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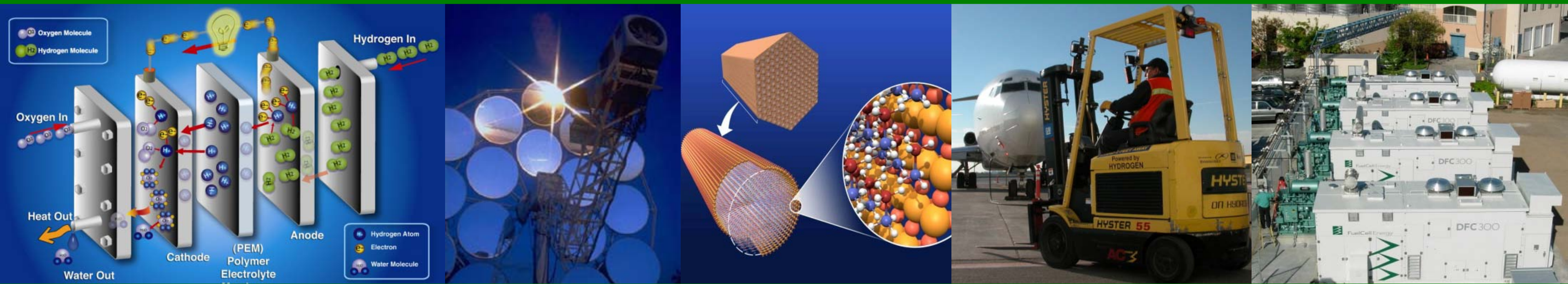
ENERGY



Fuel Cell Technologies Program Overview

Richard Farmer

Acting Program Manager

2010 Annual Merit Review and Peer Evaluation Meeting

(7 June 2010)

The Administration's Clean Energy Goals

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- ✓ **Double Renewable Energy Capacity by 2012**
- ✓ **Invest $150 billion over ten years in energy R&D to transition to a clean energy economy**
- ✓ **Reduce GHG emissions 83% by 2050**

Fuel Cells Address Our Key Energy Challenges

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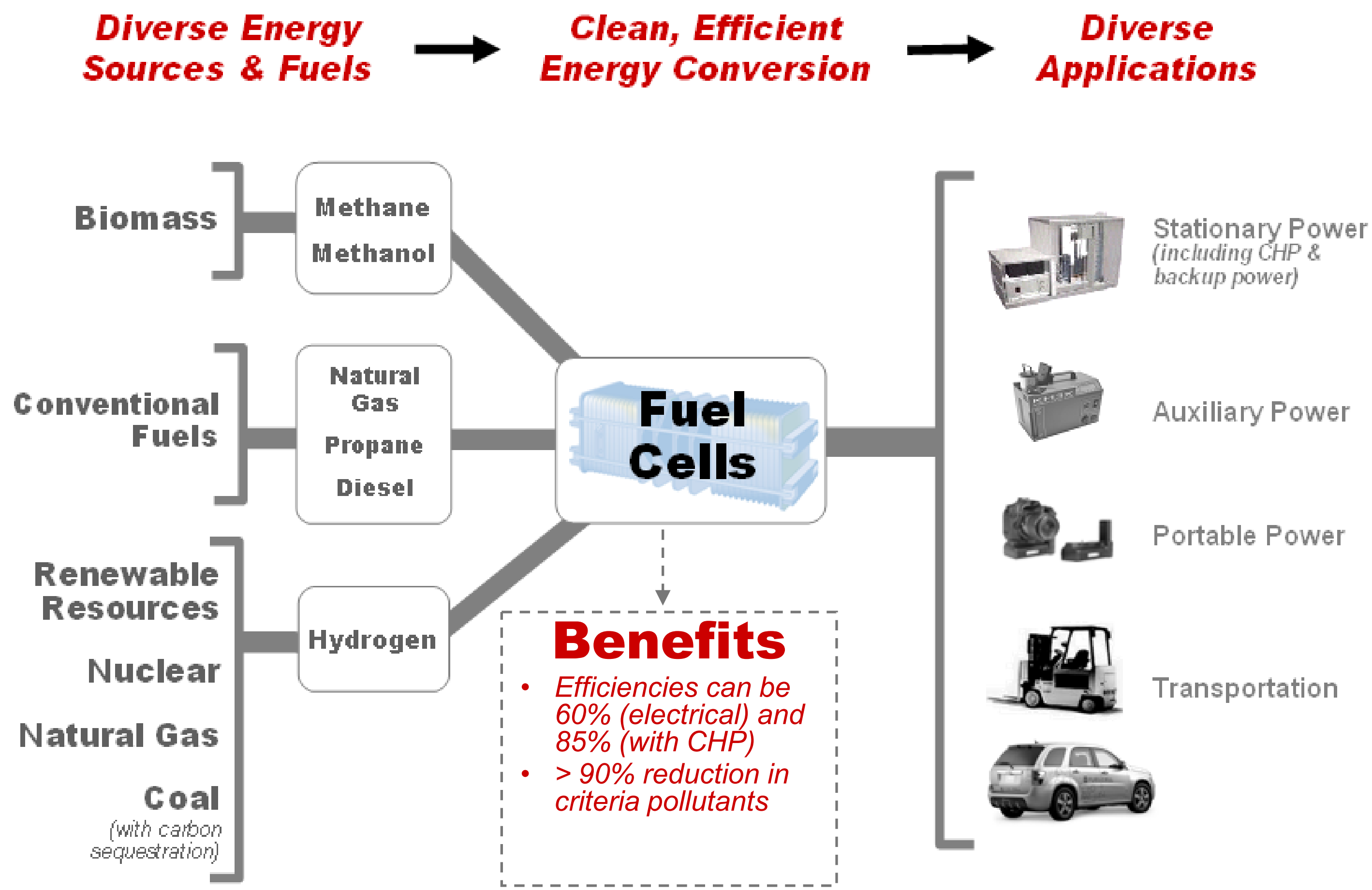
Increasing Energy Efficiency and Resource Diversity

→ *Fuel cells offer a highly efficient way to use diverse fuels and energy sources.*

Reducing Greenhouse Gas Emissions and Air Pollution:

→ *Fuel cells can be powered by emissions-free fuels that are produced from clean, domestic resources.*



State of the Industry:
Where are we today?

U.S. DEPARTMENT OF ENERGY

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 were 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 is currently:

- ~9 million metric tons of H_2 produced annually
- >1,200 miles of pipelines

Fuel Cells for Transportation

In the U.S., there are currently:

- *> 150 fuel cell vehicles*
- *~ 15 active fuel cell buses*
- *> 50 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.

State of the Industry:
Growing Markets and Capacity

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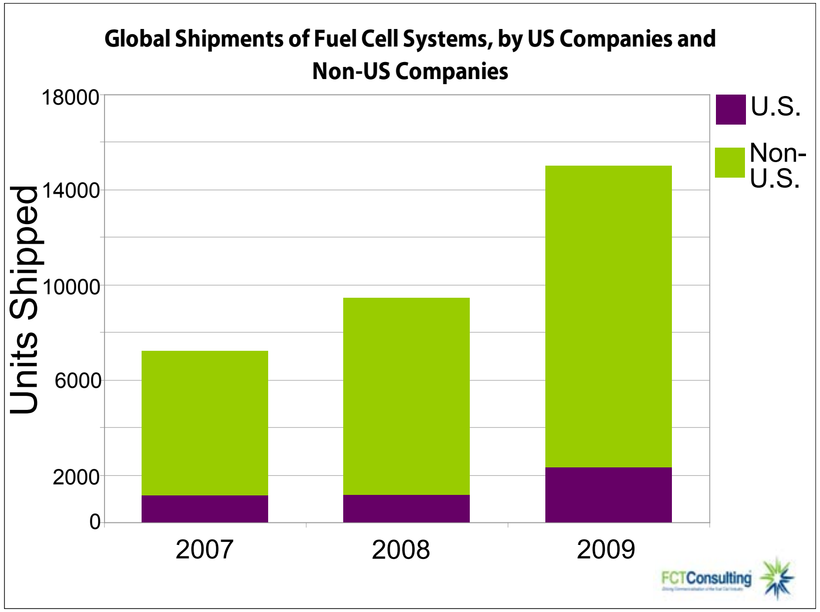
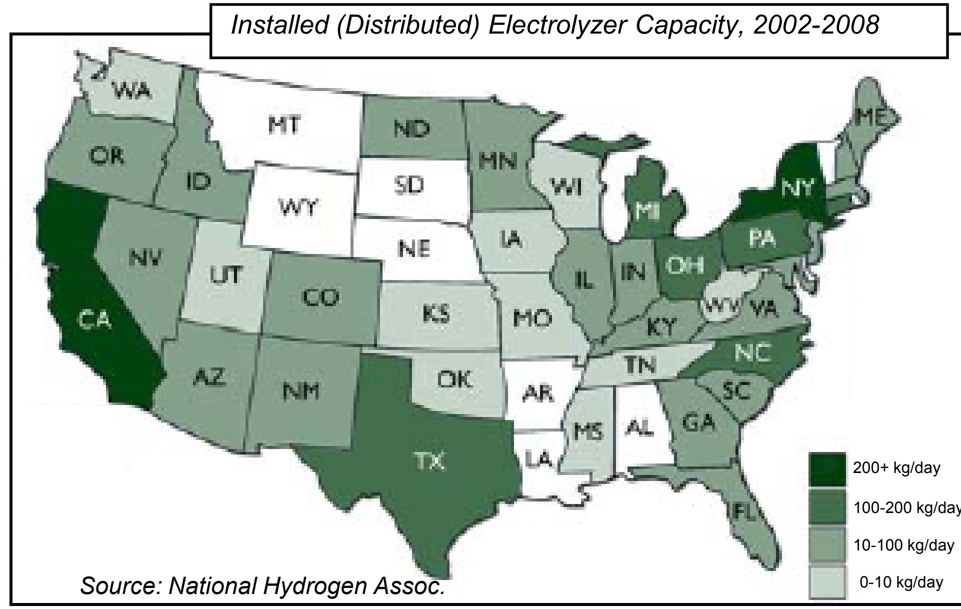
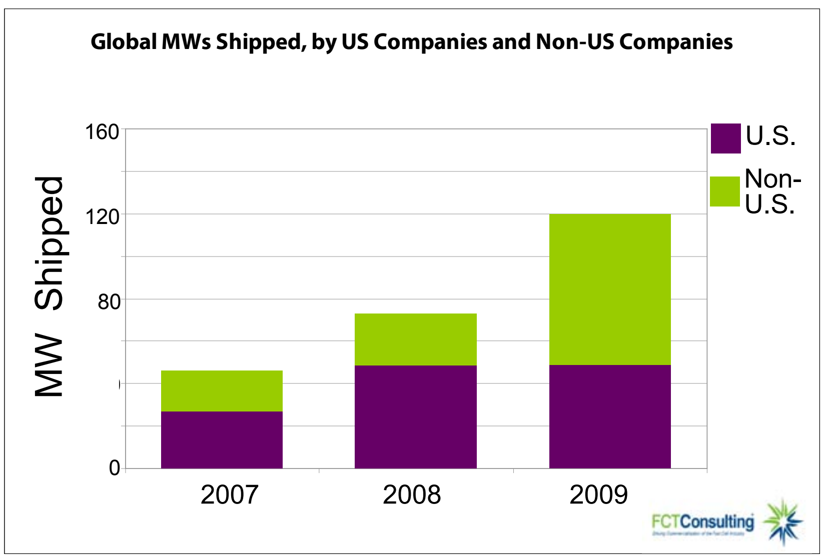
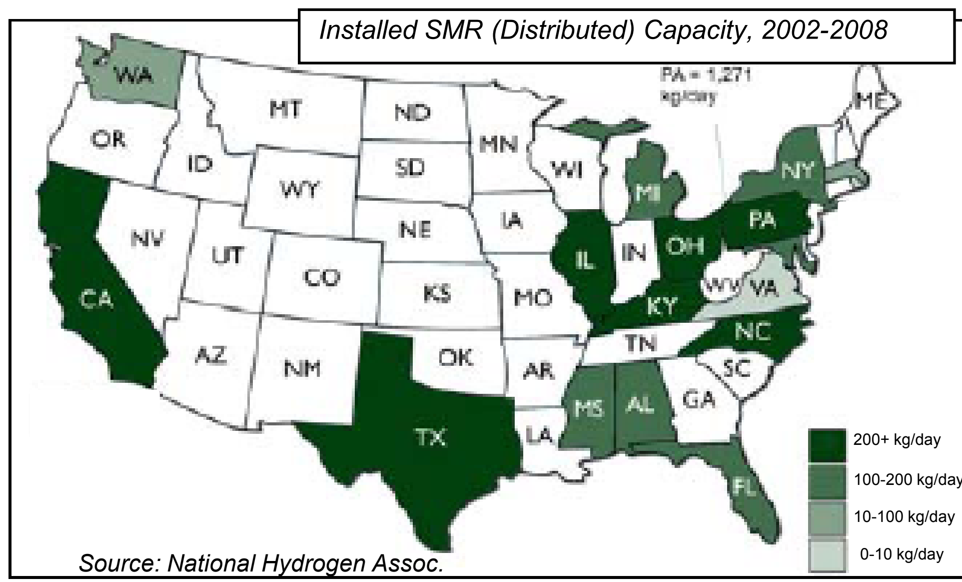
The hydrogen and fuel cell industry is growing steadily, serving key near-term markets.









