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

DOE Hydrogen & Fuel Cell Overview

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Fuel Cell Technologies Program

Agenda: DOE Fuel Cell Technologies Program

- Overview
  - Goals & Objectives
  - Technology Status & Key Challenges
- Progress
  - Research & Development
  - Deployments
  - Recovery Act Projects
- Budget
- Key Publications

Program Mission

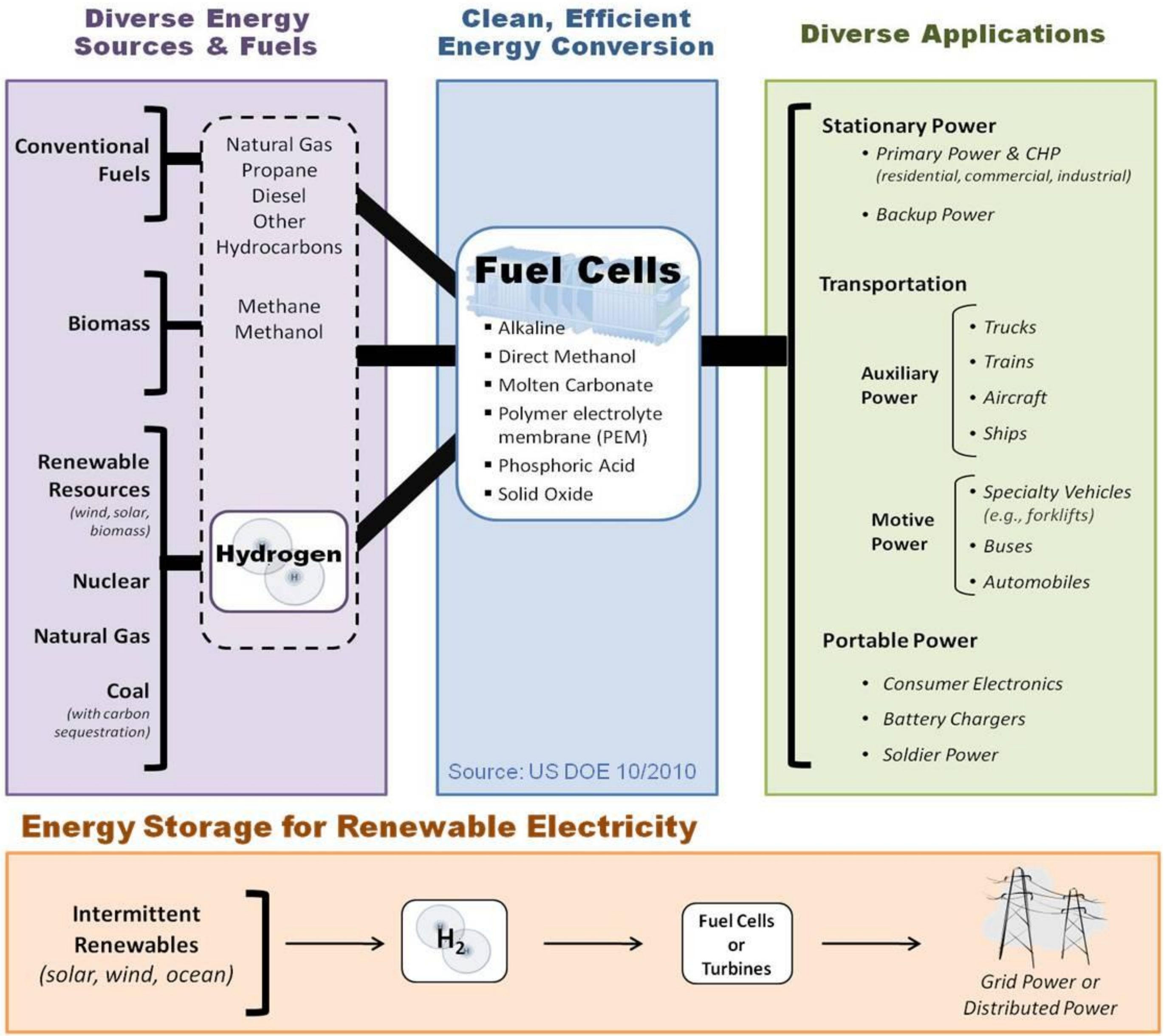
The mission of the Hydrogen and Fuel Cells Program is to enable the widespread commercialization of a portfolio of hydrogen and fuel cell technologies through basic and applied research, technology development and demonstration, and diverse efforts to overcome institutional and market challenges.

Key Goals : Develop hydrogen and fuel cell technologies for:

1. Early markets such as stationary power (prime and back up), lift trucks, and portable power
2. Mid-term markets such as residential combined-heat-and-power systems, auxiliary power units, fleets and buses
3. Long-term markets including mainstream transportation applications with a focus on light duty vehicles, in the 2015 to 2020 timeframe.

Source: US DOE 10/2010- draft Program Plan
Includes basic science through the Office of Science and applied RD&D through EERE, FE, NE

Fuel Cells: Addressing Energy Challenges



Fuel Cells - *Where are we today?*

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Fuel Cells for Stationary Power, Auxiliary Power, and Specialty Vehicles

The largest markets for fuel cells today are in stationary power, portable power, auxiliary power units, and forklifts.

~75,000 *fuel cells have been shipped worldwide.*

~24,000 *fuel cells shipped in 2009 (> 40% increase over 2008).*

Fuel cells can be a cost-competitive option for critical-load facilities, backup power, and forklifts.

Production & Delivery of Hydrogen

In the U.S., there are currently:

- ***~9 million metric tons*** *of H_2 produced annually*
- *>* ***1200 miles*** *of H_2 pipelines*

Source: US DOE 09/2010

Fuel Cells for Transportation

In the U.S., there are currently:

- *> 200 fuel cell vehicles*
- *~ 20 active fuel cell buses*
- *~ 60 fueling stations*

Sept. 2009: Auto manufacturers from around the world signed a letter of understanding supporting fuel cell vehicles in anticipation of widespread commercialization, beginning in 2015.

Global competition is increasing

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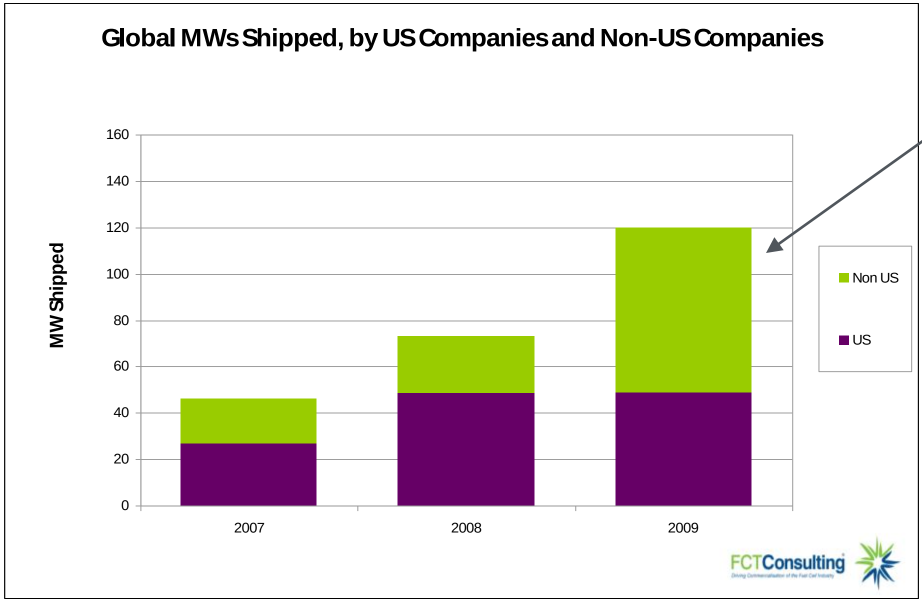
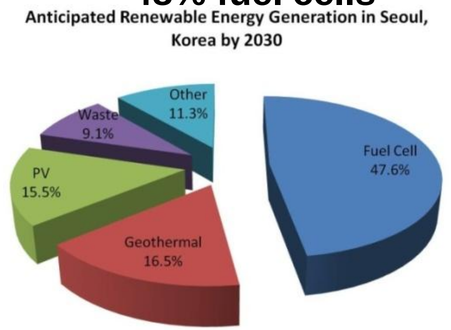


Significant increase in MW shipped by non-US companies in just 1 year

>40% market growth in just one year

Example: Seoul's

Renewable energy generation plan includes ~ **48% fuel cells**



Source: Municipal Government of Seoul

Preliminary market analysis

International Landscape favors H_2 & Fuel Cells

- Germany (>$1.2B; 1,000 H_2 stations)
- European Commission (>$1.2B, 2008-2013)
- Japan (2M vehicles, 1,000 H_2 stations by 2025)
- Korea (plans to produce 20% of world shipments & create 560,000 jobs in Korea)
- China (thousands of small units; 70 FCVs, buses, 100 shuttles at World Expo, Olympics)
- Subsidies for jobs, manufacturing, deployments (e.g. South Africa)

Example: Denmark

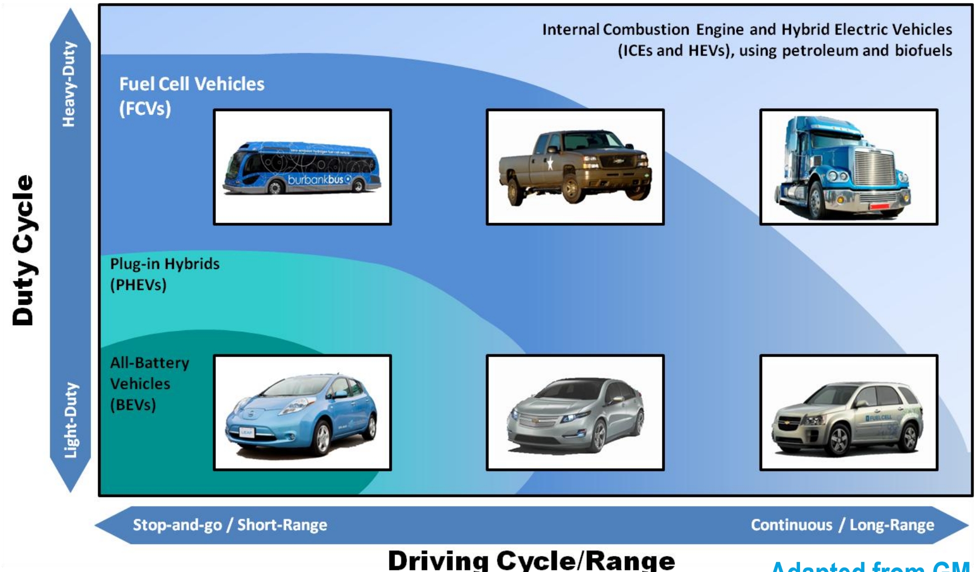
Backup Power Deployments

50,000 potential sites
>500 deployments worldwide

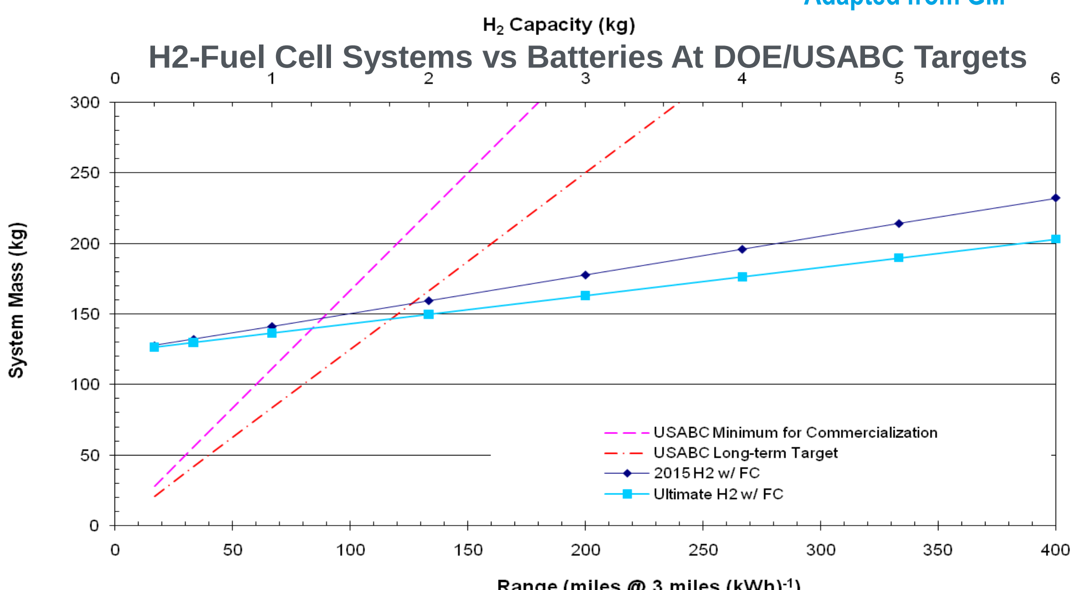
 Source: US DOE 12/2010

Specific positions and numbers are not correct

The Role of Fuel Cells in Transportation



Adapted from GM



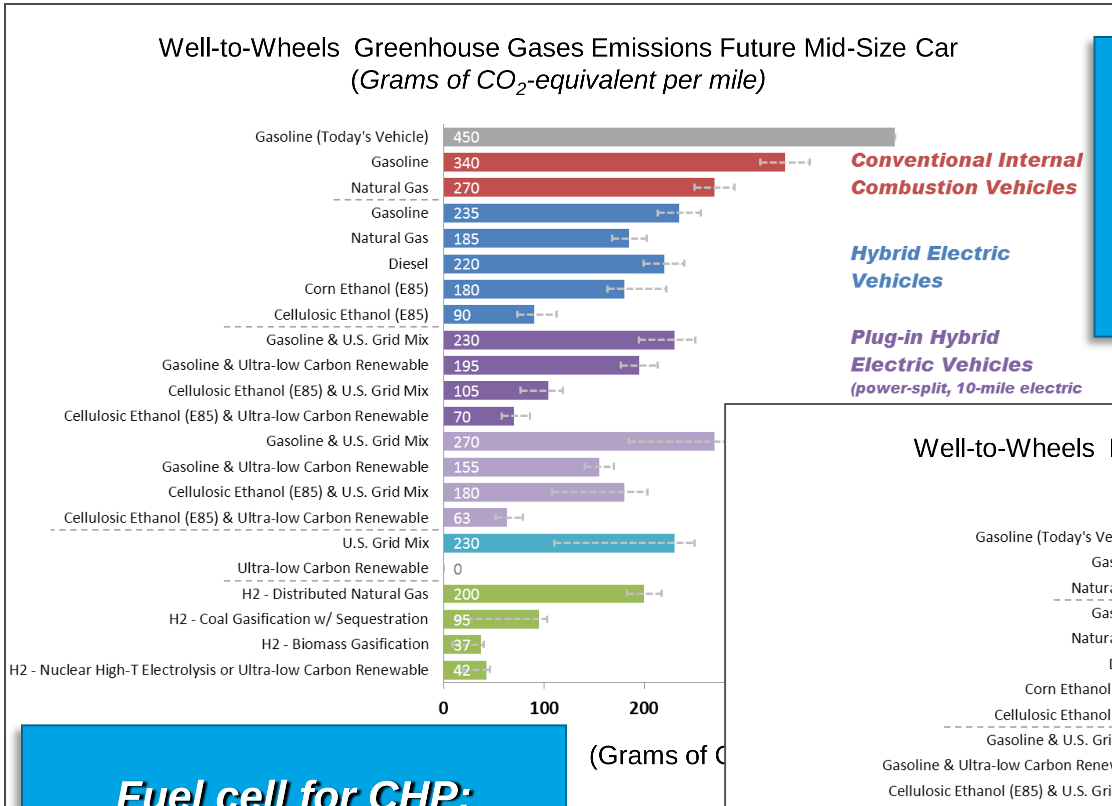
FC targets: http://www1.eere.energy.gov/hydrogenandfuelcells/mypp/pdfs/fuel_cells.pdf ; H_2 Storage targets: http://www1.eere.energy.gov/hydrogenandfuelcells/storage/pdfs/targets_onboard_hydro_storage.pdf;

