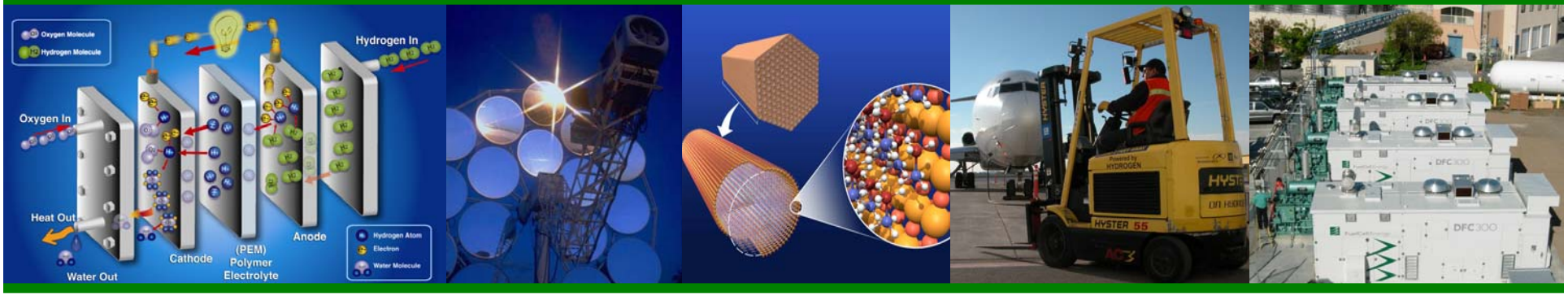
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Overview of Hydrogen and Fuel Cell Activities

Sunita Satyapal

Acting Program Manager

DOE Fuel Cell Technologies Program

Fuel Cells & Hydrogen Joint Undertaking Stakeholders General Assembly

October 27, 2009

Fuel Cells: Addressing Energy Challenges

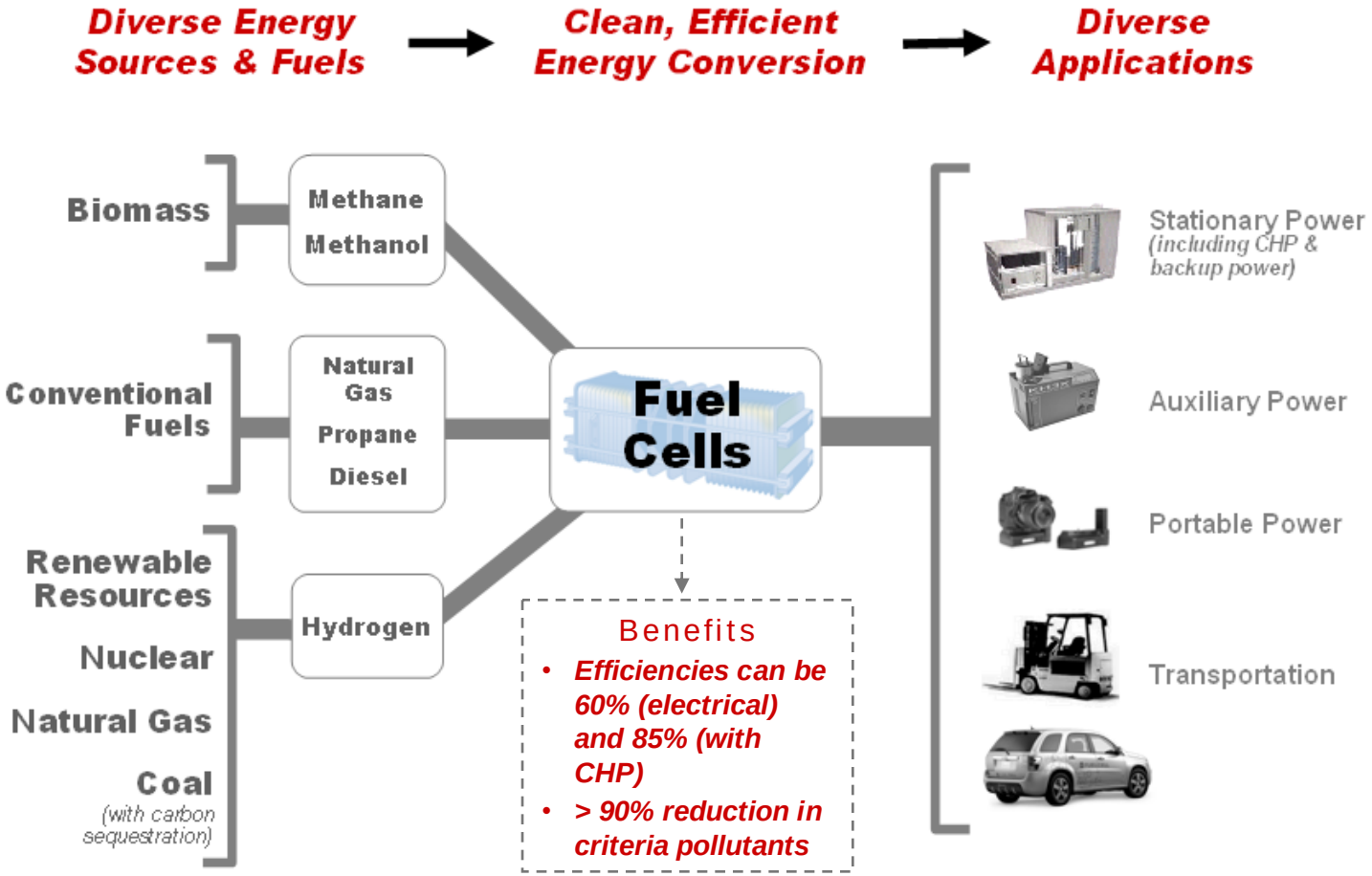
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Energy Efficiency and Resource Diversity

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

Greenhouse Gas Emissions and Air Pollution:

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



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.