Key Challenges

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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

Proposed target* ~ $6/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.

*Metrics available/under development for various applications

Funding History for Fuel Cells

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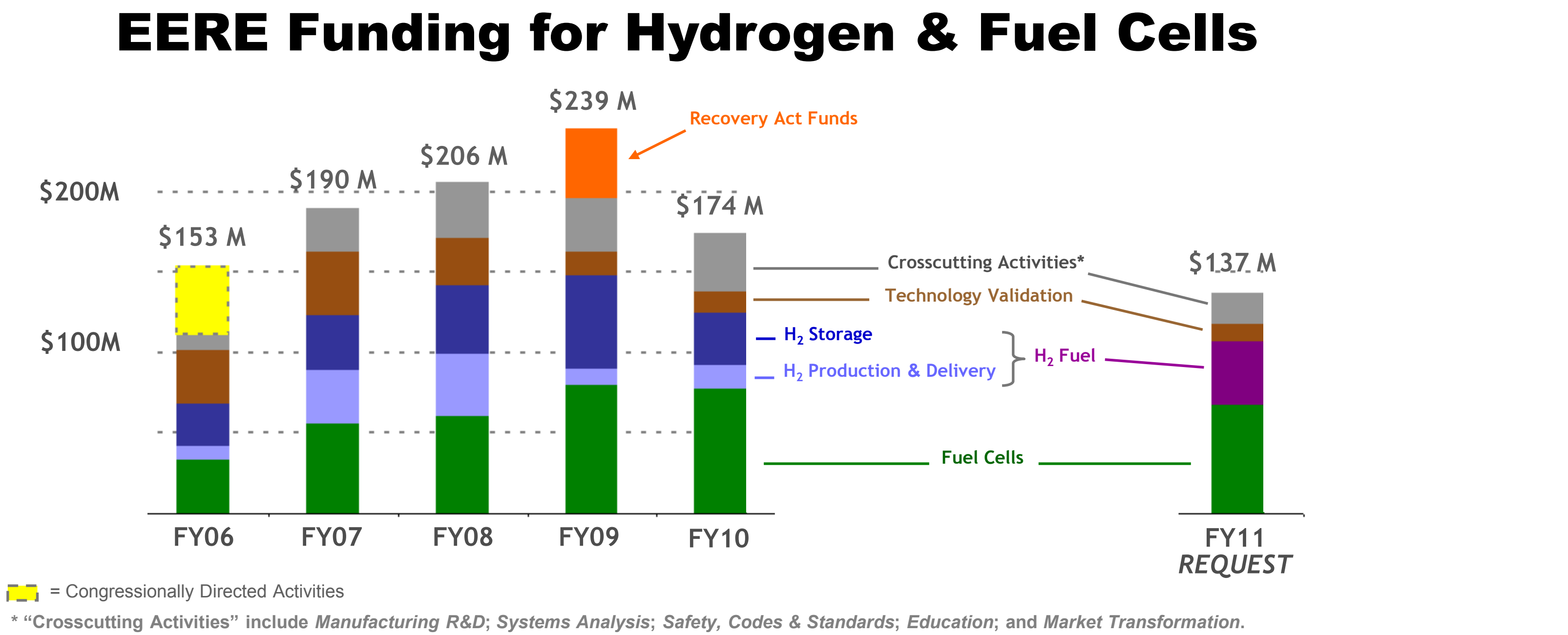

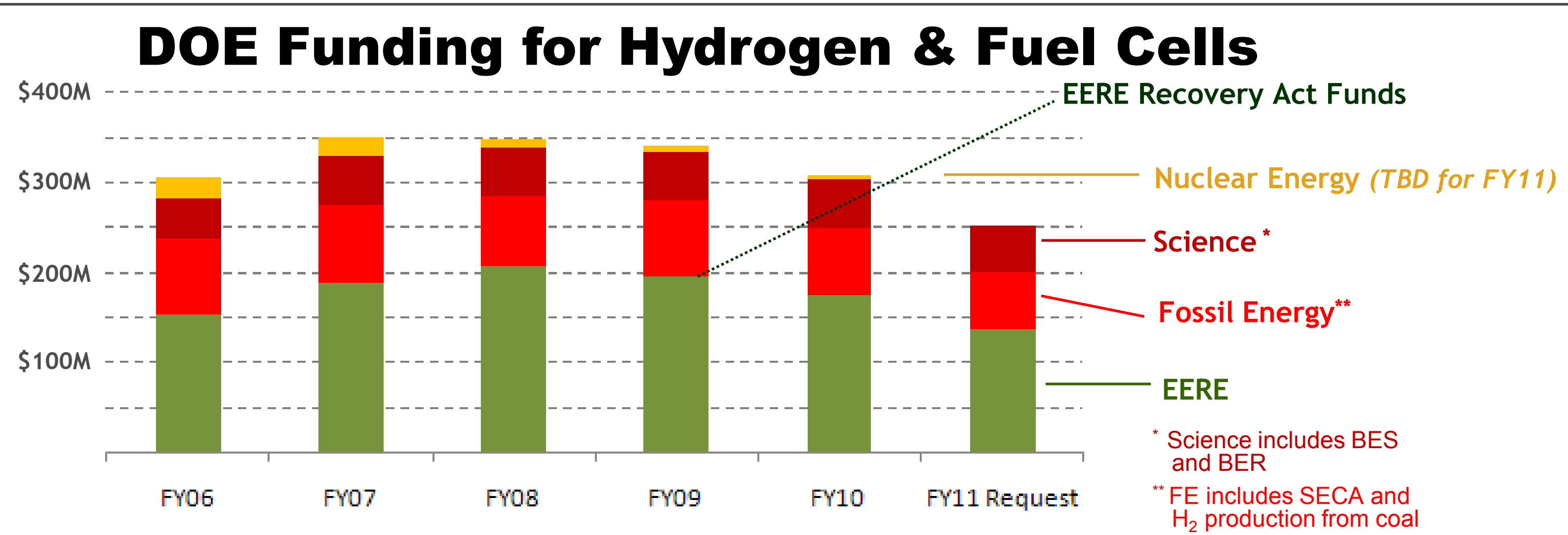

Funding for Fuel Cells and Hydrogen
DOE FY11 Budget Request

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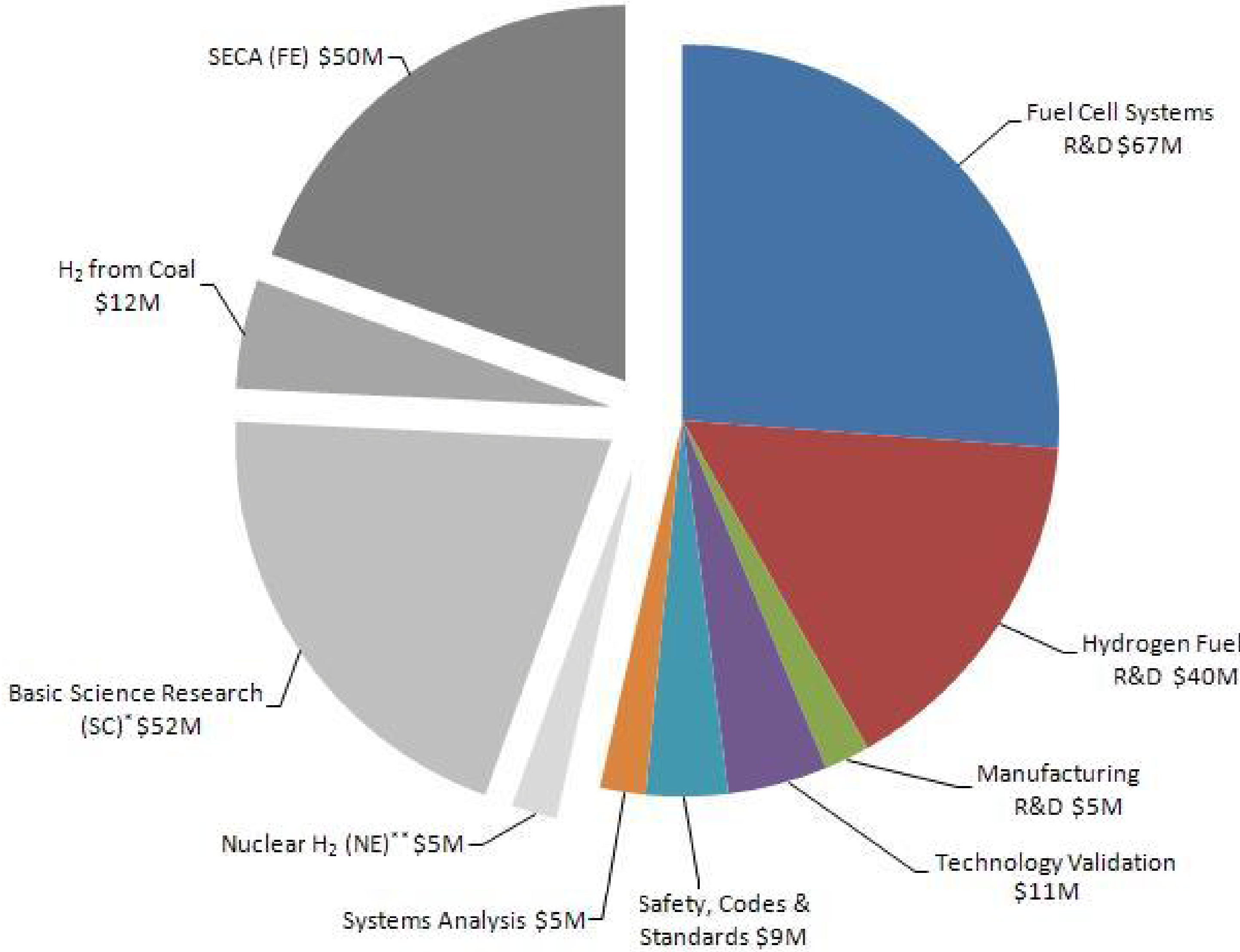
Total Requested Funding: ~$256 Million