Battery targets: http://www.uscar.org/commands/files_download.php?files_id=27

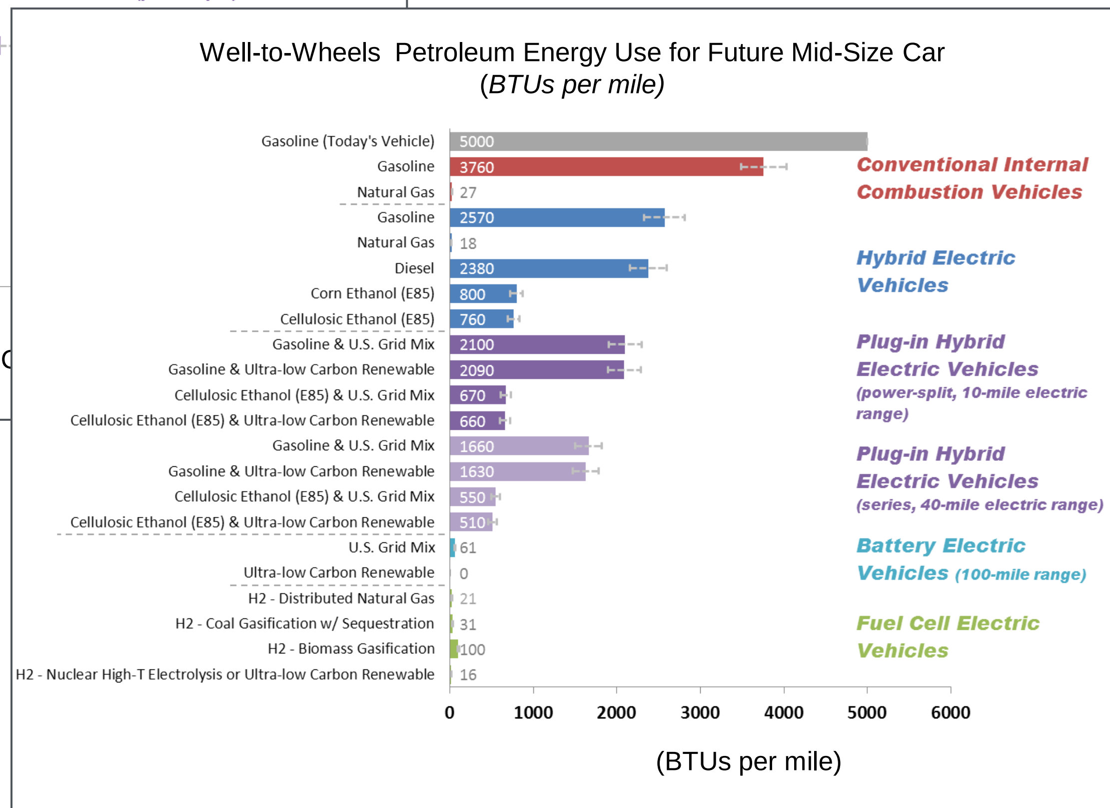
- **A variety of technologies - including fuel cell vehicles, extended-range electric vehicles (or "plug-in hybrids"), and all-battery powered vehicles – are under development to meet our diverse transportation needs.**
- **The most appropriate technology depends on the drive cycle and duty cycle of the application.**

At extended driving ranges, benefits of fuel cell vehicles become more pronounced.

 Source: US DOE 12/2010



Analysis includes portfolio of transportation technologies and latest models and updates to well-to-wheels assumptions



Fuel cell for CHP:
75-90% less Nox
75-80% less particulates
>50% less CO2 emissions

Analysis & Assumptions at:
http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning. Global warming potential of primary fuels excluded.

 Source: US DOE 10/2010

Preliminary Analysis

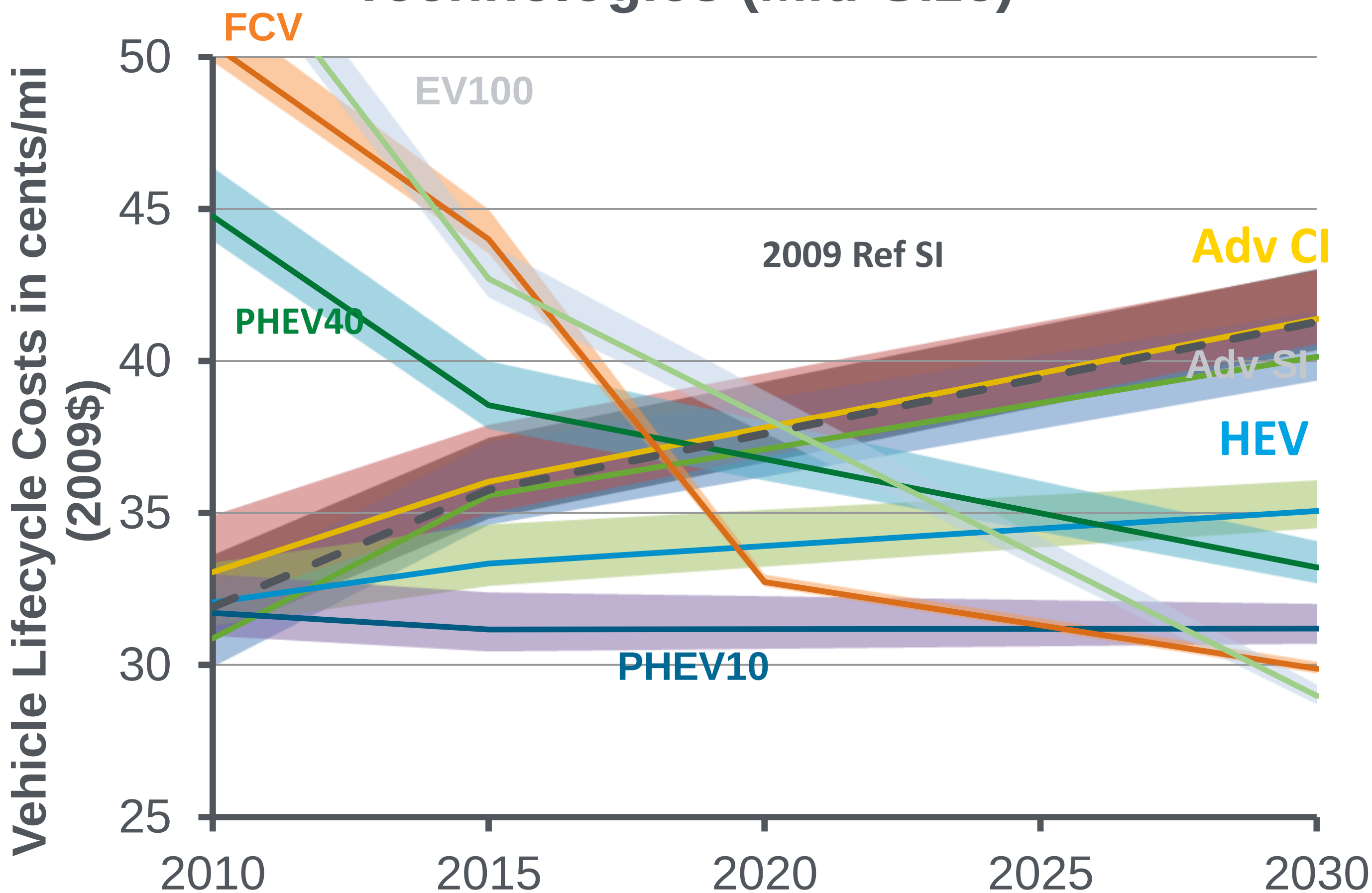
2015

- Lifetime cost of diesel ownership is roughly equivalent to an SI ICE
- HEVs and PHEV10s are competitive.
- Energy storage costs are still high for PHEV40s and EVs

2030

- Hybrid, electrified, and fuel cell vehicles are competitive
- Diesels cost is still roughly equivalent to an SI ICE

Advanced Light Duty Vehicle Technologies (Mid-Size)



* No state, local or utility incentives are included. Federal subsidy policies (e.g., Recovery Act 09 credits for PHEVs) are also excluded. Fuel prices follow AEO09 high oil projections (gases rises from $3.07 in 2010 to $5.47 in 2030; diesel increases from $3.02 in 2010 to $5.57 in 2030); fuel taxes are included in EIA estimates. The vehicle cost range represents a range of potential carbon prices, from $0 to $56 (the centerline is plotted at a carbon price of $20). Technology costs are estimated based on a 50% ("average") likelihood of achieving program goals.

Source: Presentation to ERAC, November 30, 2010

Key Challenges

The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

Stationary Systems: **$750 per kW, 40,000-hr durability**

Vehicles: **$30 per kW, 5,000-hr durability**

Hydrogen Cost

Target*: $2 – 3 /gge, (dispensed and untaxed)

Hydrogen Storage Capacity

Target: > 300-mile range for vehicles—without compromising interior space or performance

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

*** Targets and Metrics are being updated in 2010 .**

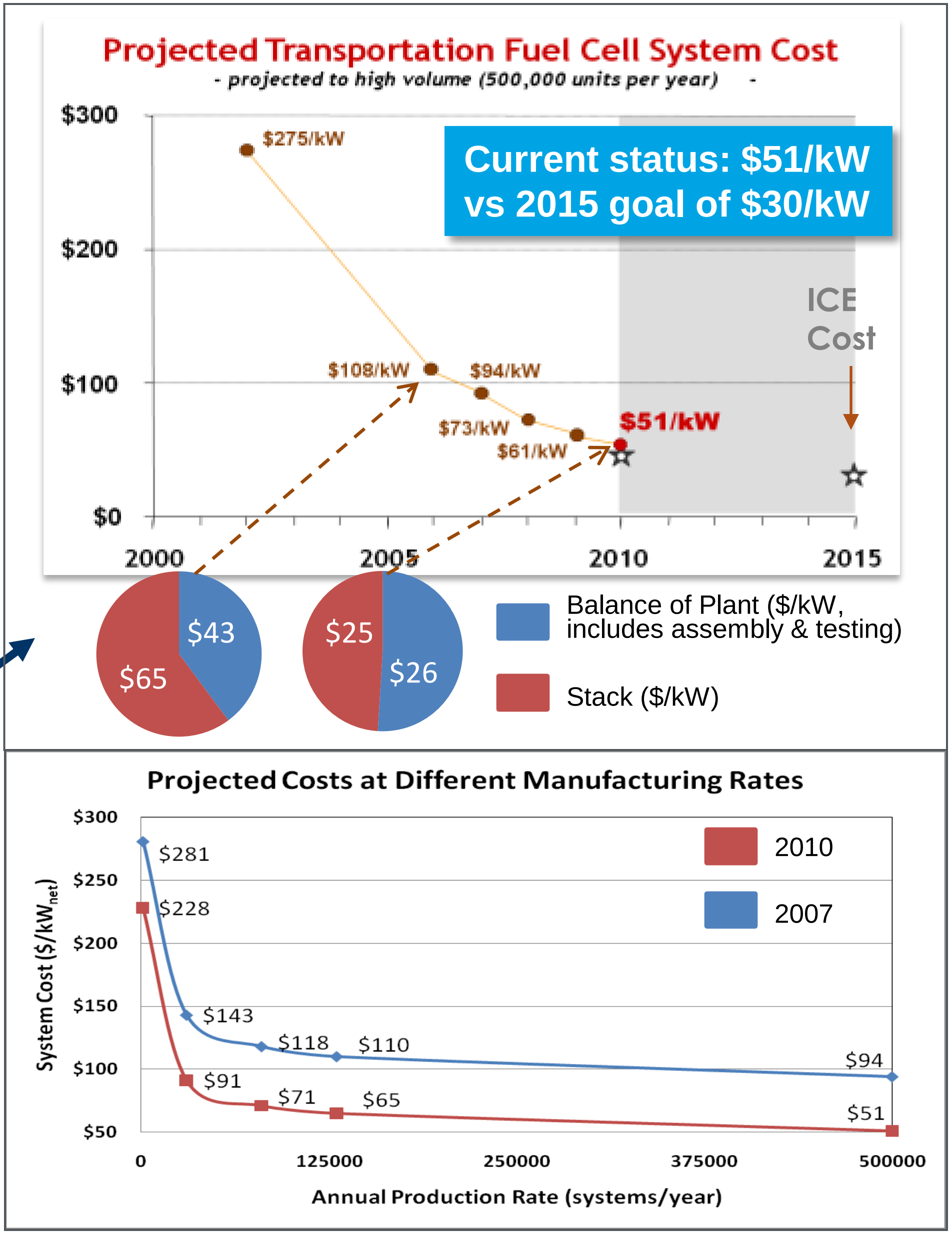
 Source: US DOE 09/2010

Progress

Projected high-volume cost of fuel cells has been reduced to $51/kW (2010)*

- ***More than 30% reduction since 2008***
- ***More than 80% reduction since 2002***
- ***2008 cost projection was validated by independent panel*****

As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.



**Based on projection to high-volume manufacturing (500,000 units/year).*

***Panel found $60 – $80/kW to be a "valid estimate": http://hydrogendoedev.nrel.gov/peer_reviews.html*

Source: US DOE 10/2010

Fuel Cell R&D — *Progress*

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The Program has reduced PGM content, increased power density, and simplified balance of plant, resulting in a decrease in system cost.

From 2008 to 2010, key cost reductions were made by:

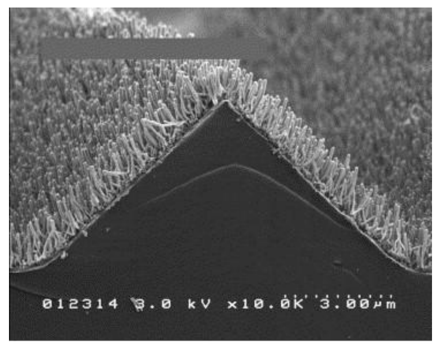
- **Reducing platinum group metal content from 0.35 to 0.18 g/kW**
- **Increasing power density from 715 to 833 mW/cm^2**
- **Simplifying balance of plant**

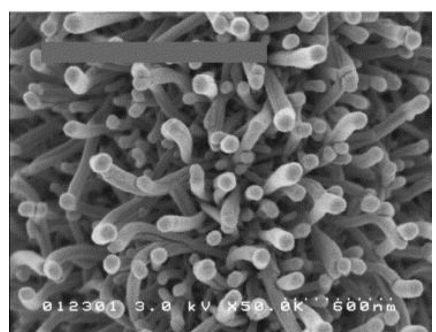
→ These advances contributed to a $22/kW cost reduction.

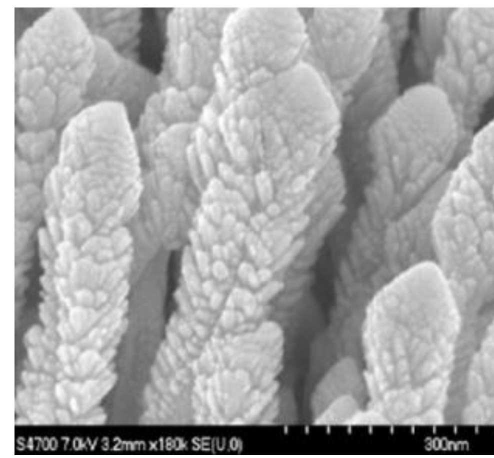
Key improvements enabled by using novel organic crystalline whisker catalyst supports and Pt-alloy whiskerettes.

There are ~ 5 billion whiskers/cm^2.

Whiskers are ~ 25 X 50 X 1000 nm.