~52,000 ***fuel cells have been shipped worldwide.***

~18,000 ***fuel cells were shipped in 2008 (> 50% increase over 2007).***

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***

Fuel Cells for Transportation

In the U.S., there are currently:

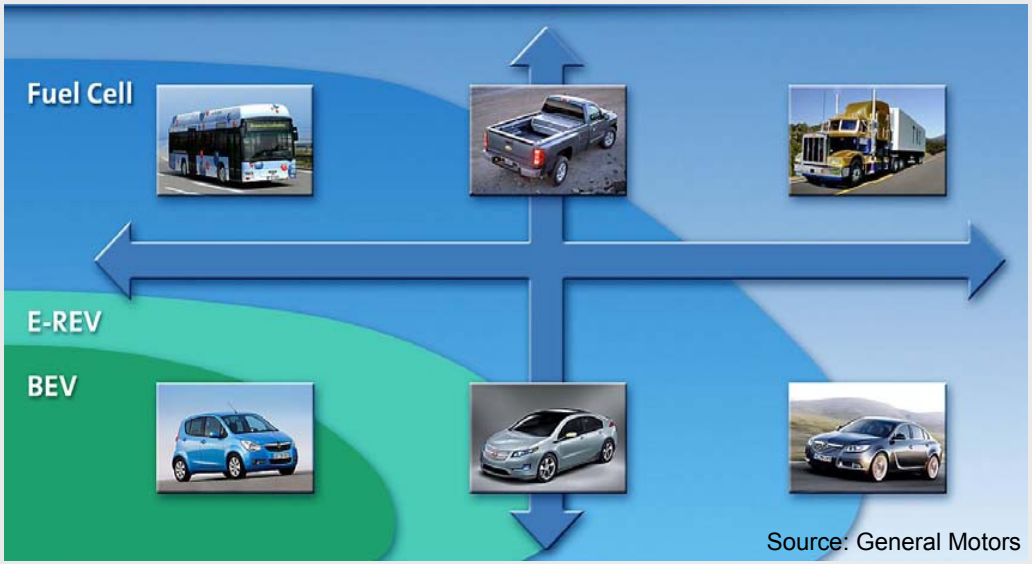
> *200* ***fuel cell vehicles***

> *20* ***fuel cell buses***

~ *60* ***fueling stations***

A variety of technologies—including fuel cell vehicles, extended-range electric vehicles (or "plug-in hybrids"), and all-battery powered vehicles—will be needed to meet our diverse transportation needs.

The most appropriate technology depends on the drive cycle and duty cycle of the application.



Source: General Motors

Systems Analysis —
Greenhouse Gas Emissions

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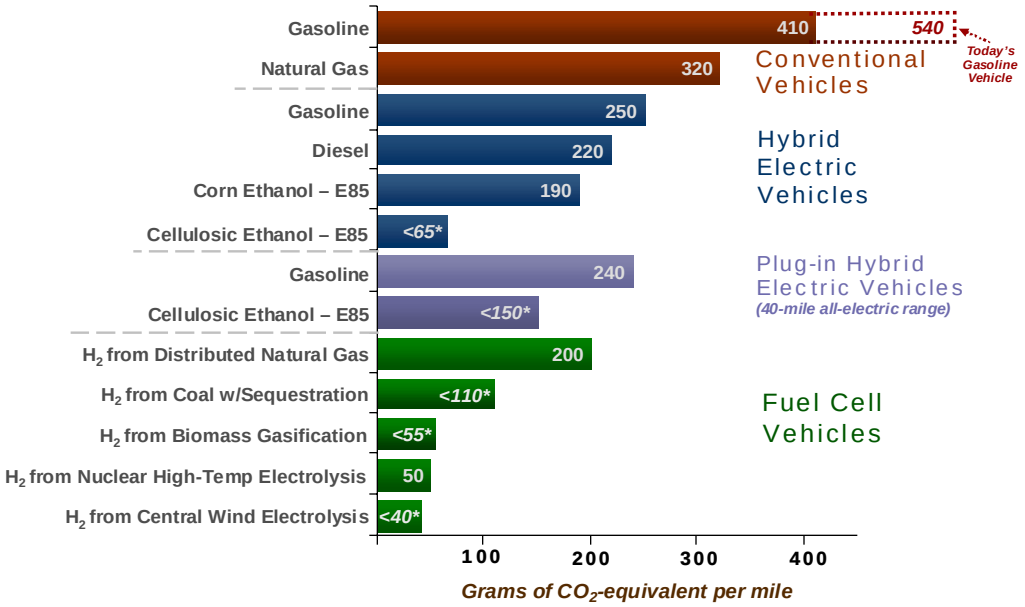
Analysis shows DOE's portfolio of transportation technologies will reduce emissions of greenhouse gases and oil consumption.

Well-to-Wheels Greenhouse Gas Emissions

(life cycle emissions, based on a projected state of the technologies in 2020)

