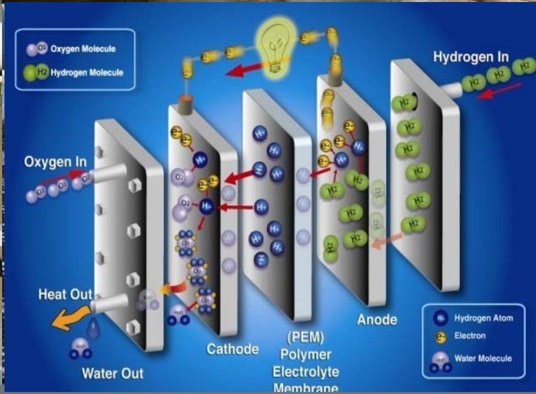
Fuel Cell Technologies Office Overview

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



Hydrogen and Fuel Cell Technical Advisory Committee

Washington, DC

04/01/2014

Dr. Sunita Satyapal

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

Agenda

- EERE Organizational Updates
- Program Overview
  - Targets & Current Status
  - Key Accomplishments & Analysis
- HTAC Recommendations
  - Program Responses and Next Steps

EERE Reorganization includes new Office of Transportation

Sustainable TRANSPORTATION - EERE Technology Offices

Hydrogen and Fuel Cells
Including stationary power

Vehicles

Bioenergy

- **Efficiency Improvement**
- **Fuel Diversification**
- **Domestic & Renewable Sources**
- **Reduced GHG**

National Energy Goals & Climate Action Plan
Reduce net oil imports by 50% by 2020, compared to 2008
Reduce GHG emissions >80% below 2005 levels by 2050

EERE Organization Chart

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

- Assistant Secretary David Danielson
  - Principal Deputy Assistant Secretary Michael Carr
    - **Office of Transportation**
      - Vehicle Technologies Office (VTO)
      - Bioenergy Technologies Office (BETO)
      - **Fuel Cell Technologies Office (FCTO)**
    - Operations & Strategic Innovation Office (OISO)
      - Office of Strategic Programs (SP)
        - Communications
        - Stakeholder Engagement
        - Legislative Affairs
        - Technology to Market
        - Policy & Analysis
        - International
      - Office of Business Operations (BO)
        - Project Management Coordination Office (PMCO)
        - Workforce Management Office (WMO)
        - Golden Service Center (GSC)
      - Information Technology Services Office (ITSO)
      - Office of Financial Management (FM)
        - Budget Office

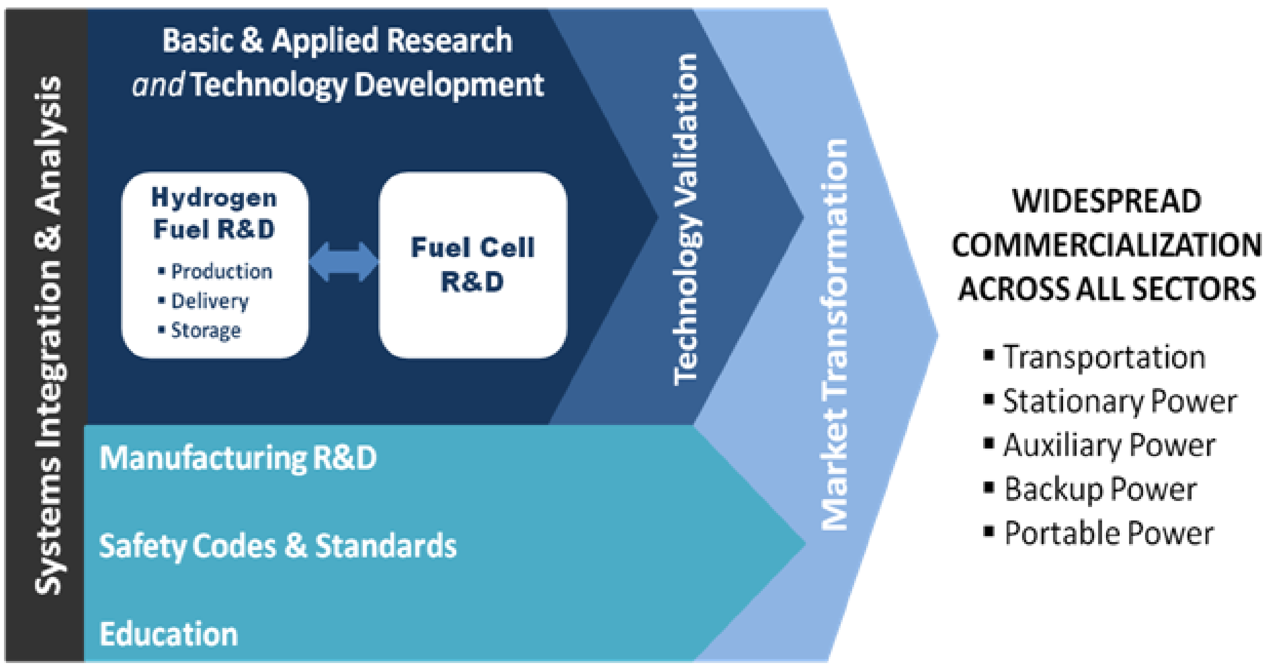
Reuben Sarkar

Deputy Assistant Secretary - Transportation

- Senior Director Business Development at Proterra, Inc. (a leading start-up manufacturer of electric buses and fast charging stations)
- Multiple fuel cell bus programs
- Lead Design Release Engineer at GM on the electric drive unit for the Chevy Volt
- BS, MS in Chemical Engineering, MBA

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.

Key Goals : Develop hydrogen and fuel cell technologies for early markets (stationary power, lift trucks, portable power), mid-term markets (CHP, APUs, fleets and buses), and long-term markets (light duty vehicles).



More than 200 projects currently funded at companies, national labs, and universities/institutes

Key Targets for Automotive Applications

- $40/kW by 2020 (ultimate target: $30/kW)
- 5000 hour durability (150,000 miles)
- 60% efficiency
- > 300 mile driving range

Key Partnerships, Overview & Activities

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

R&D	Demonstration & Deployment	Enabling Commercialization
USDRIVE (Driving Research and Innovation for Vehicle Efficiency and Energy Sustainability) *Precompetitive R&D* – USCAR, energy companies, EPRI, utilities **iea** International Energy Agency – 25 countries – Advanced Fuel Cells Implementing Agreement – Hydrogen Implementing Agreement	**California Fuel Cell Partnership** – Auto OEMs, energy companies, government, fuel cell companies **Other State Partnerships** Government, business, academia – South Carolina (SCHFCA) – CT, MA (e.g.,CCAT, H2-Fuel Cell Coalition) – Hawaii (Hawaii Hydrogen Initiative, H2I) *National lab led activities with industry* *(e.g., – SNL & NREL)*	**IPHE** *Government partnership* *Coordination on policy, lessons learned, accelerating commercialization* - 17 countries & the European Commission **H_2USA** *Public-private partnership* ~30 partners including global OEMs, H_2 providers, etc.

Key Goals

R&D	Demonstration & Deployment	Enabling Commercialization
- \$40/kW by 2020* - <\$4/gge H_2 by 2020* *modeled, projected at high volume cost	• Accelerate fuel cell technologies in early market applications • 5X increase in deployments from 2012 baseline	• Enable H_2 infrastructure for ~2017 FCEV rollout • Promote commercial introduction and widespread adoption of FCEVs

Strategic Feedback & Guidance

HTAC – Federal Advisory Committee: Review and make recommendations on the implementation of programs and activities, safety, economical, and environmental consequences of hydrogen and fuel cell technologies, and plans.

National Academics, Quadrennial Review, GAO, IG, etc.

Summary of Targets & Status

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

Category	Goal	2005/2006 Status	Current Status
Automotive Fuel Cells			
Cost	$30/kW	$124/kW (500,00 units/year)	$55/kW (500,000 units/year)
Durability	5,000 hours (150,000 miles)	950 hours (28,500 miles) 2,000 hours (lab)	2,500 hours (75,000 miles) 3,600 hour (lab)
Hydrogen Production (central electrolysis)	<$4/gge (combined)	$4.80-$7.20/gge	$3.30-$6.00/gge
Hydrogen Delivery (central)		350 bar: $4.60-$5.30/gge 700 bar: NA	350 bar: $3.00-$4.40/gge 700 bar: $3.20-$4.80/gge
Hydrogen Storage (onboard)			
High pressure tanks	2.3 kWh/L 2.5 kWh/kg	350 bar: 0.6 kWh/L 2.0 kWh/kg	700 bar: 0.9 kWh/L 1.7 kWh/kg $17/kWh
Materials-based systems	2.3 kWh/L 2.5 kWh/kg	0.5 – 1.1 kWh/kg 0.7 – 1.0 kWh/L[11]	0.4 – 1.9 kWh/kg 0.4 – 1.4 kWh/L
Driving Range	> 300 mile range	125 miles/fill	196 – 254 miles/fill
Stationary Power (100 kW – 3MW)			
Cost	$1,000/kW (natural gas) $1,500/kW (biogas)	$6,000/kWe (natural gas)	$3,500/kW (natural gas) $5,500/kW (biogas)
Durability	80,000 hours	20,000 – 60,000 hours	40,000 – 80,000 hours

Note: Costs are modeled, high-volume projected costs

HTAC: H_2 Infrastructure Report Recommendations

Recommendations	Key Responses
Emphatic public support for FCEV deployment to inspire confidence and increase public awareness.	Secretary announced $7M in new fuel cell awards and attended the DC auto show. DOE published *Pathways to Commercial Success*, and recently launched, starting with Fuel Cells, an Energy 101 Google+ Hangout series.
Stronger commitment to R&D to ensure U.S. technology leadership.	Hydrogen and fuel cell R&D is part of the President's all-of-the-above energy strategy. Focused on key areas. FY14 budget request ($100M) for FCTO was 25% higher than FY13. Stable funding: FY15 request = FY14 approps
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 the IPHE, along with Germany, (chaired by Japan). Hosted webinar on international workshop on hydrogen infrastructure. Joint workshops & AMR session planned with H2USA & global analogs.
Direct investment in hydrogen 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. Launched four working groups in key areas. Strong relationships with state organizations and activities (i.e., CEC, CARB, CAFCP)

Published more than 80 news articles in 2013 (including blogs, progress alerts, DOE news alerts)

- ***Monthly Webinar Series***
  - Register at - http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html
- ***Announcements***
  - Fuel Cells kick of Google+ Energy 101 series
  - Secretary of Energy attends DC Auto Show
  - 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)
- ***Caucus on H_2 and Fuel Cells*** *(Senate & House)*
- ***Clean Energy Technology Showcase for investors (NYC and CA)***

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

Examples of External Public Support

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

"Fuel cells are an important part of our energy portfolio…deployments in early markets are helping to drive innovations in fuel cell technologies across multiple applications."

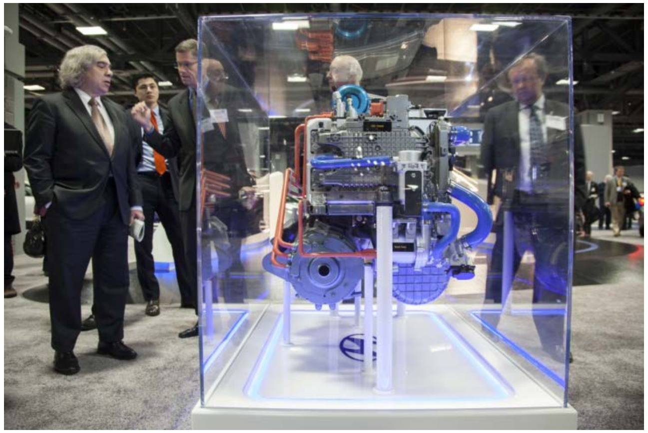
- Dr. David Danielson Assistant Secretary for Energy Efficiency and Renewable Energy, 2012

"Reduced oil dependence is an important part of President Obama's energy security and climate plans, and hydrogen and fuel cell technologies will help ensure America's continued leadership in clean energy innovation."

- Dr. Ernest Moniz Secretary of Energy

Strong Participation in Stakeholder Outreach in 2012-2013- Examples:

- **Senate H_2 and Fuel Cells Caucus**
  - Blumenthal (D-CT)
  - Coons (D-DE)
  - Graham (R-SC)
  - Hoeven (R-ND)
- **House H_2 and Fuel Cells Caucus**
  - Dent (R-PA)
  - Doyle (D-PA)
  - Larson (D-CT)
  - Wilson (R-SC)
- **Fuel Cell Summit, Washington DC 2012**



Secretary Moniz visits the Washington Auto Show, looking at the latest fuel cell vehicles from Hyundai, Honda, and Toyota.

New Awards

Demonstration and Deployment of Fuel Cell Hybrid Electric Medium-Duty Trucks

GREEN SOLUTION TO DRIVING RANGE

FedEx Express (Memphis, TN)

OBJECTIVE:
Develop fuel cell hybrid electric walk-in delivery vans, to extend battery-electric vehicle range from 56 to up to 150 miles. Validate through real-world operation.

IMPACT:
FedEx Express uses approximately 40,000 vehicles in its fleet, which could potentially be replaced with fuel cell hybrid vehicles. The 20 deployed vans could save 97,880 gallons diesel per year and 248 metric tons of CO_2 emissions per year.