* SC funding includes BES and BER
** NE FY11 Request TBD (FY10 funding was $5M)

Proposed Hydrogen Cost Target Revision
Reasons

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Previous target was set in 2005 with a target of \$2-3 / kg-H_2 (dispensed) by 2015. The new cost target accounts for adv. technologies & new EIA gasoline price projections

Reasons for Cost Target Update

- The current target is \$2 - \$3 / kg H_2 (dispensed, untaxed) by 2015
- The gasoline cost and reference vehicle have changed from original cost target derivation
  - EIA projections of gasoline price increased from \$1.29/gal in 2015 to \$4.57/gal (2007\$) in 2020
- New baseline technology instead of gasoline ICEs
  - FCEVs will be compared to HEVs and PHEV-10

	Current Case	Proposed Case
Reference Yr.	2015	2020
EIA AEO source yr./ case	2005/ Hi Oil Case	2009/ Hi Oil Case
Comparative vehicles	Gasoline ICE/HEV	Gasoline HEV/PHEV 10
Gasoline Cost (untaxed), \$/gal.	\$1.29/gal	\$4.57/gal
Reference year dollars	2005	2007
H_2 FCEV to ICE fuel economy ratio	2.40	Not used
H_2 FCEV to gasoline HEV fuel economy ratio	1.67	1.41
H_2 FCEV to PHEV 10 fuel economy ratio	Not applicable	Simple ratio not applicable
H_2 cost target, \$/gge	\$2.00-\$3.00/gge	**~ \$6.00/gge**

DRAFT

Proposed Hydrogen Cost Target Revision
Sensitivities to HEV & PHEV10 Parameters

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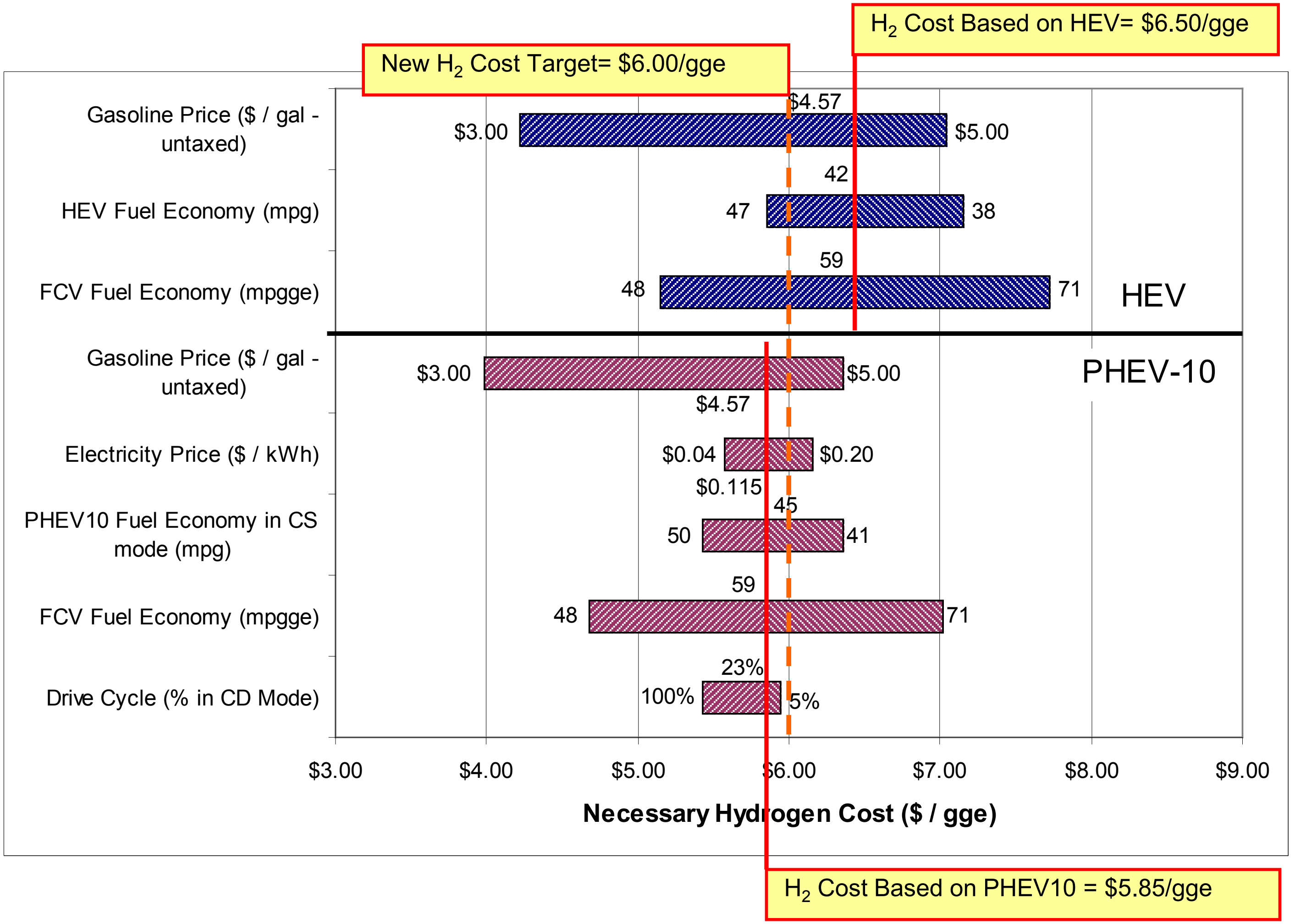
- **The cost necessary for hydrogen to be competitive depends upon the gasoline price, electricity price, vehicle fuel economies, and utility of CD mode.**



$5.00 / gal gasoline (untaxed) is approximately 10% higher than the AEO 2009 High Energy Price case
$3.00 / gal gasoline (untaxed) is the AEO 2009 Reference (including effects of ARRA) case estimate rounded down.
The HEV fuel economy sensitivity was set at the base +/-10%
The FCV fuel economy sensitivity was set at the base +/-20%
Electricity price range includes low and high residential electricity rates in the contiguous United States.
Time in CD mode depends upon vehicle's individual miles traveled between charges.

DRAFT

Proposed Hydrogen Cost Target Revision

Status vs. Targets

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Revising the hydrogen cost target will result in an assessment of Hydrogen Production and Delivery R&D priorities. Projections of high-volume / n^{th} plant production and delivery of hydrogen meet the targets for most technologies.

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

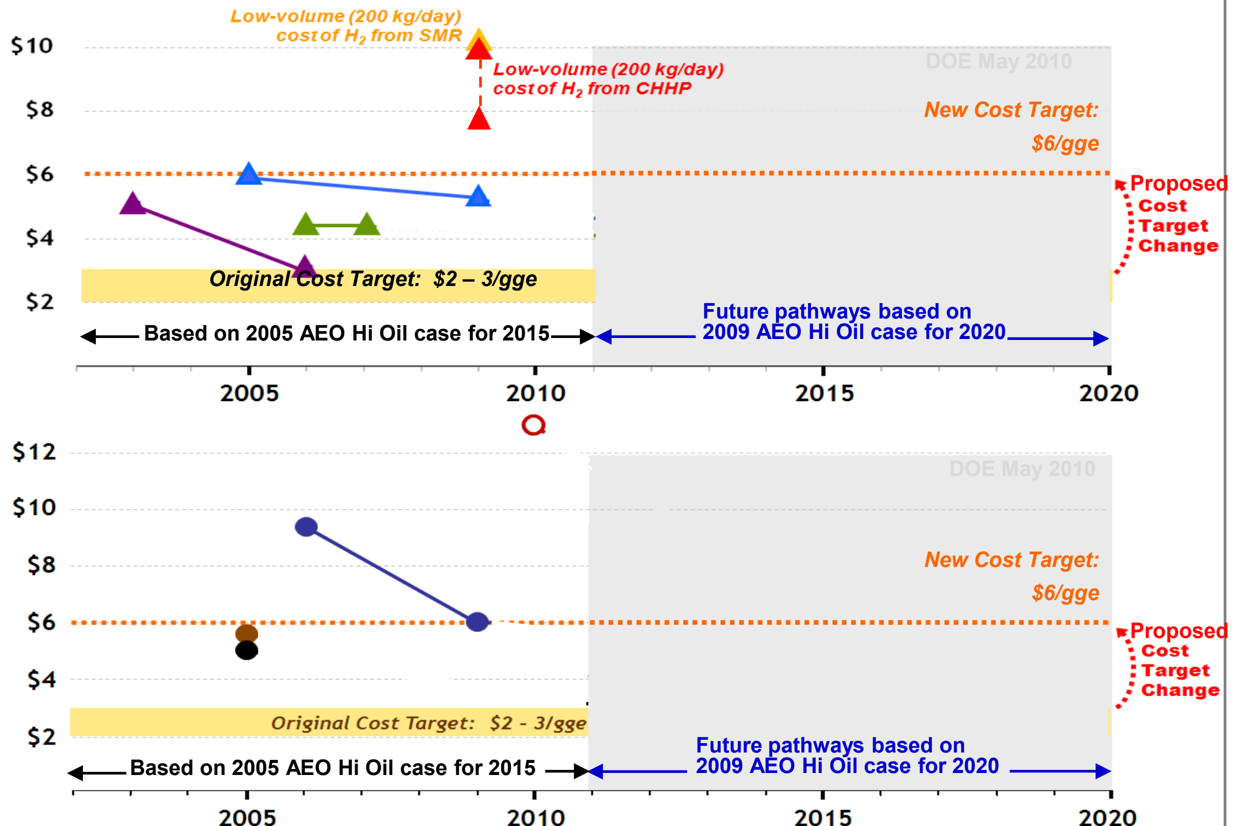
($/gallon gasoline equivalent [gge], untaxed)

NEAR TERM:
Distributed Production

- H_2 from Natural Gas
- H_2 from Ethanol Reforming
- H_2 from Electrolysis

LONGER TERM:
Centralized Production

- Biomass Gasification
- Central Wind Electrolysis
- Coal Gasification with Sequestration
- Solar Thermochemical Cycle