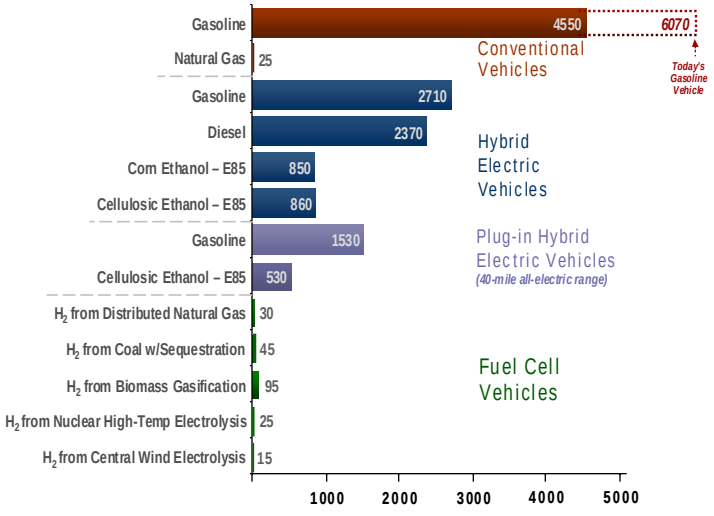


***Net emissions from these pathways will be lower if these figures are adjusted to include:**

- The displacement of emissions from grid power–generation that *will* occur when surplus electricity is co-produced with cellulosic ethanol
- The displacement of emissions from grid power–generation that *may* occur if electricity is co-produced with hydrogen in the biomass and coal pathways, and if surplus wind power is generated in the wind-to-hydrogen pathway
- Carbon dioxide sequestration in the biomass-to-hydrogen process

Well-to-Wheels Petroleum Energy Use

(based on a projected state of the technologies in 2020)



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

Key Challenges

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

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, delivered

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

Fuel 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**

Collaborations

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

Federal Agencies

- DOC
- DOD
- DOEd
- 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 the Hydrogen Economy – 16 countries, 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**
- **National Hydrogen Association**
- **U. S. Fuel Cell Council**
- **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
Argonne A, FC, P&D
Los Alamos S, FC, SC&S
Sandia P&D, S, SC&S
Pacific Northwest P&D, S, FC, A
Oak Ridge P&D, S, FC, A
Lawrence Berkeley FC, A
Lawrence Livermore P&D, S
Savannah River S, P&D
Brookhaven S, FC

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

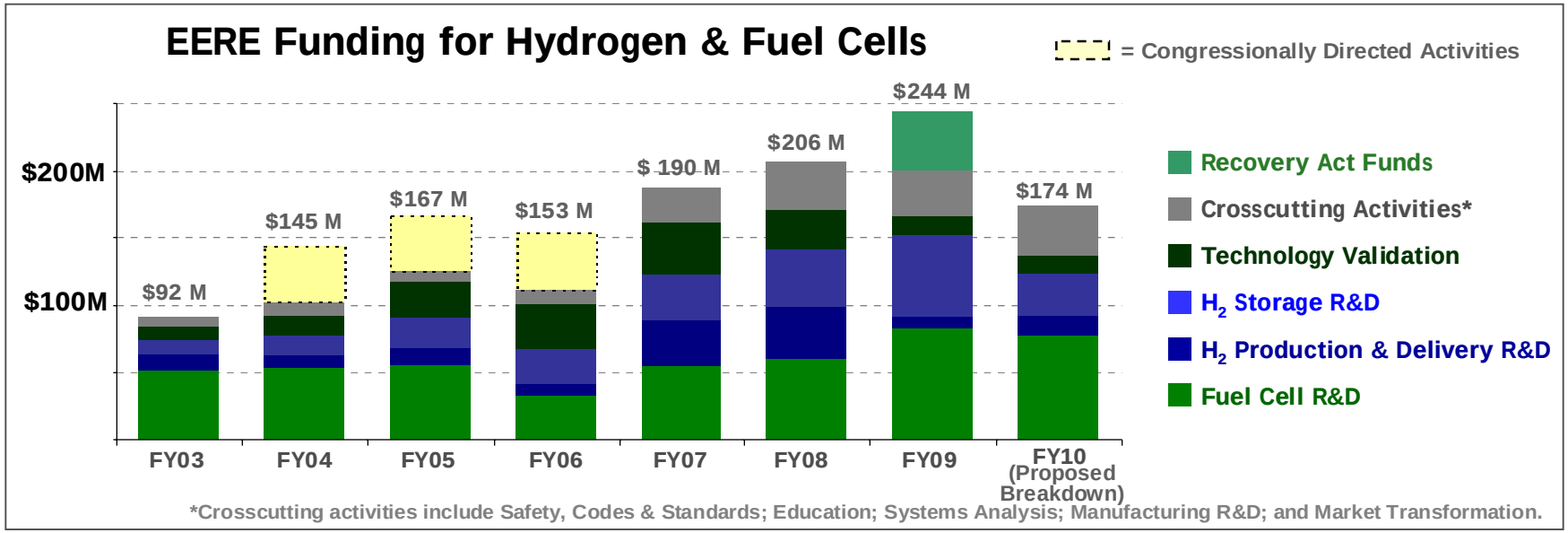
P&D *= Production & Delivery;* ***S*** *= Storage;* ***FC*** *= Fuel Cells;* ***A*** *= Analysis;* ***SC&S*** *= Safety, Codes & Standards;* ***TV*** *= Technology Validation*