PARTNERS:
- **Smith Electric Vehicles** (Kansas City, MO)—*Truck OEM and Electrical Integrator*
- **Plug Power** (Latham, NY)—*Fuel Cell System OEM*

TOTAL FUNDING PLANNED: $6M
- **DOE:** ~$3M
- **Non-Federal:** ~$3M

"FUEL CELL HYBRID ELECTRIC WALK-IN VAN DEPLOYMENT"

Center for Transportation and the Environment (Atlanta, GA)

OBJECTIVE:
Develop fuel cell hybrid electric walk-in delivery vans, to extend battery-electric vehicle range from 90 to 150 miles (75 to 125 miles usable). Validate through real-world operation.

IMPACT:
Fuel cell hybrid vehicles could potentially take place of ~46,000 diesel walk-in vans in UPS' fleet alone. The 17 deployed vans could save 44,200 gallons of diesel per year and 445 metric tons of CO_2 emissions per year.

PARTNERS:
- **University of Texas – Center for Electromechanics** (Austin, TX)—*Research Center*
- **Electric Vehicles International (EVI)** (Stockton, CA)—*Manufacturer of Alternative Energy Vehicles*
- **Hydrogenics USA** (San Diego and Torrance, CA)—*Hydrogen Supplier*
- **Valence Technology** (Austin, TX)—*Battery Manufacturer*
- **United Parcel Service** (Atlanta, GA)—*Logistics (will supply vans)*

TOTAL FUNDING PLANNED: $10.1M
- **DOE:** ~$3M
- **Non-Federal:** ~$7.1M

HTAC: H_2 Infrastructure Report Recommendations

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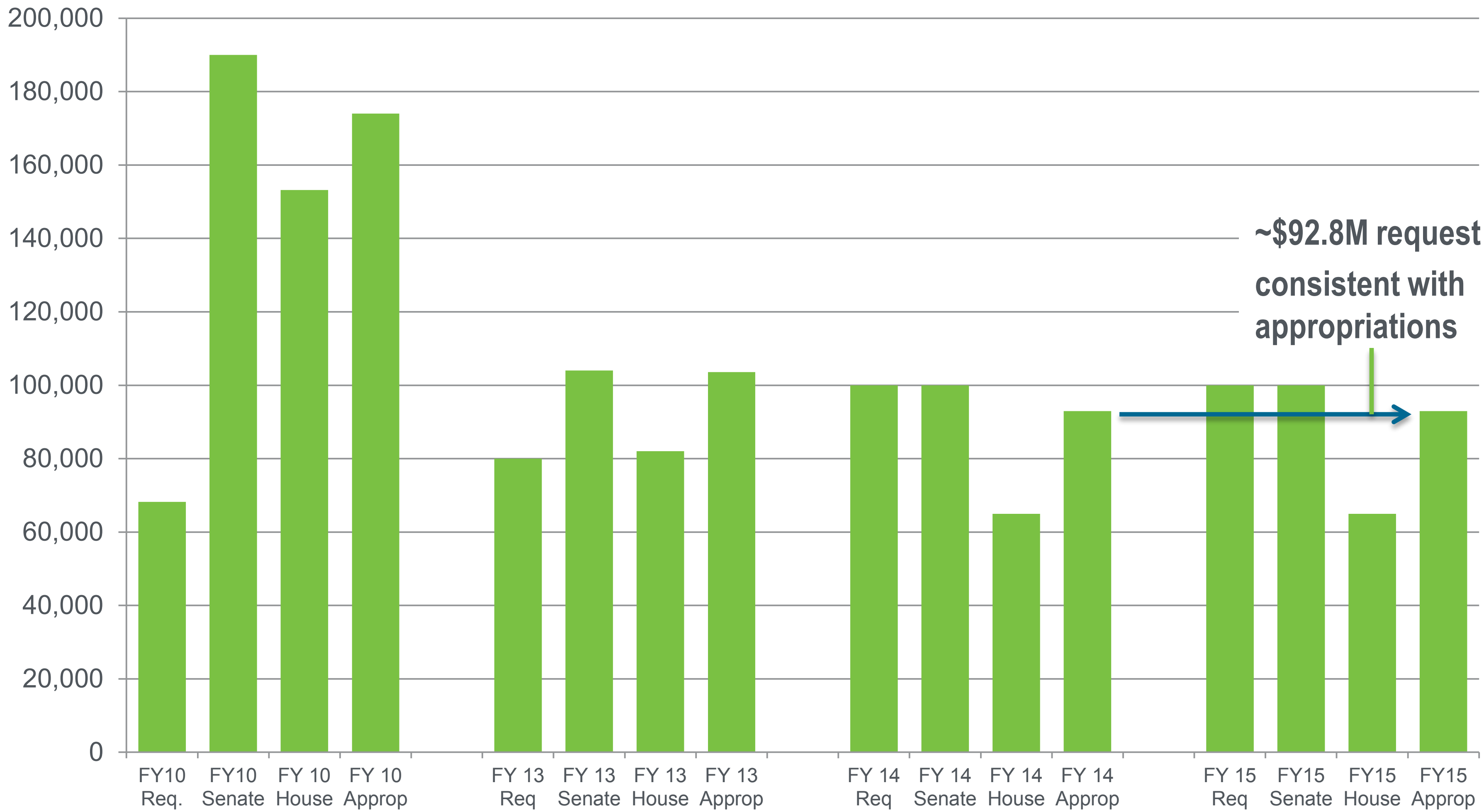
Fuel Cell Technologies – Funding History ($, thousands)- Shift towards consistent, stable funding



Appropriation – Before sequestration, rescission, and SBIR/STTR deduction

Fuel Cell Technologies – FY 2015 Budget Request & Priorities

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

Fiscal Year 2015 Priorities:

Fuel Cell R&D ($33M): Develop and demonstrate innovative technologies to reduce cost and improve durability – e.g., by increasing PEM fuel cell power output per gram of platinum-group metal catalyst to 6.5kW/g in 2015 and 8.0kW/g by 2020 (from 2.8kW/g in 2008).

Hydrogen Fuel R&D ($36.3M): Advance pioneering technologies in materials, components, and processes that will reduce the cost of hydrogen from renewable resources to $6.80/gge (dispensed and untaxed) from $8.00/gge in 2011; and the cost of hydrogen storage systems by 15% compared to the 2013 baseline of $17/kWh.

Manufacturing R&D ($3M): Demonstrate a ground-breaking 3X increase of continuous in-line measurement processes to achieve 100 ft./min for MEA and MEA component roll-to-roll processing.

Technology Validation (S6M): Demonstrate an electrolyzer capable of producing hydrogen for a refueling station with an output pressure of greater than 50 bar, a hydrogen storage and refueling system for a roof-top backup power system capable of providing power for telecommunications equipment, the potential for doubling hydrogen capacity at refueling stations, and integrating water electrolyzers and/or fuel cells with the grid.

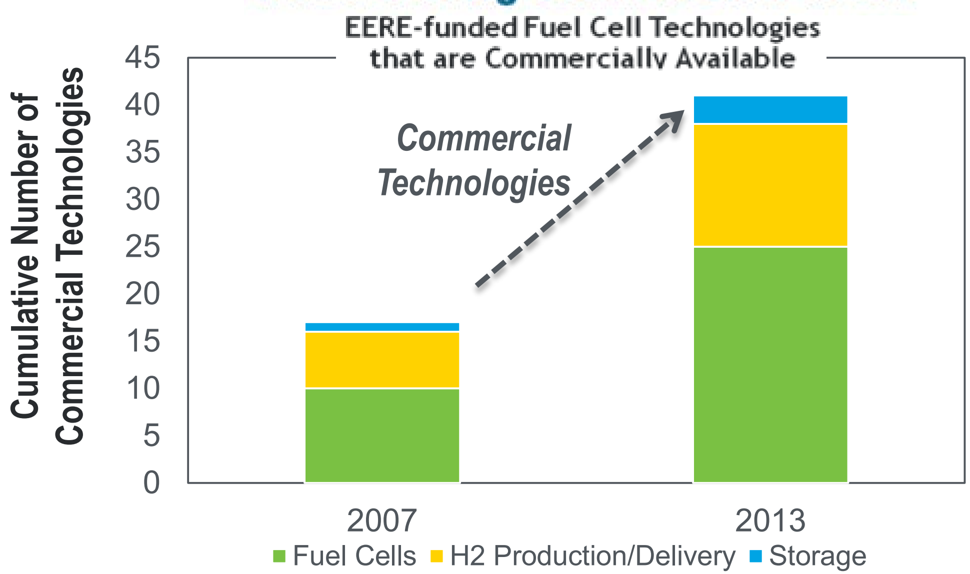
(Dollars in Thousands)	FY 2013 Current	FY 2014 Enacted	FY 2015 Request
Fuel Cell R&D	41,266	33,383	33,000
Hydrogen Fuel R&D	31,681	36,545	36,283
Manufacturing R&D	1,899	3,000	3,000
Systems Analysis	2,838	3,000	3,000
Technology Validation	8,514	6,000	6,000
Safety, Codes and Standards	6,808	7,000	7,000
Market Transformation	2,838	3,000	3,000
NREL Site Wide Facility Support	0	1,000	1,700
Total, Fuel Cell Technologies	95,844	92,928	92,983

Assessing the Impact of DOE Funding

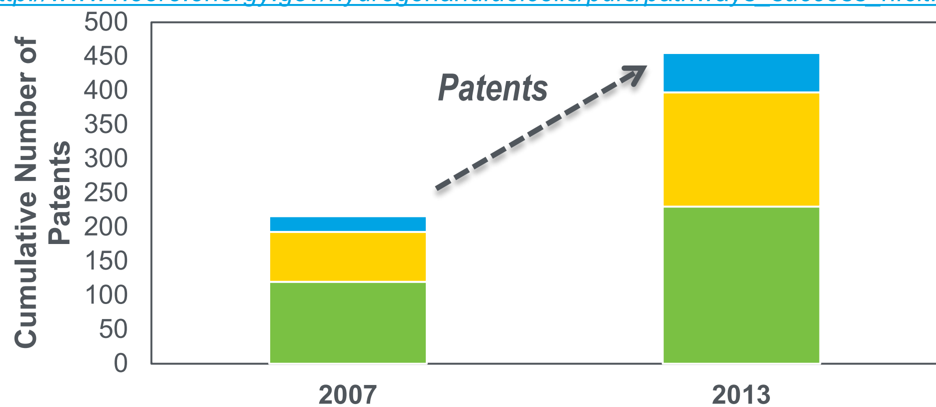
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

Accelerating Commercialization

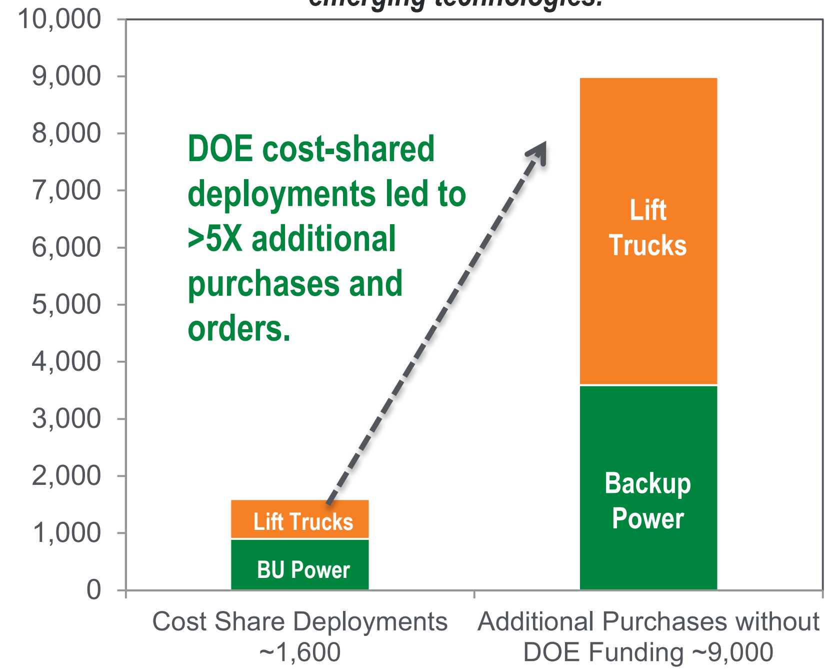


Source: Pacific Northwest National Laboratory
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_success_hfcit.pdf



Leveraging DOE Funds:

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



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

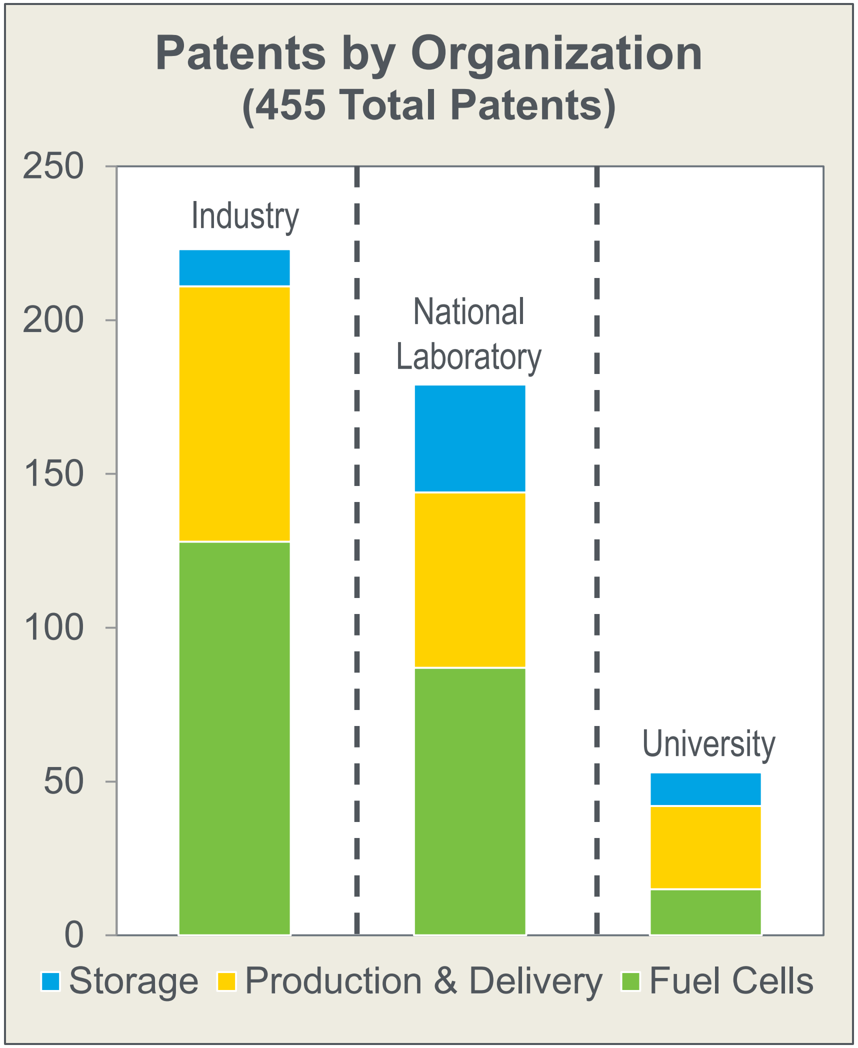
- ***Includes technologies for hydrogen production and delivery, hydrogen storage, and fuel cells***

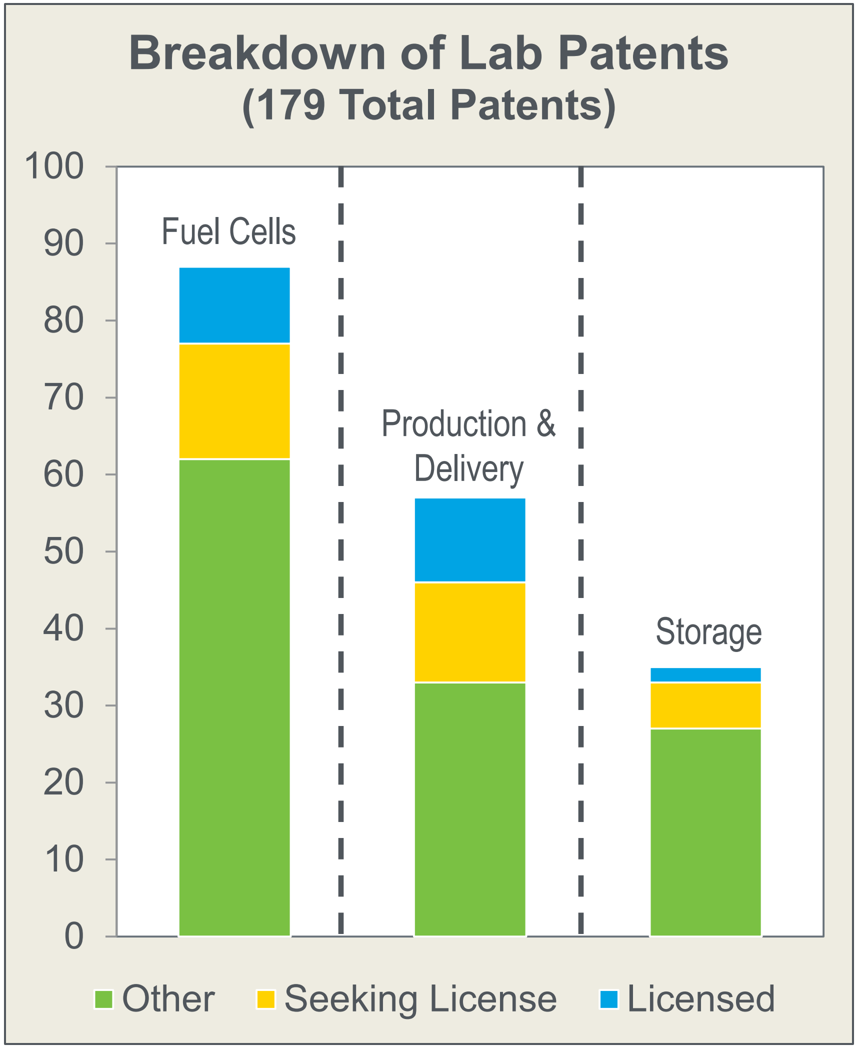
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_2013.pdf

Patent Analysis

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

FCTO has helped fund 442 patents with national labs accounting for 179 or ~40% of patents. 60 patents (over 10%) are seeking or negotiating licenses and 46 patents (~10%) are licensed.





2014 Solicitations

Topics
Hydrogen Production Research & Development (up to $4M*)
• Integrated or hybrid systems for central, semi-central, or distributed production of low-cost, low carbon hydrogen from natural gas
• Thermochemical conversion of bio-derived liquids for distributed or semi-central production of low-cost hydrogen
• Hydrogen production through direct solar watersplitting technologies: Advanced materials-based systems for direct solar water splitting for central or semi-central production of low-cost renewable hydrogen
Hydrogen Delivery Technologies (up to $4M*)
• Forecourt compressors for 700 bar gaseous hydrogen dispensing
• Integrated Intelligent Hydrogen Dispensers for 700 bar Gaseous Refueling of Fuel Cell Electric Vehicles
Research & Development of Hydrogen Storage (up to $4M*)
• Reducing the cost of compressed hydrogen storage systems
• Improved materials for fiber composites and balance of plant components
• New hydrogen storage materials discovery
• Forecourt hydrogen storage at 875 bar of greater
Fuel Cell Hybrid Electric Medium Duty Trucks, Roof-top Backup Power, and and Advanced Hydrogen Refueling Components (~$7M)
• Demonstration and deployment of fuel cell hybrid-electric medium-duty trucks
• Validation of advanced hydrogen refueling components
• Demonstration and case study for roof-top installations of hydrogen fuel cell back-up power systems
• Hydrogen meter R&D

*May include alternates and subject to appropriations.

Notice of Intent: Fuel Cell Technologies Incubator

The EERE Incubator Program is intended to identify potentially impactful technologies that are not already addressed in EERE Technology Offices' strategic plans or project portfolios. The FOA will be 'open' to any and all impactful ideas; however, some anticipated specific areas of interest include:

- Platinum Group Metal (PGM)-free catalysts and membrane electrode assemblies
- Fuel cell–based electrochemical conversion devices for stationary energy storage
- Completely innovative hydrogen production and delivery technologies (including hoses, meters, compressors, etc.)
- Breakthrough, low pressure hydrogen storage materials
- Hydrogen infrastructure: Manufacturing solutions for low-cost, standardized skid-mounted hydrogen fueling stations; and game-changing business models/financial approaches to address infrastructure costs.

FOA Planned Release:
April 2014

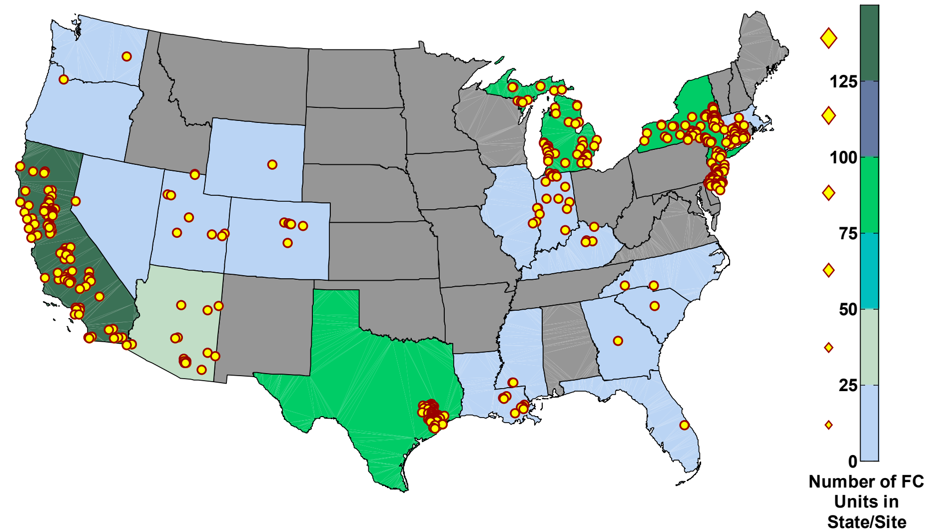
Data Collection & Analysis: Backup Power and Material Handling Equipment

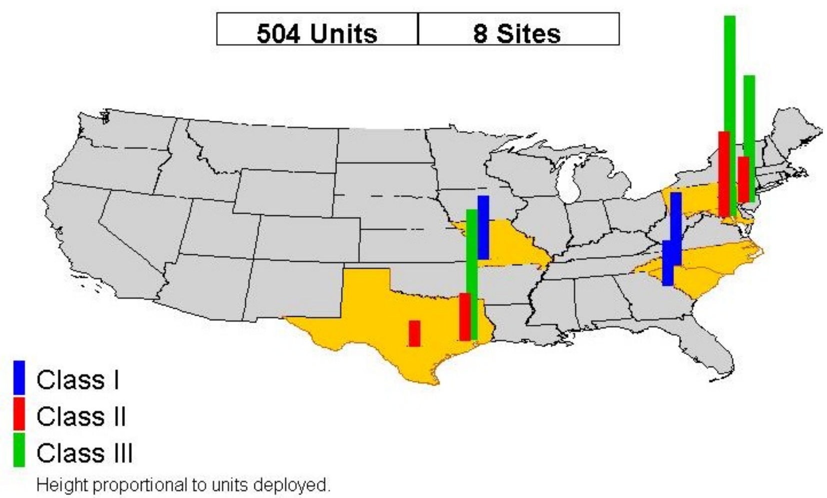
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Validated over 800 backup power units with seven industry partners

- FedEx Freight East, GENCO, Nuvera Fuel Cells, Plug Power, ReliOn Inc., Sprint Communications, Sysco of Houston –

- **842 units in operation**[1]
- **1.94 MW installed capacity**, average site capacity of 4-6 kW
- **99.7% successful starts** (2,579 start attempts)
- **65 continuous hours demonstrated**
- **>1,600 operation hours**





Validated over 450 material handling equipment units with seven industry partners

- **490 units in operation**[2]
- **>1,800,000 operation hours**, 4.4 average operation hours between fills
- **~230,000 kg of hydrogen dispensed** during more than **290,000 hydrogen fills** with an average of **0.6 kg per fill**

[1]Not all systems have detailed data reporting to NREL. [2]One project has completed.

Data from 2009 Q1 to 2013 Q2.

Launched National Fuel Cell Technology Evaluation Center (NFCTEC)

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

The Secretary of Energy, Ernest Moniz, announced the unveiling of a one-of-its-kind national secure data center dedicated to the independent analysis of advanced hydrogen and fuel cell technologies at the Energy Department's Energy Systems Integration Facility (ESIF) at NREL in Golden, Colorado.

Partner

Partner with NFCTEC to take advantage of state-of-the-art facilities.
http://www.nrel.gov/docs/fy13osti/58500.pdf

Contact Us

Interested in working with NFCTEC? Contact techval@nrel.gov

Learn More

http://www.nrel.gov/docs/fy13osti/55596.pdf

NFCTEC plays a crucial role in NREL's independent, third-party analysis of hydrogen fuel cell technologies in real-world operation.

