U.S. DEPARTMENT OF ENERGY

Hydrogen Program Overview

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2009 DOE Hydrogen Program and Vehicle Technologies Program

Annual Merit Review and Peer Evaluation Meeting

May 18, 2009

- Overview & Challenges
- Progress & Accomplishments
- A New Direction for the Program

Key Challenges

The Program has been working to address a number of key challenges facing the widespread commercialization of hydrogen and fuel cells.

Technology Barriers

Fuel Cell Cost & Durability

Targets:

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

Vehicles: **$30 per kW, 5000-hr durability**

Hydrogen Cost

Target: $2 – 3 /gge

Hydrogen Storage Capacity

Greater than 300-mile range, without reducing interior space or compromising performance

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Hydrogen Supply & Delivery Infrastructure

Domestic Manufacturing & Supplier Base

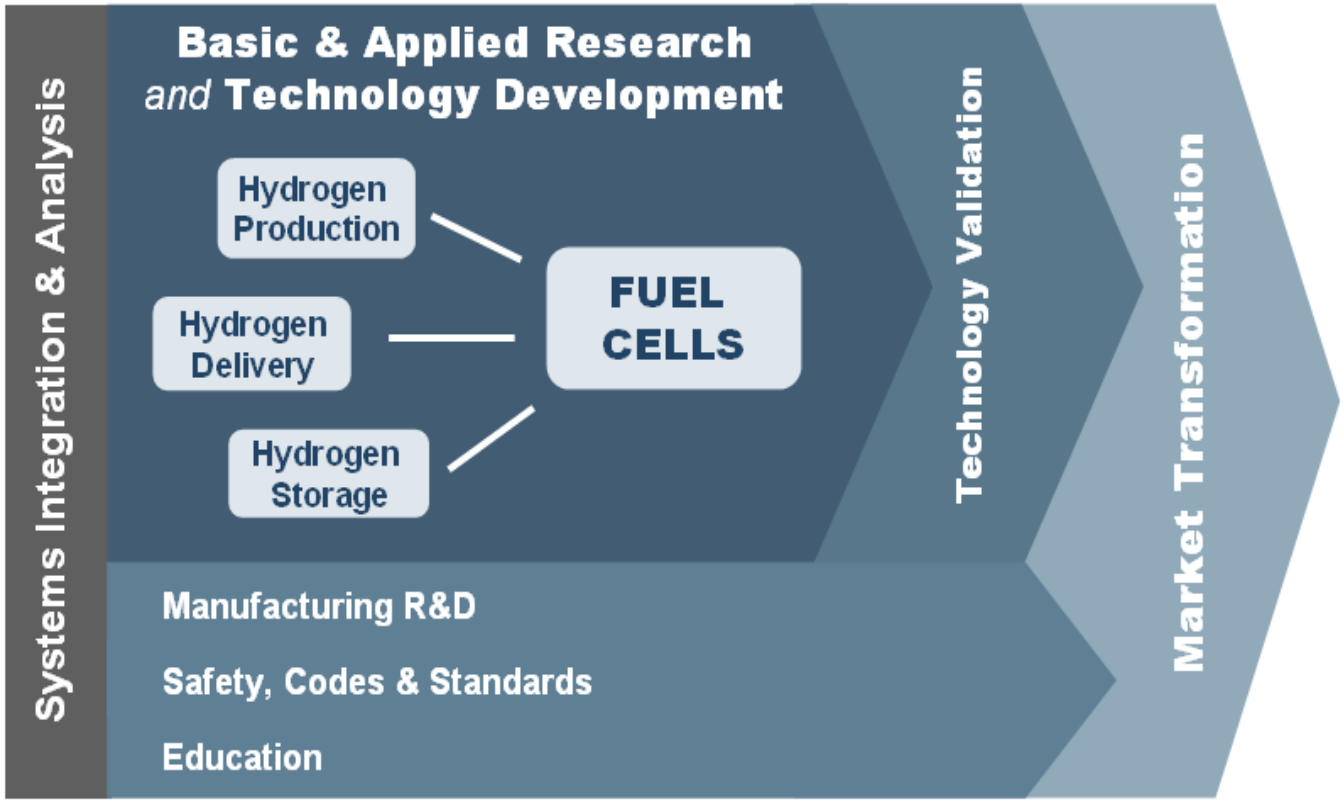
Public Awareness & Acceptance

Market Transformation