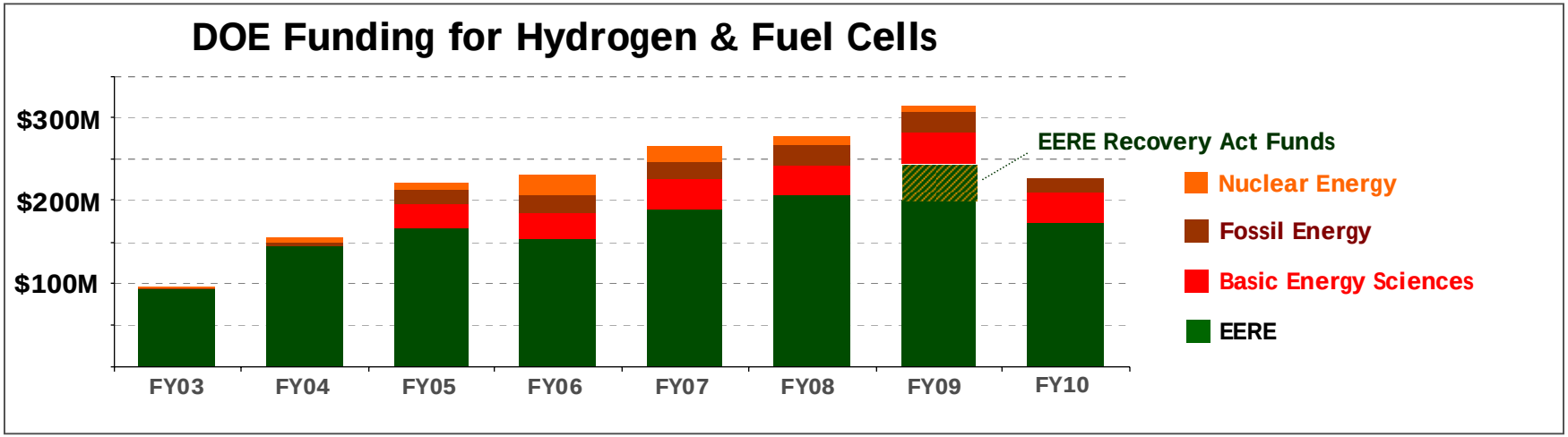
*** Office of Energy Efficiency and Renewable Energy**

Budget

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

Program activities are an integrated, comprehensive effort addressing the full range of technical, institutional, and economic barriers.





Fuel Cell R&D

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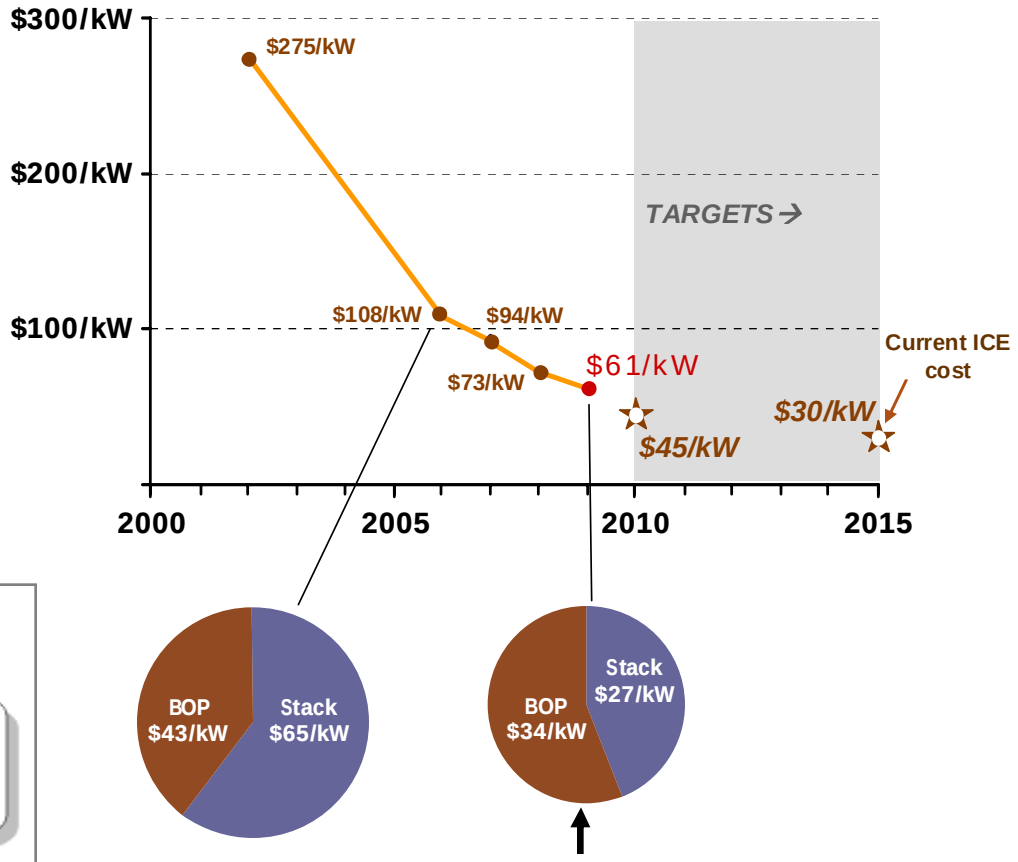
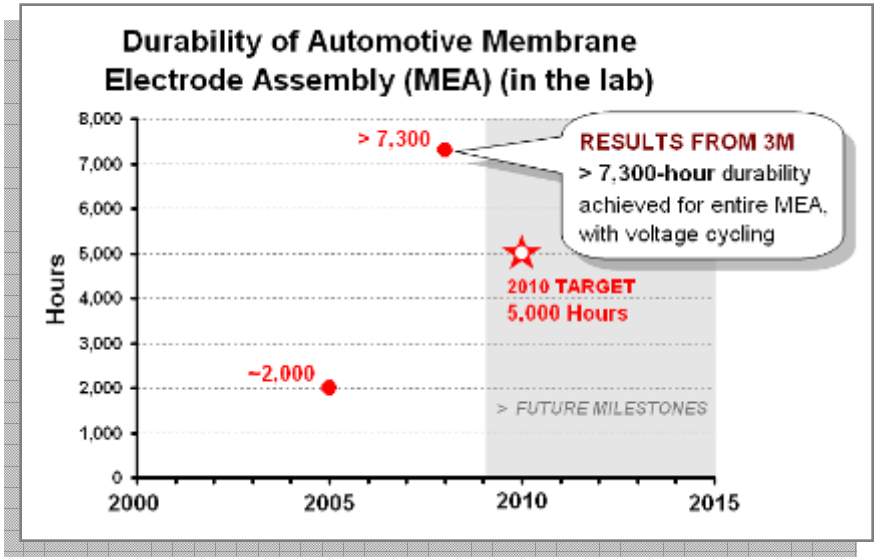
We've reduced the cost of fuel cells by 75% since 2002*

- ***2008 cost projection validated by independent panel*****



***As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs** (BOP costs shown here include system assembly & testing).*



Demonstrated >7,300-hour durability

*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

Hydrogen Production & Delivery R&D

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

The Program is developing technologies to produce hydrogen from clean, domestic resources at reduced cost.