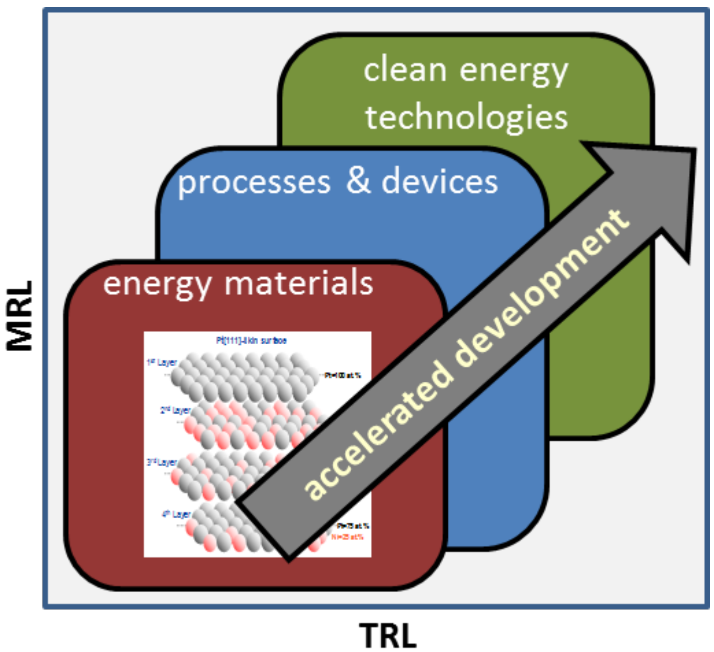
- Designed for secure management, storage, and processing of proprietary data from industry.
- Technology Validation Team analyzes detailed data and reports on fuel cell technology status, progress, and technical challenges.
- Detailed data products provided to partners, composite data products available online

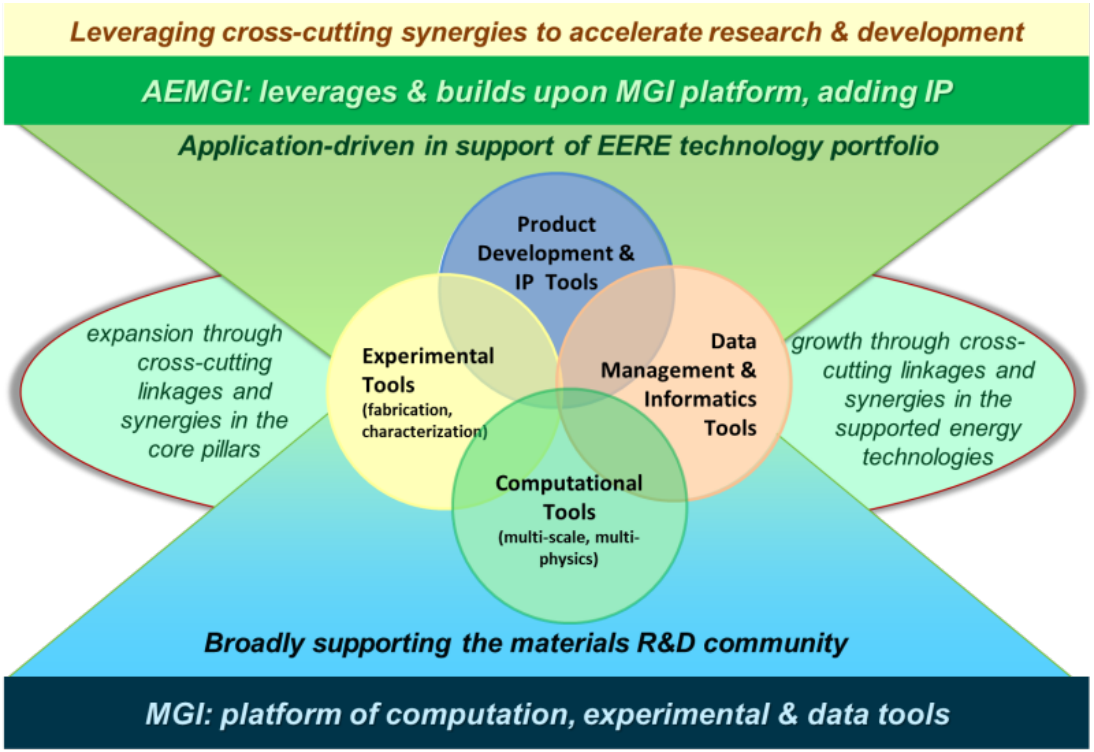
http://www.nrel.gov/hydrogen/facilities_nfctec.html

Applied Energy Materials Genome - RFI & Workshop planned

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

Goal: Develop approach to accelerate progress across EERE portfolio.
Concepts will expand on the *Materials Genome Initiative (MGI)* approach, combining multi-scale, multi-physics computational methods with high-throughput synthesis and characterization for intelligent, focused development of improved ***MATERIALS, PROCESSES & PRODUCTS*** across the EERE technology portfolio.





HTAC: H_2 Infrastructure Report Recommendations

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

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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

ICHS International Conference on Hydrogen Safety

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

Hydrogen Safety, Codes and Standards

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

Codes and Standards - Conduct critical R&D needed for the development of technically sound codes and standards and facilitate harmonization of domestic and international regulations, codes, and standards

Identify R&D needs
- Lead stakeholder workshops, develop R&D roadmaps
- Analyze existing codes and standards, safety knowledge
- Participate in technical working groups

→

Perform High-Priority R&D
- Foundational hydrogen behavior
- Quantitative Risk Assessments
- Compatible materials and components
- Test protocols
- Fuel Quality
- Sensors

→

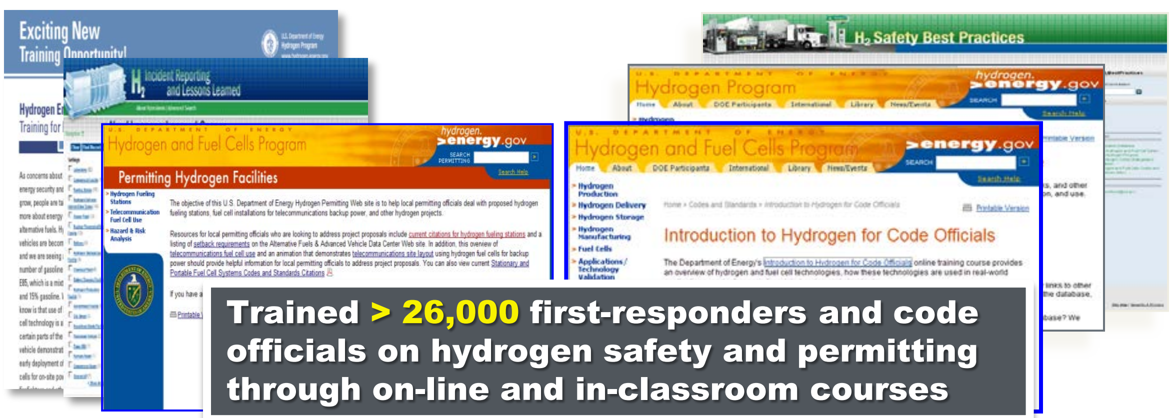
Impact Codes and Standards
- Participate in and lead technical committees to develop requirements
- Harmonize critical regulations, codes, and standards domestically and internationally (i.e. SAE 2719 and ISO 14687-2)
- Publish R&D results

Critical areas for FY14 for Acceleration of hydrogen infrastructure:

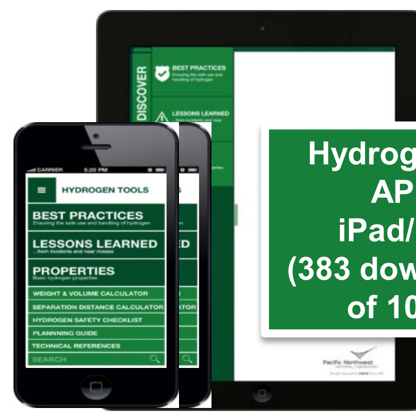
1. NFPA 2 Chapter 5 Validation for Performance Based Approach
2. Initiating LH2 Release Behavior to decrease separation distances in conjunction with NFPA 55
3. Development of Quantitative Risk Assessment Toolkit (HyRAM)
4. Development of a National Permitting Template in conjunction with H2USA and FCHEA

Station Footprint (Cost) Reduction - Critical Separation Distances were reduced by **~50% for GH2 due to supported SCS R&D efforts** and direct participation in code development of NFPA 2 Hydrogen Technologies Code.

Safety - Develop and implement safety practices and procedures to ensure the safe operation, handling, and use of hydrogen and fuel cell technology



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



Hydrogen Tools APP for iPad/iPhone (383 downloads as of 10/2013)

International Hydrogen Infrastructure Workshop

The workshop, held in Berlin in June 2013, was organized by NOW, DOE and NEDO and included ~60 participants from Germany, the EU, Scandinavia, Japan and the United States.

Objective: *To enable international information exchange on hydrogen infrastructure challenges in four key areas: Refueling, Hydrogen Quality, Metering, and Hardware Reliability & Reliability.*

NOW National Organisation Hydrogen and Fuel Cell Technology | NEDO


Photo: courtesy of the CAFCP

Key outcomes:

- Refueling: Identified the need for a test apparatus in each region to validate station fueling performance.

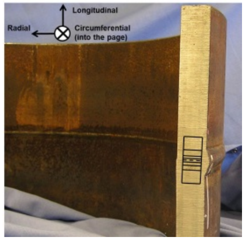
  There is an opportunity to share information on the design of the test apparatus and validation results.
- H2 Quality: The value of sharing information on hydrogen quality test methods was identified. Some regions are testing yearly at great expense and others are not testing at all. A minimum test requirement for fuel quality is needed.
- Metering: The requirements for hydrogen metering accuracy vary by region. Data presented showed great variation in the accuracy of the meters. Sharing information on meter development may help speed R&D and identify the most accurate meters available internationally.
- Station Hardware: Key reliability concerns varied by region, however 700 bar dispenser hoses were consistently identified with on going development efforts in the Japan, the EU, and the US

A follow on workshop will be held May 8th& 9th, 2014 in Los Angeles, CA

Delivery Workshop

The workshop was held February 25th and 26th, 2014 at The National Renewable Energy Laboratory.

- The workshop brought together approximately 30 experts from industry and public sector to discuss the challenges to reducing the cost of hydrogen transmission and distribution from the point of production to the point of consumption at forecourt stations, and identify RD&D areas to address those challenges identified.
- The workshop sessions were organized into four topic areas: pipelines (compression and storage) and over-the-road (gaseous, liquid and hybrid approaches), top issues and activities from each session have been captured with a full report to follow before AMR.



1.) Pipeline Compression
- Compressor maintenance/reliability
- High efficiency, low capital cost compressors
- Optimal hydrogen pressure management

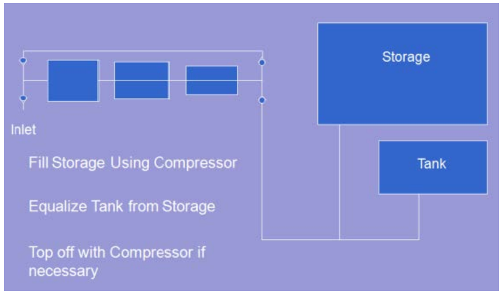
2.) Pipeline Materials
- H_2 fatigue properties w/t microstructure
- Develop lower cost joining technologies (welding and FRP)
- Codes and Standards Issues

3.) Gaseous Delivery
- Lack of understanding of degradation mechanisms
- High cost of materials
- Need for advanced tube trailer design
- Improved efficiency for standards and regulations development

4.) Liquid delivery
- CAPEX reduction for smaller plants/Smaller scale, low cost modular liquefiers
- Light-weight materials to increase payload
- Reducing bleed off during filling, transport, off loading/Boil off recovery
- Liquid Carriers R&D: Simple Chemistry
- Liquefaction Efficiency/Refrigeration efficiency

The workshop was held March 20th and 21st, 2013 at Argonne National Laboratory just out side of Chicago, IL

- The workshop brought together approximately 30 experts from Industry and public sector to discuss the challenges to reducing the cost of hydrogen infrastructure at the forecourt and identify RD&D areas to address those challenges identified.
- The workshop sessions were organized into three topic areas, Compression, Storage, and Other and the top issues and activities from each session have been captured with a full report to follow during the AMR.

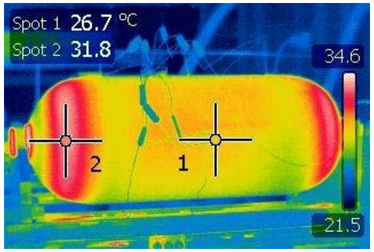


1.) Materials Research
- Dynamic seals
- Carbon fiber (cost and batch quality)
- Hydrogen compatible metals

2.) Station Optimization Analysis
- Near, Mid and Long term markets
- Storage vs. Compression trade offs

3.) Metering, Quality & Performance Testing for Dispensing
- Meter accuracy
- Hydrogen quality measurement device
- Station dispensing test apparatus

4.) Data for codes and standards development
- Setback distances
- Tank cycle life



HTAC: H_2 Infrastructure Report Recommendations

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

Recommendations	Key Responses
Emphatic public support for FCEV deployment to inspire confidence and increase public awareness.	Secretary announced $7M in new fuel cell awards and attended the DC auto show. DOE published *Pathways to Commercial Success*, and recently launched, starting with Fuel Cells, an Energy 101 Google+ Hangout series.
Stronger commitment to R&D to ensure U.S. technology leadership.	Hydrogen and fuel cell R&D is part of the President's all-of-the-above energy strategy. Focused on key areas. FY14 budget request ($100M) for FCTO was 25% higher than FY13. Stable funding: FY15 request = FY14 approps
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 the IPHE, along with Germany, (chaired by Japan). Hosted webinar on international workshop on hydrogen infrastructure. Joint workshops & AMR session planned with H2USA & global analogs.
Direct investment in hydrogen 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. Launched four working groups in key areas. Strong relationships with state organizations and activities (i.e., CEC, CARB, CAFCP)

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

Global Automakers

GM

DAIMLER

HYDROGENICS Advanced Hydrogen Solutions

HONDA The Power of Dreams

EDTA Electric Drive Transportation Association

NISSAN

HYUNDAI

Mercedes-Benz

Oak Ridge National Laboratory

AGA American Gas Association

ITM POWER Energy Storage | Clean Fuel

California Fuel Cell Partnership DRIVING FOR THE FUTURE

SCRA

Sandia National Laboratories

PROTON THE LEADER IN ON SITE GAS GENERATION.

Pacific Northwest NATIONAL LABORATORY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

AIR LIQUIDE

arc:HYDROGEN

plug power

NUVERA Making hydrogen make sense.

Massachusetts Hydrogen Coalition

TOYOTA

Argonne NATIONAL LABORATORY

H2 Refuel Competition Summary

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

The Goal:

Make a system that does on-site generation of hydrogen, using electricity or natural gas, to fuel hydrogen vehicles, that can be used in homes, community centers, retail sites or similar locations. The best entry, based on technical and cost criteria, will win $1 million!

The Challenge:

Month	
1-12	When the competition opens, teams will have one year to find partners, design a system, test components, find a place to install the system, and register for the prize.
12-14	After one year, the teams will submit data and designs, and the top five will be selected by a team of independent judges to go to the testing phase.
14-21	Finalist teams will have seven months to build, install, and prepare their systems for testing.
22-24	Remote and on-site testing will be used to collect data for the technical criteria, and independent financial experts will evaluate the cost criteria. An open house will let the public get a peek at the entries!
27	Once the data is analyzed, the H-Prize winner will be announced.