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

Program Structure

The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



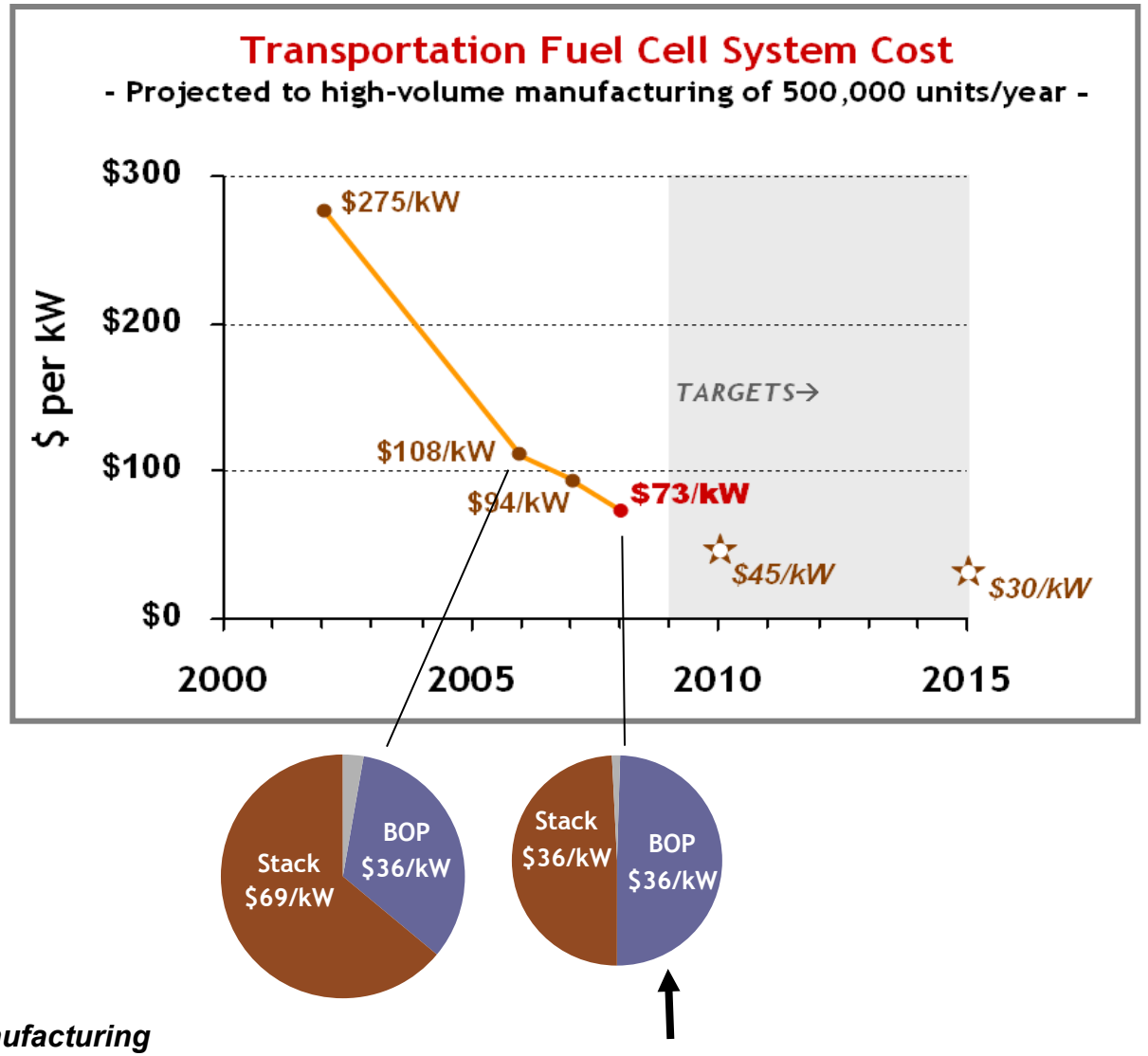
Widespread Commercialization

The DOE Hydrogen Program includes activities within the Offices of Energy Efficiency & Renewable Energy, Fossil Energy, Nuclear Energy, and Science.

Fuel Cell R&D — *Progress*

We've reduced the cost of fuel cells to $73/kW*

- ***Cost projection validated by independent panel*****
- ***More than 20% reduction in one year***
- ***Nearly 75% reduction since 2002***



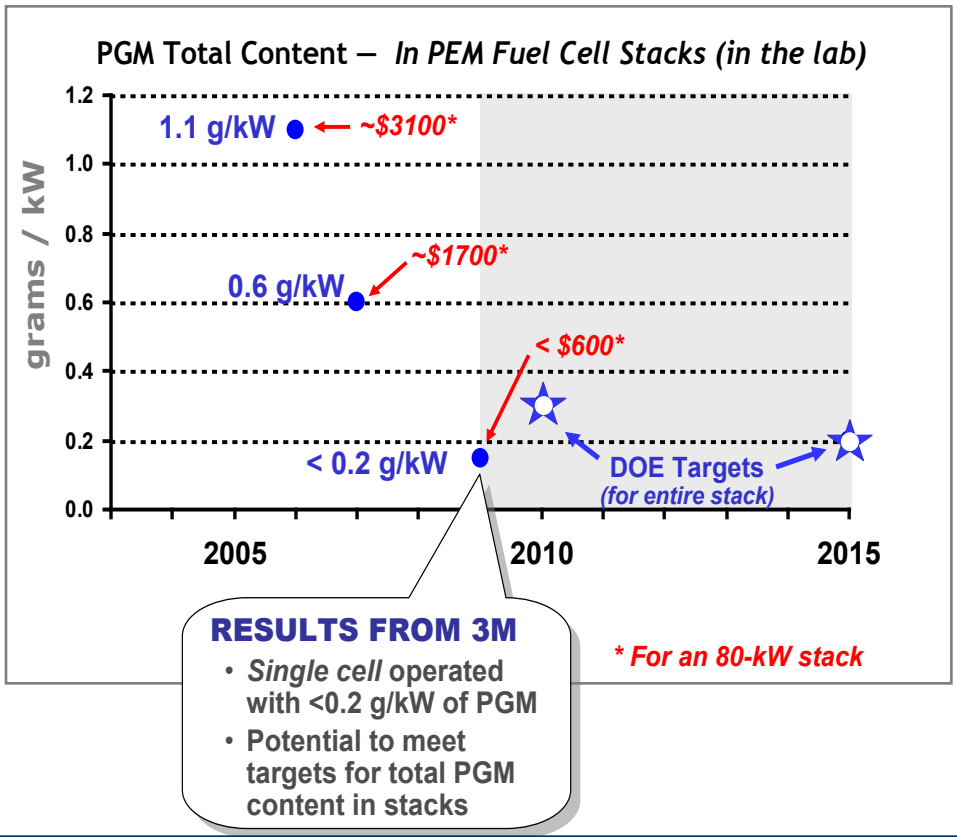
As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs.

**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*

Fuel Cell R&D — *Accomplishments*

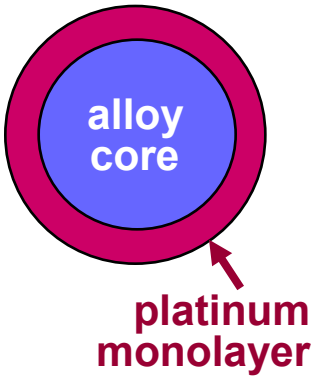
Reducing Cost: *Catalyst research has reduced platinum group metal (PGM) content.*

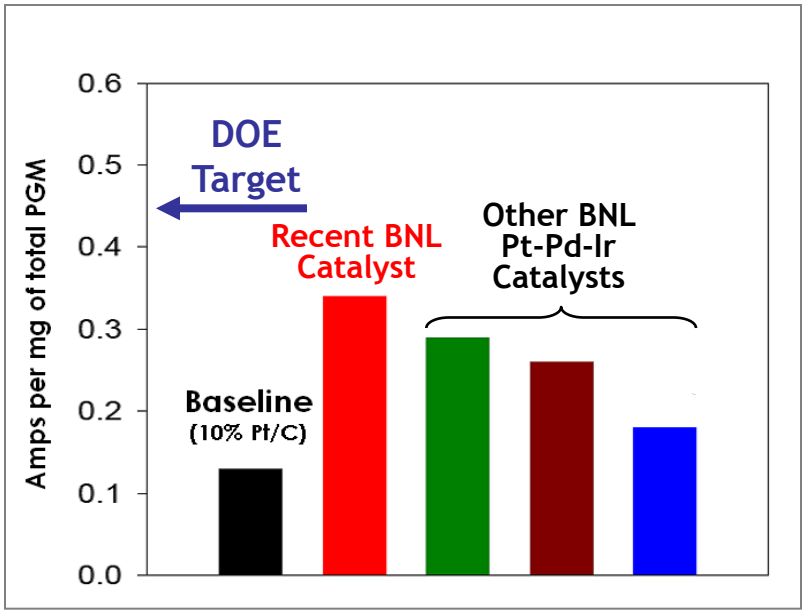


Demonstrated MEA with > 7,300-hour durability with cycling, exceeding 5,000-hr target (3M).