Whiskerettes:
6 nm x 20 nm

Source: 3M

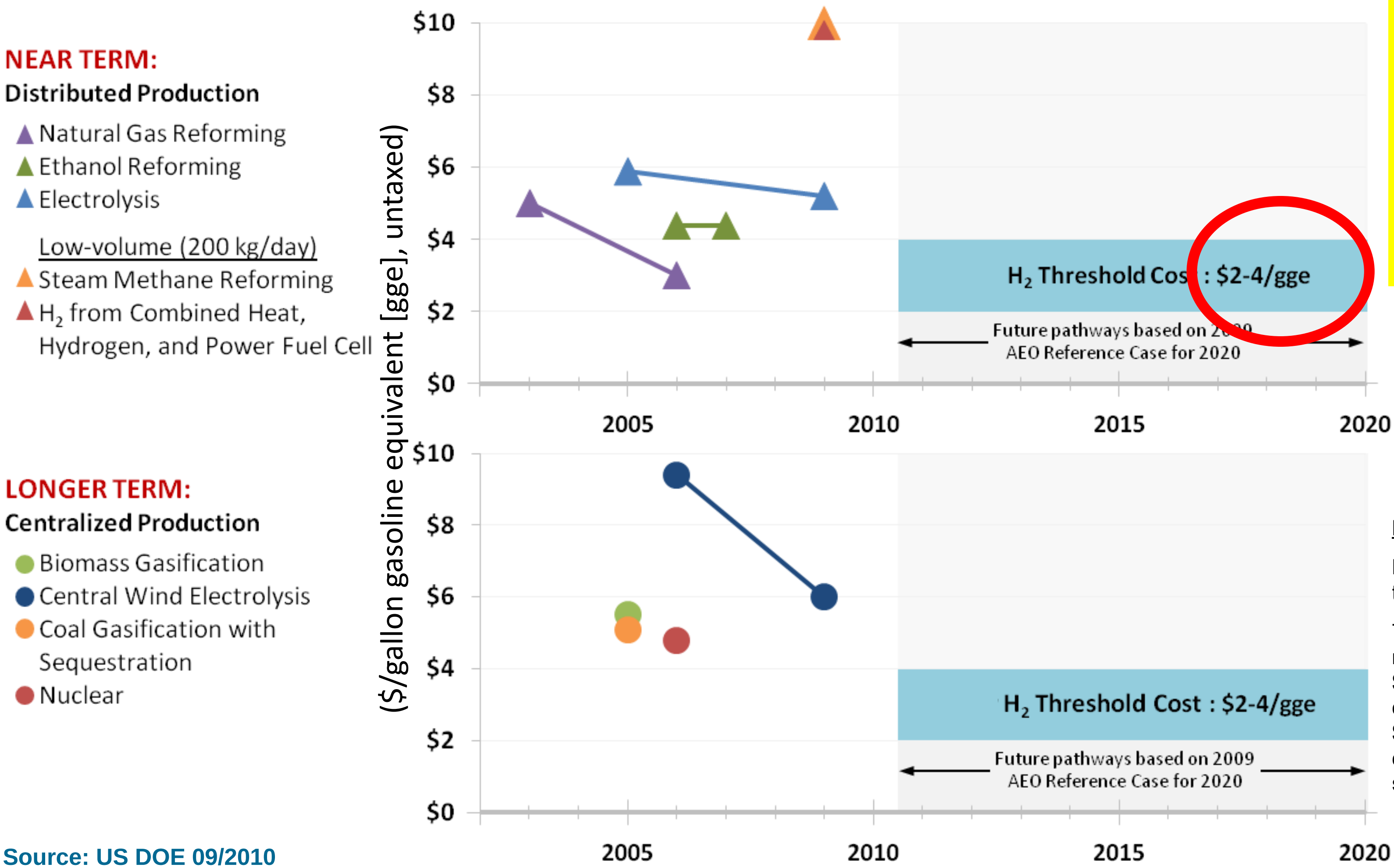
Source: US DOE 08/2010

Hydrogen Threshold Cost Analysis

High volume projected costs for hydrogen production technologies continue to decrease. Low volume/early market costs are still high. Hydrogen cost range reassessed – includes gasoline cost volatility and range of vehicle assumptions.

Projected High-Volume Cost of Hydrogen (Dispensed)—Status

Being updated to address gasoline cost volatility and range of vehicle assumptions



Notes:

Data points are being updated to the 2009 AEO reference case.

The 2010 Technology Validation results show a cost range of $8-$10/gge for a 1,500 kg/day distributed natural gas and $10-$13/gge for a 1,500 kg/day distributed electrolysis hydrogen station.

Source: US DOE 09/2010

R&D Progress - Examples

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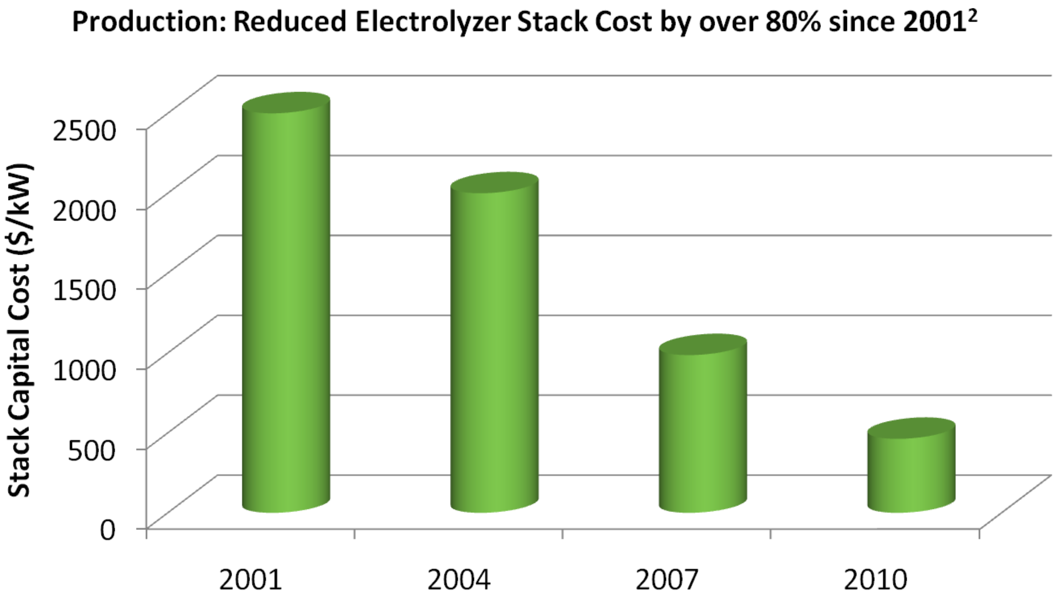
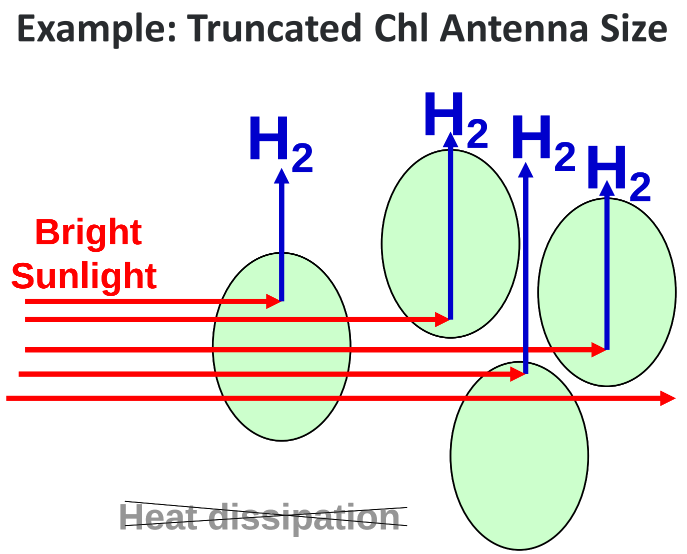


Source: Giner Electrochemical Systems, LLC
[2] Total cost of delivery hydrogen ($/kg) in H2A Model Rev. 2.0 is $5.20
(Cost of delivery in Rev. 1.0.11 is $0.69; Rev 2.0, $1.92



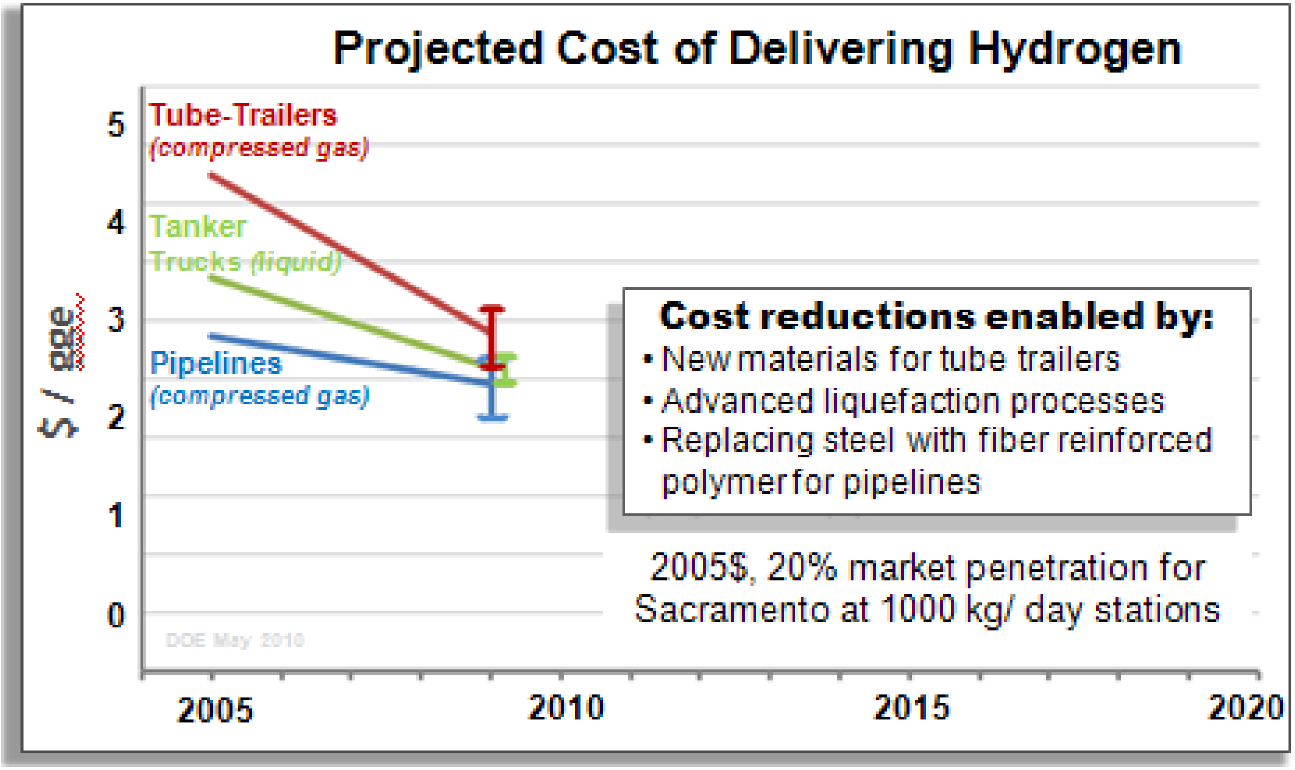
UC Berkeley

- ❑ Improved photosynthetic solar –to-chemical energy conversion from 3 to 25% for photobiological hydrogen production by truncating the chlorophyll antenna size (Berkeley)
- ❑ Demonstrated bandgap tailoring in photoactive MoS_2 nanoparticles. Increased bandgap from 1.2eV to 1.8 eV for more optimal photoelectrochemical (PEC) water splitting (by quantum effects). (Stanford U.)

Source: US DOE 12/2010

Hydrogen Delivery R&D

The Program is developing technologies to deliver hydrogen from centralized production facilities, efficiently and at low cost.



We've reduced the cost of hydrogen delivery* —

- **~30% reduction in tube trailer costs**
- **>20% reduction in pipeline costs**
- **~15% reduction liquid hydrogen delivery costs**

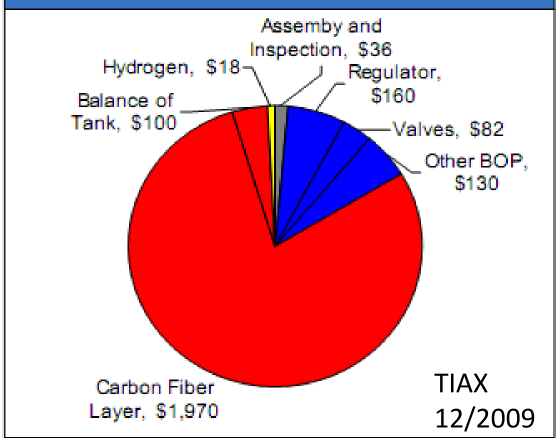
***Projected cost, based on analysis of state-of-the-art technology**

Significant progress has been made but meeting all weight, volume, performance and cost requirements is still challenging.

Compressed gas storage offers a near-term option for initial vehicle commercialization and early markets

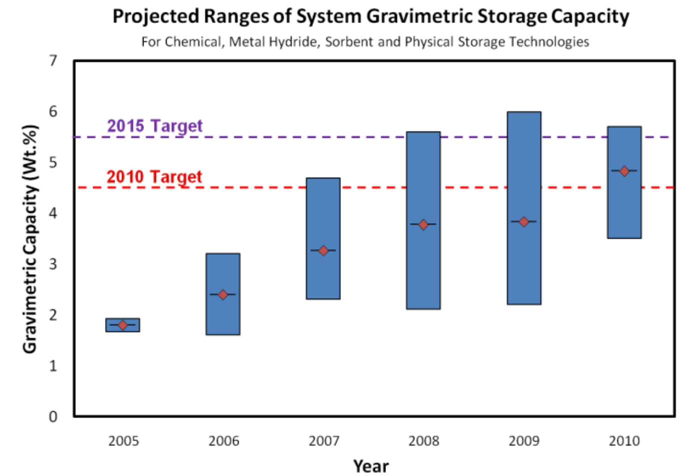
- Validated driving range of up to ~ 430 mi
- Cost of composite tanks is challenging
  - carbon fiber layer estimated to be >75% of cost
- Advanced materials R&D under way for the long term

350-bar Base Case Factory Cost[1] = $2,500
$13/kWh based on 5.6 kg usable H_2 (6 kg stored H_2)

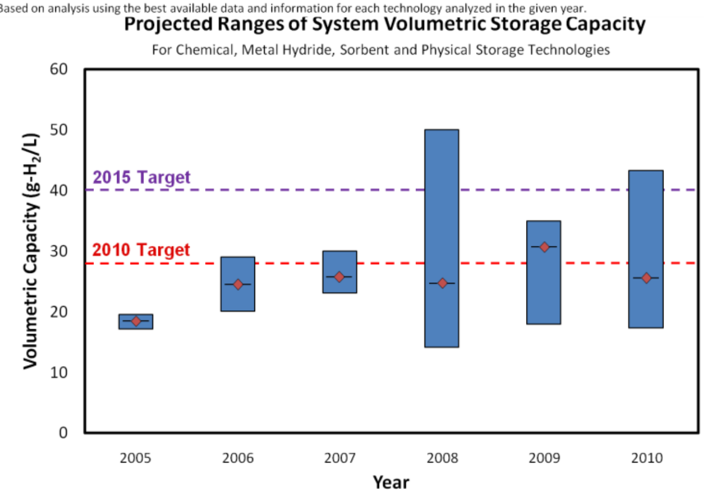


[1] Cost estimate in 2005 USD. Includes processing costs.

Projected Capacities for Complete 5.6-kg H_2 Storage Systems



Based on analysis using the best available data and information for each technology analyzed in the given year.



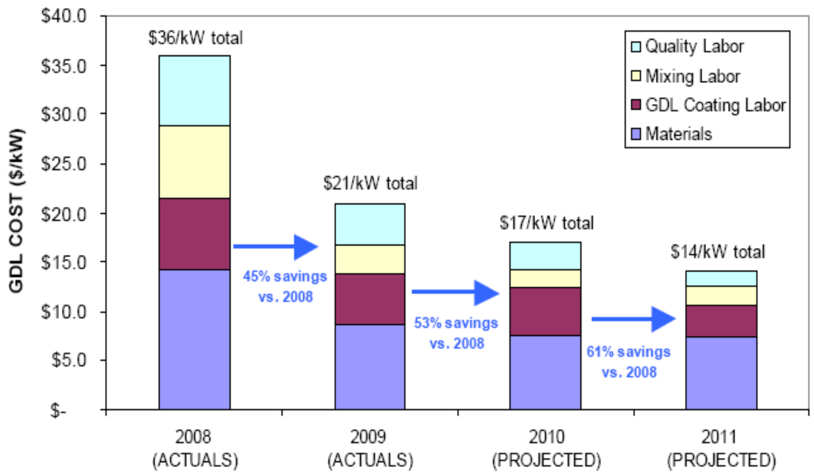
Based on analysis using the best available data and information for each technology analyzed in the given year.