H-Prize Scoring Criteria- open for public comment (March 2014)

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

- Each criteria has a scoring criteria table
  – Criteria topics the same for all entries, but some score targets are different for home and community/fleet scale
- Because some of the criteria are considered more critical, the criteria have different weights

Criteria	Weight
Pressure	3
1 kg dispensing time	2
1-kg refuels per day	1
Tested Availability	2
System install cost	2
Cost per kg	1

Cost criteria

	System Install Cost		Cost per kg	
Score	Home	Community	Home	Community
1	$25k/kg or less	$15k/kg or less	$20 or less	
2	20k/kg or less	$12.5k/kg or less	$17 or less	
3	$15k/kg or less	$10k/kg or less	$14 or less	
4	$10k/kg or less	$7.5k/kg or less	$11 or less	
5	$5k/kg or less	$5k/kg or less	$8 or less	

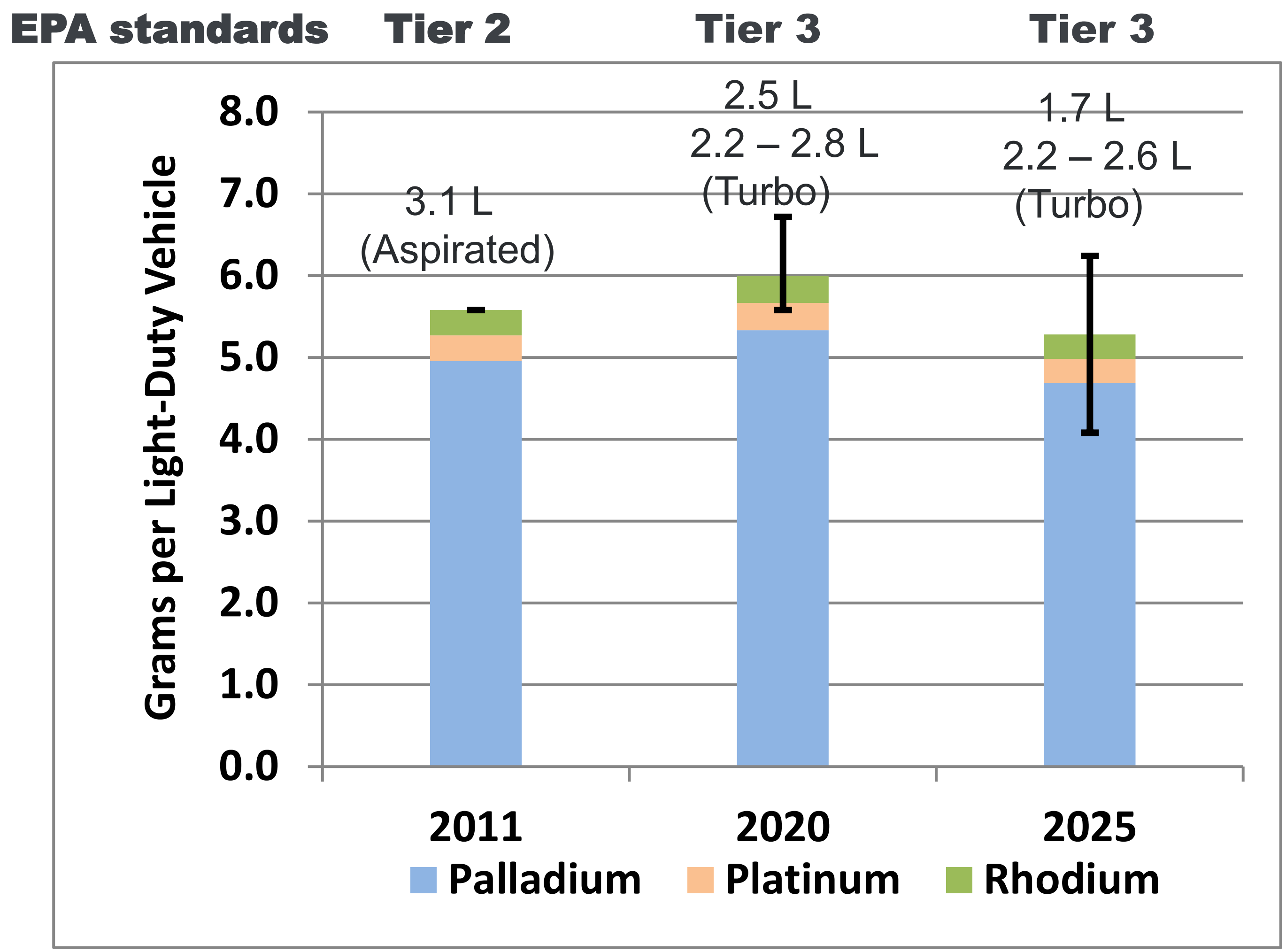
Technical criteria

	Dispensed pressure		1 kg dispensing time		1-kg refuels per day		Tested Availability	
Score	Home	Community	Home	Community	Home	Community	Home	Community
2	350 bar or higher		10 hours or less	60 minutes or less	1 or more	5 or more	80% or higher	
			8 hours or less	30 minutes or less	2 or more	10 or more	85% or higher	
3	500 bar or higher		5 hours or less	15 minutes or less	3 or more	20 or more	90% or higher	
			2 hours or less	10 minutes or less	4 or more	40 or more	95% or higher	
5	700 bar or higher		30 minutes or less	3 minutes or less	5 or more	50 or more	98% or higher	

Analysis Summary - Results

- Examples of key activities since previous HTAC meeting
  - PGM Loading
  - LCOE for Stationary Fuel Cells
  - Fuel Cell Cost analysis
  - Electrolysis Independent Assessment
  - H2SCOPE Model

Platinum Group Metals for New Gasoline LDV in the U.S.



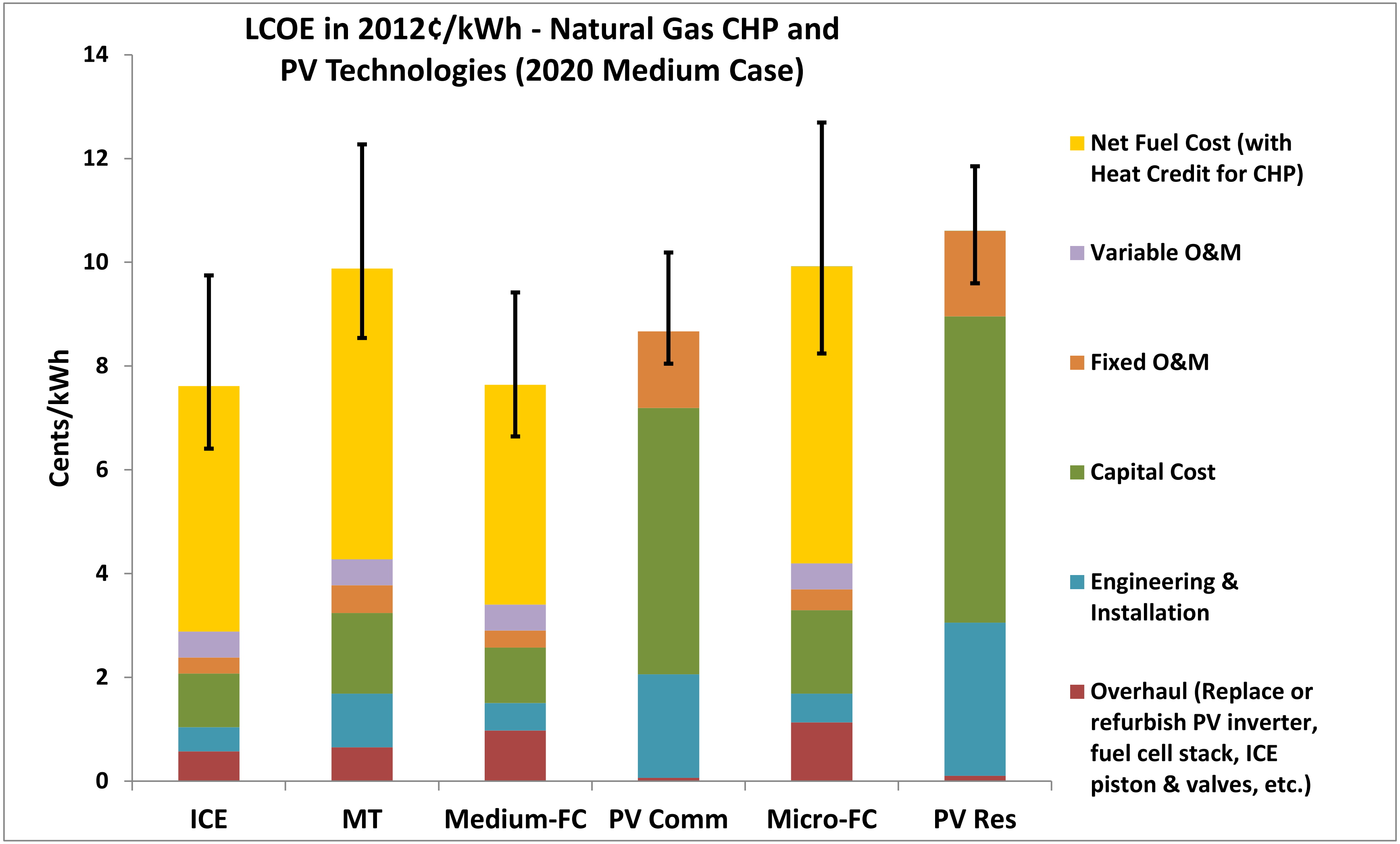
PGM catalyst loadings expected to be ~5 g/vehicle (LDV, gasoline) by 2025.

Will drive lower PGM targets for fuel cells

EPA: Future ICEV mix may be dominated by turbocharged vehicles with smaller engines, in part a result of fuel economy rules decreasing catalyst requirements. However, Tier 3 emissions standards will have the effect of increasing catalyst loadings.

Levelized Cost of Electricity

LCOE in 2012 Cents/kWh (Technology in 2020, No Incentive Assumed)



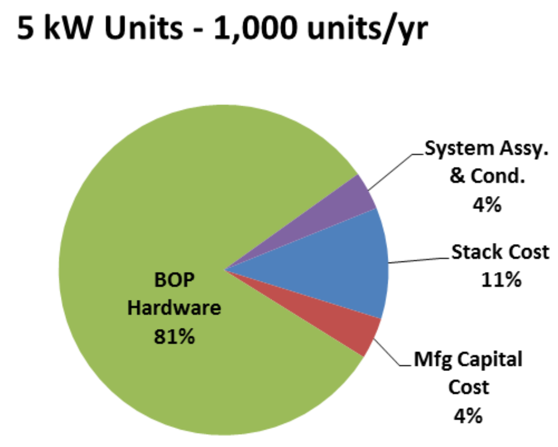
Note: Medium-FC is 200 kWe and Micro-FC is 7.0 kWe

Modeled System Costs

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

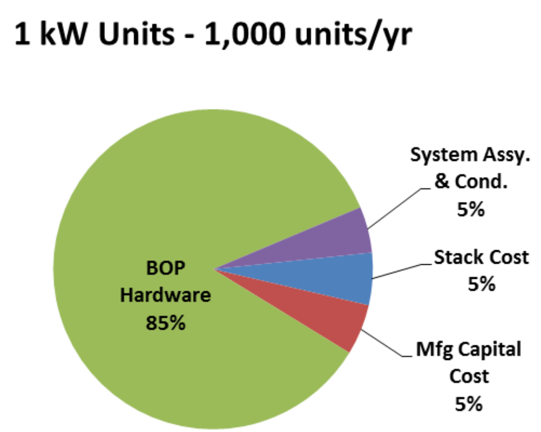
5kW APU SOFC System Cost per Unit Summary

Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$1,476	$1,327	$1,267	$1,257
Stack manufacturing capital cost	$4,757	$495	$82	$73
Balance of plant	$11,323	$9,802	$8,738	$8,738
System assembly, test, and conditioning	$481	$456	$454	$454
Total system cost, pre-markup	$18,037	$12,080	$10,541	$10,522
System cost per net KW, pre-markup	$3,607	$2,416	$2,108	$2,104
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$27,056	$18,120	$15,812	$15,783
System cost per net KW, with markup	$5,411	$3,624	$3,162	$3,156