Will re-baseline data points to the 2009 AEO Hi Oil Case for 2020

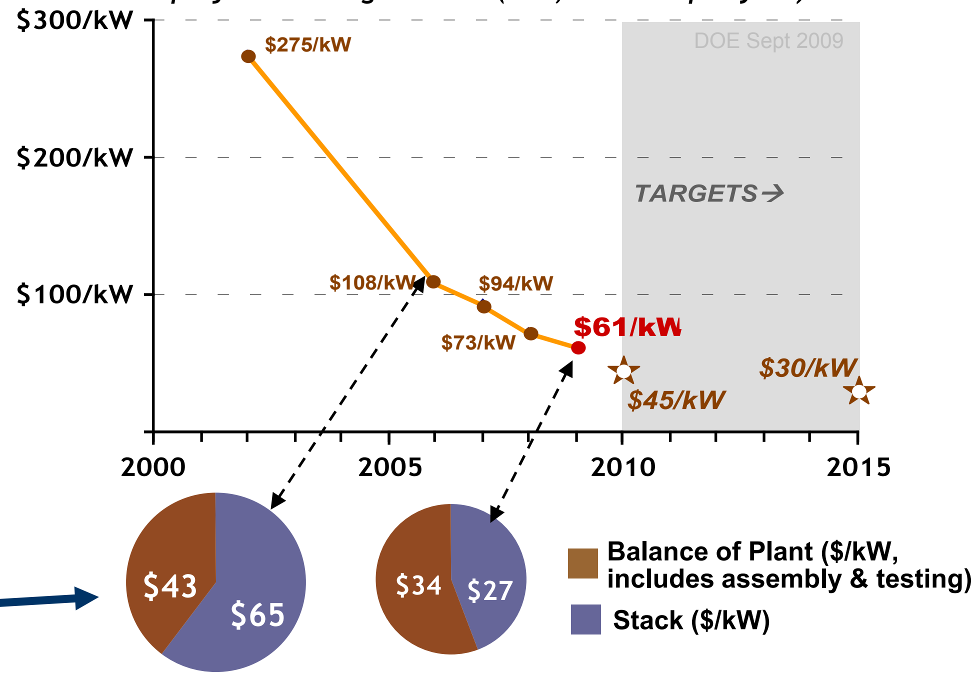
DRAFT

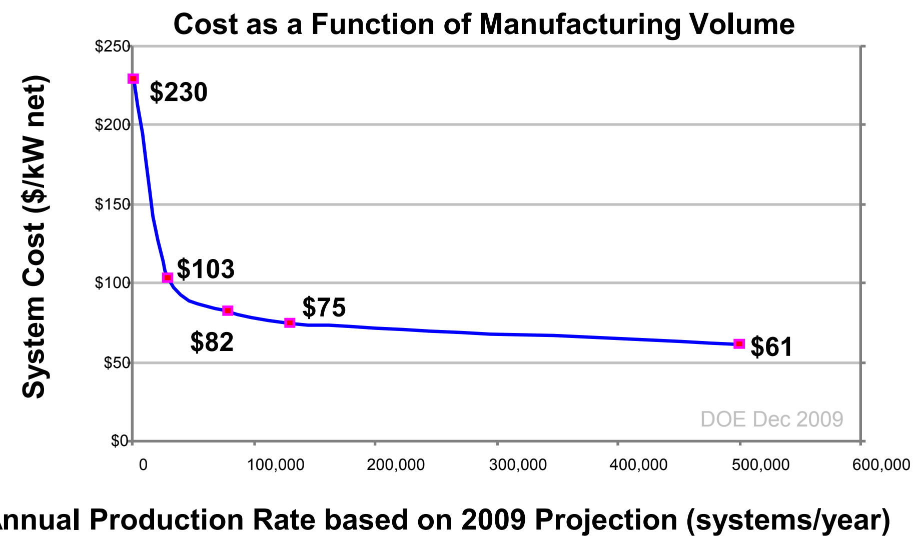
We've reduced the cost of fuel cells to $61/kW*

- ***More than 35% reduction in the last two years***
- ***More than 75% 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.**

Projected Transportation Fuel Cell System Cost

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





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

In 2008, an Independent Panel found $60 – $80/kW to be a "valid estimate": http://hydrogendoedev.nrel.gov/peer_reviews.html

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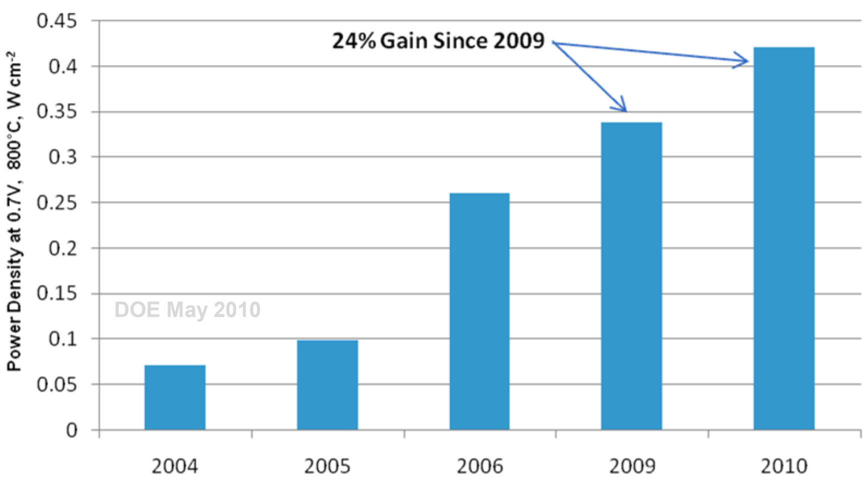
Progress has been made in many components and systems

Advances in SOFC Technology

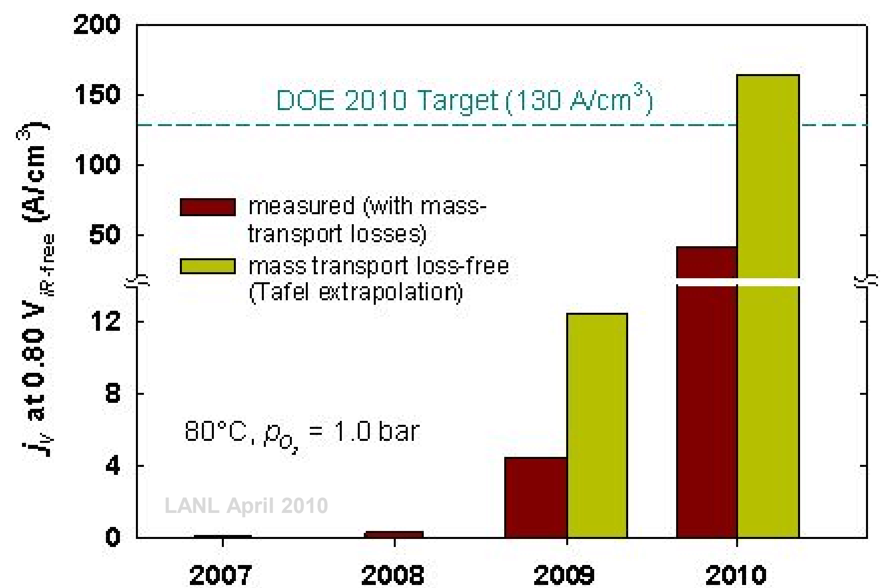
- Acumentrics demonstrated 24% increase in SOFC power density, enabling 33% reduction in stack volume and 15% reduction in stack weight
  - Low degradation rate of 0.86% / 1000 hours during 1500 hours of testing

SOFC Stack Performance Progress



Advances in Non-PGM Catalysts

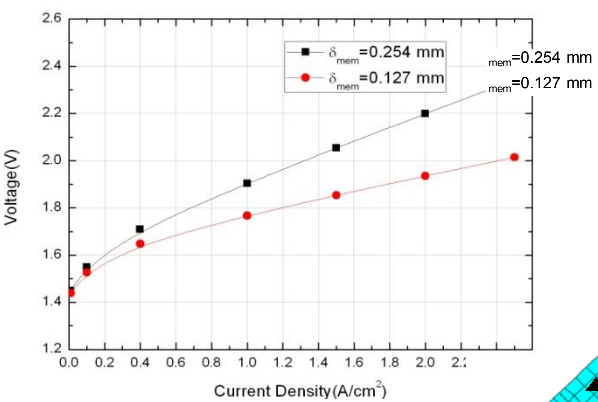
- Non-PGM catalysts by LANL improved fuel cell performance by more than 100x since 2008, exceeding DOE 2010 target of 130 A / cm^3 at 0.80 V

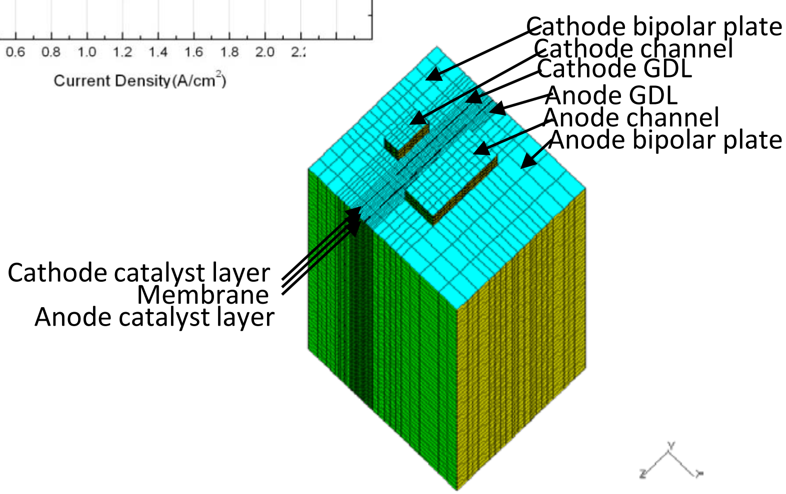


The key objective is to reduce cost of H_2 (delivered, dispensed & untaxed)

Electrolysis

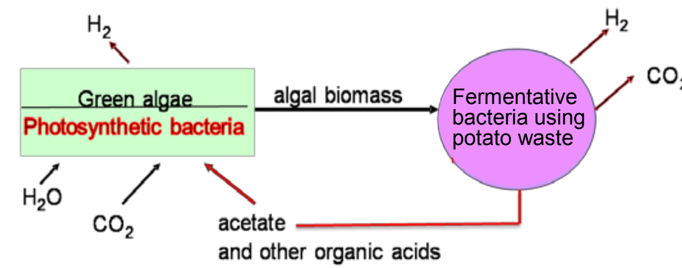
> 20% reduction cost of electrolyzer cell via a 55% reduction in catalyst loading from new process techniques (Proton Energy)

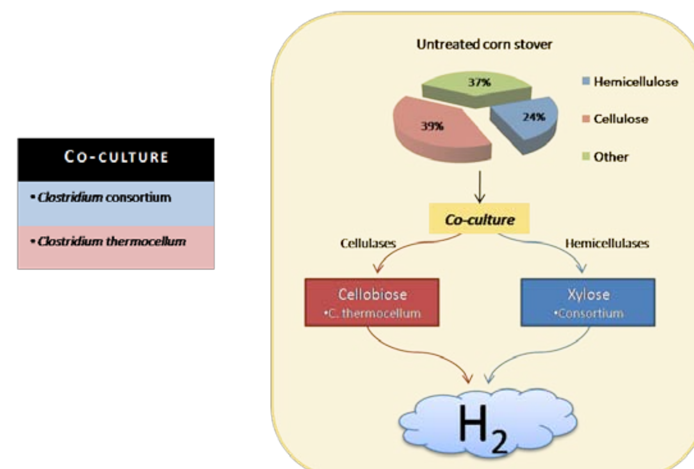




Algae

Continuous fermentative / photobiological H_2 production from potato waste achieved a maximum molar yield of 5.6 H_2 / glucose (NREL)