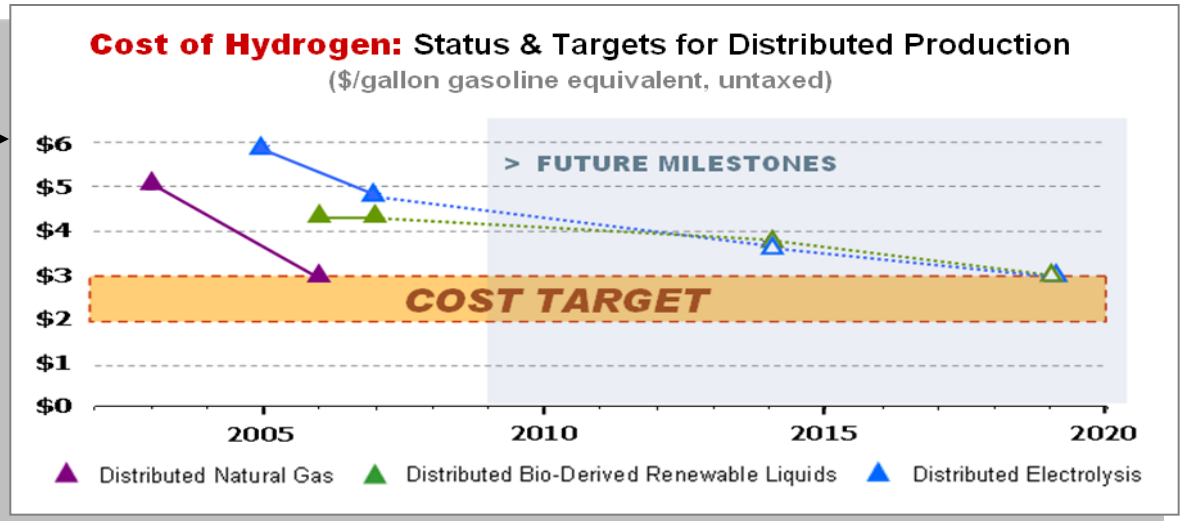
Improving performance *and* **reducing cost** *with innovative, low-Pt catalysts*

Developed core-shell catalyst with 2.5x higher activity than baseline, and uses less platinum *(Brookhaven National Lab)*





We've reduced the cost* of hydrogen from multiple sources.



**projected cost, assuming 1500 kg/day, 500 units/year*

RECENT ACCOMPLISHMENTS

***BIO-DERIVED LIQUIDS** (UTRC, PNNL):*

- Achieved 95% conversion of cellulosic biomass & 74% H_2 yield by aqueous phase reforming
- Increased H_2 yields to more than 92% from vapor phase reforming

***ELECTROLYSIS** (Giner):*

- Improved durability (45,000 – 55,000 hrs, projected)
- Increased stack efficiency to 72% with improved membrane

***HIGH-TEMPERATURE ELECTROLYSIS – Nuclear** (INL):*

- Exceeded expected production rate by more than 10% (achieved peak output of 0.5 kg/hr at 18kWe)

***HYDROGEN FROM COAL** (Eltron, SWRI):*

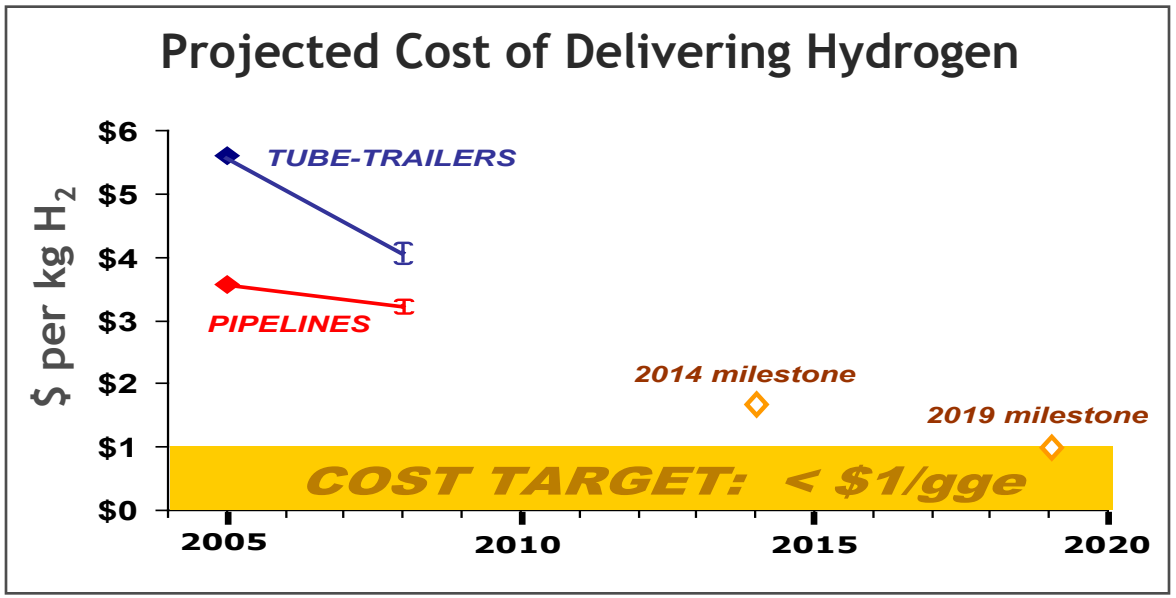
- Demonstrated membranes that meet 2010 targets, at lab-scale