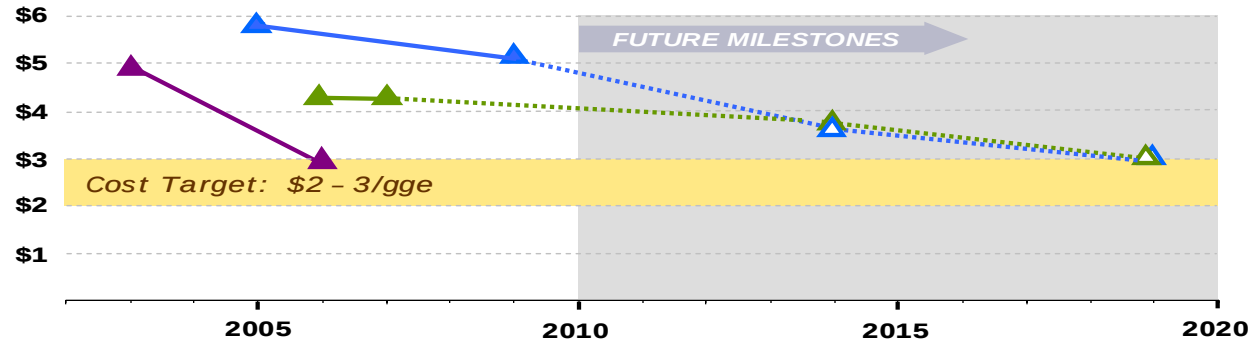
KEY PRODUCTION OBJECTIVE: **Reduce the cost of hydrogen (delivered & untaxed) to $2 – 3 per gge (gallon gasoline equivalent)**

Projected* High-Volume Cost of Hydrogen (Delivered) — Status & Targets

– $/gallon gasoline equivalent (gge), untaxed –

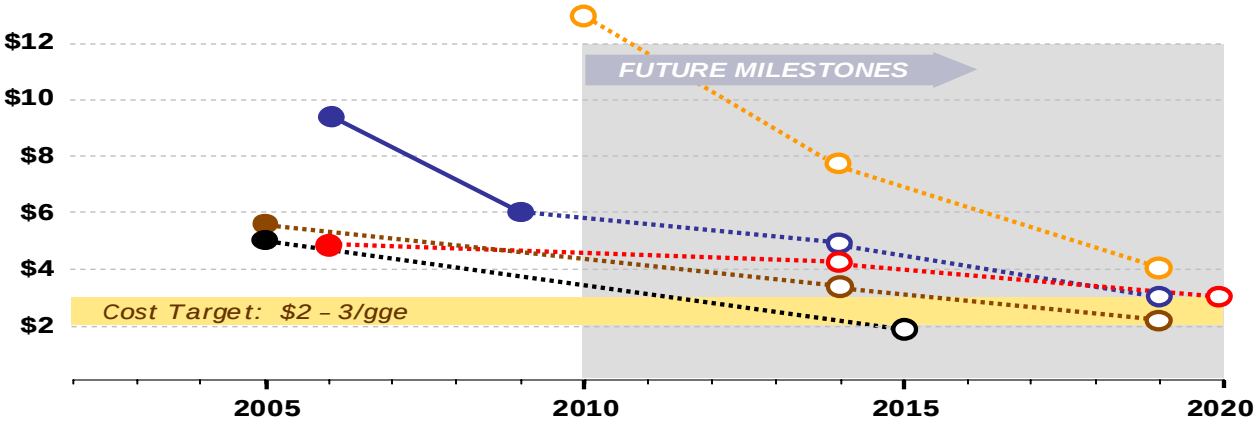
NEAR TERM:
Distributed Production

- H_2 from Natural Gas
- H_2 from Bio-Derived Renewable Liquids
- H_2 from Electrolysis