1kW APU SOFC System Cost per Unit Summary

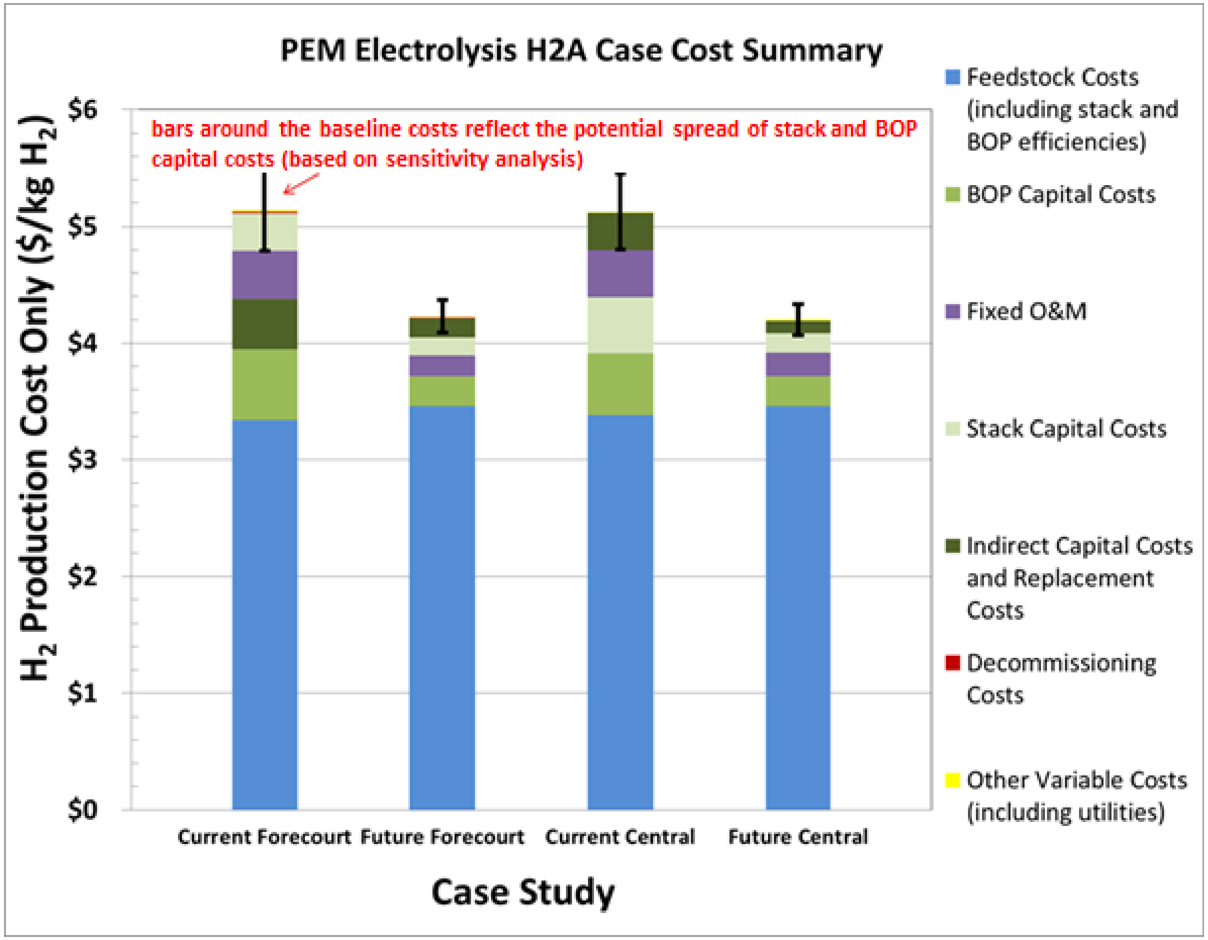
Description	100 Units	1,000 Units	10,000 Units	50,000 Units
Total stack manufacturing cost, with scrap	$590	$511	$481	$473
Stack manufacturing capital cost	$4,757	$495	$69	$43
Balance of plant	$9,597	$8,204	$7,383	$7,383
System assembly, test, and conditioning	$475	$451	$448	$448
Total system cost, pre-markup	$15,419	$9,661	$8,381	$8,347
System cost per net KW, pre-markup	$15,419	$9,661	$8,381	$8,347
Sales markup	50.00%	50.00%	50.00%	50.00%
Total system cost, with markup	$23,129	$14,491	$12,571	$12,520
System cost per net KW, with markup	$23,129	$14,491	$12,571	$12,520



Completed Independent Assessment of H2 Production Costs via PEM Electrolysis

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

High efficiency is very important for minimizing electricity usage



Four PEM Electrolysis cases developed in H2A v3[a]

Case	Plant Start Date	Production of H_2 (kg/day)	Plant Life (years)
Current[b] Forecourt	2010	1,500	20
Future Forecourt	2025	1,500	20
Current Central	2010	50,000	40
Future Central	2025	50,000	40

Results:

- Baseline costs & cost ranges for the four PEM cases;
- Key cost drivers identified and quantified, including:
  - Electricity cost; electrolyzer efficiency; electrolyzer capital cost

	Low Range ($/kg H_2)	Baseline Cost ($/kg H_2)	High Range ($/kg H_2)
Forecourt			
Current Case	$4.80	$5.10	$5.50
Future Case	$4.10	$4.20	$4.40
Central			
Current Case	$4.80	$5.10	$5.40
Future Case	$4.10	$4.20	$4.30

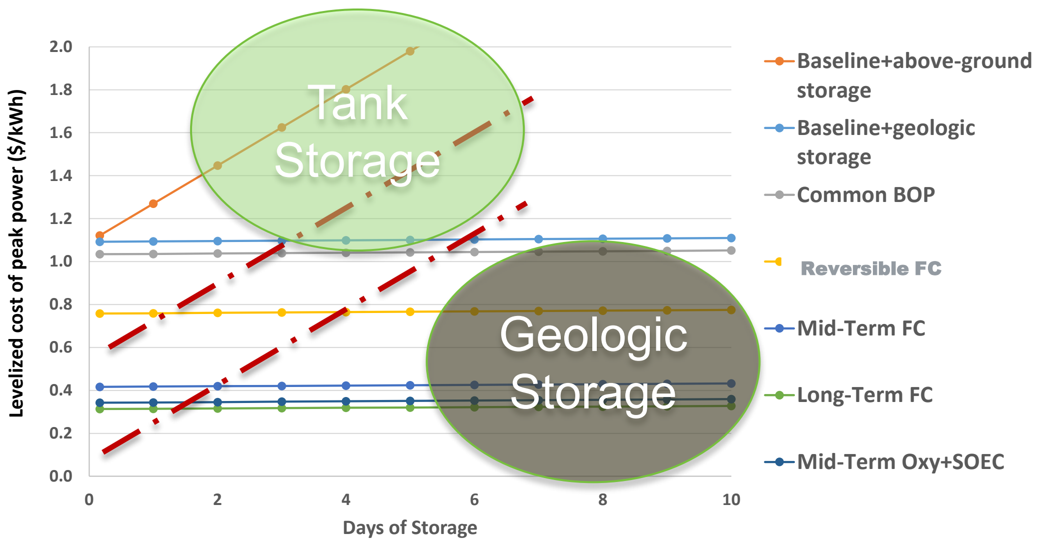
[a]Discounted cash flow model using technoeconomic inputs to project H_2 production costs incorporating economies of scale:
[b]Current case based on demonstrated technology manufactured at volume; different from existing costs based on low production commercially available electrolyzers

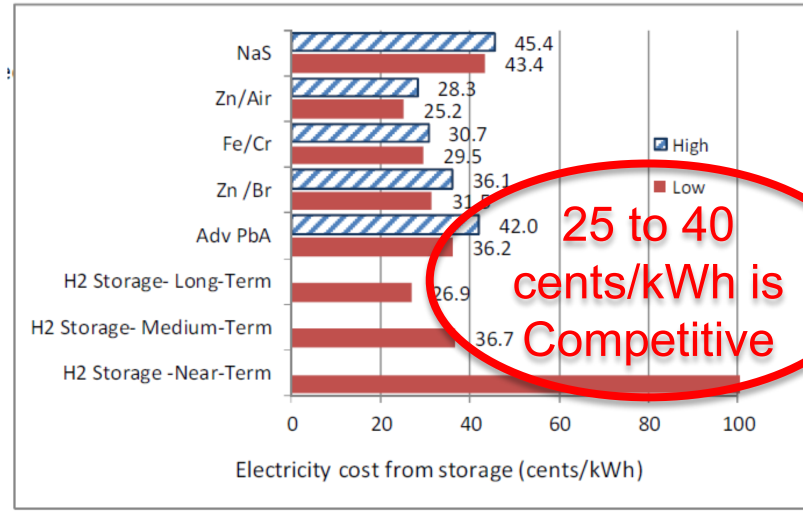
HTAC: Hydrogen Enabling Renewable Report – Recommendations & Response

Recommendations	Responses
Determine if national policies are being considered that would significantly increase renewable penetration	Renewables feature strongly in the President's Climate Action Plan. Since 2008 the U.S. has doubled electricity generation from renewables with a goal to double that number again by 2020
Conduct sensitivity analyses to estimate the value of hydrogen energy storage projects; determine scale and economics required to make hydrogen storage competitive; investigate potential for "power-to-gas" energy storage systems	DOE is planning a 2014 workshop on Hydrogen Energy Storage for Variable Electricity Generation Investigating the potential of hydrogen energy systems as a grid management tool and to provide H_2 as transportation fuel. Invested $135M for a state-of-the-art Energy Systems Integration Facility at NREL where further analysis and demonstration may be done

Examples of Analyses

Costs increase rapidly with above ground storage ($700/kg vs. $7/kg)
Additional Storage capacity is extremely low cost and the main strength





HTAC simple model EPRI test case.XLS, WS 'DashBoard' AG-31;4/7/2012

Figure 1. Estimated costs of electricity from storage using the HTAC /NREL model & EPRI battery $/kWh cost estimates

<u>Underground</u> hydrogen storage is competitive with most battery options at medium and long term

Input Values:

10MW FC, 40 MWhr storage, 10% free electricity, 33.3% capacity factor electrolyzer (8 hr/d), FC operating 4 hr/d

Storage Times		Near-term H2	Medium-Term H2	Long-term H2	Adv PbA	Zn/Br	FeCr	Zn/Air	NaS
4 hours	Capex ($M)	$ 75.9	$ 16.9	$ 10.9	$ 3.1	$ 3.2	$ 3.2	$ 2.6	$ 4.6
	Cents/kWh	121.1 c/kWh	36.6 c/kWh	26.8 c/kWh	11.0 c/kWh	12.7 c/kWh	10.9 c/kWh	10.2 c/kWh	13.2 c/kWh
1 day	Capex ($M)	75.9	16.9	10.9	18.9	19.3	19.2	15.5	27.7
	Cents/kWh	121.1 c/kWh	36.7 c/kWh	26.9 c/kWh	36.2 c/kWh	31.5 c/kWh	29.5 c/kWh	25.2 c/kWh	43.4 c/kWh
2 days	Capex ($M)	75.9	16.9	10.9	37.8	38.7	38.4	30.9	55.5
	Cents/kWh	121.1c/kWh	36.7c/kWh	26.9c/kWh	[illegible]6.3c/kWh	53.9c/kWh	51.8c/kWh	43.1c/kWh	79.5c/kWh
1 week	Capex ($M)	76.0	17.0	11.0	132.[illegible]	135.3	134.4	108.3	194.1
	Cents/kWh	121.4 c/kWh	36.9 c/kWh	27.1 c/kWh	217.1 c/kWh	166.2 c/kWh	163.3 c/kWh	132.9 c/kWh	260.3 c/kWh
2 weeks	Capex ($M)	76.1	17.1	11.1	264.4	270.7	268.8	216.5	388.3
	Cents/kWh	121.7c/kWh	37.2c/kWh	27.3c/kWh	428.2c/kWh	323.4c/kWh	319.4c/kWh	258.7c/kWh	513.5c/kWh
1 month	Capex ($M)	76.4	17.3	11.3	574.5	588.1	584.0	470.4	843.6
	Cents/kWh	122.4c/kWh	37.8c/kWh	27.9c/kWh	923.3c/kWh	692.0c/kWh	685.5c/kWh	553.6c/kWh	1107.1c/kWh
2 months	Capex ($M)	76.9	17.8	11.8	1149.1	1176.1	1168.0	940.9	1687.1
	Cents/kWh	123.7 c/kWh	38.9 c/kWh	29.0 c/kWh	1841 c/kWh	1375 c/kWh	1364 c/kWh	1100 c/kWh	2207 c/kWh

HTAC simple model EPRI test case.XLS, WS 'Storage TIme' K-19;4/11/2012

Save the Date! Hydrogen Energy Storage

What: Hydrogen Energy Storage Workshop (Grid and Transportation)
Who: U.S. Department of Energy and Industry Canada
Where/When: Sacramento, California, May 14-15, 2014
Why: Identify benefits and opportunities for commercial hydrogen energy storage applications which support:

1. *Grid Services*
2. *Variable Electricity Generation*
3. *Hydrogen vehicles*

Key topics: (1) Business models and early applications, (2) Specific policy barriers and incentives, (3) Modeling and econometric approaches, and (4) Potential opportunities for effective demonstrations






FCTO: Workshops

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

Recent and Upcoming Workshops

- Hydrogen Transmission and Distribution Workshop (February 25-26th, 2014)
- Electrolytic Hydrogen Production (February 27-28th, 2014)
- Infrastructure Financing Workshop (April 2014)
- Hydrogen Safety Resource Tools (April 2014)
- 2nd International Workshop on Hydrogen Infrastructure (May 8-9th, 2014)
- Energy Storage Workshop (May 2014)
- Contaminant Detection at the Forecourt (June 12th, 2014)
- Applied Energy Materials Genome (TBD)

2013 Workshops

- Hydrogen Compression, Storage, and Dispensing Cost Reduction Workshop (March 2013)
  - https://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_hydrogen_csd.html
- Biological Hydrogen Production Workshop (September 2013)
  - https://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_bio_h2_production.html
- EERE Quality Control Workshop (December 2013)
  - https://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_eere_quality_control.html

Examples of Key Activities: HTAC and Program Impact

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

Additional Areas of Interest:

- Manufacturing R&D (subcommittee)
- Feedback on National Lab Initiative
- Opportunities for Energy Systems Integration Facility (ESIF) at NREL
- RFI on financial models/strategies for infrastructure
- Feedback on H-gallon concept