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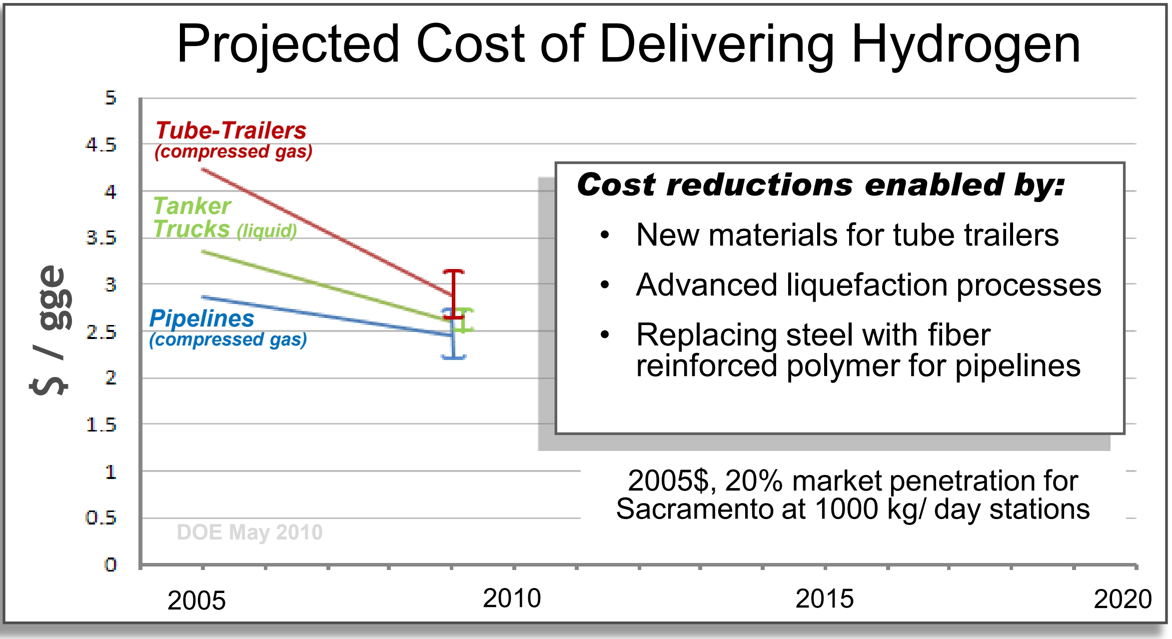
We've reduced the cost of hydrogen delivery* —

- *~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*



RECENT ACCOMPLISHMENTS

- Testing demonstrated Cryopump flow rates up to 2 kg / min exceeding targets (BMW, Linde, LLNL)
  - Provides lowest cost compression option for a station and meets the challenges of sequential vehicle refueling
- Demonstrated manufacturability and scalability of glass fiber wrapped tanks through sequential prototypes (3 to 24 to 144 inches in length) (LLNL)
- Completed design criteria and specifications for centrifugal compression of hydrogen which are projected to meet or exceed DOE targets. Compressor designed using off-the-shelf parts is in testing (Concepts NREC)

H_2 Storage
2010 Progress & Accomplishments

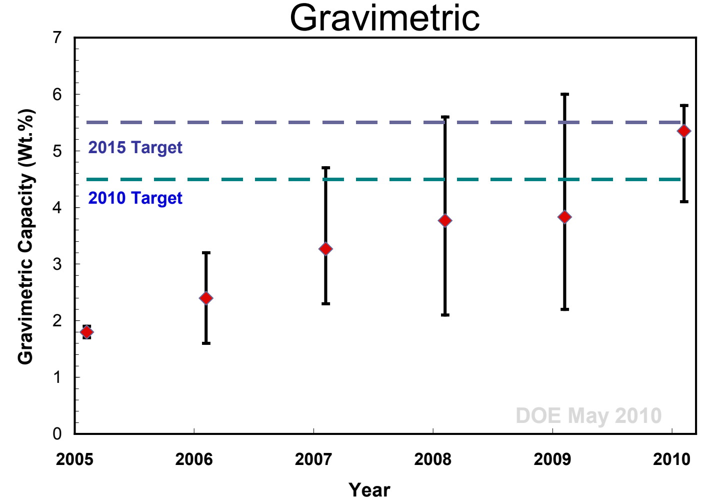
In just *five years* of accelerated investment, DOE has made significant progress in near- and long-term approaches.

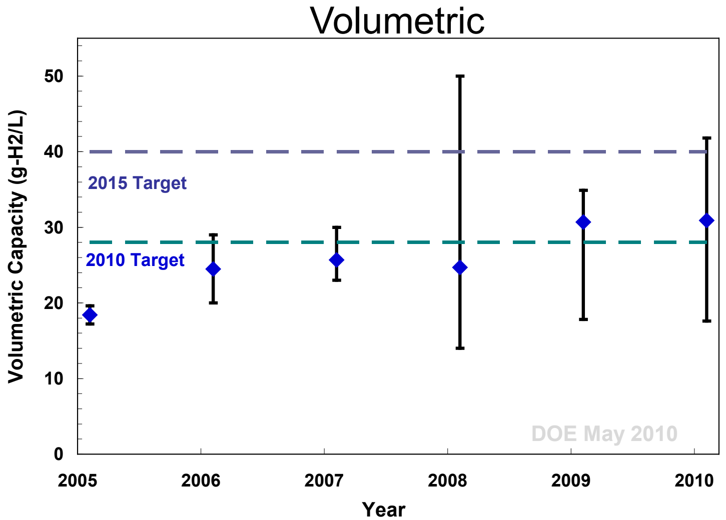
RECENT ACCOMPLISHMENTS

- Centers of Excellence
  - Developed “one-pot” hydrazine method to regenerate spent material from ammonia-borane (H_3NBH_3) dehydrogenation (CHSCoE)
  - Demonstrated 2 methods to rehydrogenate alane (AlH_3) under mild conditions (MHCoE)
  - Confirmed experimentally that boron-doped carbon has increased hydrogen binding energies (HSCoE)
- Systems Analysis
  - Finalized performance and cost projections for 350 & 700 bar compressed storage
  - Completed preliminary analysis of MOF-177 sorbent-based material system
  - Completed preliminary analysis of a cryo-compressed system with potential to meet 2015 targets

Gravimetric and volumetric capacities continue to show year-to-year improvements

Projected Capacities for Complete 5.6-kg H_2 Storage Systems





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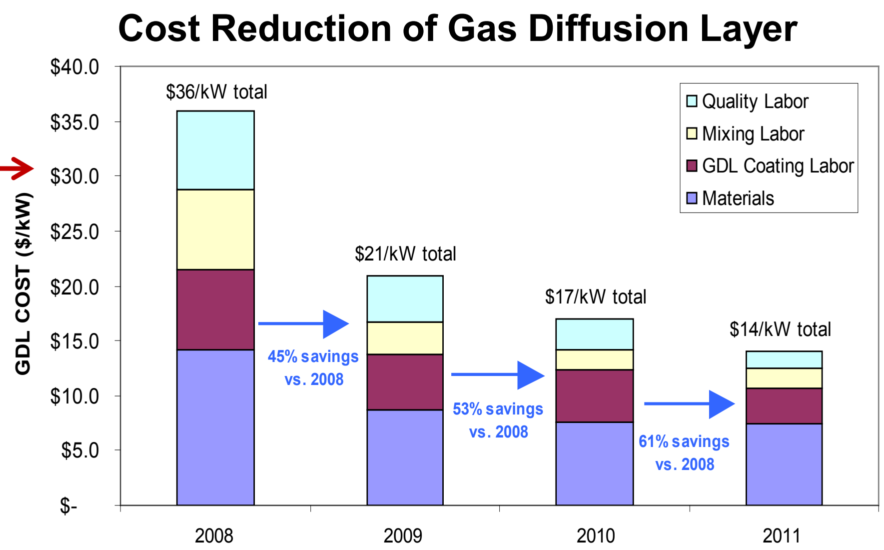
RECENT ACCOMPLISHMENTS

- Developed process model for controlling GDL coating conditions (Ballard)
  - Significant improvement in quality yields and GDL cost reduction estimated at 53% to-date
- Manufacturing of Low-Cost, Durable MEAs Engineered for Rapid Conditioning (Gore)
  - Cost model results indicate that a new three layer MEA process has potential to reduce MEA cost by 25%
- Adaptive process controls and ultrasonics for high temp PEM MEA manufacturing allows for more than 95% energy savings during the sealing process (RPI)
- Developed an innovative online X-ray fluorescence for high-speed, low-cost fabrication of gas diffusion electrodes (BASF)



This is the first time a scanning XRF has been used on GDEs – BASF

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

RECENT ACCOMPLISHMENTS

Vehicles & Infrastructure

- Fuel cell durability
  - 2,500 hours projected (nearly 75K miles)
- Over 2.5 million miles traveled
- Over 106,000 total vehicle hours driven
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles
- Over 150,000 kg- H_2 produced or dispensed*
- 144 fuel cell vehicles and 23 hydrogen fueling stations have reported data to the project

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)
  - H_2 fuel cell buses have a range of 39% to 141% better fuel economy when compared to diesel and CNG buses

Forklifts

- Forklifts at Defense Logistics Agency site have completed more than 10,000 refuelings

Recovery Act

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

* Not all hydrogen produced is used in vehicles

Education and Safety, Codes, & Standards
2010 Progress & Accomplishments

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INCREASE YOUR H_2IQ
hydrogen.energy.gov

- **Safety & Code Officials**
  - Trained >90 first responders in 3 advanced-level first responder training courses in 18 states and deployed an Intro to Hydrogen web course for code officials
- **Schools & Universities**
  - Working with 5 universities to finalize & teach over 25 university courses and curriculum modules specializing in H_2 and fuel cells
- **End Users**
  - Provided day-long educational seminars to lift truck users, including hands-on forklift demos and real-world deployment data
- **State & Local Governments**
  - Conducted >19 workshops and seminars across the country to educate decision-makers on fuel cell deployments

- **CNG H_2 Fuels Workshop**
  - Brazil, Canada, China, India and U.S. identified critical gaps and lessons learned from CNG vehicles.
- **H_2 Fuel Quality Specification**
  - Technical Specification published and harmonized with SAE J2719
- **Separation Distances**
  - Incorporated Quantitative Risk Assessment for separation distances into codes (NFPA2)
- **Materials & Components Compatibility**
  - Completed testing to enable deployment of 100 MPa stationary storage tanks
  - Forklift tank lifecycle testing program underway to support the development of CSA HPIT1

The Program is facilitating the adoption of fuel cells across government and industry.

Recent Deployments

Warner-Robins, GA -	20 forklifts
New Cumberland, PA -	40 forklifts
Fort Louis, WA -	19 forklifts
Los Alamitos, CA -	PAFC 200kW Prime Power Fuel Cell
NREL -	1 Ford H_2 ICE Bus

Upcoming Projects

Hawaii Installation

PEM electrolyzer produces 65kg-H_2 / day from Geothermal-Wind power to fuel two H_2 buses

South Carolina Landfill Gas

Landfill gas reformation generates H_2 that powers onsite material handling equipment

Ford H_2 ICE Bus Deployments

Six to go to DOD / DLA sites & five to National Labs

CERL Backup Power

More than 250 kW of emergency backup fuel cell power at 14 federal facilities across the DOD, DOE, NASA, GSA, and the National Park Service

Market Transformation fuel cell deployments

American Reinvestment and Recovery Act projects - up to 1,000 fuel cell deployments planned (e.g. forklifts, backup power). Companies include FedEx, Sprint, and AT&T.