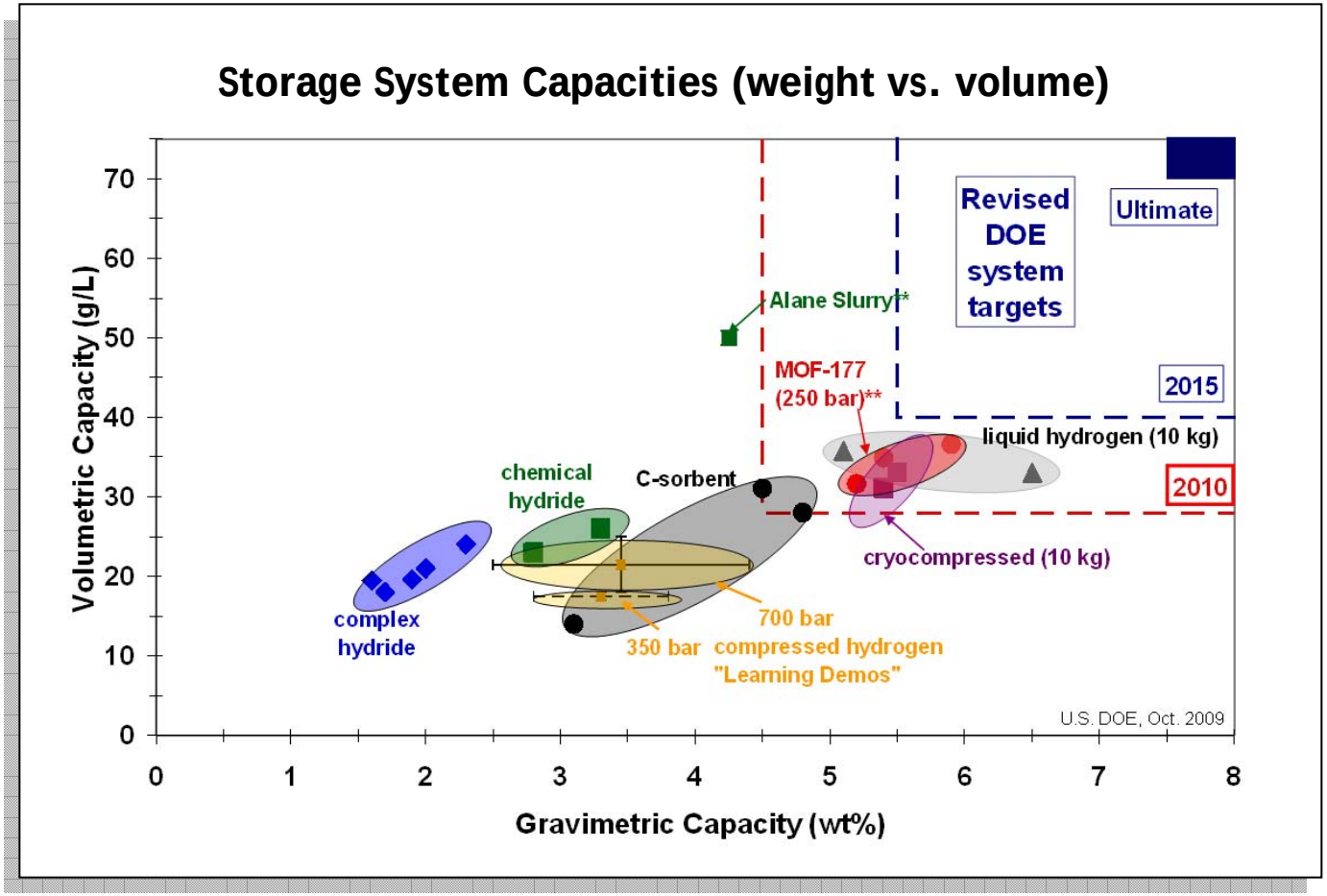
LONGER TERM:
Centralized Production

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



* Distributed status and targets assume station capacities of 1500 kg/day, with 500 stations built per year. Status and targets for centralized production assume the following production capacities: biomass gasification—155,000 to 194,000 kg/day; central wind electrolysis—50,000 kg/day; coal gasification—308,000 kg/day; nuclear—768,000 kg/day; and solar high-temperature thermochemical—100,000 kg/day.

Storage R&D



- Assessed and updated targets as planned **— based on real-world experience with vehicles, weight and space allowances in vehicle platforms, and needs for market penetration**
- Developed and evaluated more than 350 materials approaches
- Launched the Storage Engineering Center of Excellence **— to address systems integration and prototype development; efforts coordinated with materials centers of excellence**

Technology Validation

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

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

DOE Vehicle/Infrastructure Demonstration

Four teams in 50/50 cost-shared projects with DOE



- **140 fuel cell vehicles and 20 fueling stations demonstrated**
- **> 2.2 million miles traveled, > 90,000 kg H_2 produced & dispensed**
- **Analysis by NREL shows:**
  - **Efficiency:** 53 – 58% **(>2x higher than gasoline engines)**
  - **Range:** ~196 – 254 miles
  - **Fuel Cell System Durability:** ~ 2,000 hrs **(~60,000 miles)**

Demonstrations of Specialty Vehicles: *NREL is collecting operating data from federal deployments and Recovery Act projects—to be aggregated, analyzed, and reported industry-wide.*

→ **Will include data such as:** reliability & availability; time between refueling; operation hours & durability; efficiency; H_2 production; refueling rate; costs (installation, operation, and lifecycle); and others.

→ 40 forklifts at a Defense Logistics Agency site have already completed 7,000 refuelings in 7 months.

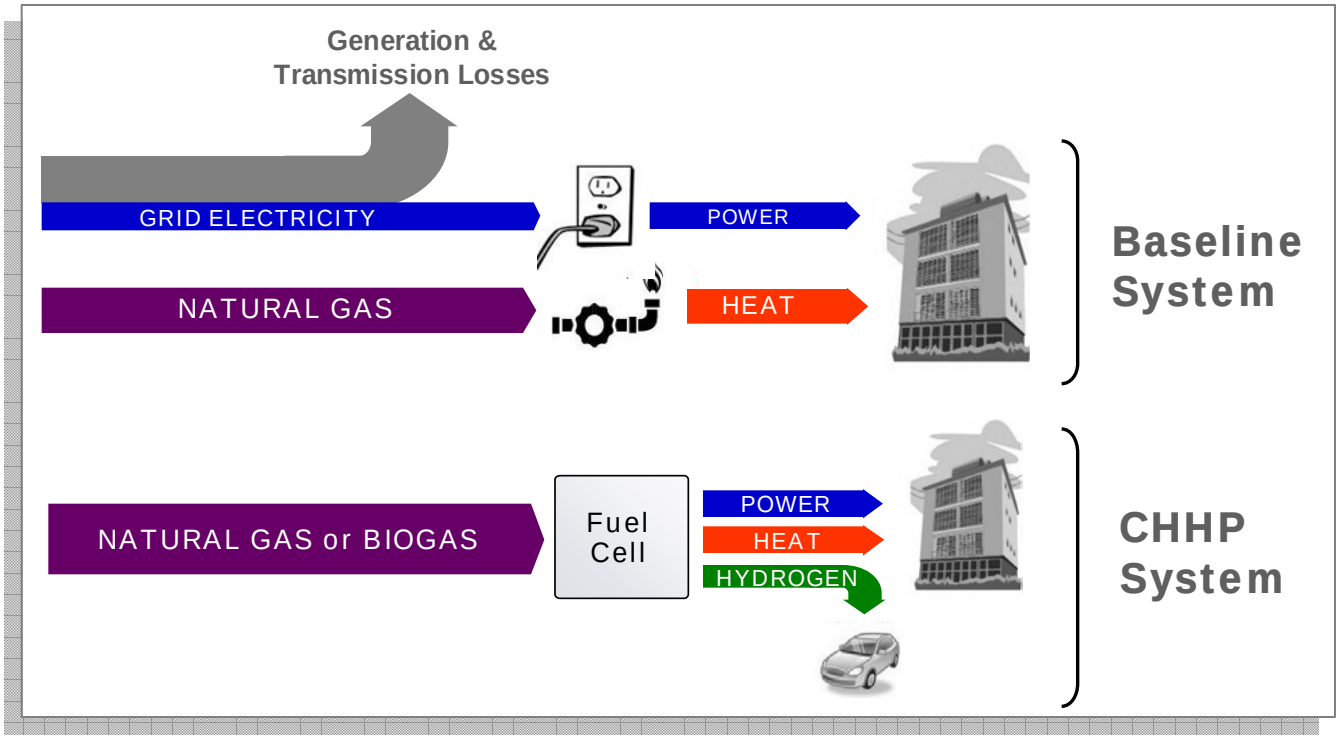
Other Demonstrations: *DOE is also evaluating real-world bus fleet data (DOD and DOT collaboration) and demonstrating stationary fuel cells — e.g., tri-generation (combined heat, hydrogen & power w biogas).*

