogen stations and report its findings to CEC.
- CEC and ARB to review and report on the progress toward establishing a hydrogen network that provides the coverage and capacity to fuel vehicles.
- Permits CEC, after consulting with ARB, to cease to provide funding to hydrogen stations if the private sector is establishing stations without need for public funds.
- Gives the CEC four years to encumber the $20 million and four more years to expend the funds to build hydrogen stations.
- Authorizes CEC to design grants, loan incentive programs, revolving loan programs, and other forms of financial assistance.

Source: CA Fuel Cell Partnership

Southern CA Public Hydrogen Stations

Open

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

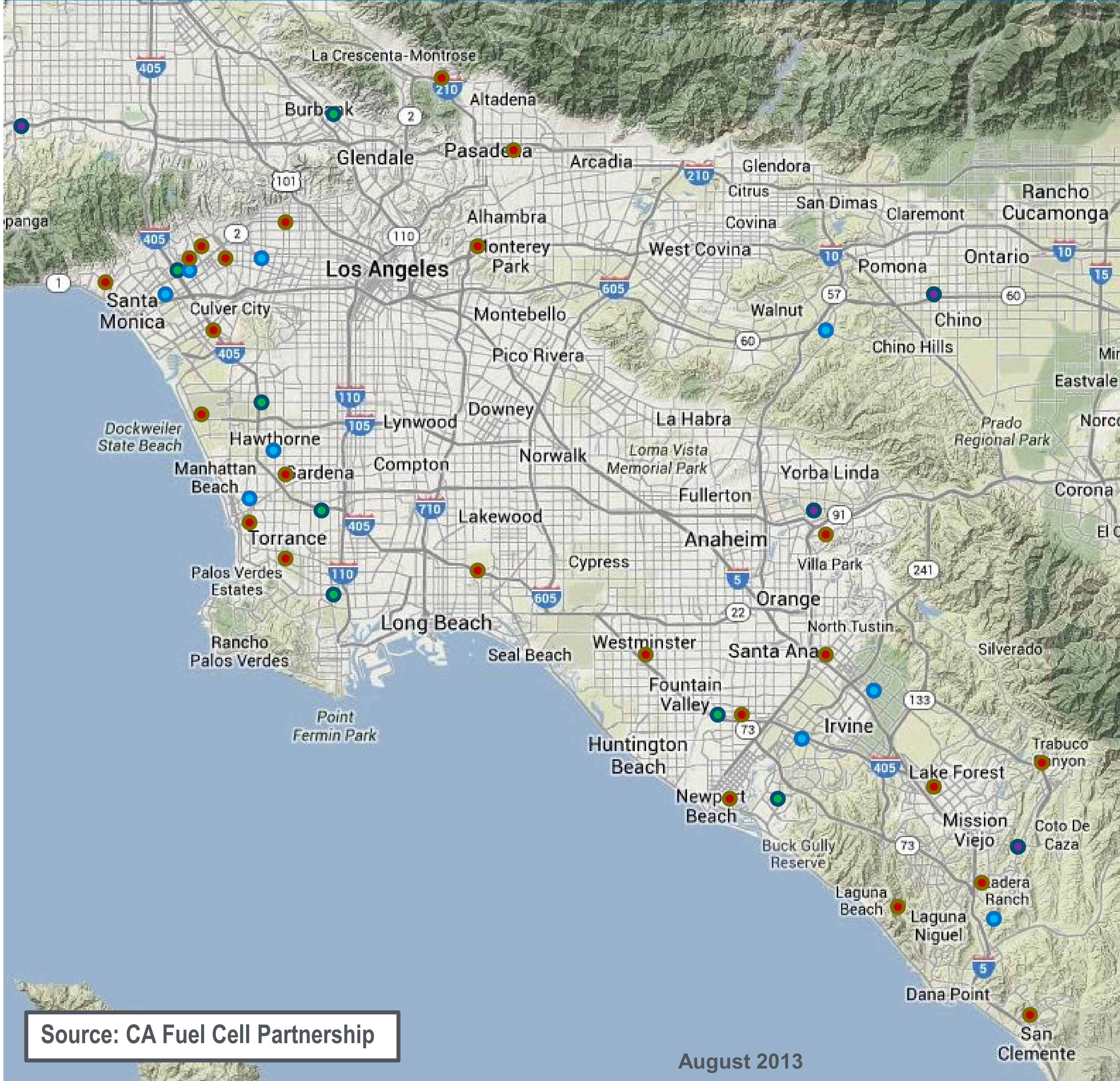
In Development

- 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



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