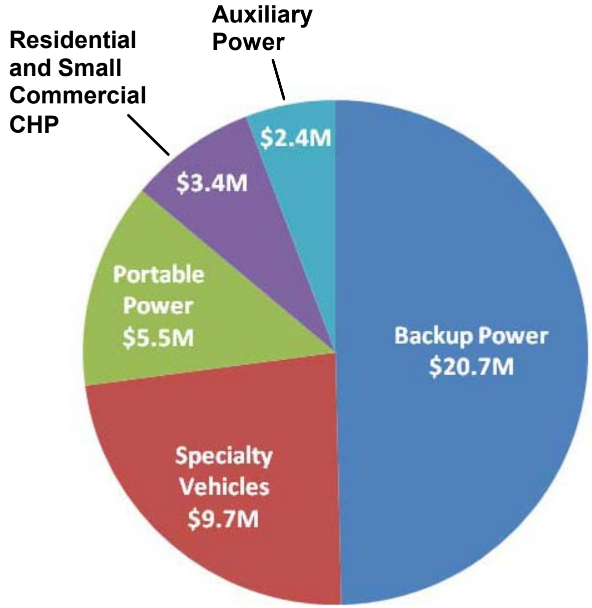
Recovery Act Funding for Fuel Cells

U.S. DEPARTMENT OF ENERGY

DOE announced ~$42 million from the American Recovery and Reinvestment Act to fund 12 projects, which will deploy up to 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

FROM the LABORATORY to DEPLOYMENT:

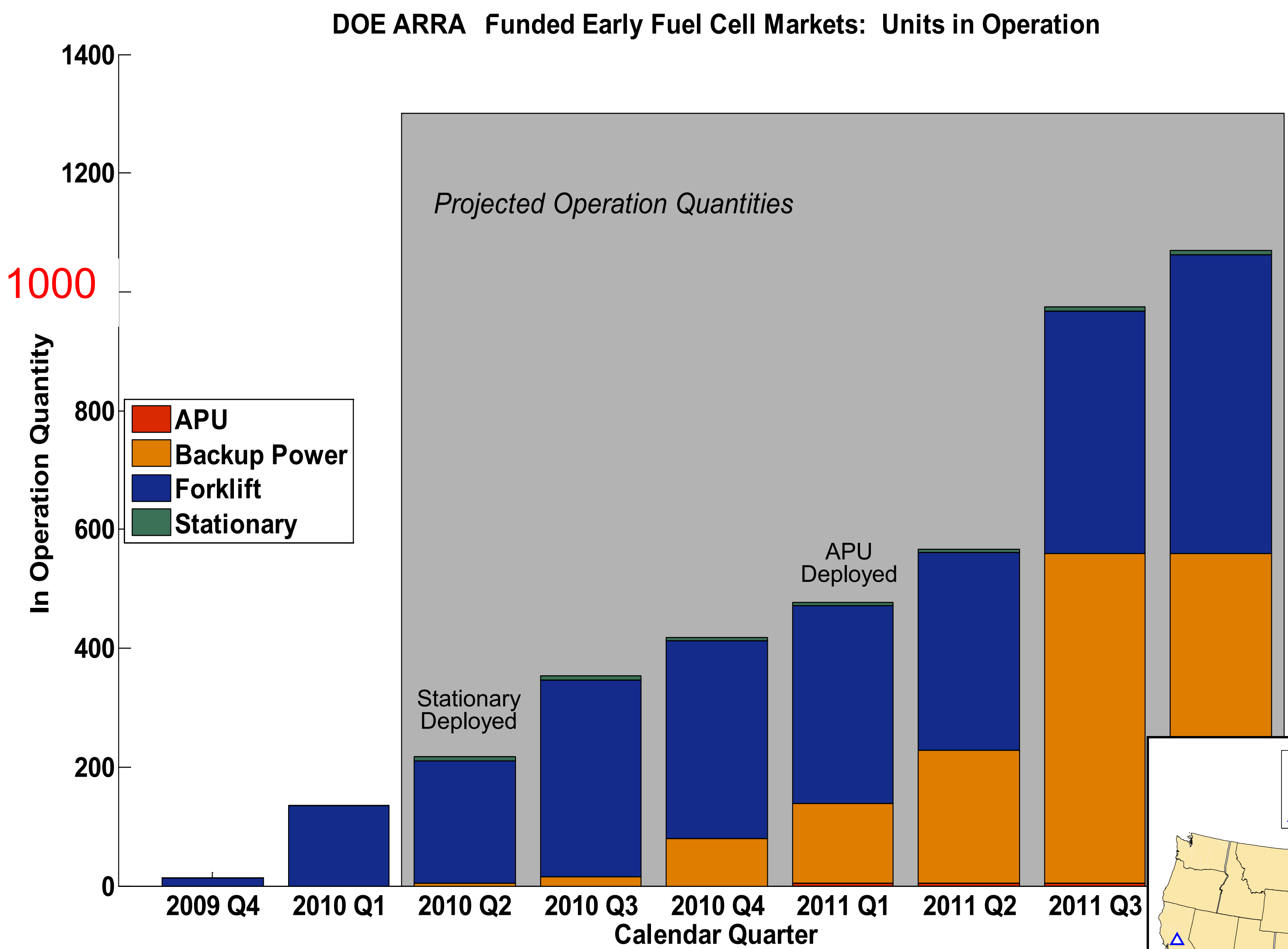
DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.

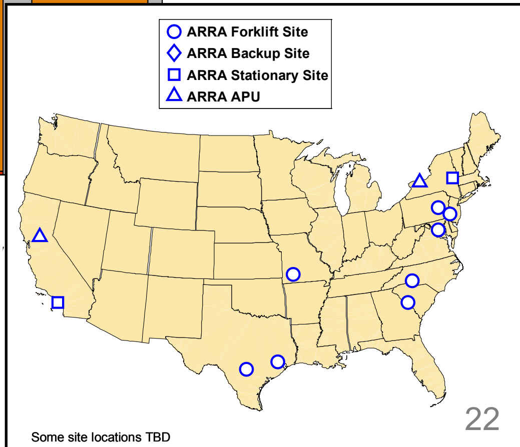


Approximately $51 million in cost-share funding from industry participants—for a total of about $93 million.

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

Recovery Act Fuel Cell Estimated Deployments





From National Renewable Energy Laboratory

Systems Analysis

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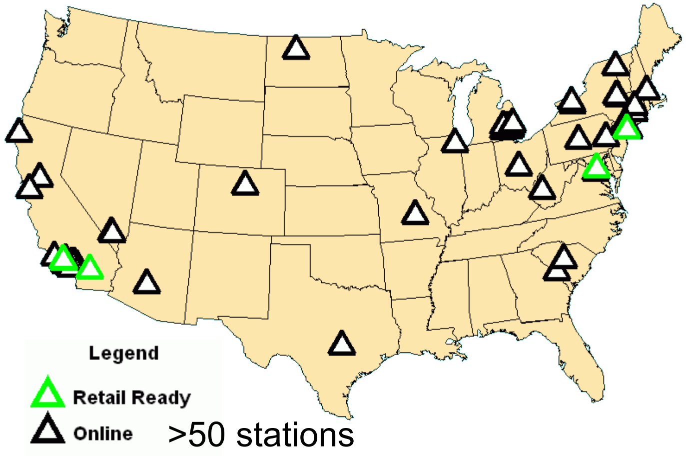
We are assessing the costs and benefits of various technology pathways and identifying key technological gaps, by conducting:

Life-cycle analysis, Emissions analysis, Environmental analysis, Systems integration analysis

Hydrogen fuel cell vehicles are being introduced in the U.S. over the next 5 years

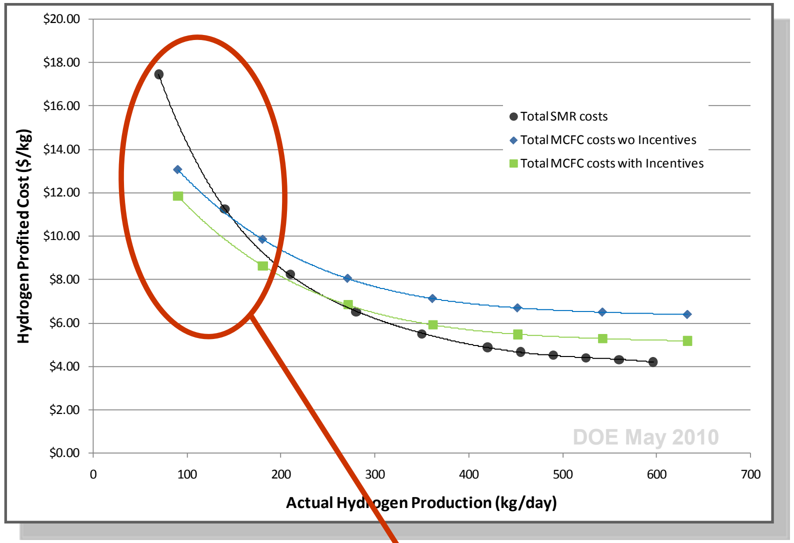


Industry Survey Results from the CA Fuel Cell Partnership*

	Phase 1 (hundreds) 2011	Phase 2 (thousands) 2012-14	Phase 3 (tens of thousands) 2015-17
Pass. vehicles	710	4,300	49,600
Buses	15	20-60	150

Assessing Novel Pathways for H_2 Production

(e.g. cost of combined hydrogen, heat and power)



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

* For details, see full report at:
http://www.cafcp.org/hydrogen-fuel-cell-vehicle-and-station-deployment-plan

Source: Fuel Cell Power Model

Assessing the Program
Independent Assessments of R&D Progress

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NREL convened independent experts to provide rigorous, unbiased analyses for the technology status, expected costs and benefits, and effectiveness of the Program.

2009 Independent Assessment of Electrolysis Cost

- **Delivered H_2 costs:**
  - **~$4.90 - $5.70/gge from distributed electrolysis**
  - **~$2.70 - $3.50/gge from centralized electrolysis**
- **Electrolysis conversion efficiency is 67%**
  (just below the DOE 2014 target of 69%)
- **Distributed electrolyzer capital cost is expected to fall to $380/kW by 2015 (vs. DOE target of $400/kW)**
- **Centralized electrolyzer capital cost is expected to fall to $460/kW by 2015 (vs. DOE target of $350/kW)**

2010 Independent Assessment of Stationary Fuel Cell Status & Targets

- Confident that by 2015, LT-PEM & HT-PEM can achieve 40,000 hr.
- 45% electrical efficiency for 1-10kW systems is feasible for HT-PEM, but depends on improved catalysts and higher operating temps for LT-PEM
- SOFC systems are likely to achieve DOE targets for electrical and CHP efficiencies. 90% CHP efficiency is likely to be attainable by SOFC systems
- Confident that by 2020, LT-PEM & HT-PEM can achieve $450-$750/kW, while SOFC can achieve $1000-2000/kW

Independent Review of Hydrogen Production Cost Estimate Using Biomass Gasification
Expected in Late 2010

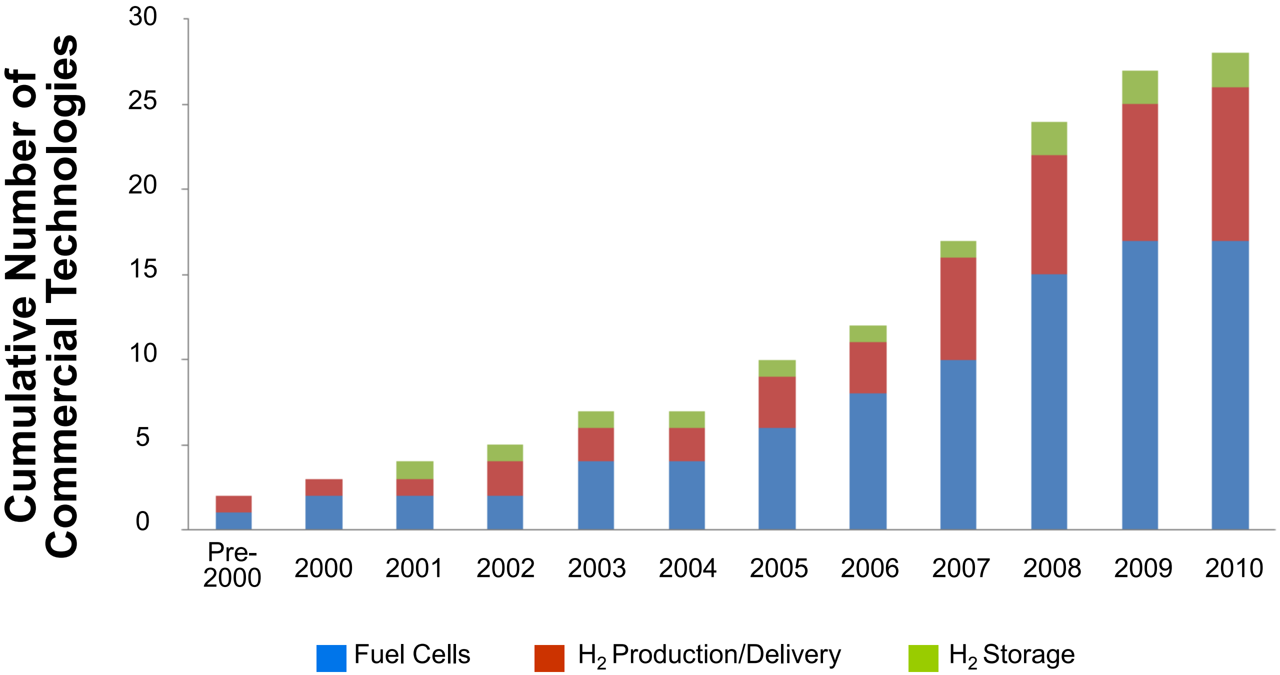
National Research Council of the National Academies
3rd Review of the FreedomCAR and Fuel Partnership

www.hydrogen.energy.gov/peer_reviews.html

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

Accelerating Commercialization

EERE-funded Fuel Cell Technologies that are Commercially Available



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

143 PATENTS resulting from EERE-funded R&D:

- 73 fuel cell
- 49 H_2 production and delivery
- 21 H_2 storage

50% 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

Federal Interagency Coordination

U.S. DEPARTMENT OF ENERGY

DOE Hydrogen Program

Secretary of Energy

Under Secretary

Program Secretarial Officers

Energy Efficiency and Renewable Energy – EERE
Fossil Energy – FE
Nuclear Energy – NE
Science - SC