Technology Validation – *Tri-Gen Highlight*

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

We are participating in a project to demonstrate a combined heat, hydrogen, and power system using biogas.

- **System has been designed, fabricated and shop-tested.**
- **Improvements in design have led to higher H_2-recovery (from 75% to >85%).**
- **On-site operation and data-collection planned for FY09 – FY10.**



Combined heat, hydrogen, and power systems (CHHP) can:

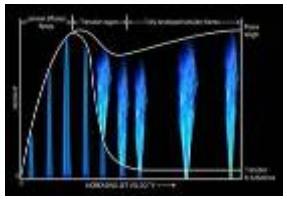
- ***Produce clean power and fuel for multiple applications***
- ***Provide a potential approach to establishing an initial fueling infrastructure***

Safety, Codes & Standards *and* Education

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

Safety, Codes & Standards

- ***Facilitating the development & adoption of codes and standards for fuel cells***
- ***Identifying and promoting safe practices industry-wide***



ACTIVITIES

Develop data needed for key codes & standards (C&S)

Harmonize domestic and international C&S

Simplify permitting process

Promote adoption of current C&S and increase access to safety information

PROGRESS *(key examples)*

Published Web-based resources, including: *Hydrogen Safety Best Practices Manual; Permitting Hydrogen Facilities*

Through R&D, enabled harmonized domestic and international Fuel Quality Specifications

Developed safety course for researchers and hands-on training for emergency responders

Growing number of C&S published

Education: ***We are working to increase public awareness and understanding of fuel cells.***

ACTIVITIES

Educate key audiences to facilitate demonstration, commercialization, and market acceptance

PROGRESS *(key examples)*

Launched courses for code officials and first responders (>7000 users)

Conducted seminars and developed fact-sheets and case studies for end-users

Conducted workshops to help state officials identify deployment opportunities

Market Transformation activities seek to overcome barriers to commercialization

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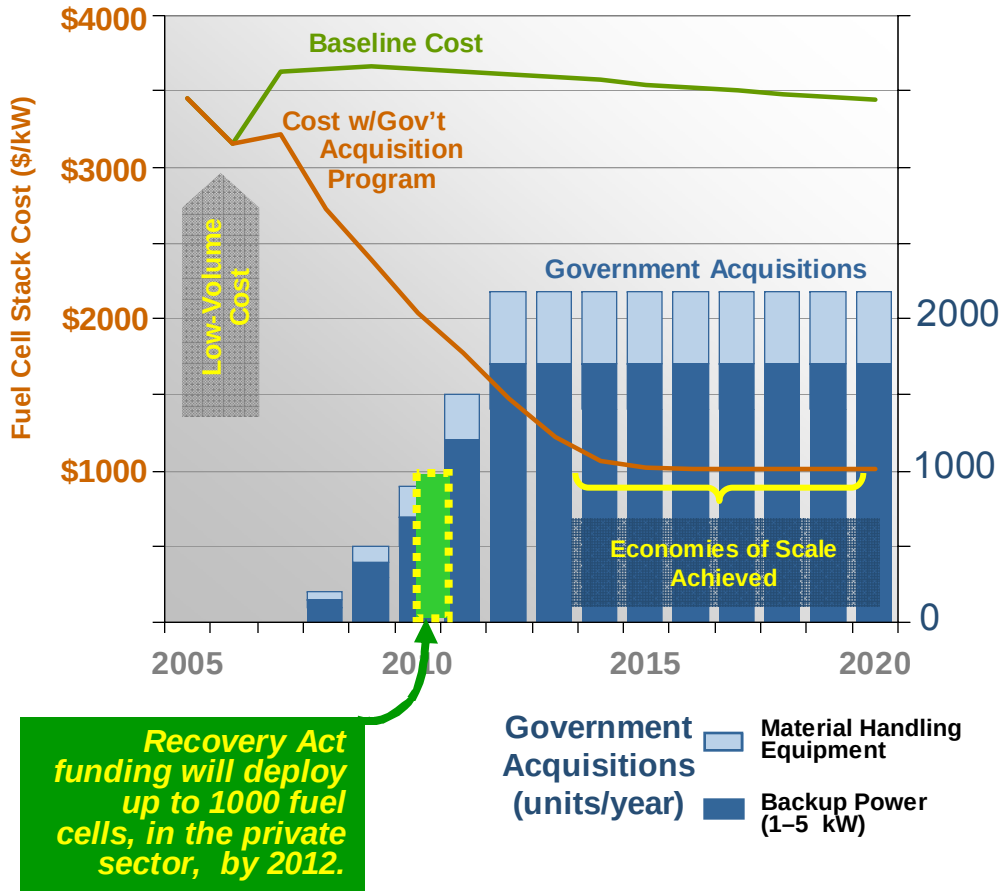
	BARRIERS
Market/Industry	Lack of domestic supply base and high volume manufacturing. Estimated backlog > 100 MW
	Low-volume capital cost is >2-3x of targets
	Policies — e.g., many early adopters not eligible for $3,000/kW tax credit
Delivery Infrastructure	Significant investment needed—~$55B gov't funding required over 15 years for ~5.5M vehicles ($~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	>7,000 teachers trained; online tools average 300-500 visits/month, but 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