H_2 Delivery R&D — *Progress & Accomplishments*

We've reduced the cost of hydrogen delivery* —

~30% reduction in tube trailer costs

>10% reduction in pipeline costs



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

RECENT ACCOMPLISHMENTS

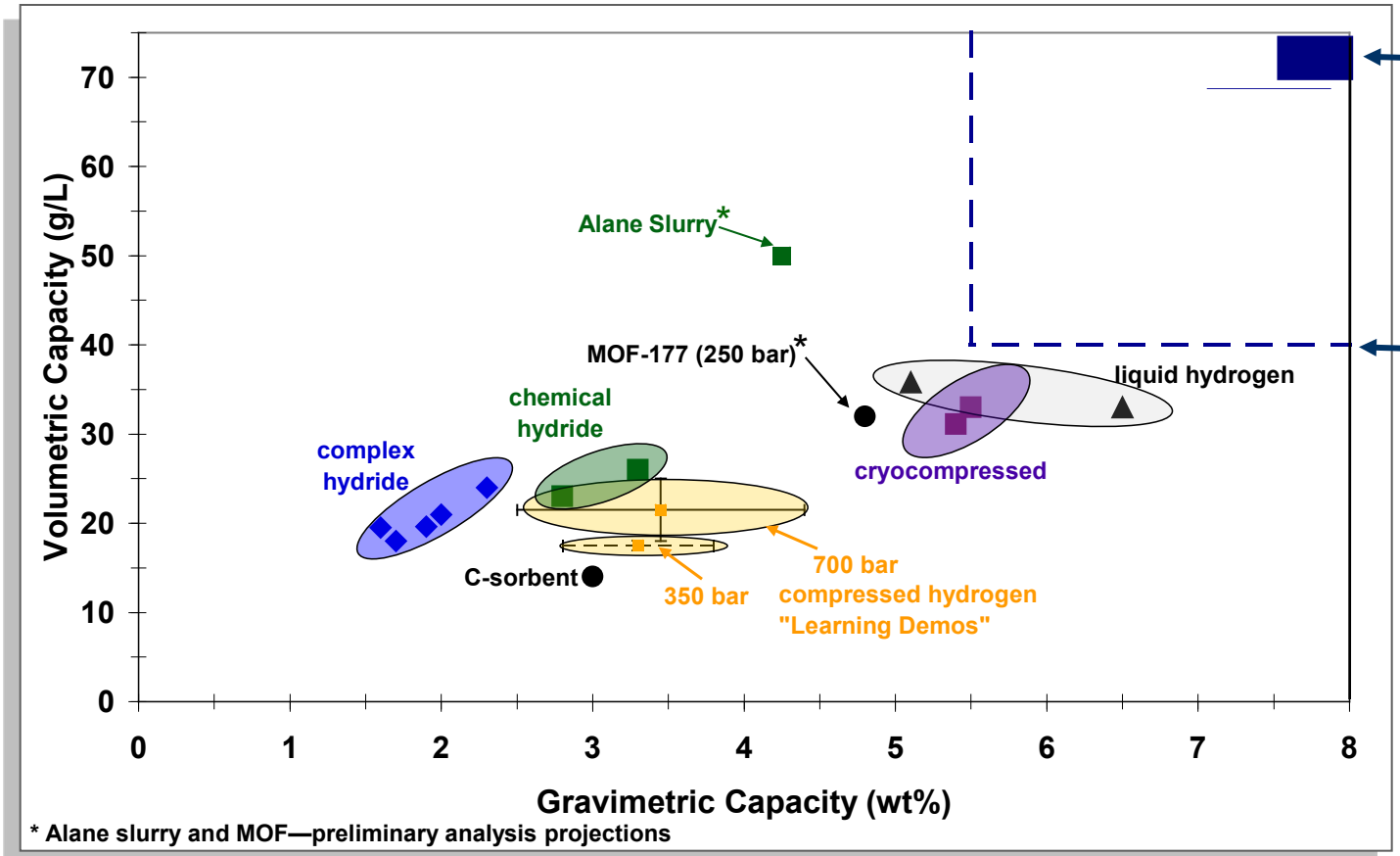
TUBE TRAILERS (Lincoln Composites, LLNL)

- **Doubled H_2 capacity (from 300kg to 600kg),** using new manufacturing technique to enable higher pressures in carbon fiber.
- Demonstrated potential to **nearly triple capacity** using glass fibers instead of carbon fiber.

DELIVERY ANALYSIS (ANL, LLNL & partners)

- Evaluated cryo-pump technology—results show the potential to **reduce station costs by 70%.**

H_2 Storage R&D — *Status & Accomplishments*



New "ultimate" targets

7.5 wt%, 70 g/L

Revised 2015 targets

5.5 wt%, 40 g/L

- **Assessed and updated targets as planned** (based on real-world experience with vehicles, weight & space in vehicle platform, and needs for market penetration)
- **Developed and evaluated more than 200 materials approaches**
- **Launched New Storage Engineering Center of Excellence** to address systems integration and prototype development—efforts coordinated with materials centers

Technology Validation — *Accomplishments*

DOE Vehicle/Infrastructure Demonstration

(four teams in 50/50 cost-shared projects with DOE Vehicle Technologies Program)

Validated performance in 140 fuel cell vehicles and 20 hydrogen stations:

More than 1.9 million miles traveled and 90,000 kg hydrogen produced/dispensed (Analysis by NREL)