 Source: US DOE 12/2010

Manufacturing R&D

- Fuel Cell MEA Measurement R&D (NREL)
  - Developed IR-based test stand to detect defects such as pinholes, shorts, and electrode thickness in variations
- High Speed, low cost fabrication of gas diffusion electrodes for MEAs (BASF)
  - Developed an innovative on-line XRF
  - Developed a predictive model for electrode variation and defect impacts on MEA performance
- Developed process model for controlling GDL coating conditions (Ballard)
  - Significant improvement in quality yields and GDL cost reduction estimated at 53% to-date in 2 years

GDL Actual Costs



Source: Ballard

Near-term Goal for Early Markets

Lower fuel cell stack manufacturing cost by $1000/kW (*from $3,000/kW to $2,000/kW, for low-volume manufacturing*)

Project Emphasis

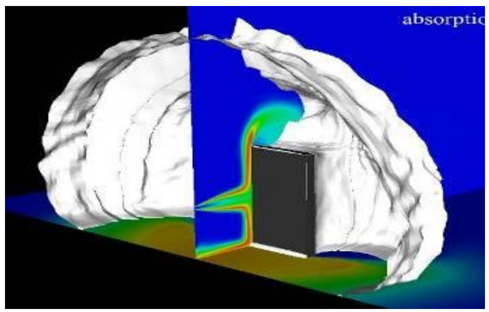
- Electrode Deposition (BASF, PNNL)
- High Pressure Storage (Quantum Technologies)
- MEA Manufacturing (Gore, LBNL, RPI)
- Gas Diffusion Layer (GDL) Fabrication (Ballard)
- Effective Testing of Fuel Cell Stacks (PNNL, UltraCell)
- Effective Measurement of Fuel Cell Stacks (NREL, NIST)

 Source: US DOE 12/2010

Separation Distances

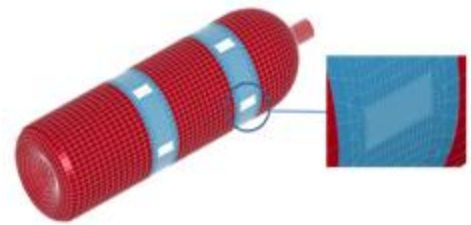
Provided technical data and incorporated risk-informed approach that enabled NFPA2 to update bulk gas storage separation distances in the 2010 edition of NFPA55

Barrier walls reduce separation distances – simulated position of allowable heat flux iso-surface for 3-minute employee exposure (2009 IFC).



Materials and Components Compatibility

- Performed testing of forklift tank materials to enable design qualification
- Added two additional Nickel alloy chapters to the Technical Reference



Fuel Quality Specification

- Draft International Standard (DIS) was submitted to ISO TC197 Nov 2010
- Technical Specification (TS) published and harmonized with SAE J2719, Committee Draft (CD) prepared
- Developing standardized sampling and analytical methodologies with ASTM

Safety Sensor Development

- Completed extensive life testing - 4,000 hrs and 10,000 thermal cycles - of a robust, ceramic, electrochemical Hydrogen safety sensor with exceptional baseline stability and resistance to H2 signal degradation

Technical Performance Requirements	
Sensitivity: 1 vol% H_2 in air	Temperature: -40ºC to 60ºC
Accuracy: 0.04-4% ±1% of full scale	Durability: 5 yrs without calibration
Response time: <1 min at 1% And <1 sec at 4% Recovery <1 min	Low cross-sensitivity to humidity, H_2S, CH_4, CO, and VOCs

Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.

RECENT PROGRESS

Vehicles & Infrastructure

- 152 fuel cell vehicles and 24 hydrogen fueling stations
- Over 2.8 million miles traveled
- Over 114 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles (independently also validated 430 mile range)

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
- H_2 fuel cell buses have a 41% to 132% better fuel economy when compared to diesel & CNG buses

Forklifts

- Over 18,000 refuelings at Defense Logistics Agency site

Recovery Act

- DOE (NREL) is collecting operating data from deployments for an industry-wide report

 Source: US DOE 09/2010

Technology Validation

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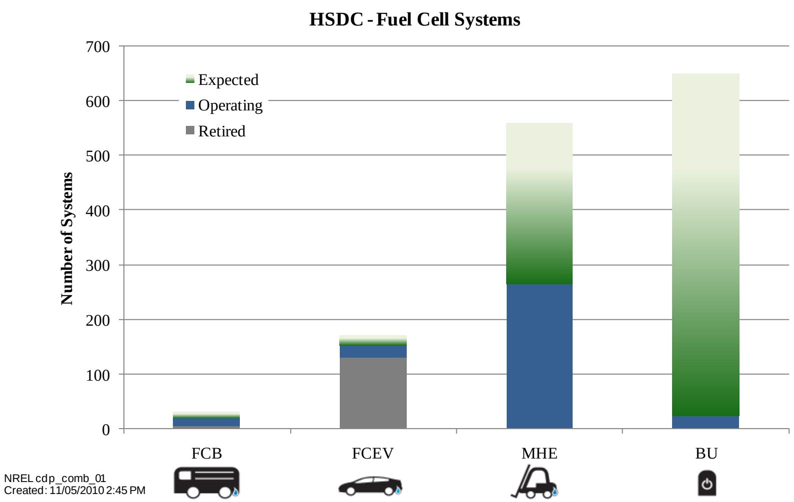
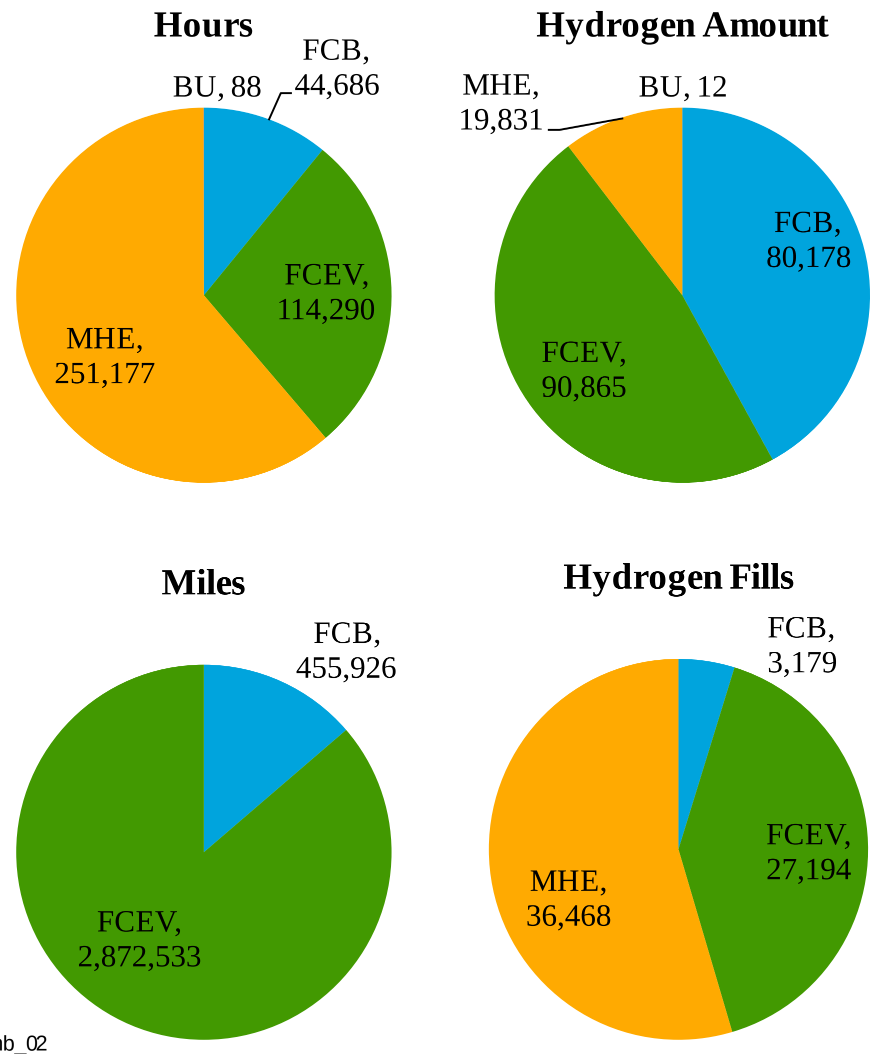
Demonstrations are essential for validating the performance of technologies in integrated systems, under real-world conditions.





NREL cdp_comb_02
Created: 11/15/2010 9:45 AM

 Source: US DOE 12/2010

Summary for Early Gen FCBs

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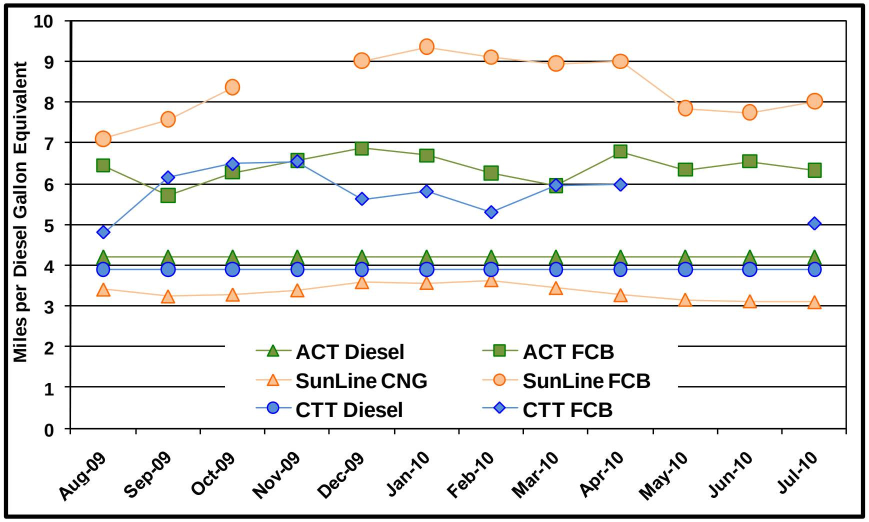
Site	AC Transit	SunLine	CTTRANSIT	
Technology	UTC Power/Van Hool/ISE	UTC Power/Van Hool/ISE	UTC Power/Van Hool/ISE	
Project Status	Complete, Buses Retired	In operation	In operation	Totals
Data Period	4/06 - 7/10	1/06 - 9/10	4/07 - 9/10	
Number of buses	3	1	1	8
Number months	52	57	43	
Total Miles	253,166	110,118	46,468	449,960
Total Hours	25,244	8,411	7,235	44,109
Hydrogen used (kg)	41,317	15,365	9,585	79,171
Avg Speed (mph)	10	13	6.4	
Fuel Economy Mi/kg	6.12	7.17	4.85	
Fuel Economy Mi/DGE	6.92	8.10	5.48	
Baseline technology	diesel	CNG	diesel	
Fuel Economy difference	65%	132%	41%	

*Missing data from VTA buses from '05-'06

Same FCB Technology at these three locations

Note: Blue shaded columns indicate completed projects – data are final

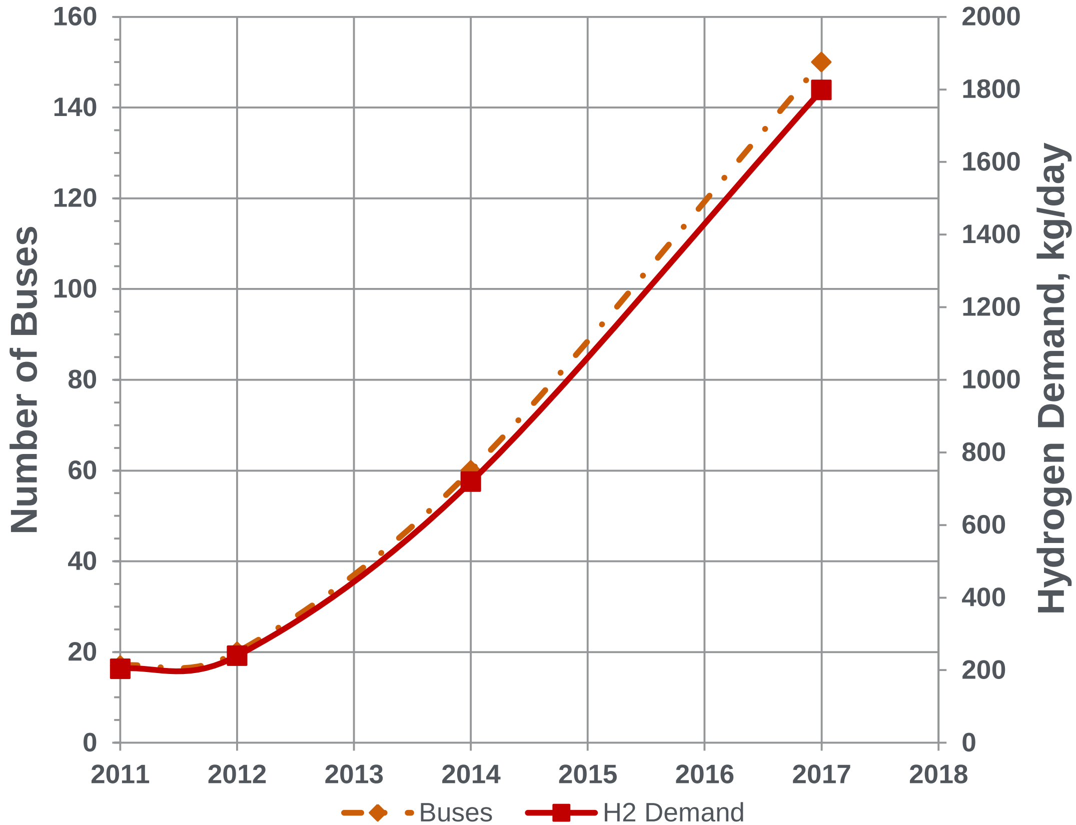


- ✓ **Fuel economy consistently better than baseline buses.**
- ✓ ~450,000 miles travelled since 2005

Source: US DOE 12/2010

Fuel Cell Bus Example

Potential deployment strategies envisioned for Fuel Cell Buses deployment scenario analysis identified in California's Action Plan.



	Phase I 2010-2011	Phase II 2012-2014	Phase III 2015-2017
Number of Fuel Cell Buses	17	20-60	60-150

http://www.cafcp.org/sites/files/FINALProgressReport.pdf

Assumptions

- Fuel cell bus fuel economy: 8 mpgge [a]
  - ~2x diesel bus fuel economy [a]
- Fuel cell fuel storage capacity is ~30 kg. [a]
- Annual miles traveled: 35,000
- Fuel demand based on fuel cell bus rollout rates.

a DOE Joint Fuel Cell Bus Workshop Summary Report http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_fcbus10.html

 Source: US DOE 2010

Combined Heat, Hydrogen & Power (CHHP)

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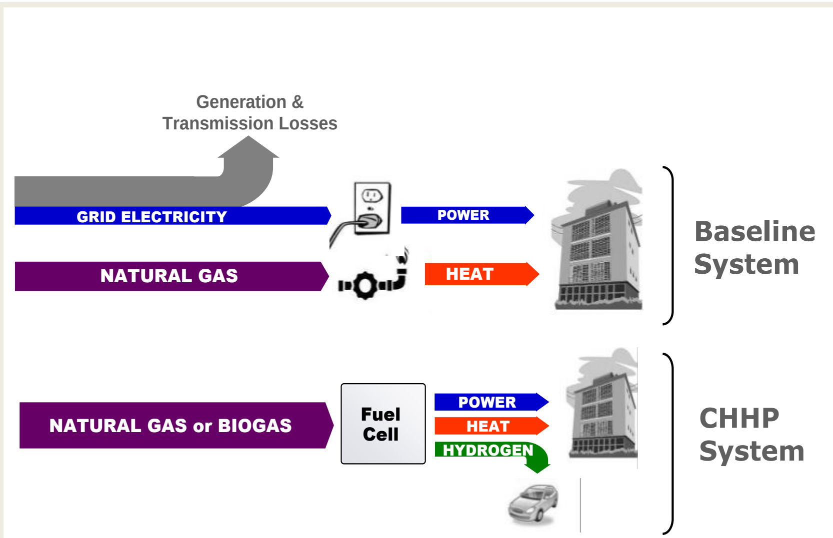
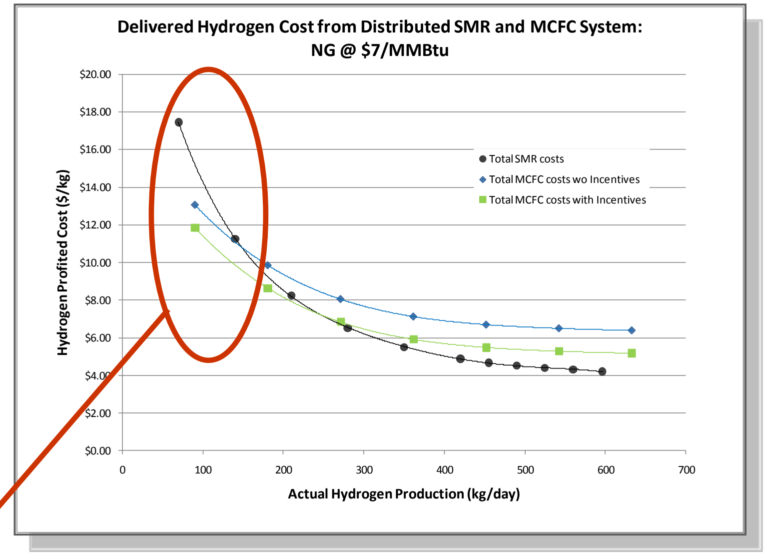
The cost of hydrogen production from CHHP can be comparable to distributed SMR at low volumes.