DOE Program Manager

Program Coordination Group*:

Coordinates H_2 activities of EERE, FE, NE, SC

Interagency Task Force

- High-level
- Coordinates Federal Deployments

Interagency Working Group

- Staff-level
- Coordinates RD&D

Other Federal Agencies Involved in H_2 & FC RD&D and Deployments

- Dept. of Agriculture
- Dept. of Commerce
- Dept. of Defense
- Dept. of Education
- Dept. of the Interior
- Dept. of Homeland Security
- Dept. of Transportation
- Environmental Protection Agency
- Executive Office of the President
- General Services Administration
- National Aeronautics and Space Administration
- National Science Foundation
- U.S. Postal Service

****Also coordinates activities with Dept. of Transportation***

Acknowledging Partners

U.S. PARTNERSHIPS

- **FreedomCAR & Fuel Partnership:** Ford, GM, Chrysler, BP, Chevron, ConocoPhillips, ExxonMobil, Shell, Southern California Edison, DTE Energy
- **Hydrogen Utility Group:** Xcel Energy, Sempra, DTE, Entergy, New York Power Authority, Sacramento Municipal Utility District, Nebraska Public Power Authority, Southern Cal Edison, Arizona Public Service Company, Southern Company, Connexus Energy, etc.
- **State/Local Governments:** California Fuel Cell Partnership, California Stationary Fuel Cell Collaborative, co-coordinators of Bi-Monthly Informational Call Series for State and Regional Initiatives with the National Hydrogen Association and the Clean Energy Alliance
- **Industry Associations:** US Fuel Cell Council, National Hydrogen Association
- **Federal Interagency Partnerships:** Hydrogen and Fuel Cell Interagency Task Force and Working Group, Interagency Working Group on Manufacturing, Community of Interest on Hydrogen and Fuel Cell Manufacturing

INTERNATIONAL PARTNERSHIPS

IPHE

International Partnership for Hydrogen and Fuel Cells in the Economy—
A partnership among 16 countries and the European Commission

International Energy Agency — Implementing Agreements

- Hydrogen Implementing Agreement — 21 countries and the European Commission
- Advanced Fuel Cells Implementing Agreement — 19 countries

For More Information …

U.S. DEPARTMENT OF ENERGY

Fuel Cell Program Plan

Outlines a plan for fuel cell activities in the Department of Energy

→ *Replacement for current* Hydrogen Posture Plan

→ *To be released in 2010*

Annual Merit Review Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

→ *Latest edition released June 2009*

www.hydrogen.energy.gov/annual_review09_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

→ *Latest edition released October 2009*

www.hydrogen.energy.gov/annual_review08_report.html

Annual Progress Report

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

→ *Latest edition published November 2009*

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 7 – 13, 2011
Washington, D.C.
http://annualmeritreview.energy.gov/

Thank you

Additional Information

ARRA established the advanced energy manufacturing tax credit to encourage the development of a US-based renewable energy manufacturing sector.

ARRA authorizes the Department of the Treasury to issue $2.3 billion of credits under the program.

The investment tax credit is equal to 30 percent of the qualified investment that establishes, re-equips, or expands a manufacturing facility.

The specified review criteria included:

- Greatest domestic job creation (direct and indirect)
- Greatest net impact in avoiding or reducing air pollutants or emissions of greenhouse gases; lowest levelized cost of energy
- Greatest potential for technological innovation and commercial deployment
- Shortest project time from certification to completion

Results

- 160 applications out of over 500 were selected
- 2 fuel cell manufacturers were selected (very few fuels cell applications were submitted)
- New legislation being proposed to extend the program adding an additional $5 billion in new tax credits

2010 Progress & Accomplishments

U.S. DEPARTMENT OF ENERGY

NREL has collected data for DOE and FTA on 8 FCBs in service at 4 sites:

- AC Transit
- SunLine
- CTTRANSIT
- VTA

Traveled:
~ 368,000 miles

Dispensed:
72,931 kg H_2

NREL Hydrogen Bus Evaluations for DOE and FTA

Site/Location	State	Eval. Funding	Project (2009–2012)
AC Transit/ SF Bay Area	CA	DOE Technology Validation	CA ZEB Advanced Demo
SunLine/ Thousand Palms	CA	DOE Technology Validation	FCB
SunLine/ Thousand Palms	CA	DOE Technology Validation	Advanced FCB Project
CTTRANSIT/ Hartford	CT	DOE Technology Validation	FCB Demo
City of Burbank/ Burbank	CA	DOE Technology Validation	Burbank FCB
AC Transit/ Oakland	CA	FTA National Fuel Cell Bus Program	Accel.Test
SunLine/ Thousand Palms	CA	FTA National Fuel Cell Bus Program	American FCB Demo
CTTRANSIT/ Hartford	CT	FTA National Fuel Cell Bus Program	Nutmeg Hybrid FCB Demo
USC, CMRTA/ Columbia UT/ Austin	SC, TX	FTA National Fuel Cell Bus Program	Hybrid FCB
Logan Airport / Boston	MA	FTA National Fuel Cell Bus Program	MA H2 FCB Demo
Albany / NY	NY	FTA National Fuel Cell Bus Program	Light-wt FCB
TBD / NY	NY	FTA National Fuel Cell Bus Program	NYPA H2 Powered FCB
SFMTA / San Francisco	CA	FTA National Fuel Cell Bus Program	FC APU Hybrid

Demonstration site: National Fuel Cell Bus Program

- Northern California
- Southern California
- New England
- New York
- Southeast
- South

Fuel economy results: 39% to 141% better than diesel and CNG buses

www.nrel.gov/hydrogen/proj_tech_validation.html

Estimate of data collection/evaluation - schedule subject to change based on progress of each project

Proposed Hydrogen Cost Target Revision
Methodology

U.S. DEPARTMENT OF ENERGY

The fuel cost per mile for a hydrogen vehicle is set equivalent to the cost of competing vehicles using the following methodology

H_2 FCV to Gasoline HEV:

$$\frac{\text{Target } H_2 \text{ Cost}}{\text{Fuel Economy } H_2\text{FCEV}} = \frac{\text{EIA Gasoline Price in 2020}}{\text{Fuel Economy Competitive Vehicle}}$$

H_2 FCV to Gasoline PHEV 10:

$$\frac{\text{Target } H_2 \text{ Cost}}{\text{Fuel Economy } H_2 \text{ FCV}} = \text{Fraction of Miles in CS mode}\left(\frac{\text{Gasoline Cost}}{\text{Gasoline HEV Fuel Economy in CS mode}}\right) + \text{Fraction of Miles in CD mode}\left(\frac{\text{Gasoline Cost}}{\text{Gasoline Fuel Economy in CD mode}} + \frac{\text{Electricity Cost}}{\text{Electric Fuel Economy in CD mode}}\right)$$

CS = Charge Sustaining
CD = Charge Depleting

Technologies compared on a $ / mile basis

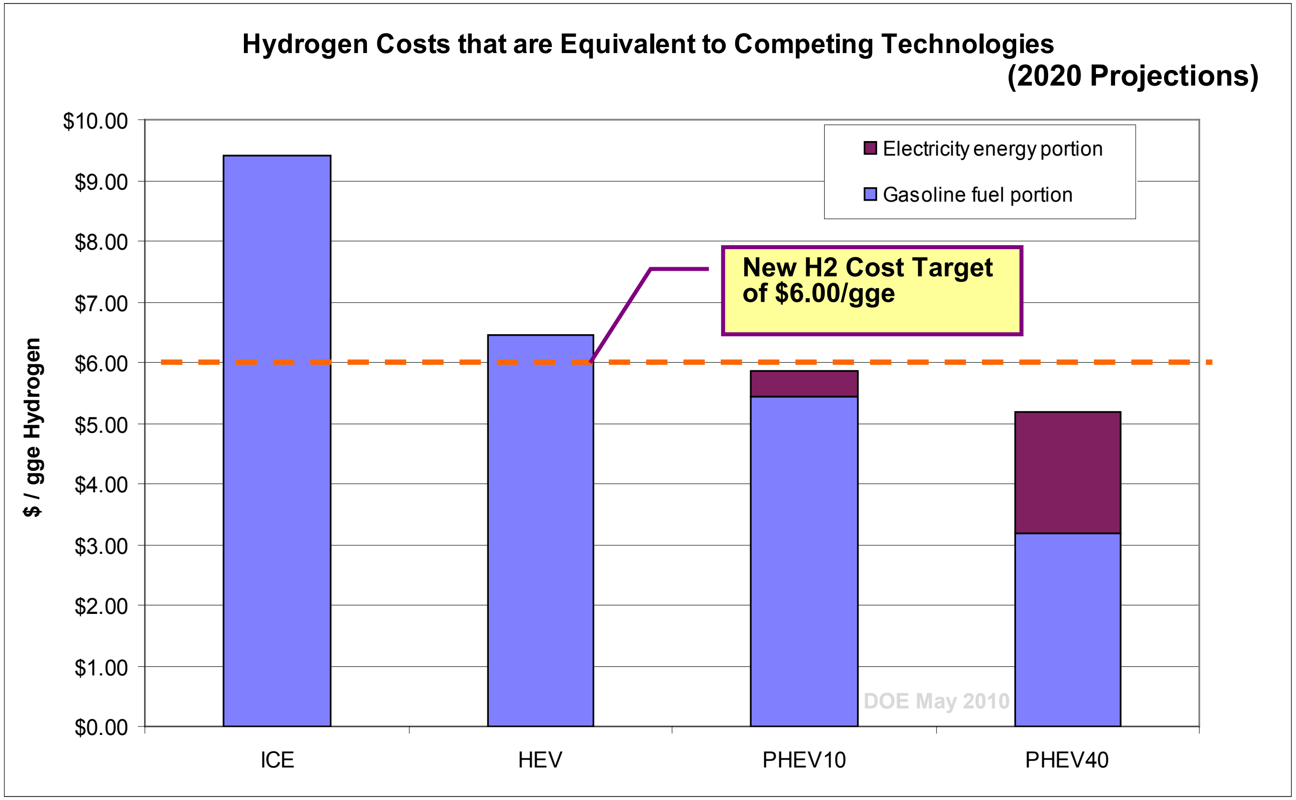
DRAFT

Proposed Hydrogen Cost Target Revision
Fuel Costs of Competing Technologies

U.S. DEPARTMENT OF ENERGY

New Hydrogen Cost Target is recommended to be ~$6.00/gge or $0.10/mile (untaxed, $2007)

Hydrogen costs that are equivalent to competitive technologies were calculated by multiplying competing technologies' fuel cost per mile by the hydrogen FCEV's projected fuel economy (59 mile / gge)



AEO 2009 High Energy Price projections for 2020 were used for this analysis. Gasoline is $5.04/gal with U.S. average gasoline fuel taxes - $4.57 without. The projected residential electricity rate is $0.1152 / kWh. (both in 2007$). Fuel economies were provided by VTP based on PSAT model runs (details in appendix).