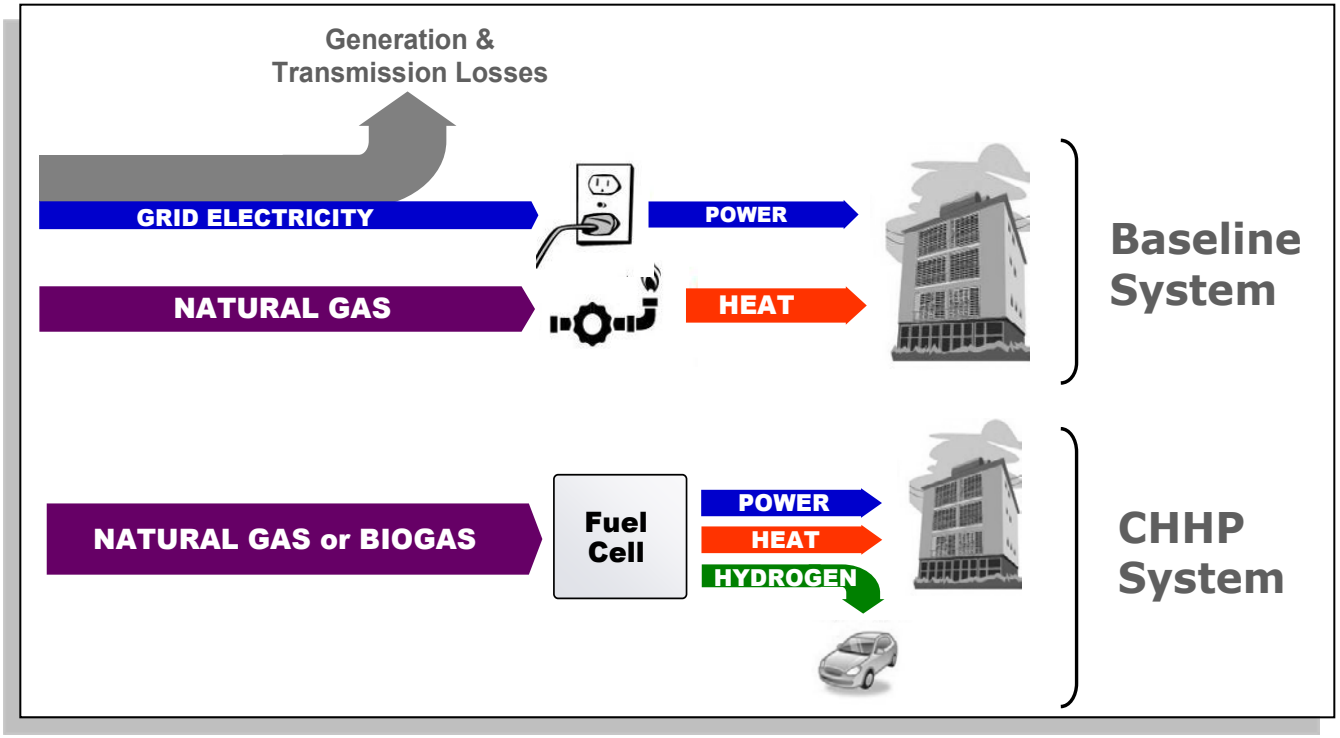
- **EFFICIENCY: 53 – 58%** (>2x higher than gasoline internal combustion engines)
- **RANGE: ~196 – 254 miles**
- **FUEL CELL SYSTEM DURABILITY:**
  - **Nearly 2,000 hrs (~60,000 miles)**

Evaluating real-world forklift and bus fleet data (DOD and DOT collaboration)

Potential Early Market Application — *CHHP Accomplishments*

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***



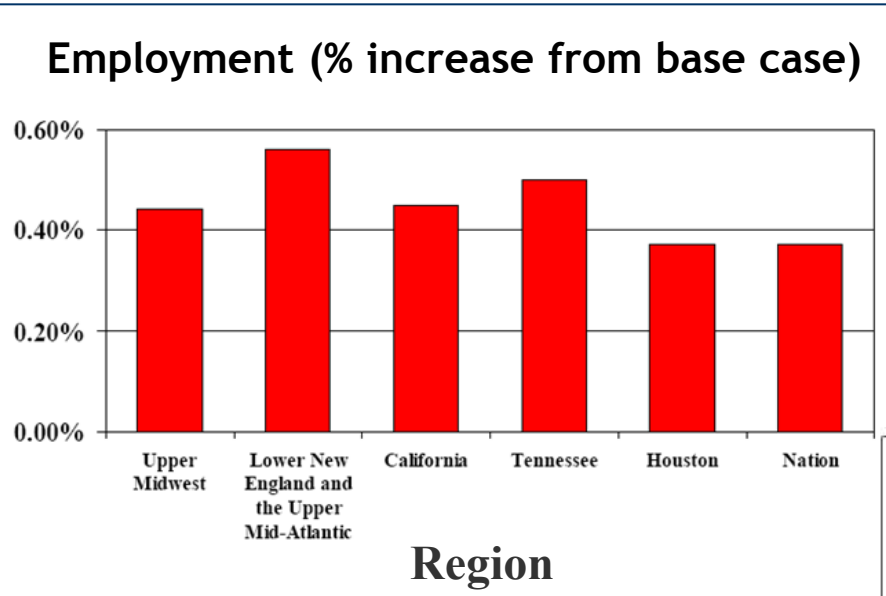
CHHP Project is Underway:

Orange County Sanitation District in Fountain Valley, CA—Air Products & FuelCell Energy

- **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.**

Systems Analysis — *Accomplishments*

Systems Analysis continues to provide data on costs & benefits of fuel cell technologies.



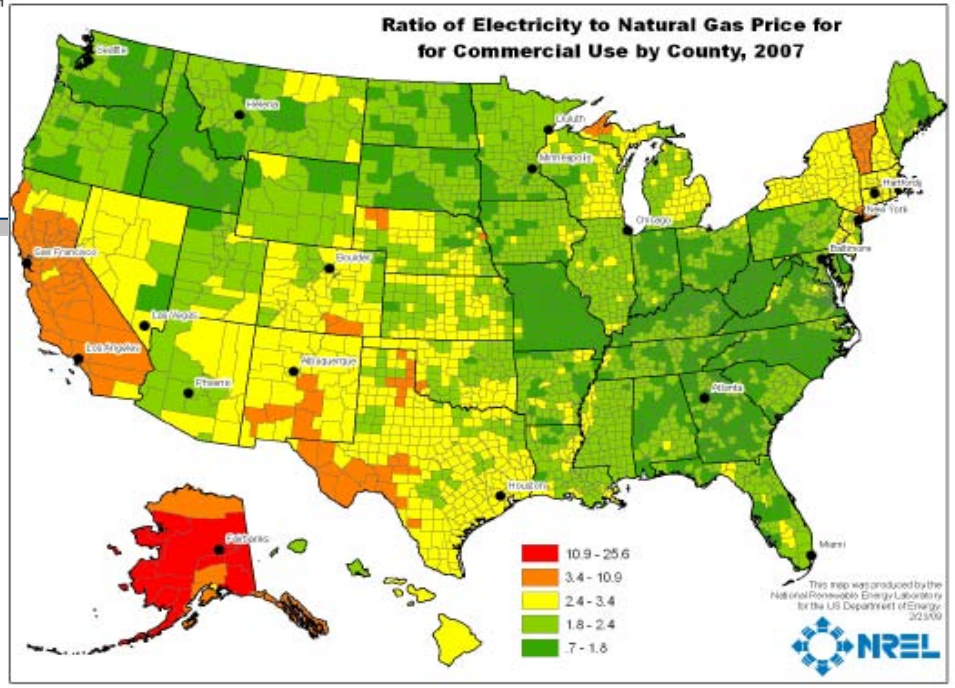
www.hydrogen.energy.gov/pdfs/epact1820_employment_study.pdf

New resources include:

- ***Updated well-to-wheels emissions & petroleum use results***
- ***Employment Study***
- ***Analysis of costs of tri-generation of hydrogen, heat, and power***

Analysis shows potential for 360,000 – 675,000 new jobs from growth of hydrogen and fuel cell industries, across 41 industries.