Combined Heat, Hydrogen, and Power (CHHP)





In cases where there is a low demand for hydrogen in early years of FCV deployment, CHHP may have cost advantages over on-site SMR production.

- CHHP is an innovative approach that can :
  - Help establish an initial infrastructure for fueling vehicles, *with minimal investment risk*
  - Produce clean power and fuel for multiple applications
- The Program is demonstrating a CHHP system using biogas.

Model Calculation of Energy Cost

- **Calculated cost of energy (electricity, heat, and hydrogen)**
- **Electricity assumed to have the same value as purchased electricity**
- **Heat valued at 1/2 value of electricity**
- **Hydrogen value calculated by difference**

Biogas Resource Example: Methane from Waste Water Treatment

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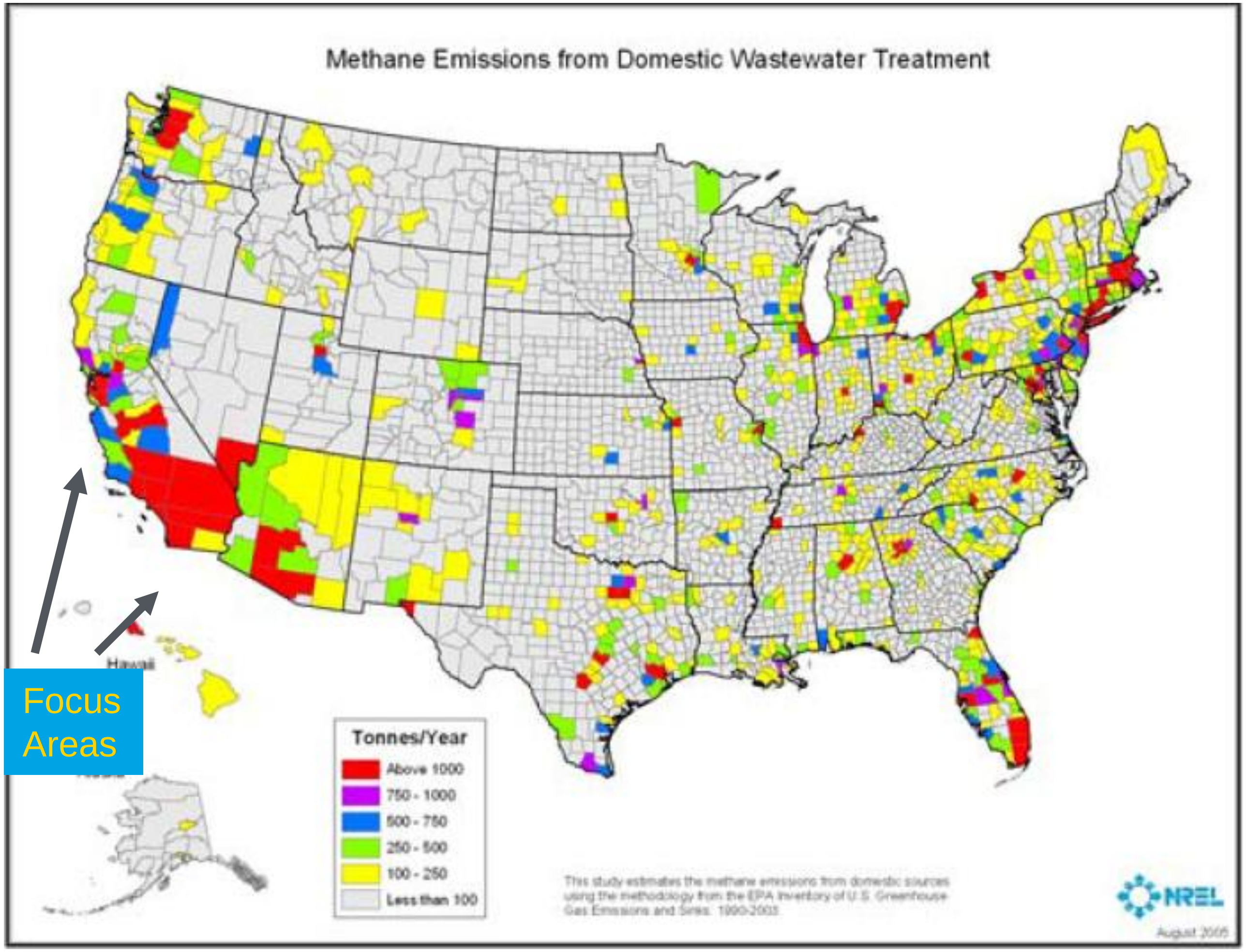
Biogas from waste water treatment plants is ideally located near urban centers to supply hydrogen for fuel cell vehicles.

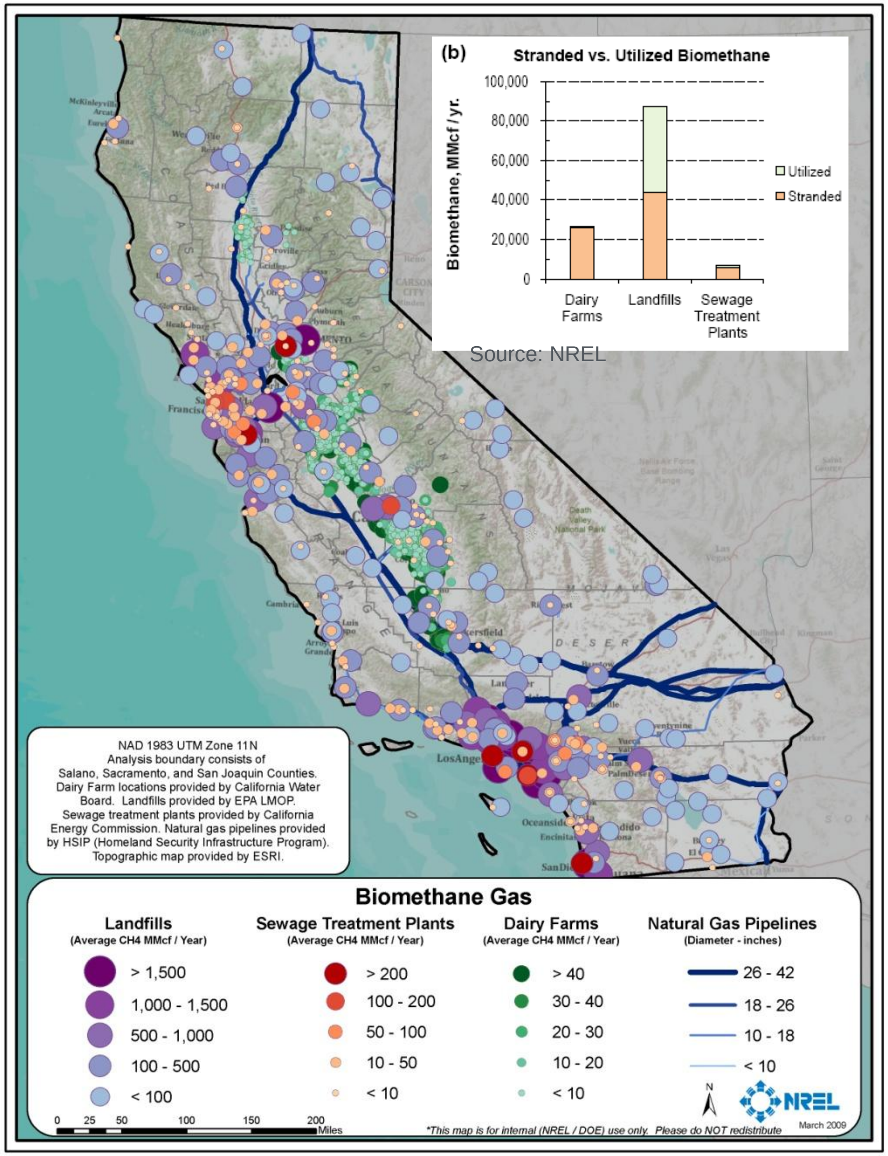


Source: NREL report *A Geographic Perspective on Current Biomass Resource Availability in the United States*, 2005

- 500,000 MT per year of methane available from waste water treatment plants in U.S.
- Majority of resource located near urban centers.
- If ~50% of the bio-methane was available, ~340,000 kg/day of renewable hydrogen could be produced from steam methane reforming.
- Renewable hydrogen is enough to fuel ~340,000 fuel cell vehicles per day.

 Source: US DOE 2010

GIS Map of California Potential Sources of Biogas



- Select categories of biogas resources: Landfills, sewage treatment plants, and dairy farms.
- California landfills offer greater biogas potential at ~1.6 million tons/yr of bio-methane.
- ~50% of the landfill biomethane is utilized currently.
- Sewage treatment plants in California produce ~0.1 million tons/yr of bio-methane.
- Pipelines are reasonably accessible to most of biogas sources.
- Exact locations of the number of potential applications for CHHP are being identified.

- Increased demand for DG: Annual distributed power installed has increased from ~9.5 MW to ~70 MW between 2004 and 2009. [a]
- Focuses on 2 urban areas (LA, San Fran.) with extremely high grid congestion. [b]
- Focus on the other top urban areas with highest population density and most likely for early deployment of early market fuel cell buses. [c]

a Energy Information Administration, *Electric Power Annual 2007,* Table 2.7.C: "Total Capacity of Dispersed and Distributed Generators by Technology Type, http://www.eia.doe.gov/cneaf/electricity/epa/epaxlfile2_7_c.pdf AND Fuel Cell Today, 2009.
b DOE, Office of Electricity, *National Electric Transmission Congestion Study*, August 2006, http://nietc.anl.gov/documents/docs/Congestion_Study_2006-9MB.pdf
c *Hydrogen Fuel Cell Vehicle and Station Deployment Plan: A Strategy for Meeting the Challenge Ahead,* April 2010, California Fuel Cell Partnership

Market Transformation activities seek to overcome barriers to commercialization

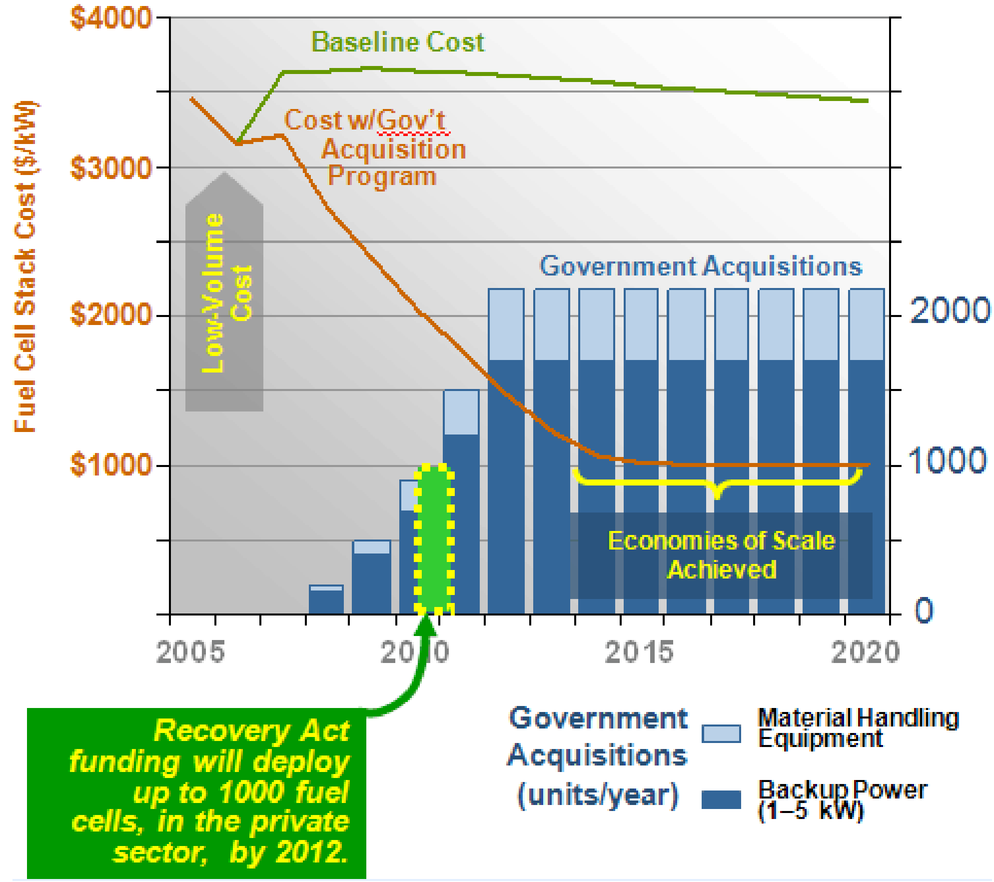
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

	BARRIERS
Market/Industry	Lack of domestic supply base and high volume manufacturing. Estimated backlog > 100 MW
	Low-volume capital cost is >2-3x of targets
	Policies — e.g., many early adopters not eligible for $3,000/kW tax credit
Delivery Infrastructure	Significant investment needed—~$55B gov't funding required over 15 years for ~5.5M vehicles ($~10B for stations)*
Codes and Standards	Complicated permitting process. 44,000 jurisdictions
	H_2-specific codes needed; only 60% of component standards specified in NFPA codes and standards are complete
	Need for domestic and international consistency
Education	In spite of >7,000 teachers trained and online tools averaging 300-500 visits/month, negative public perception and safety concerns remain.

*2008 National Academies Study, *Transitions to Alternative Transportation Technologies—A Focus on Hydrogen*

ADDRESSING BARRIERS—Example:

A government acquisition program could have a significant impact on fuel cell stack costs



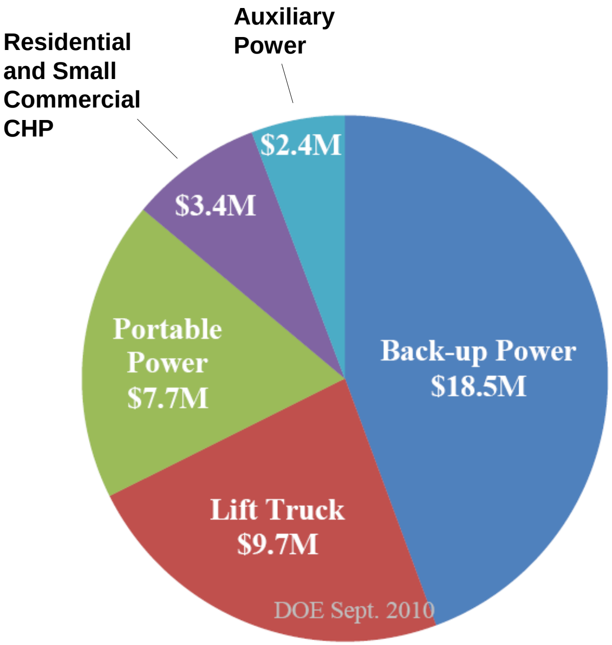
Source: David Greene, ORNL; K.G. Duleep, Energy and Environmental Analysis, Inc., *Bootstrapping a Sustainable North American PEM Fuel Cell Industry: Could a Federal Acquisition Program Make a Difference?*, 2008.

Recovery Act Funding for Fuel Cells

More than $40 million from the 2009 American Recovery and Reinvestment Act to fund 12 projects to deploy up to 1,000 fuel cells

FROM the LABORATORY to DEPLOYMENT:

DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.



Approximately $54 million in cost-share funding from industry participants—for a total of about $96 million.