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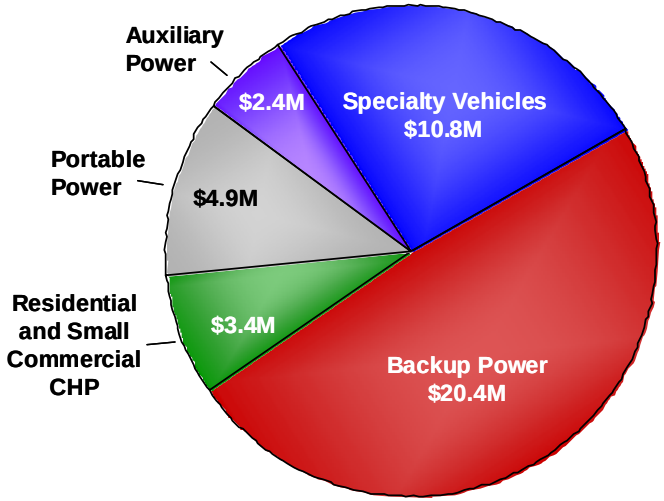
DOE announced $41.9 million from the American Recovery and Reinvestment Act to fund 13 projects to deploy more than 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

FROM the LABORATORY to DEPLOYMENT:

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



Approximately $72 million in cost-share proposed by industry participants—for a total of nearly $114 million.

COMPANY	AWARD	APPLICATION
Anheuser-Busch	$1.1 M	Specialty Vehicle
Delphi Automotive	$2.4 M	Auxiliary Power
FedEx Freight East	$1.3 M	Specialty Vehicle
GENCO	$6.1 M	Specialty Vehicle
Jadoo Power	$1.8 M	Backup Power
MTI MicroFuel Cells	$2.4 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
PolyFuel, Inc.	$2.5 M	Portable
ReliOn Inc.	$8.6 M	Backup Power
Sprint Comm.	$7.3 M	Backup Power
Sysco of Houston	$1.2 M	Specialty Vehicle

New and Expanded Policy Mechanisms

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

Some tax credits affecting fuel cells have recently been expanded. Through new financing mechanisms, these credits can help facilitate federal deployments.

Hydrogen Fueling Facility Credit	**Increases the hydrogen fueling credit from 30% or $30,000 to 30% or $200,000.**
Grants for Energy Property in Lieu of Tax Credits	**Allows facilities with insufficient tax liability to apply for a grant instead of claiming the Investment Tax Credit (ITC) or Production Tax Credit (PTC). Only entities that pay taxes are eligible.**
Manufacturing Credit	**Creates 30% credit for investment in property used for manufacturing fuel cells and other technologies**
Residential Energy Efficiency Credit	**Raises ITC dollar cap for residential fuel cells in joint occupancy dwellings to $3,334/kW.**
Fuel Cell Investment Tax Credit	**Increases the investment tax credit to 30%, up to $3,000/kW for business installations, and extends the credit from 2008 to 2016.**

Key Partnerships

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

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*
- **Industry Associations:** *US Fuel Cell Council, National Hydrogen Association*

INTERNATIONAL PARTNERSHIPS

International Partnership for the Hydrogen Economy—
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***

U.S. - EC Collaboration

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

Past and Existing Collaboration

- DOE-EC Science and Technology Agreement
- IEA Hydrogen and Advanced Fuel Cells Implementing Agreements
- IPHE
- Information Exchange and Cross Participation in Peer Reviews
- Technical collaborations in safety, codes & standards, hydrogen production, storage, fuel cells, and analysis.

Potential Future Collaboration

- Cross-participation in project solicitations
- Data exchange on projects (e.g., energy storage)
- Collaboration on technology readiness levels and targets
- Lessons learned on market transformation and policies
- Increase collaboration on analysis (e.g, CO_2 reduction potential)

Summary

- Hydrogen and fuel cells are part of a diverse portfolio of strategies to address both stationary and transportation applications.
- RD&D has resulted in significant progress- future work is still needed and will continue.
- "Market transformation" activities will help to:
  - *Achieve and build upon synergies between the stationary and transportation sectors*
  - *Accelerate cost reduction*
  - *Promote consumer acceptance*
  - *Establish domestic supply and manufacturing base and increase employment opportunities*
  - *Acquire operational data and validate progress toward targets.*

Key Program Documents

Fuel Cell Program Plan

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

→ ***Replacement for current* Posture Plan**

→ ***To be released in early 2010***

Annual Merit Review & Peer Evaluation Report

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

→ ***Next edition to be published in Fall 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

→ ***Next edition to be published in Fall 2009***

www.hydrogen.energy.gov/annual_progress.html

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

Next Annual Review: June 7 – 11, 2010

Washington, D.C.

http://annualmeritreview.energy.gov/

www.hydrogen.energy.gov

www.hydrogenandfuelcells.energy.gov

Thank you

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