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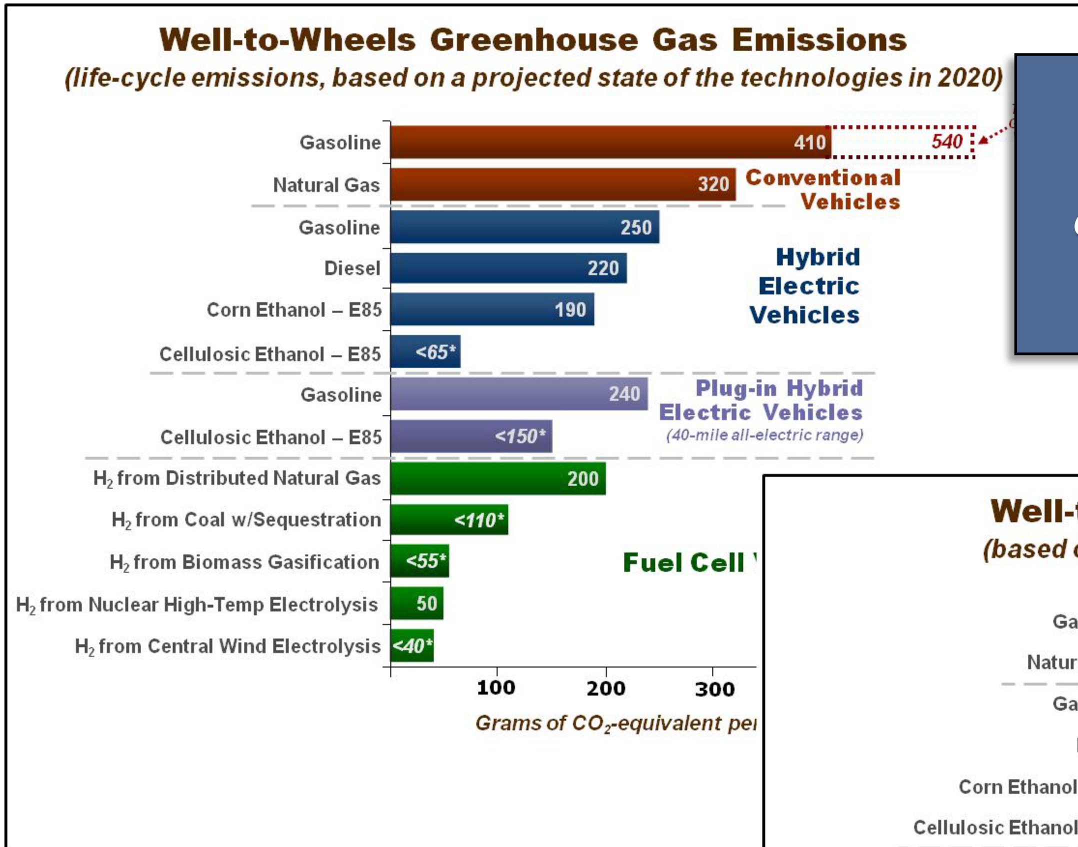
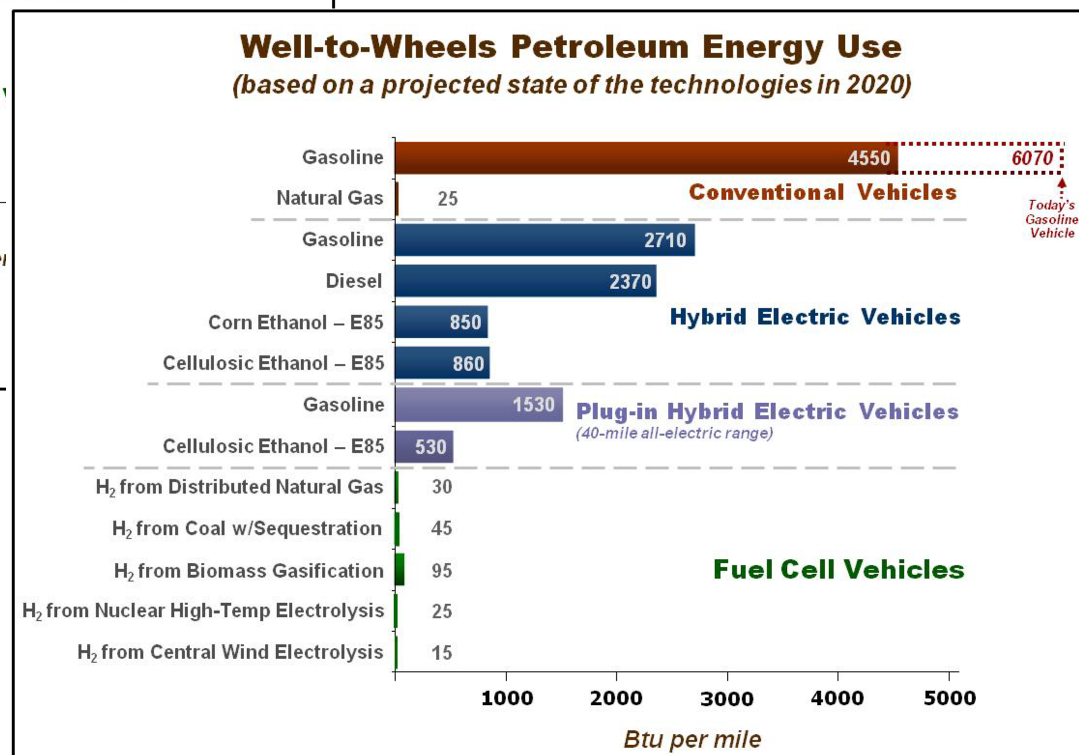
Systems Analysis — *Examples of Benefits*



Analysis shows DOE's portfolio of transportation technologies will reduce emissions of greenhouse gases and oil consumption.

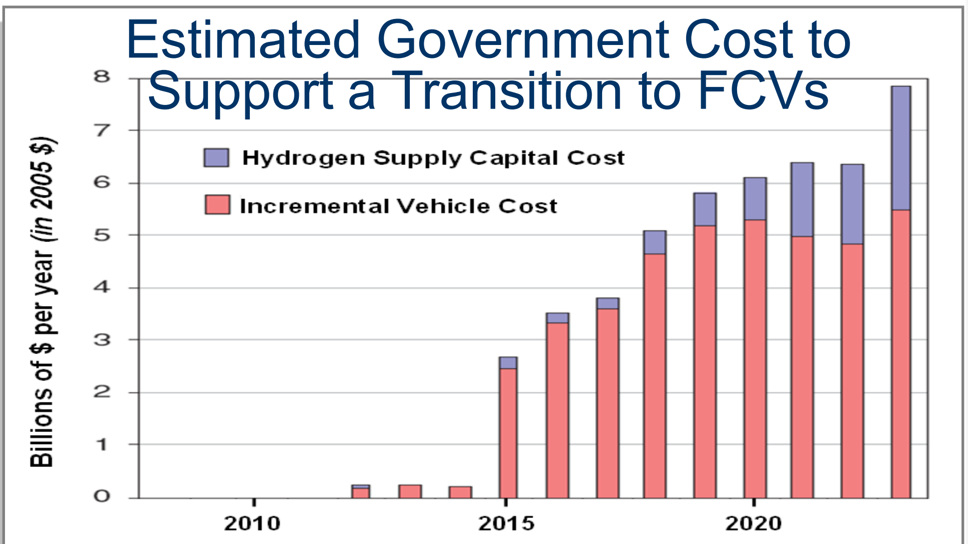
DOE Program Record #9002, www.hydrogen.energy.gov/program_records.html.

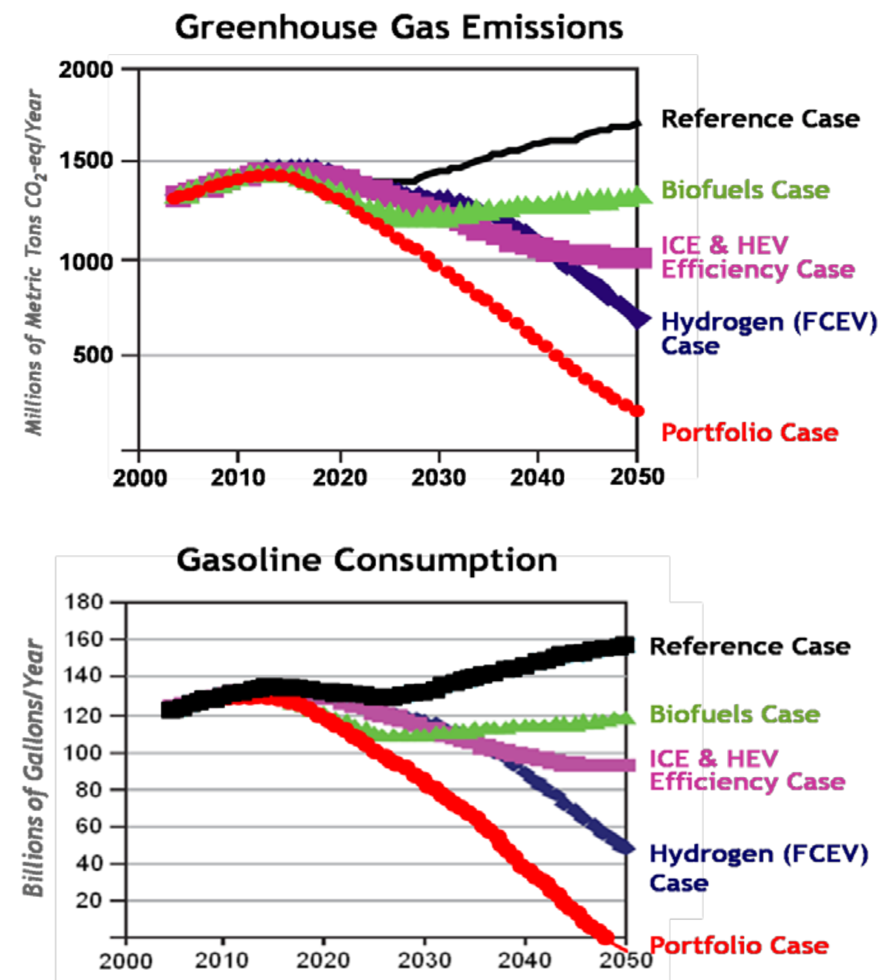


NAS study, "Transitions to Alternative Transportation Technologies: A Focus on Hydrogen," estimated costs and benefits

Key Findings Include:

- By 2020, there could be 2 million FCVs on the road (60 million and by 2050).
- A portfolio of technologies has the potential to reduce greenhouse gas emissions from light-duty vehicles
  - 20% of current levels—by 2050.





Source: *Transitions to Alternative Transportation Technologies: A Focus on Hydrogen*, National Academies, 2008.