Feedback Requested on RFI

Light Duty Vehicle Hydrogen Fueling Infrastructure Financing Strategies

- Closed: February 28th, 2014
- Seeking feedback from interested stakeholders regarding strategies for a robust market introduction of hydrogen supply, infrastructure, and fuel cell electric vehicles (FCEVs). This input will augment financing strategies that DOE analyzes for public deployment of infrastructure for supporting FCEV introduction in U.S. markets. Such financing strategies should maximize financing, for example, with debt and equity, while minimizing public incentives.
- For more information, visit: https://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=21255

Thank You

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hydrogenandfuelcells.energy.gov

FY 2015 Budget Summary Table

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

Dollars in Thousands	FY 2013 Current	FY 2014 Enacted	FY 2015 Request	FY 2015 vs FY 2014
Transportation	**584,199**	**614,955**	**705,183**	**+90,228**
- Vehicle Technologies	303,165	289,737	359,000	+69,263
- Bioenergy Technologies	185,190	232,290	253,200	+20,910
- Hydrogen and Fuel Cell Technologies	95,844	92,928	92,983	+55
Renewable Electricity	**444,891**	**449,524**	**521,300**	**+71,776**
- Solar Energy	269,050	257,058	282,300	+25,242
- Wind Energy	86,129	88,126	115,000	+26,874
- Water Power	54,687	58,565	62,500	+3,935
- Geothermal Technologies	35,025	45,775	61,500	+15,725
End-Use Efficiency	**535,354**	**617,449**	**857,700**	**+240,251**
- Advanced Manufacturing	114,254	180,471	305,100	+124,629
- Federal Energy Management Program	28,265	28,248	36,200	+7,952
- Building Technologies	204,601	177,868	211,700	+33,832
- Weatherization and Intergovernmental Activities	188,234	230,862	304,700	+73,838
Corporate Support Programs	**208,889**	**231,513**	**237,779**	**+6,266**
Subtotal, Energy Efficiency and Renewable Energy	**1,773,333**	**1,913,441**	**2,321,962**	**+408,521**
- Use of Prior Year Balances	-81,576	-2,382	-5,213	N/A
- Rescission of Prior Year Balances	0	-10,418	0	N/A
Total, Energy Efficiency and Renewable Energy	**1,691,757**	**1,900,641**	**2,316,749**	**+416,108**

DOE Funding in Hydrogen and Fuel Cells

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

		Funding *($ in thousands)*								
		FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Approp.	FY 2011 Allocation	FY 2012 Approp.	FY 2013 Approp.	FY 2014 Approp.	FY 2015 Request
EERE Hydrogen & Fuel Cells	**H2**	133,878	145,822	115,797	95,228	53,931	57,692	54,579	59,600	59,598
	FC	55,633	60,419	80,068	75,069	41,916	43,634	41,266	33,383	33,000
Fossil Energy (FE- H2 related)		21,513	14,891	20,151	13,970	11,394	0	0	0	0
Nuclear Energy (NE)		18,855	9,668	7,340	5,000	2,800	0	0	0	0
Science (SC) (Basic Energy Sciences)	**H2**	~20,006	20,058	21,186	19,734	17,640	13,664	~13,720	TBD	TBD
	FC	~16,382	16,425	17,098	18,318	16,971	13,802	~12,595	TBD	TBD
Fossil Energy (SECA)		63,400	56,000	58,000	50,000	49,500	25,000	23,800	25,000	3,000
ARPA-E (FC related)		0	0	1,248	0	0	0	2,114	TBD	TBD
DOE H2 SUBTOTAL		**194,252**	**190,439**	**164,474**	**133,932**	**85,765**	**71,356**	**68,299**	**59,600**	**59,598**
DOE FC SUBTOTAL		**135,415**	**132,844**	**156,414**	**143,387**	**108,387**	**82,436**	**79,775**	**58,383**	**36,000**
DOE TOTAL		**329,667**	**323,283**	**320,888**	**277,319**	**194,152**	**153,792**	**~148,074**	**117,983**	**95,598**

FCTO: 2013 RFIs

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

Rotating Disk Electrode Diagnostics for PEMFC Electrocatalyst Screening

- Rotating disk electrode experiments and best practices for experimental conditions for characterization of the activity and durability of PEM fuel cell ORR electrocatalysts.

Hydrogen Delivery Technologies

- Hydrogen delivery R&D activities aimed at lowering cost. DOE is requesting comments from interested parties about compression, storage, and dispensing technologies, as well as high-efficiency hydrogen liquefaction technologies.

Home Hydrogen Refueling Systems and Potential H-Prize Topics

- H-Prize competition for home hydrogen refueling systems to provide supplemental hydrogen for vehicle fueling at single- or multi-family dwellings using common feedstocks. Information regarding individual components but emphasis on complete systems.

Hydrogen and Fuel Cell Technology Readiness

- Technology validation and deployment activities aimed at ensuring commercial readiness and stimulating commercialization of fuel cell and hydrogen technologies. Information on which hydrogen and fuel cell technologies are ready for technology validation.

Automotive Fuel Cell Cost and Durability Target

- Proposed cost and durability targets for fuel cells designed for automotive applications. Proposed cost target is $40/kW for automotive fuel cell system cost, and the proposed durability target is 5,000 hours (~150,000 miles).

FCTO Webinars

R&D Advancements

- Additive Manufacturing for Fuel Cells
- Micro-Structural Mitigation Strategies for PEM Fuel Cells
- Testing Oxygen Reduction Reaction Activity with the Rotating Disc Electrode Technique
- Advanced Electrocatalysts for PEM Fuel Cells

Technical Information Sharing

- International Hydrogen Infrastructure Challenges Workshop Summary – NOW, NEDO, and DOE
- Hydrogen Compatibility of Materials
- Hydrogen Storage Materials Requirements
- Hydrogen Refueling Protocols

Education & Outreach

- Energy 101: Fuel Cells Discussion
- 2014 Hydrogen Student Design Contest
- Fuel Cell Buses
- What Can We Learn from Hydrogen Safety Event Databases?

Analysis

- DOE Analysis Related to H2USA
- Hydrogen Production Analysis Using the H2A v3 Model
- Automotive and MHE Fuel Cell System Cost Analysis
- Wind-to-Hydrogen Cost Modeling and Project Findings

For more information and slides, please visit:
http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html#upcoming

Key Cost-Reduction Opportunities for FCEVs

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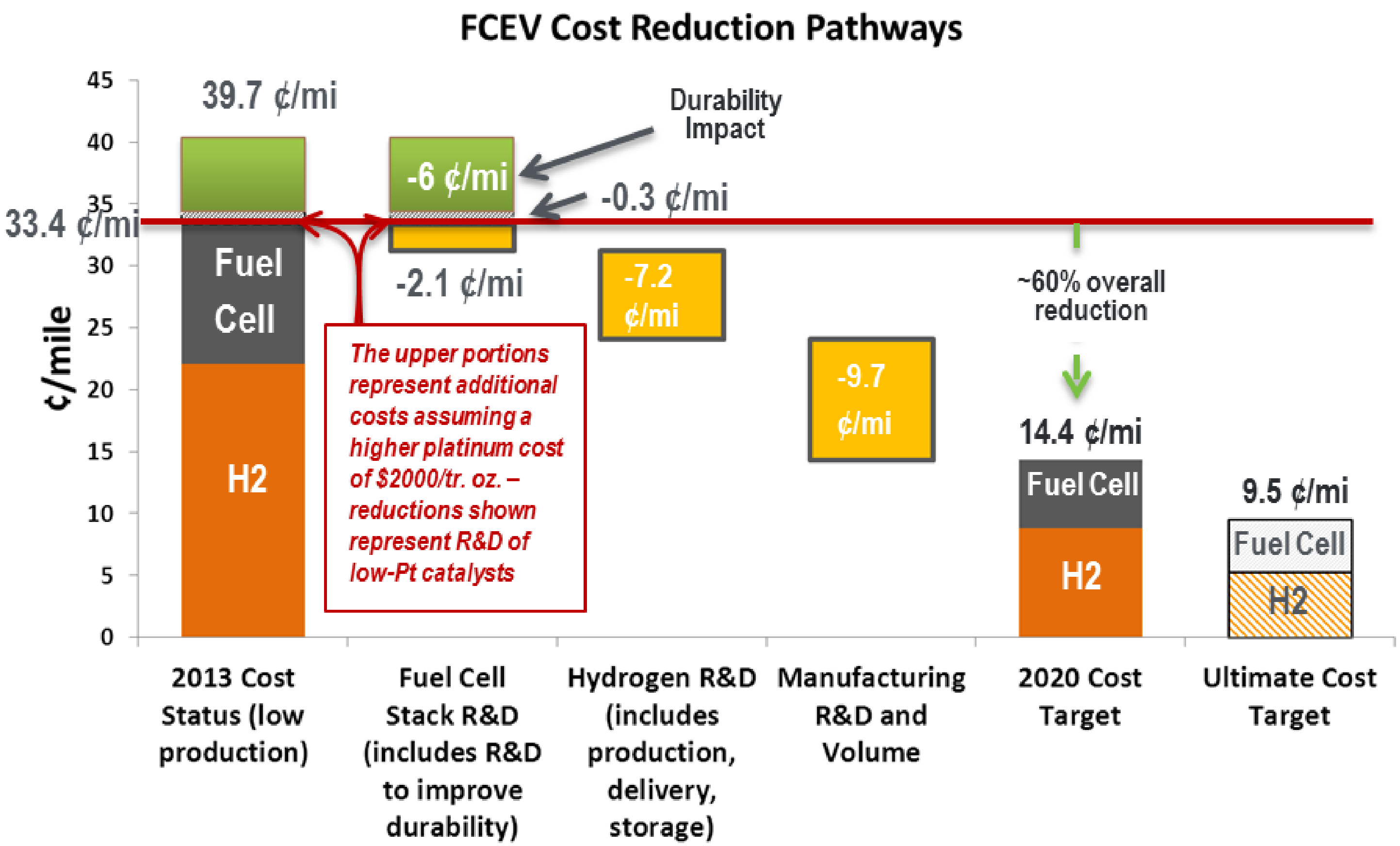


Technology Assumptions @ Target

- **Fuel Cell Cost:** \$55/kW → \$40/kW
- **Fuel Cell Durability:** 150,000 miles
- **Hydrogen Production Cost:** \$6.00/gge → \$4.00/gge
- **H_2 Storage Cost:** \$3,170 (\$17/kWhr)→ \$1,700 (\$10/kWhr)
- **FCEV fuel economy :** 51 mpgge → 67 mpgge
- **Annual miles driven:** 14,500 mi

Manufacturing R&D Assumptions

Fuel Cell Cost: \$80/kW (@ 30,000 units/yr) → \$55/kW

H2 Production: \$8.00 → \$6.00/gge

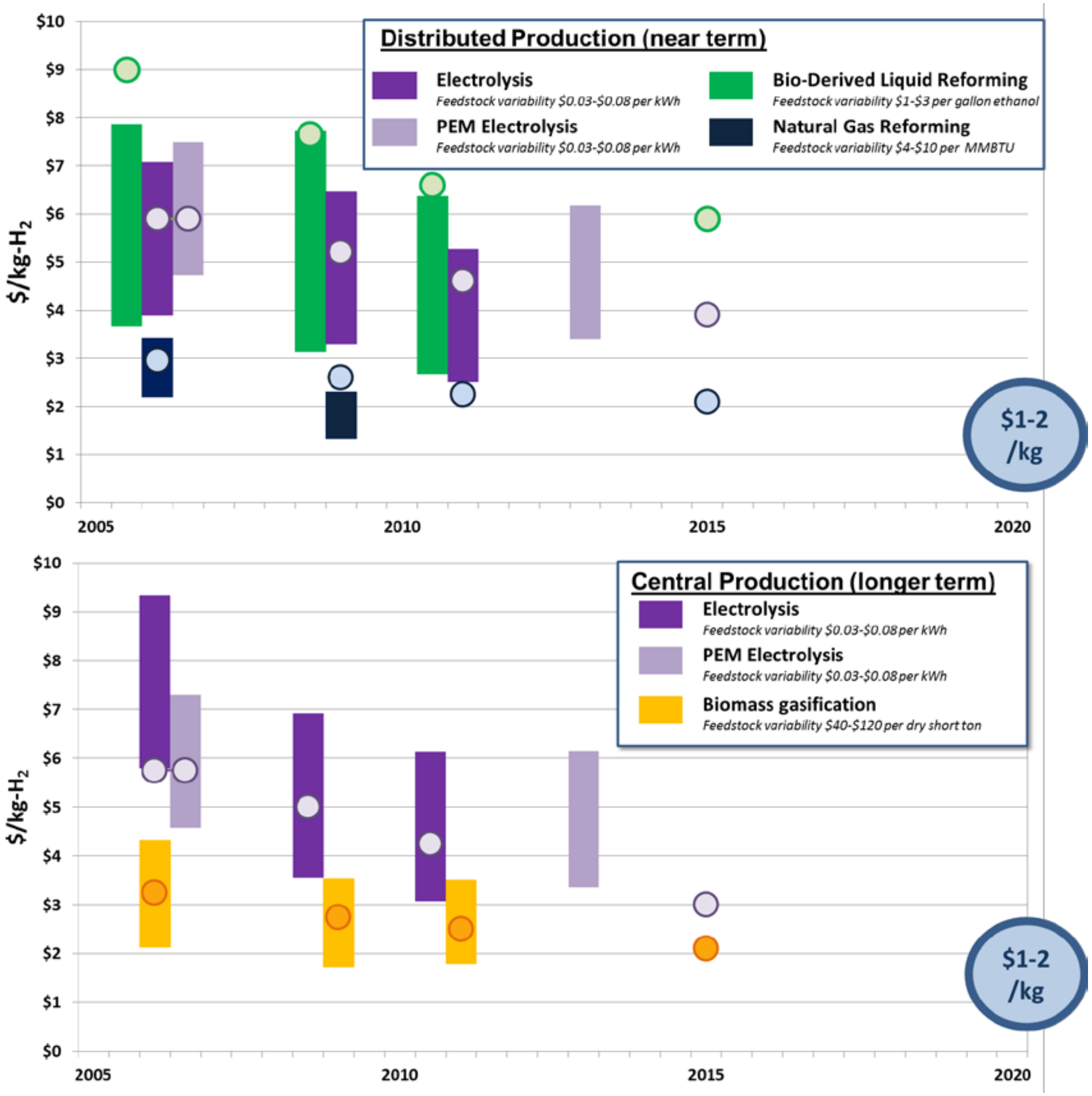
H2 Storage: \$4,848 (@30,000 units/yr)→ \$3,170 (\$17/kWhr)