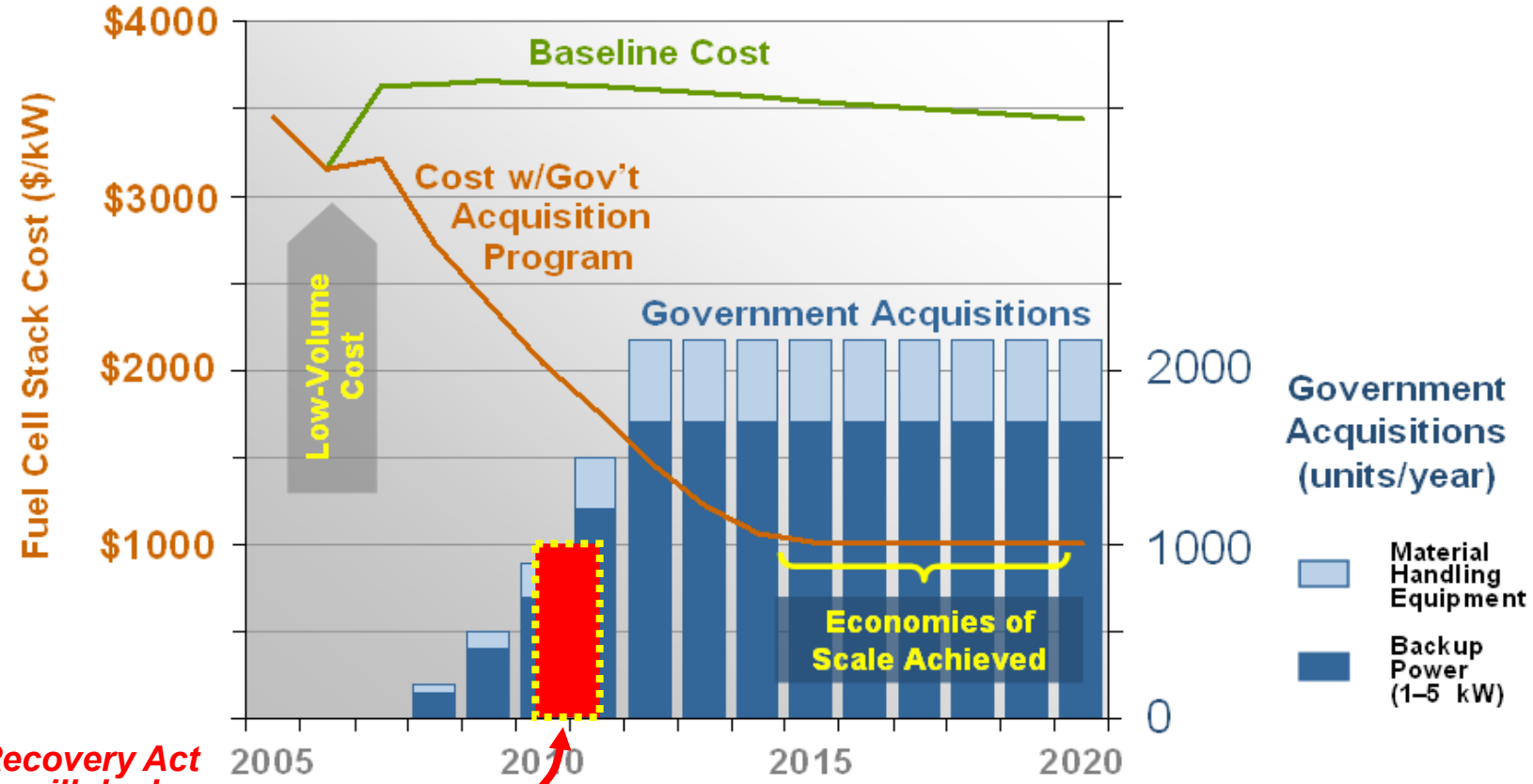
Preliminary analysis shows areas where fuel cells for CHP can be cost-competitive.



Market Transformation

Government acquisitions could significantly reduce the cost of fuel cells through economies of scale, and help to support a growing supplier base.

Impact of Government Acquisitions on Fuel Cell Stack Costs (for non-automotive fuel cells)



Recovery Act funding will deploy up to 1000 fuel cells, in the private sector, by 2012.

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.

Federal Interagency Coordination

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

***Also coordinates codes & standards activities within Dept. of Transportation**

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

Market Transformation

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

RECENT ACCOMPLISHMENTS
Leveraging federal collaborations

4 interagency agreements under development

- Deployment of up to 100 fuel cells underway
- Army Construction Engineering Research Lab, Federal Aviation Administration, Department of Homeland Security, Office of Naval Research

Developed Investment Tax Credit fact sheet and case studies

Identifying locations for fuel cells across federal facilities

40 fuel cell forklifts are in operation at the Defense Logistics Agency, Defense Depot Susquehanna, PA.

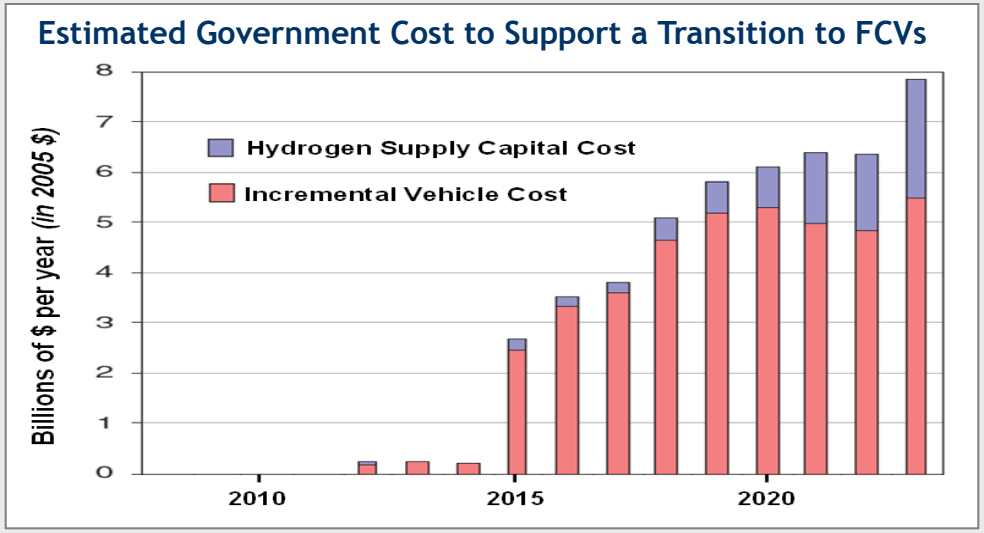
The Program and DOE are working with the Treasury Department on the "grant in lieu of a tax credit" option for installing and using energy efficient and renewable energy systems—including FUEL CELLS. Final guidance expected ~ July 2009.