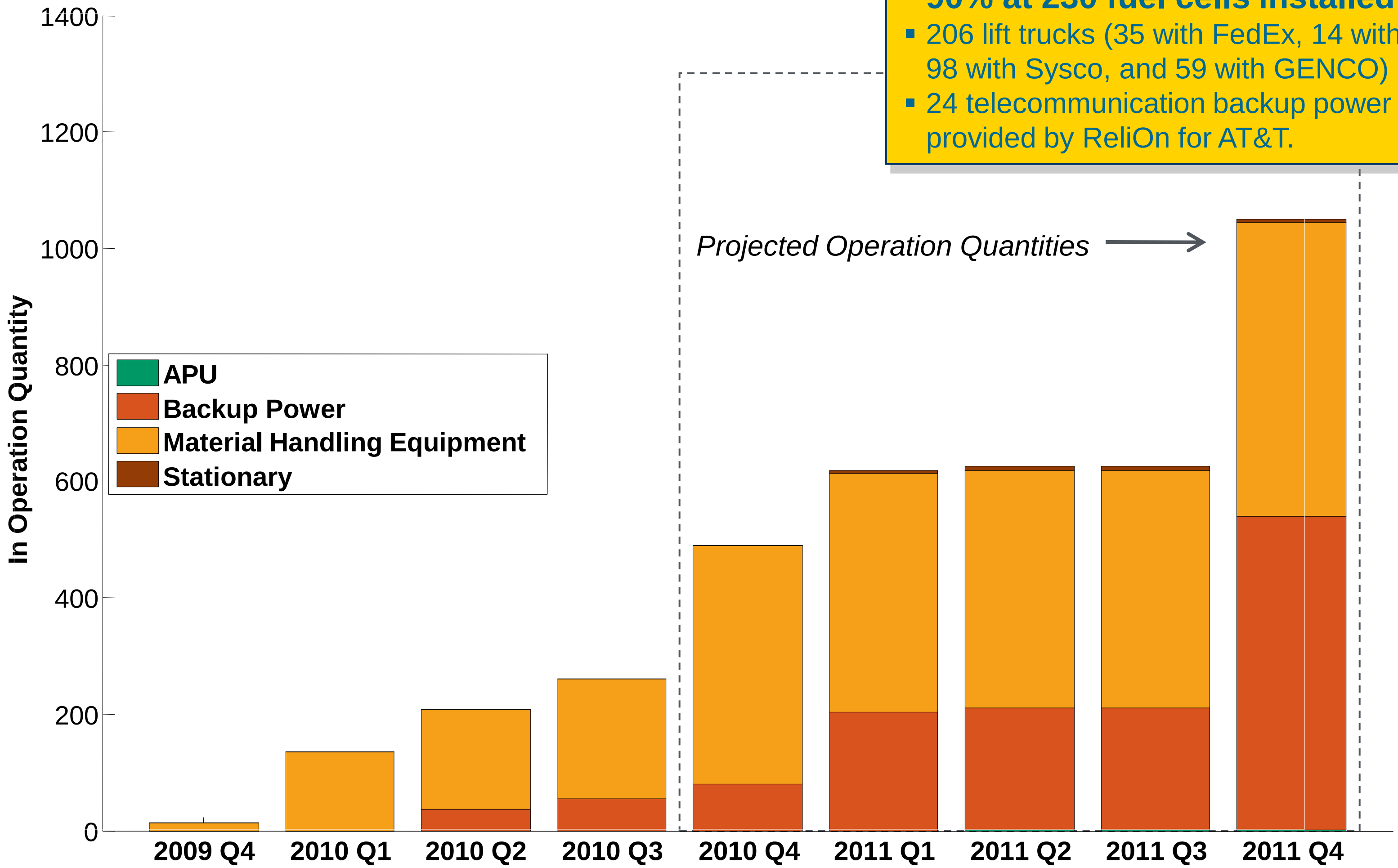
COMPANY	AWARD	APPLICATION
Delphi Automotive	$2.4 M	Auxiliary Power
FedEx Freight East	$1.3 M	Lift Truck
GENCO	$6.1 M	Lift Truck
Jadoo Power	$2.2 M	Portable
MTI MicroFuel Cells	$3.0 M	Portable
Nuvera Fuel Cells	$1.1 M	Lift Truck
Plug Power, Inc. (1)	$3.4 M	CHP
Plug Power, Inc. (2)	$2.7 M	Back-up Power
Univ. of N. Florida	$2.5 M	Portable
ReliOn, Inc.	$8.5 M	Back-up Power
Sprint Nextel	$7.3 M	Back-up Power
Sysco of Houston	$1.2 M	Lift Truck

 Source: US DOE 10/2010

DOE ARRA Fuel Cell Deployments

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

DOE ARRA-funded Early Market Fuel Cell Installations
(actual and projected)



Exceeded 2010 target for Recovery Act fuel cell installations by more than 90% at 230 fuel cells installed:

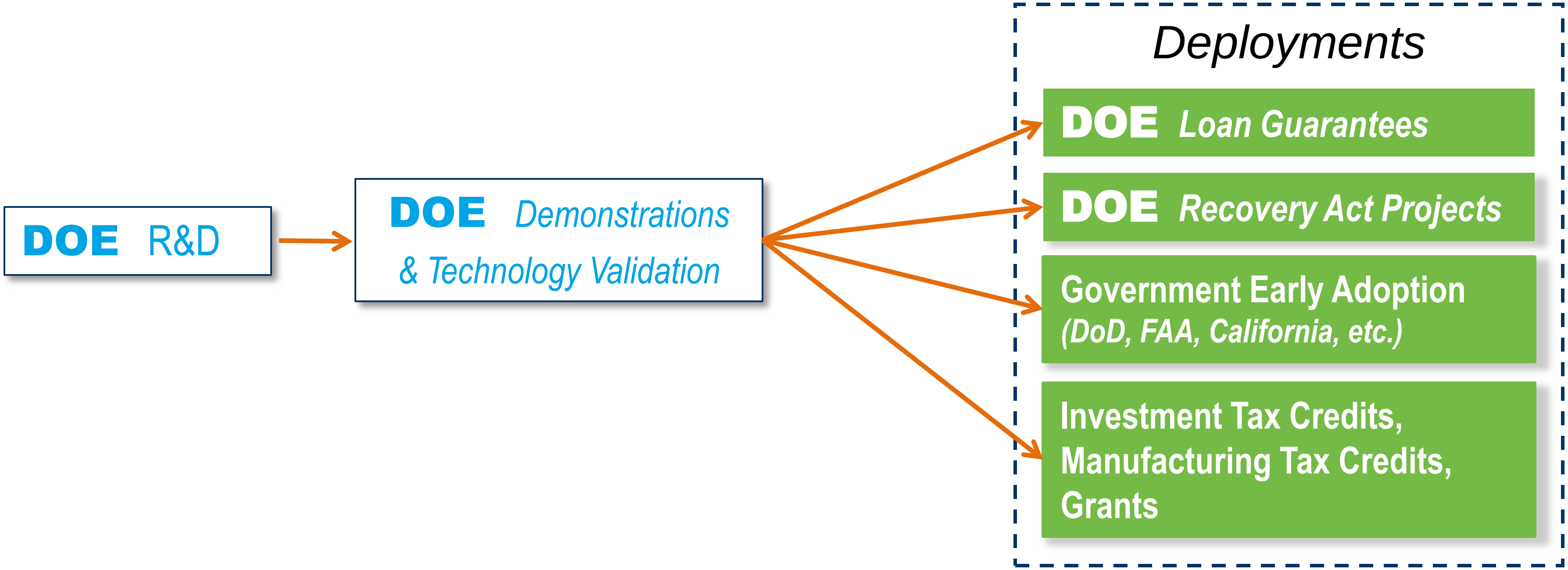
- 206 lift trucks (35 with FedEx, 14 with Nuvera, 98 with Sysco, and 59 with GENCO)
- 24 telecommunication backup power units provided by ReliOn for AT&T.

From National Renewable Energy Laboratory

Source: US DOE 12/2010

U.S. Fuel Cell Deployments Using DOE Market Transformation and Recovery Act Funding

Example of RD&D to Deployments



Project Example:

- Stationary fuel cells (hundreds of kW to tens of MW) for commercial applications including combined heat and power (and/or cooling).
- Multimillion $ loan guarantee available.

What more can Government do to accelerate commercialization?

Source: US DOE 12/2010

Recent Federal Grants and Tax Credits

Section 1603: Payments in Lieu of Tax Credits			
Business	**Property Location**	**Fuel Cell MWe**	**Amount**
Gills Onions, LLC	California	0.6	$1,141, 560
M&L Commodities, Inc.	California	0.6	$997,913
Preservation Properties, Inc.	California	0.1	$300,000
Logan Energy Corporation	Hawaii	0.3	$900,000
Plug Power, Inc.	Illinois	0.28	$723,334
Logan Energy Corporation	South Carolina	0.05	$148,988
Totals		**1.9**	**$4,211,795**

Section 48C: Manufacturing Tax Credit			
Business	**Location**	**Product**	**Amount**
UTC Power Corporation	Connecticut	Fuel Cells	$5,300,100
W.L. Gore & Associates	Maryland	Fuel Cell Membranes	$604,350
Total			**$5,904,450**

 Source: US DOE & US Treasury10/2010

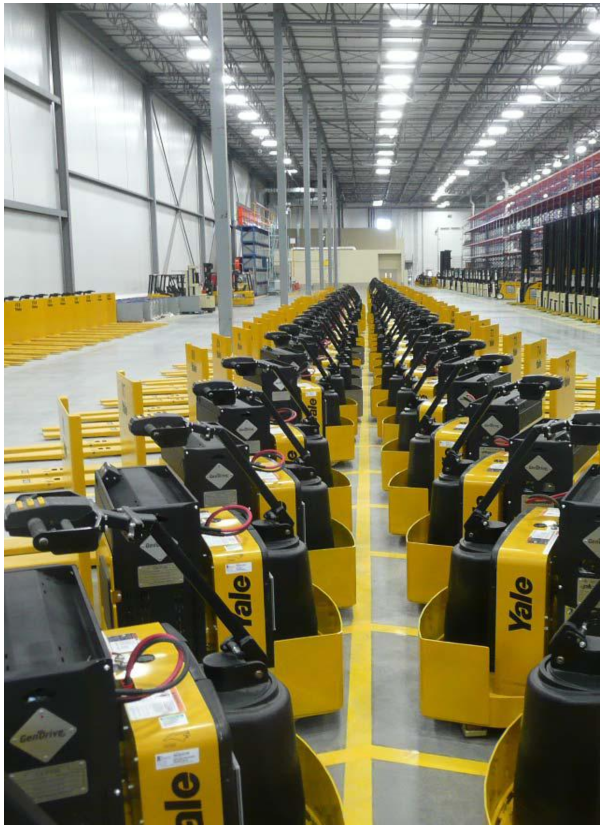
Federal incentives, including §1603 grant-in-lieu of tax credit and §48, have helped facilitate commercial transition to fuel cell forklifts.

Examples[1]:

- $660K: Central Grocers (Joliet, IL)
- $420K: United Natural Foods (Sarasota, FL)
- $600K: Sysco Foods (Houston, TX)
- $620K: Wegmans (Pottsville, PA)
- $320K: Kimberly Clark (Graniteville, SC)
- $400K: Coca-Cola Bottling (Charlotte, NC)
- $390K: Whole Foods (Landover, MD)

Other examples: H-E-B, Walmart, and more

[1] Source: Plug Power



Super Store Industries - First Grocery Warehouse and Distributor to Deploy Methanol Fuel Cells for Material Handling Equipment

Source: US DOE 12/2010

Executive Order 13514

On October 5, 2009 President Obama signed Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance

- **Requires Agencies to:**
  - **Set GHG reduction Targets**
  - **Develop Strategic Sustainability Plans and provide in concert with budget submissions**
  - **Conduct bottom up Scope 1, 2 and 3 baselines**
  - **Track performance**

Examples:

- **Achieve** 30% reduction in vehicle fleet petroleum use by 2020
- **Requires** 15% of buildings meet the *Guiding Principles for High Performance and Sustainable Buildings* by 2015
- **Design** all new Federal buildings which begin the planning process by 2020 to achieve zero-net energy by 2030

Potential opportunities for fuel cells and other clean energy technologies….

http://www1.eere.energy.gov/femp/regulations/eo13514.html

Source: US DOE 09/2010

Budget

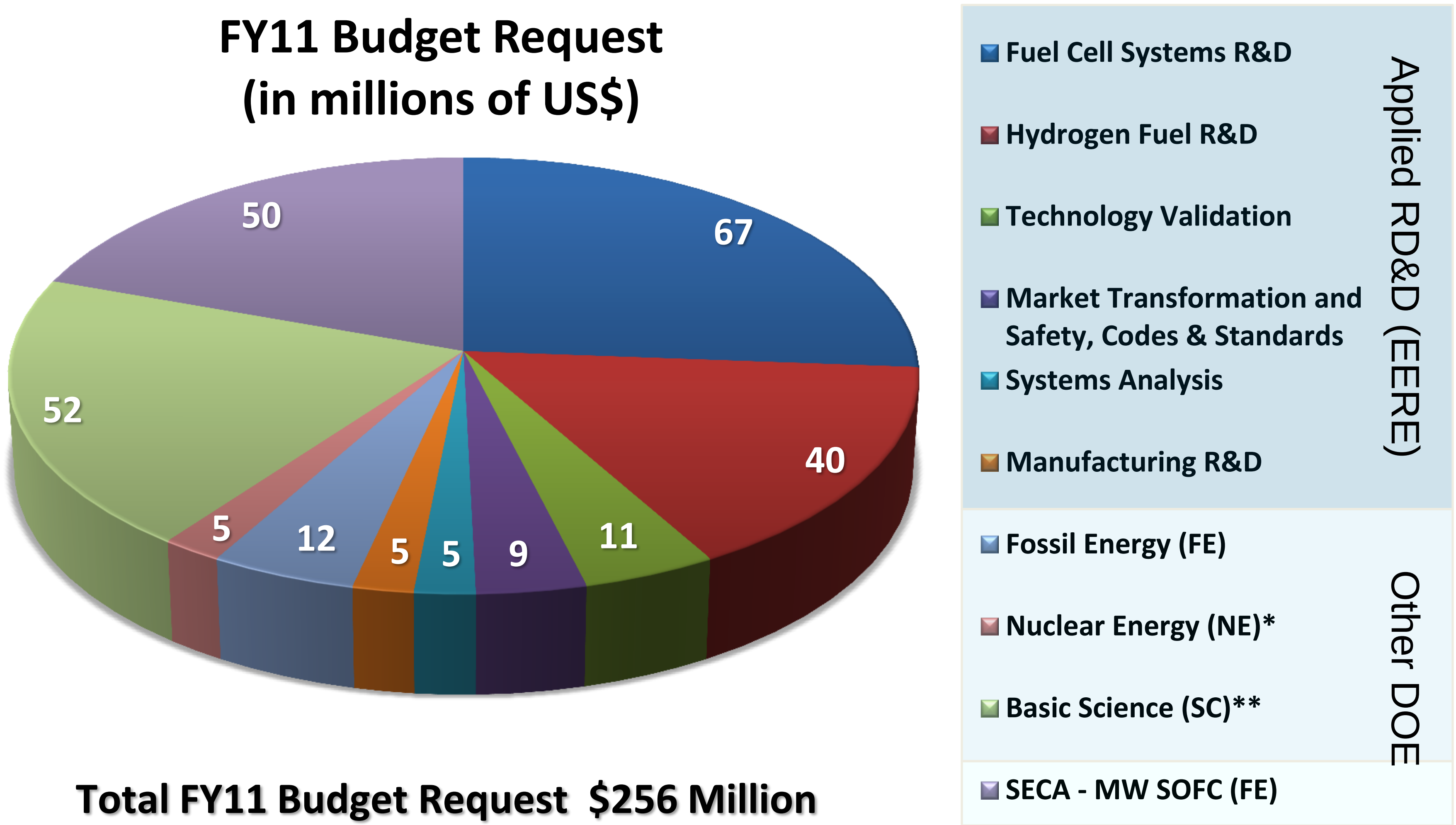
EERE H_2 & Fuel Cells Budgets

Funding ($ in thousands)						
Key Activity	**FY 2008**	**FY 2009[4]**	**FY 2010**	**FY 2011 *Request***	**FY 2011 House**	**2011 Senate**
Fuel Cell Systems R&D[1]	-	-	-	67,000	67,000	67,000
Fuel Cell Stack Component R&D	42,344	61,133	62,700	-	-	
Transportation Systems R&D	7,718	6,435	3,201	-	-	
Distributed Energy Systems R&D	7,461	9,750	11,410	-	-	
Fuel Processor R&D	2,896	2,750	171	-	-	
Hydrogen Fuel R&D[2]	-	-	-	40,000	40,000	47,000
Hydrogen Production & Delivery R&D	38,607	10,000	15,000	-	-	
Hydrogen Storage R&D	42,371	57,823	32,000	-	-	
Technology Validation	29,612	14,789[5]	13,097	11,000	11,000	20,000
Market Transformation[3]	0	4,747	15,026	0	0	20,000
Safety, Codes & Standards	15,442	12,238[5]	8,839	9,000	9,000	9,000
Education	3,865	4,200[5]	2,000	0	0	1,000
Systems Analysis	11,099	7,520	5,556	5,000	5,000	5,000
Manufacturing R&D	4,826	4,480	5,000	5,000	5,000	5,000
Total	**$206,241**	**$195,865**	**$174,000[6]**	**$137,000**	**$137,000**	**$174,000**