Tech Assumptions @ Ultimate Target

- **Fuel Cell Cost:** \$30/kW
- **H_2 Prod. Cost:** \$2.00/gge
- **H_2 Stor. Cost:** \$1,350 (\$8/kWhr)

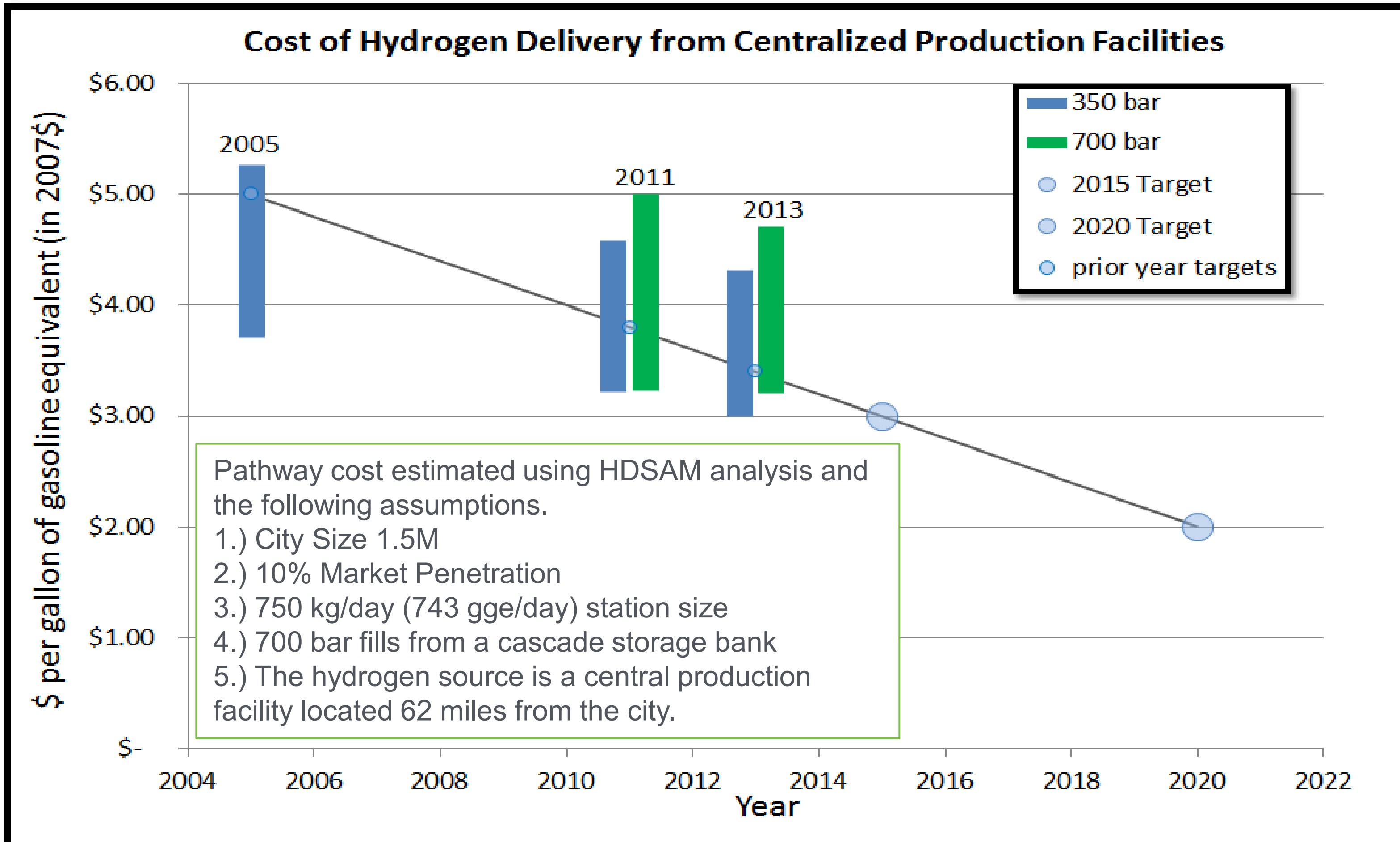
Production Cost Status for Near/Mid-Term Pathways

Projected high-volume cost of hydrogen for near-term production pathways



- **Status of hydrogen cost (production only, does not include delivery or dispensing costs) is shown in vertical bars, reflecting values based on a range of assumptions (feedstock/capital costs).**
- **Targets for hydrogen cost are shown in circles.**
- **Targets shown are normalized for consistency in feedstock assumptions and year-cost basis (2007 dollars)**
- ***Targets prior to 2015 are extrapolated based on 2015 and 2020 targets in the FCT Office's Multi-year RD&D Plan.***
- **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.**

Current Status and Hydrogen Delivery Cost Targets[a]



Range of HDSAM projected costs of hydrogen delivery from central production facilities in 2005, 2011, and 2013 along with the relevant targets.

[a] See Fuel Cell Technologies Office Record 13013 for details : http://hydrogen.energy.gov/program_records.html

Hydrogen Storage

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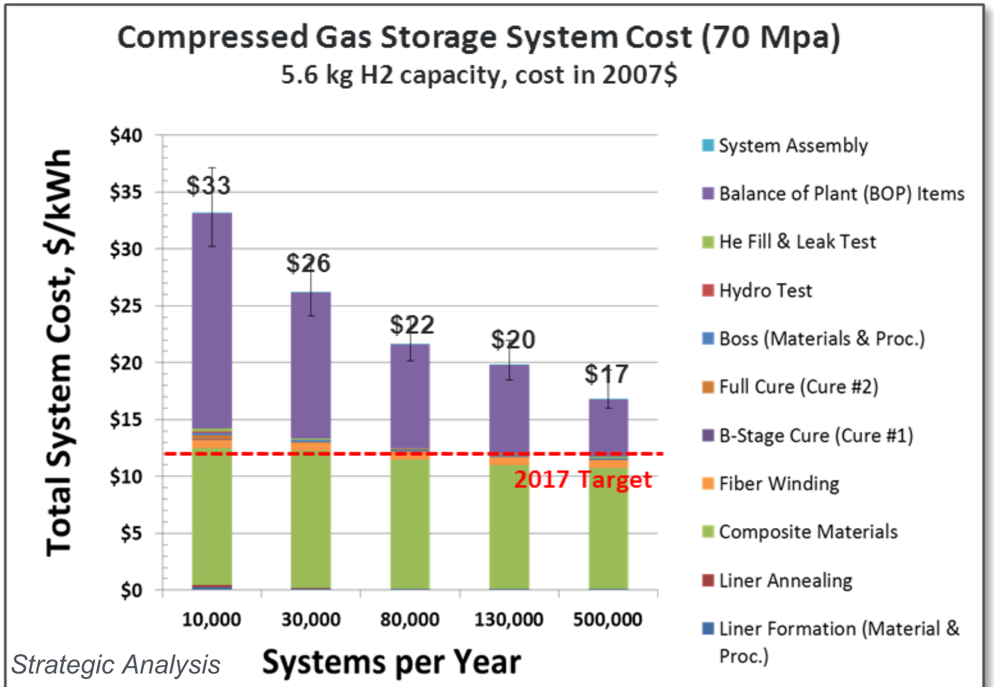
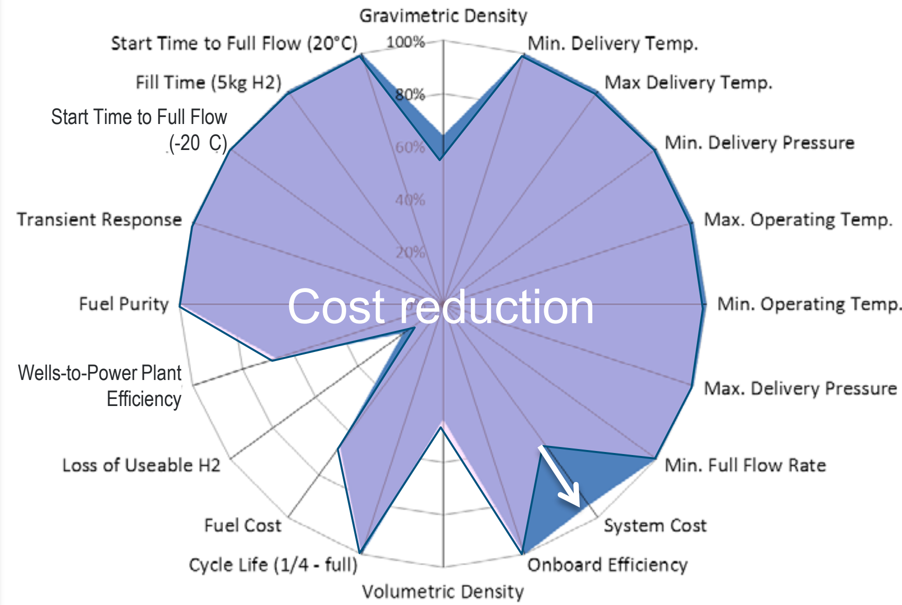
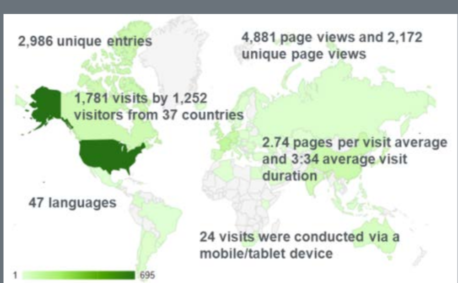


Cost Reduction for Hydrogen Adsorption Systems



Accomplishments: 3X increase in tensile strength demonstrated in C-fiber from melt-spun PAN precursor (ORNL)

- **Projected ~30% cost reduction through lower pressure operation, avoiding C-fiber tanks (HSECoE)**



Launched open source database* on Hydrogen Storage Materials Properties

(http://hydrogenmaterialssearch.govtools.us/)

* Included in President's Materials Genome Initiative, http://www.whitehouse.gov/mgi

Recommended Best Practices for the Characterization of Engineering Properties of Hydrogen Storage Materials

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

Manufacturing Areas of Interest

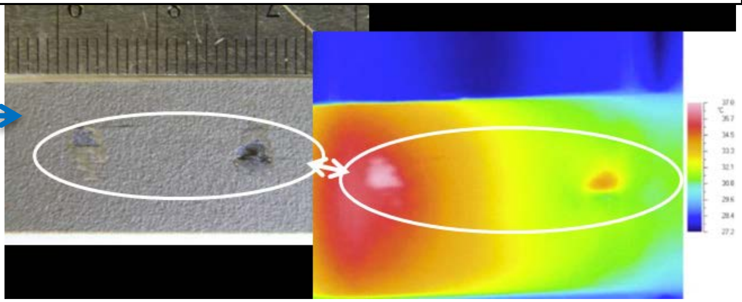
(1) Manufacturing Competitiveness Analysis - focus on global manufacturing capabilities for hydrogen and fuel cell manufacturing including fuel cells, electrolyzers, hydrogen storage tanks, and steam methane reforming;

(2) Supply Chain Development - analysis of supply chains and approaches to enhance the supply chain for hydrogen and fuel cell products; the use of workshops and exchanges (meetings between suppliers and OEMs) to expand the supply chain are encouraged.

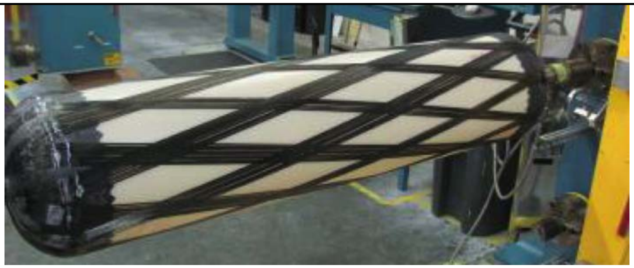
Key Accomplishments:

- NREL: demonstrated in-line QC techniques able to detect defects in web-line speeds of 30 ft/min
- Ballard (AvCarb): Reduced cost & increased throughput of GDLs by 50% & 400%, respectively
- RPI: Demonstrated ability to bond membrane layers in <1 s w/ ultrasonic bonding technique
- Quantum: Reduced cost & weight of Type IV H_2 storage tanks by >15% w/ advanced fiber placement (AFP) manufacturing techniques

Defect detected in GDL by IR at 30 ft/min



700 bar tank w/ AFP reinforced dome caps



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*)

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Dr. Joan Ogden, Co-director
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Citizens for Affordable Energy;
President & U.S. Country Chair (retired), Shell Oil Company

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

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