[1] Fuel Cell Systems R&D includes Fuel Cell Stack Component R&D, Transportation Systems R&D, Distributed Energy Systems R&D, and Fuel Processor R&D, [2] Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D, [3] Market Transformation will fund only Safety, Codes and Standards in FY 2011, [4] FY 2009 Recovery Act funding of $42.967M not shown in table, [5] Under Vehicle Technologies Budget in FY 2009
[6] Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

Source: US DOE 10/2010

Total DOE Hydrogen and Fuel Cell Technologies FY11 Budget Request (in millions of US$)



Total FY11 Budget Request $256 Million

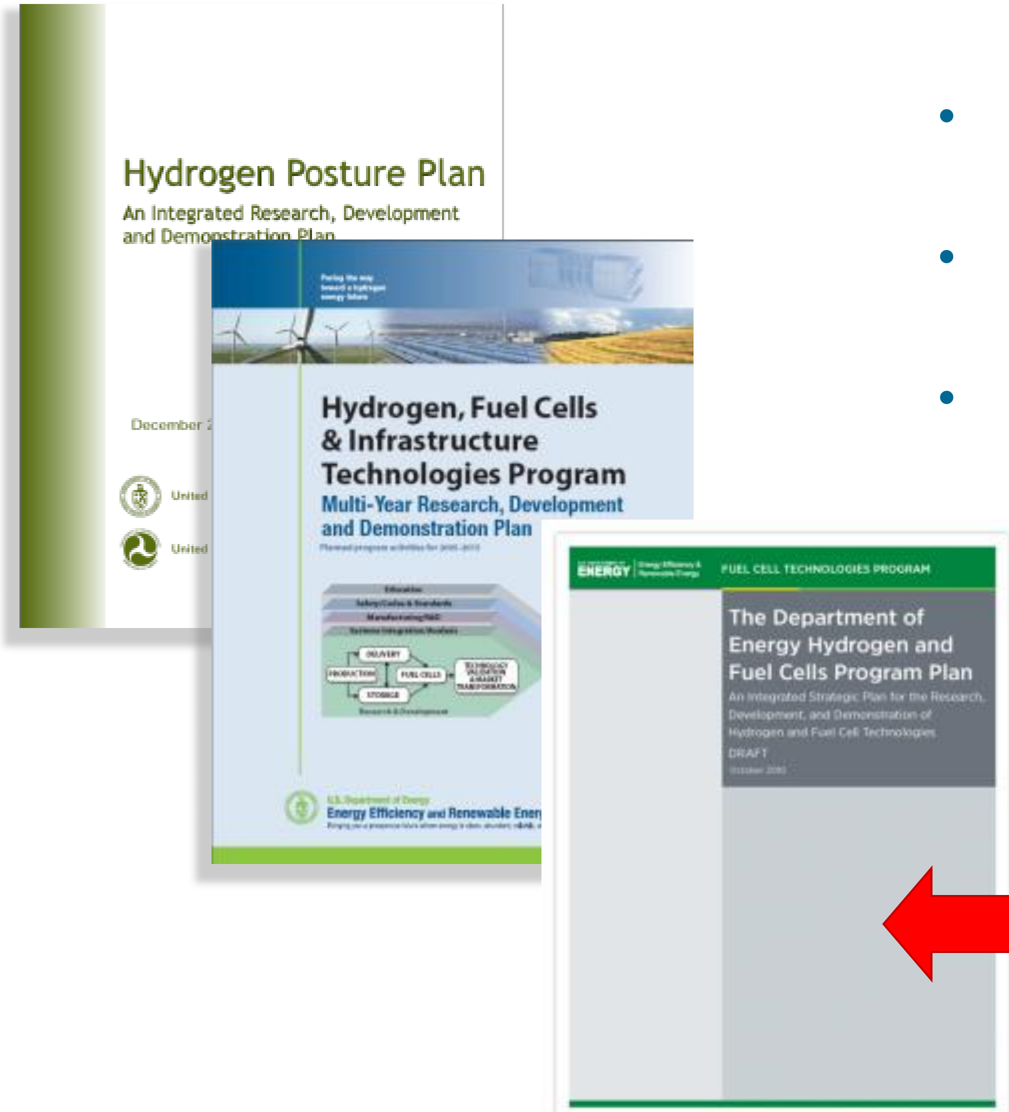
*NE: $5M represents FY10 funding
**SC Includes BES and BER

Source: US DOE 09/2010

Key Publications

Program Plan

Describes the planned RD&D activities for hydrogen and fuel cell technologies

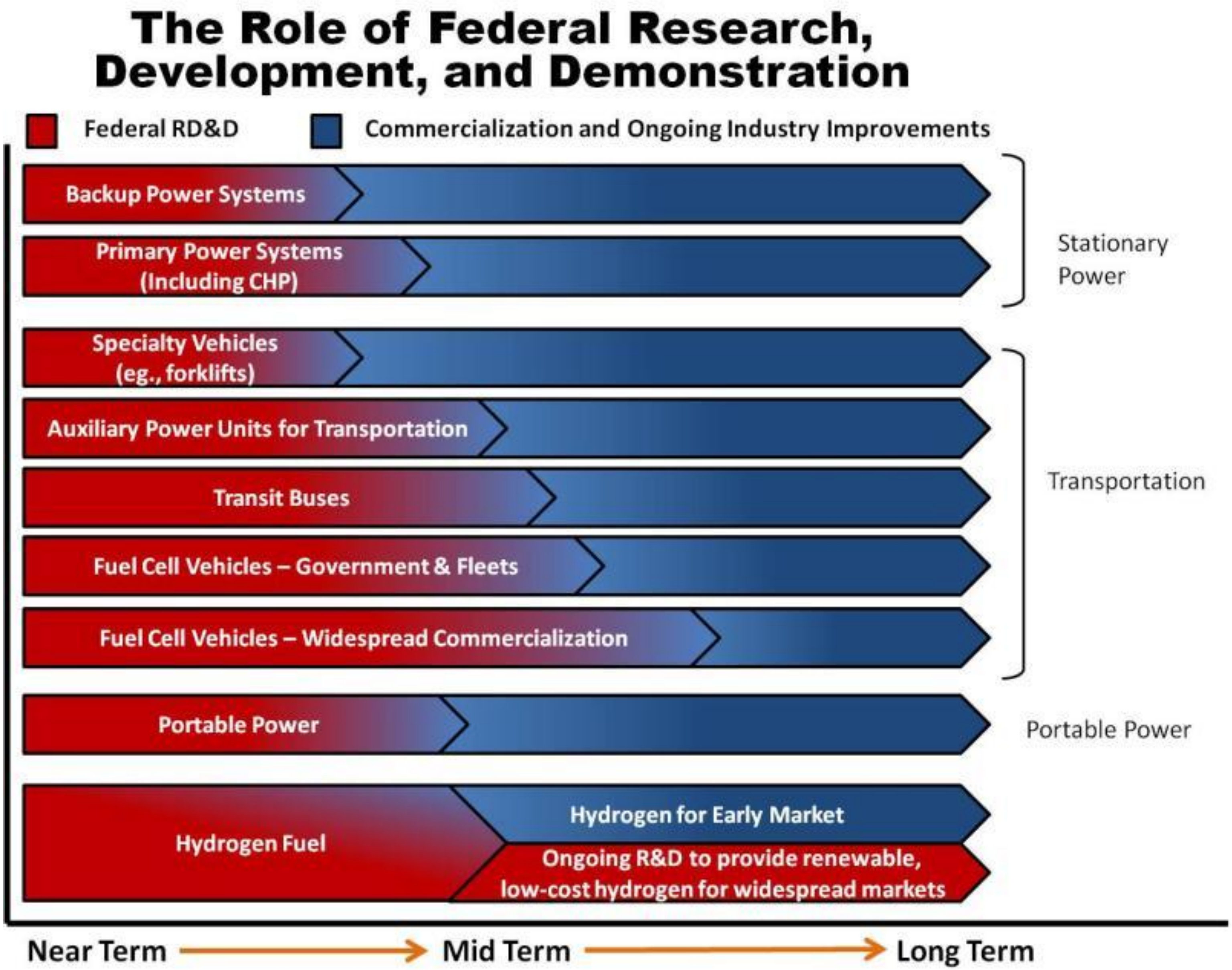


- **Update to the Hydrogen Posture Plan published in 2006**
- **Addresses previous reviews (e.g. GAO, HTAC, NAS, etc.)**
- **Hard copy of Draft available for HTAC review and comment**

Draft available 10/22/10 for stakeholder public comment until 11/30/10. Final will be published in early 2011.
DOEH2ProgramPlan@ee.doe.gov

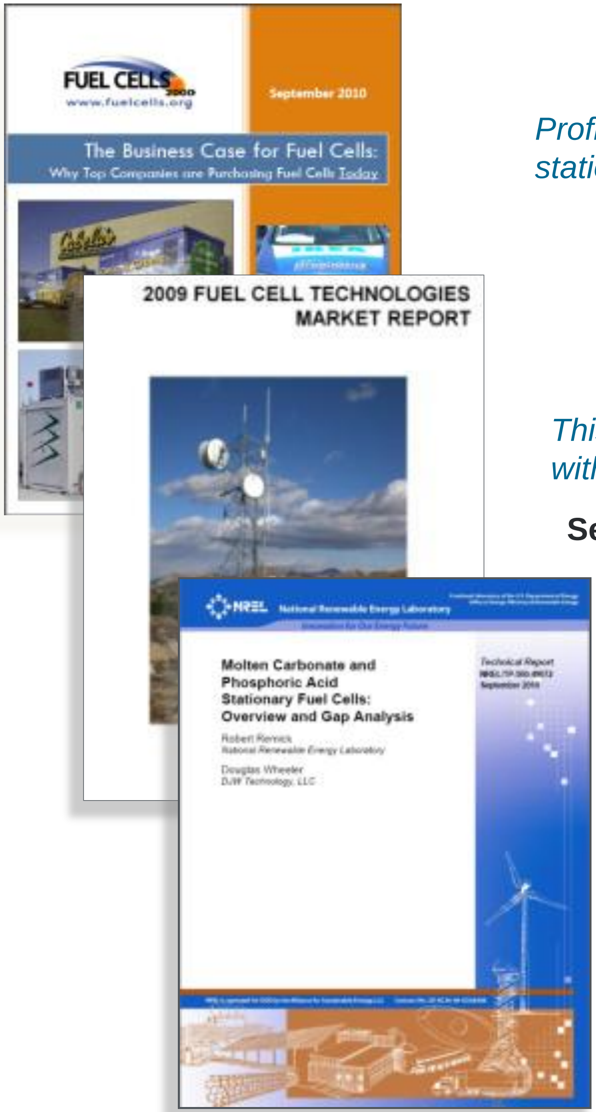
Source: US DOE 10/2010

Program Plan includes Portfolio



 Source: US DOE 10/2010

Key Reports Recently Published



The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today

By FuelCells2000, http://www.fuelcells.org

Profile of 38 companies who have ordered, installed, or deployed fuel cell forklifts, stationary fuel cells or fuel cell units.

See report: http://www.fuelcells.org/BusinessCaseforFuelCells.pdf

2009 Fuel Cell Technologies Market Report

By Breakthrough Technologies Institute, http://www.btionline.org/

This report describes data compiled in 2010 on trends in the fuel cell industry for 2009 with some comparison to previous years. (July 2010).

See report: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/48219.pdf

Molten Carbonate and Phosphoric Acid Stationary Fuel Cells: Overview and Gap Analysis

By NREL and DJW Technology, LLC

This report describes the technical and cost gap analysis performed to identify pathways for reducing the costs of molten carbonate fuel cell (MCFC) and phosphoric acid fuel cell (PAFC) stationary fuel cell power plants.

See report: http://www.nrel.gov/docs/fy10osti/49072.pdf

Fuel Cell Today 2009 Market Analysis

The report describes sales of fuel cells in US and worldwide.
October 2010

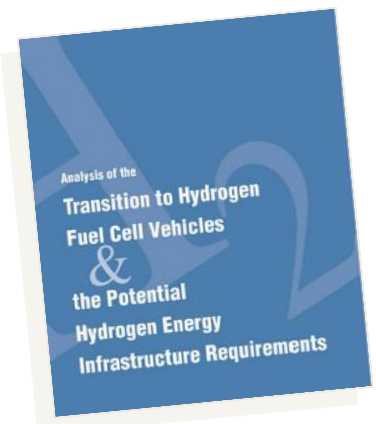
Source: US DOE 10/2010

Analysis of Policies for FCEVs & Hydrogen Infrastructure

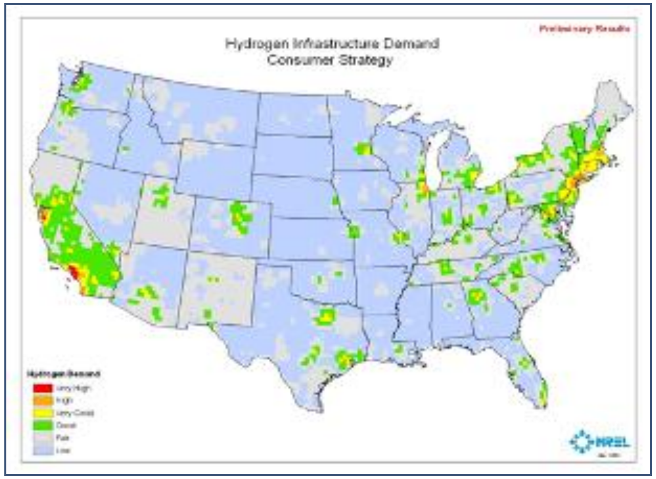
Analysis by Oak Ridge National Laboratory explores the impacts and infrastructure and policy requirements of potential market penetration scenarios for fuel cell vehicles.

Key Findings:

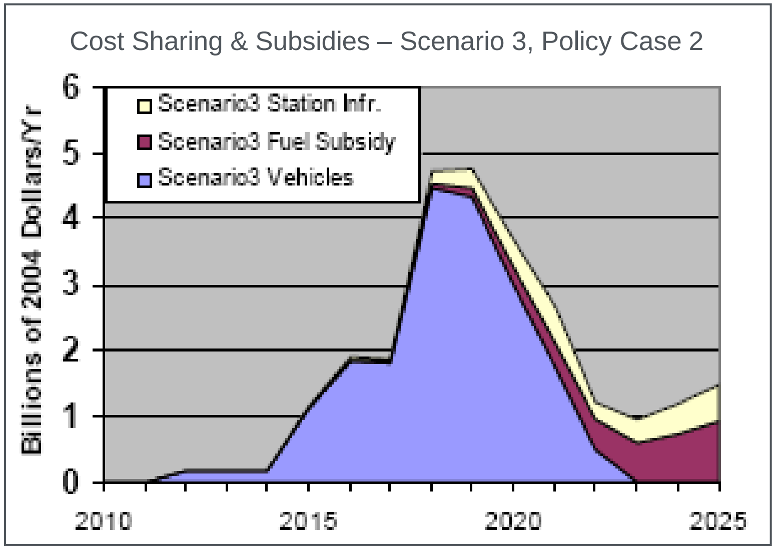
- Transition policies will be essential to overcome initial economic barriers.
- Cost-sharing & tax credits (2015 – 2025) would enable industry to be competitive in the marketplace by 2025.
- With targeted deployment policies from 2012 to 2025, FCV market share could grow to 50% by 2030, and 90% by 2050.
- Cost of these policies is not out of line with other policies that support national goals.
  - The annual cost would not exceed $6 billion—*federal incentives for ethanol are expected to cost more than $5 billion/year by 2010.*
  - Cumulative costs would range from $10 billion to $45 billion, from 2010 to 2025—*federal incentives for ethanol have already cost more than $28 billion, and these cumulative costs are projected to exceed $40 billion by 2010.*



http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf



Areas of projected fuel cell vehicle use—and fuel demand

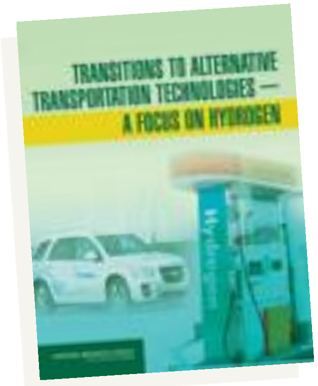


Projected cost of policies to sustain a transition to fuel cell vehicles and H_2 infrastructure, based on the most aggressive scenario

Analysis of Policies for FCEVs & Hydrogen Infrastructure

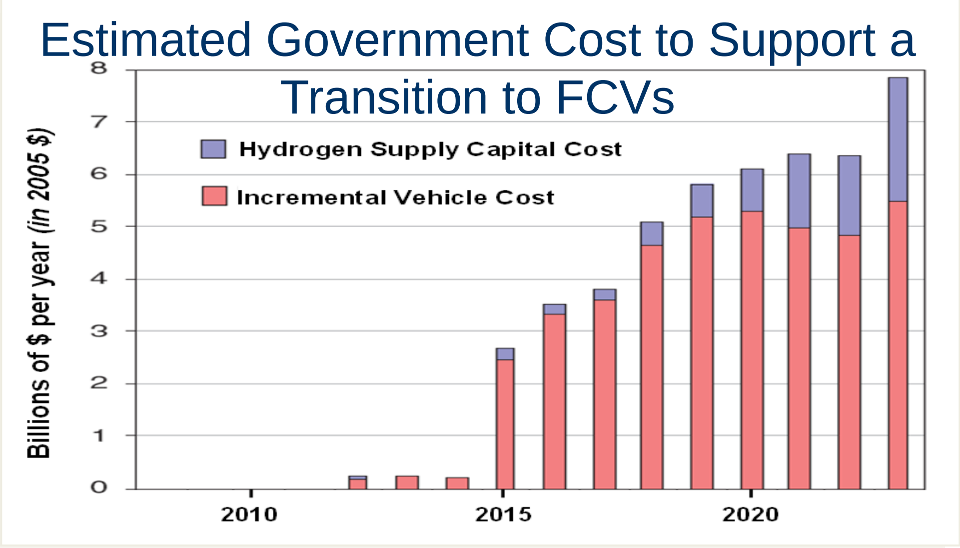
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

NAS study, "Transitions to Alternative Transportation Technologies: A Focus on Hydrogen," shows positive outlook for fuel cell technologies—results are similar to ORNL's "Transition Scenario Analysis."



The study was required by EPACT section 1825 and the report was released in 2008, by the Committee on Assessment of Resource Needs for Fuel Cell and Hydrogen Technologies.

www.nap.edu/catalog.php?record_id=12222



Key Findings Include:

- By 2020, there could be 2 million FCVs on the road. This number could grow rapidly to about 60 million by 2035 and 200 million by 2050.
- Government cost to support a transition to FCVs (for 2008 – 2023) estimated to be $55 billion—about $3.5 billion/year.
- The introduction of FCVs into the light-duty vehicle fleet is much closer to reality than when the NRC last examined the technology in 2004—due to concentrated efforts by private companies, together with the U.S. FreedomCAR & Fuel Partnership and other government-supported programs around the world.
- A portfolio of technologies has the potential to eliminate petroleum use in the light-duty vehicle sector and to reduce greenhouse gas emissions from light-duty vehicles to 20 percent of current levels—by 2050.

 Source: US DOE 12/2010

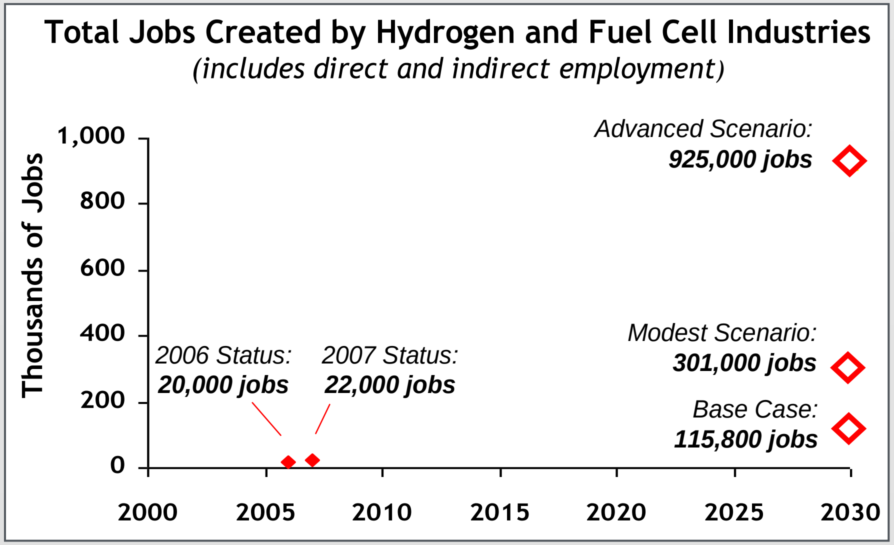
Fuel Cells - *The Economic Potential*

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

The fuel cell and hydrogen industries could generate substantial revenues and job growth.

Renewable Energy Industry Study*

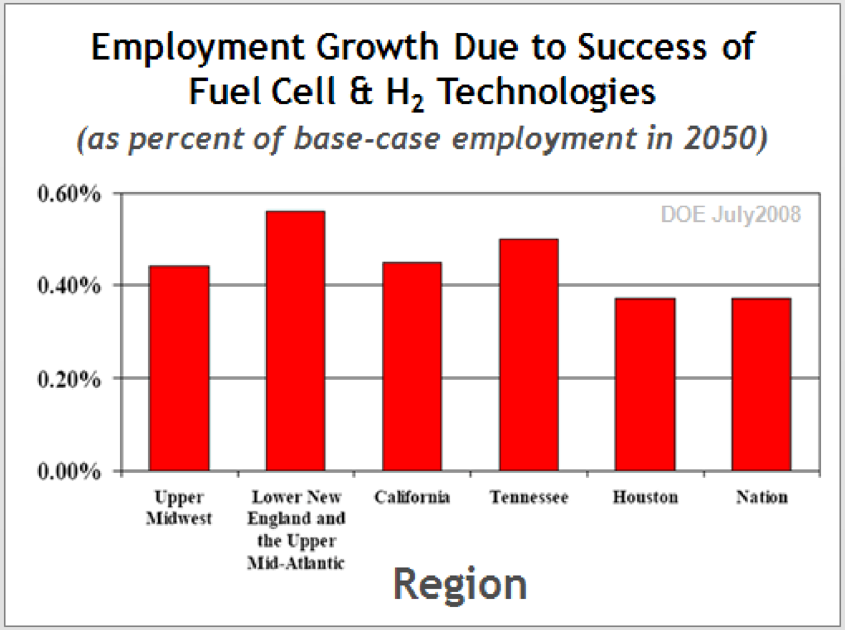
- **Fuel cells are the third-fastest growing renewable energy industry** (after biomass & solar).
- Potential U.S. employment from fuel cell and hydrogen industries of **up to 925,000 jobs** (by 2030).
- Potential gross revenues up to **$81 Billion/year** (by 2030).



***Study Conducted by the American Solar Energy Society**
www.ases.org/images/stories/ASES/pdfs/CO_Jobs_Final_Report_December2008.pdf

DOE Employment Study

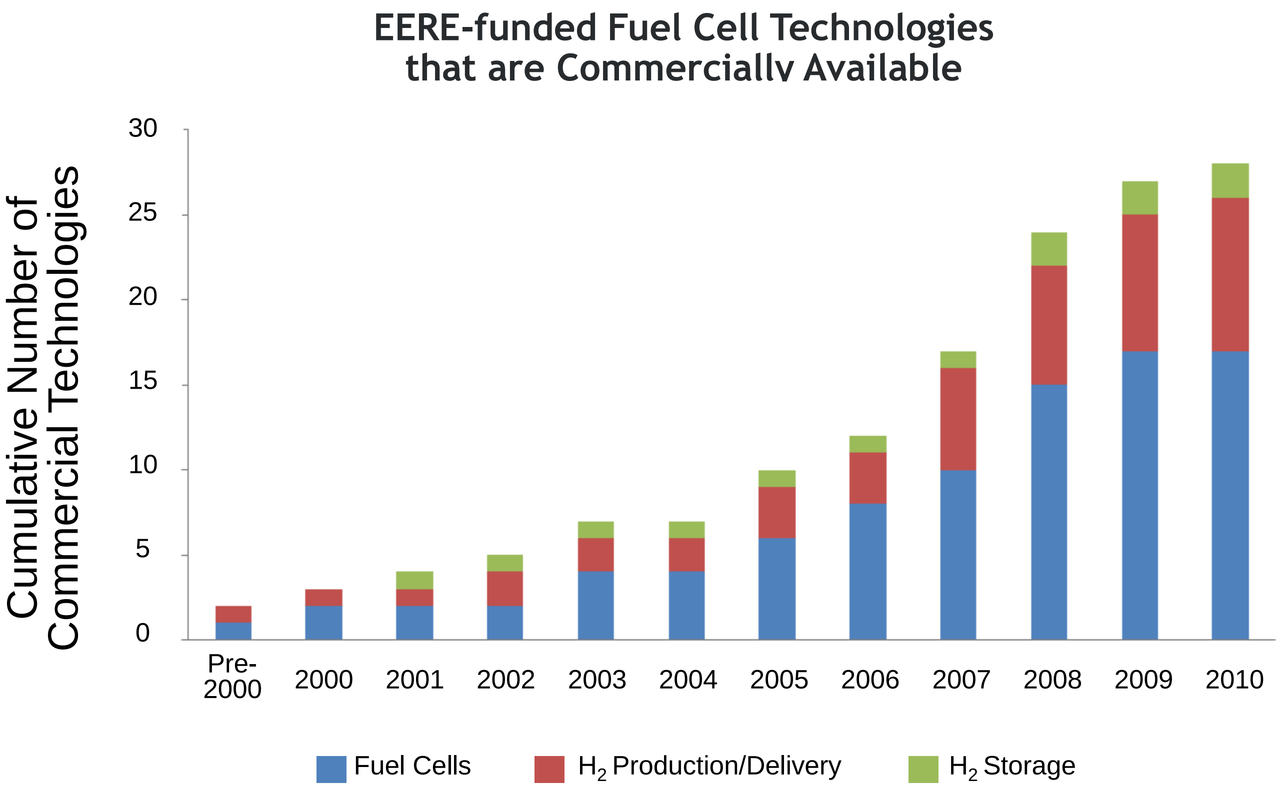
- Projects net increase of **360,000 – 675,000** jobs.
- Job gains would be distributed across up to 41 industries.
- Workforce skills would be mainly in the vehicle manufacturing and service sectors.



www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf

Close to 30 hydrogen and fuel cell technologies developed by the Program entered the market.

Accelerating Commercialization



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

198 PATENTS resulting from EERE-funded R&D:

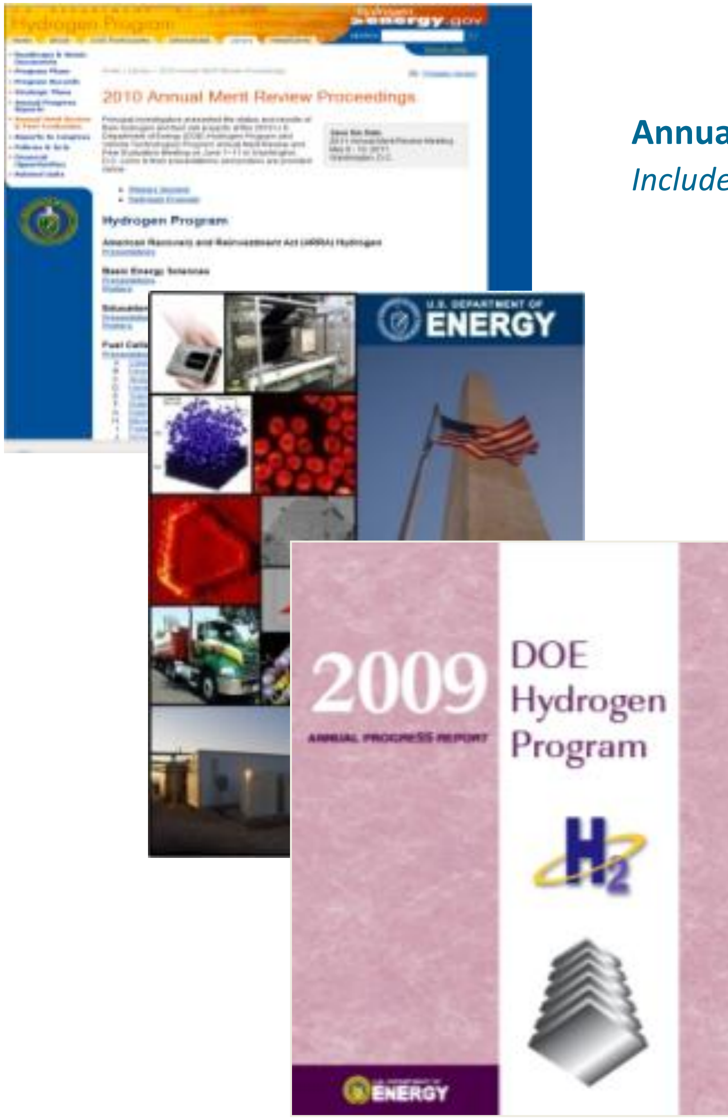
- 99 fuel cell
- 74 H_2 production and delivery
- 25 H_2 storage

60% are actively used in:

1) Commercial products
2) Emerging technologies
3) Research

Completed Fuel Cell Market Report provides an overview of market trends and profiles for select fuel cell companies

Key Program Documents



Annual Merit Review & Peer Evaluation Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- **Latest edition released June 2010**

  www.hydrogen.energy.gov/annual_review10_proceedings.html

Annual Merit Review & Peer Evaluation Report

Summarizes the comments of the Peer Review Panel at the Annual Merit Review and Peer Evaluation Meeting

- **Released January 2011**

  http://www.hydrogen.energy.gov/annual_review10_report.html

Annual Progress Report

Summarizes activities and accomplishments within the Program over the preceding year, with reports on individual projects

- **To be released 2011**

  www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 9 – 13, 2011

Washington, D.C.

http://annualmeritreview.energy.gov/

Collaborations

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

Federal Agencies

- DOC
- DOD
- DOE
- DOT
- EPA
- GSA
- DOI
- DHS
- NASA
- NSF
- USDA
- USPS

– *Interagency coordination through staff-level Interagency Working Group (meets monthly)*

– *Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.*

Universities

~ 50 projects with 40 universities

International

- **IEA Implementing agreements – 25 countries**
- **International Partnership for Hydrogen & Fuel Cells in the Economy – 17 countries & EC, 30 projects**

DOE Fuel Cell Technologies Program*

– ***Applied RD&D***

– ***Efforts to Overcome Non-Technical Barriers***

– ***Internal Collaboration with Fossil Energy, Nuclear Energy and Basic Energy Sciences***

Industry Partnerships & Stakeholder Assn's.

- **FreedomCAR and Fuel Partnership**
- **Fuel Cell and Hydrogen Energy Association (FCHEA)**
- **Hydrogen Utility Group**
- **~ 65 projects with 50 companies**

State & Regional Partnerships

- **California Fuel Cell Partnership**
- **California Stationary Fuel Cell Collaborative**
- **SC H_2 & Fuel Cell Alliance**
- **Upper Midwest Hydrogen Initiative**
- **Ohio Fuel Coalition**
- **Connecticut Center for Advanced Technology**

National Laboratories

National Renewable Energy Laboratory P&D, S, FC, A, SC&S, TV, MN

Argonne A, FC, P&D, SC&S

Los Alamos S, FC, SC&S

Sandia P&D, S, SC&S

Pacific Northwest P&D, S, FC, SC&S, A

Oak Ridge P&D, S, FC, A, SC&S

Lawrence Berkeley FC, A

Lawrence Livermore P&D, S, SC&S

Savannah River S, P&D

Brookhaven S, FC

Idaho National Lab P&D

Other Federal Labs: **Jet Propulsion Lab, National Institute of Standards & Technology, National Energy Technology Lab (NETL)**

***P&D** = Production & Delivery; **S** = Storage; **FC** = Fuel Cells; **A** = Analysis; **SC&S** = Safety, Codes & Standards; **TV** = Technology Validation, **MN** = Manufacturing*

 Source: US DOE 09/2010

*** Office of Energy Efficiency and Renewable Energy**

Thank you

For more information, please contact

Sunita.Satyapal@ee.doe.gov

hydrogenandfuelcells.energy.gov

Additional Information

New Solicitations

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

Fuel Cell FOA

- Up to $65 million over three years to fund continued R&D on fuel cell components. Topics include:
  1. Balance-of-Plant components
  2. Fuel Processors
  3. High Temperature Stack Component Research
  4. PEMFC MEA Integration
  5. Catalysts/Electrodes
  6. Membranes
  7. Innovative Concepts

Letter of Intent Due: January 28, 2011
Applications Due: March 3, 2011

Source: US DOE 12/2010

Cost Analysis FOA

- Up to $9 million to conduct independent cost analyses. Topics include:
    1. Transportation PEM Fuel Cell System Cost Assessment
    2. Stationary and Emerging Market Fuel Cell System Cost Assessment
    3. Hydrogen Storage System Assessment

Applications Due: February 18, 2011

Source: US DOE 12/2010