Independent Assessments

Recent independent analyses assess technology status, expected costs and benefits, and effectiveness of the Program.

National Academies Study[1]

- By 2050, a portfolio of technologies—including FCVs—could eliminate petroleum use by light-duty vehicles (LDVs) and reduce CO_2 emissions from LDVs to 20% of current levels.
- FCVs could reach 2 million by 2020, 60 million by 2035, and 200 million by 2050.
- Transition cost to Govt: $55B ($40B vehicles, $10B infrastructure, $5B R&D from 2008 – 2023).
- Study is being updated to include impacts of PHEVs



[1]*Transitions to Alternative Transportation Technologies: A Focus on Hydrogen*

Independent Assessment of Fuel Cell System Cost

NREL convened independent experts to provide rigorous, unbiased analysis.

- **$60 – $80 per kW is a "valid estimation" of the potential manufactured cost for an 80-kW fuel cell system based on 2008 technology, extrapolated for high volumes (500,000 units/yr).**
- **Validates DOE estimate of $73/kW.**

www.hydrogen.energy.gov/peer_reviews.html

Independent Assessment of Electrolysis Cost

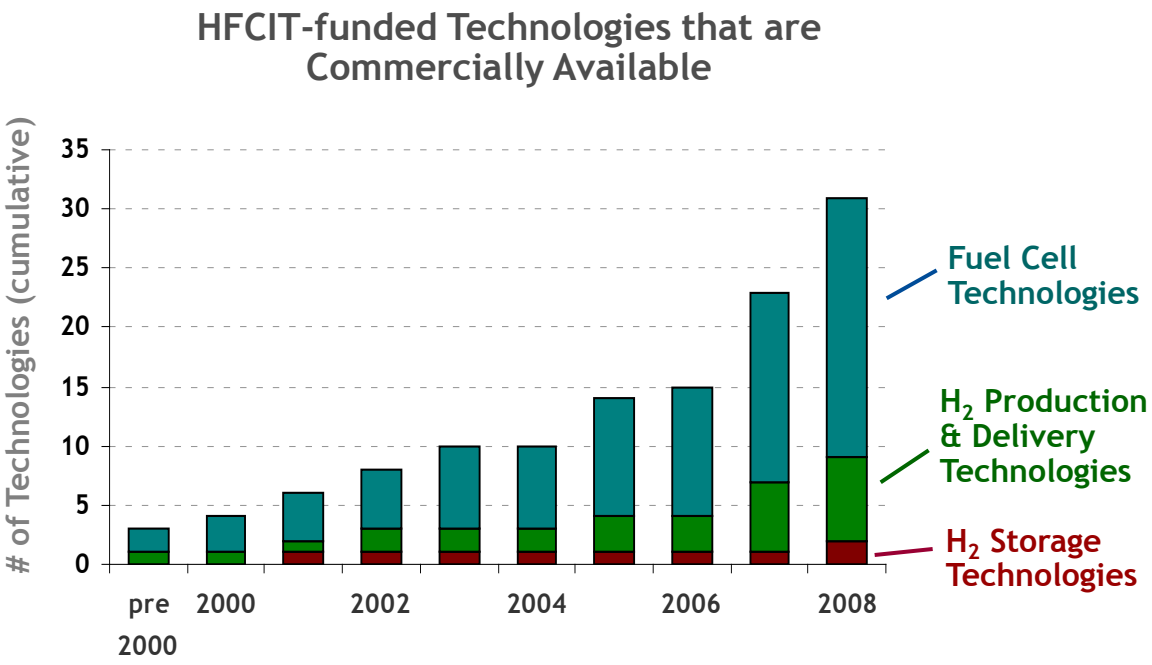
- **Preliminary analysis indicates ~$5 – $5.50/gge for H_2 from distributed electrolysis.**

Additional Tracking of Program Effectiveness

Pacific Northwest National Lab is tracking commercial successes of technologies developed by the Hydrogen, Fuel Cells and Infrastructure Technologies Program.

Accelerating Commercialization:

An increasing number of HFCIT-funded technologies have been entering the market.



PATENTS resulting from HFCIT-funded R&D:

118 patents reviewed:

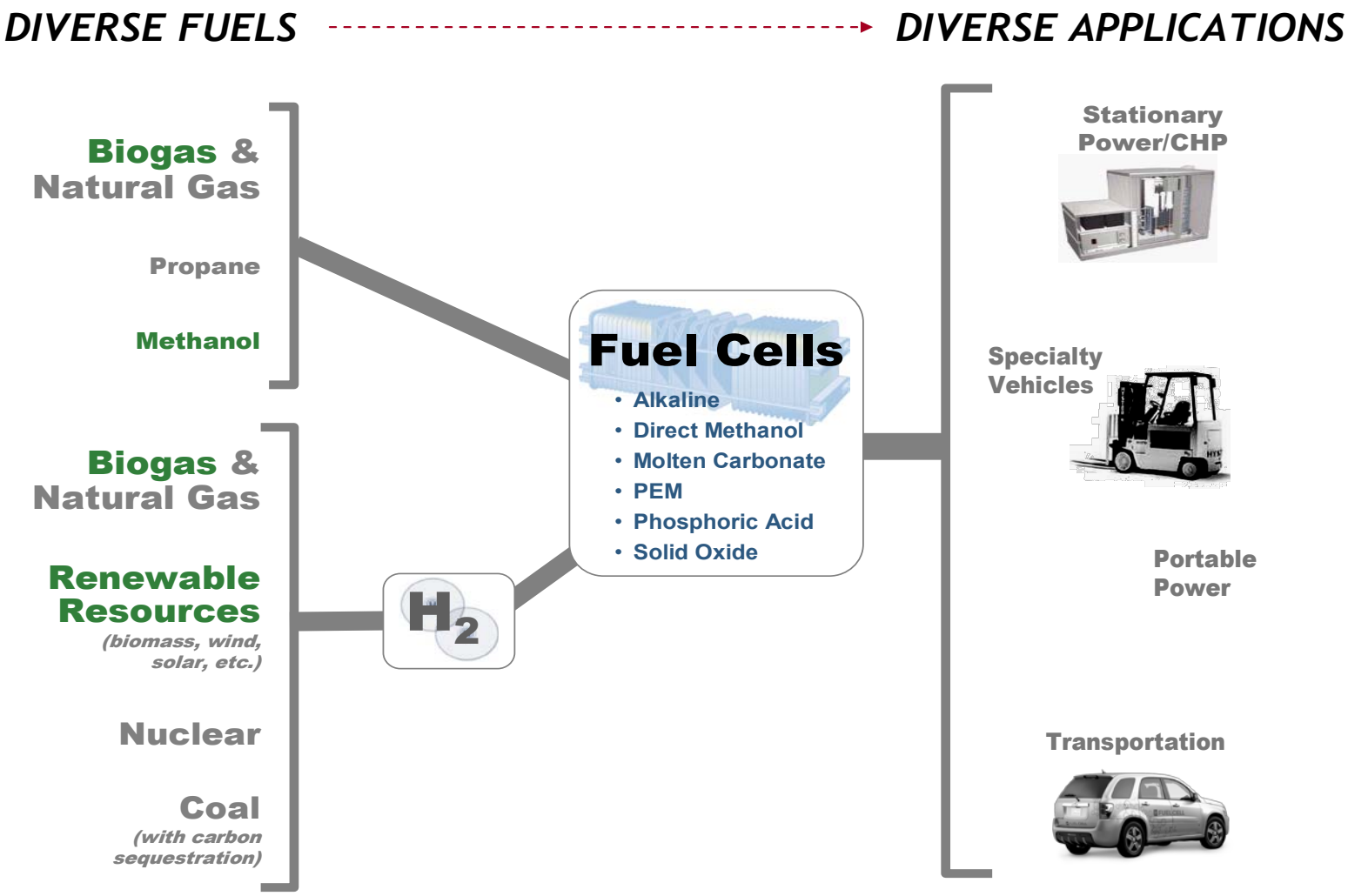
- 60 fuel cell patents
- 37 hydrogen production/delivery patents
- 21 storage patents

Results will be documented in a report:

"Pathways to Commercial Success: Technologies and Products Supported by the Hydrogen, Fuel Cell Infrastructure Technology Program"

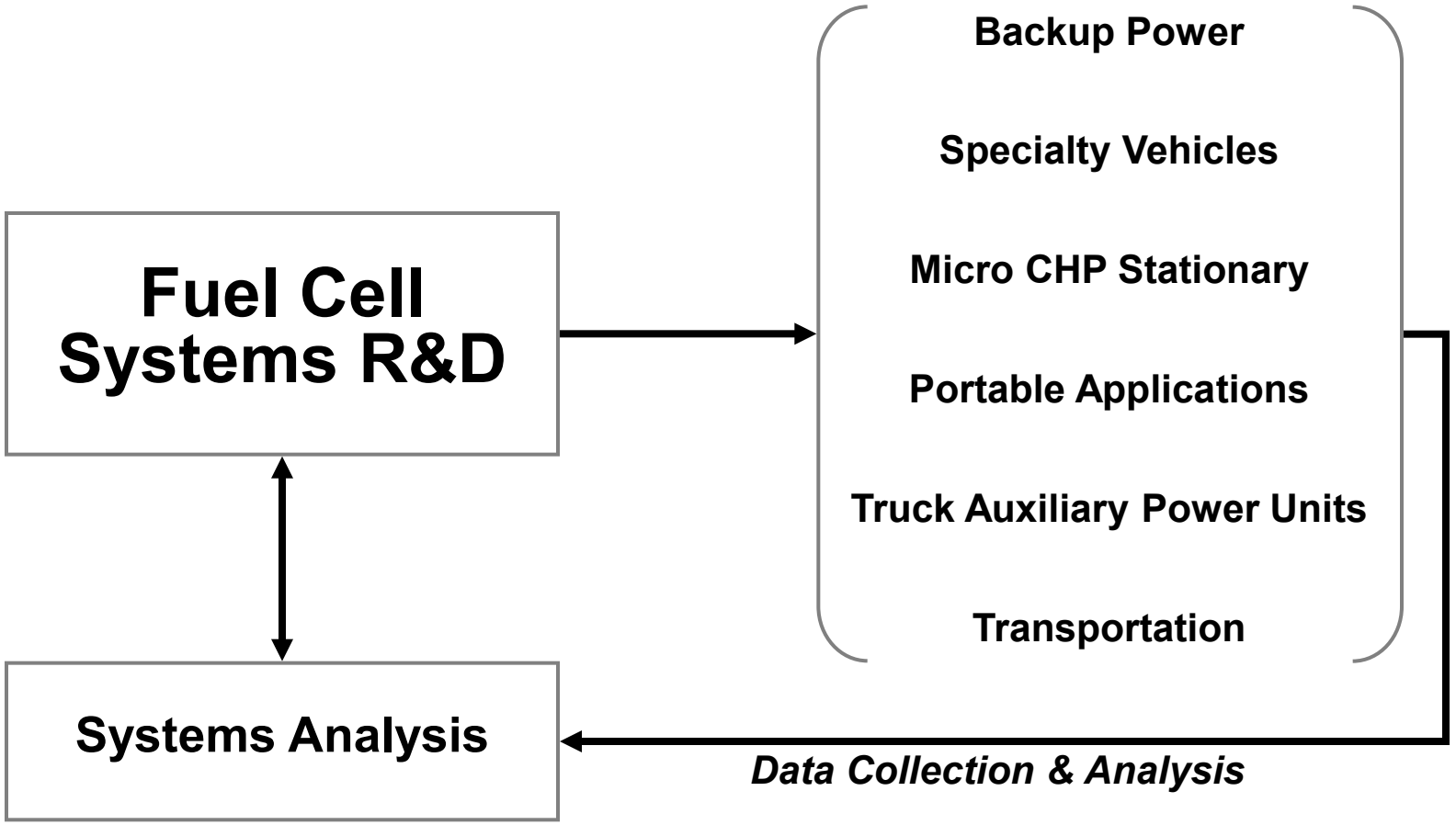
New Directions — *Balancing the Program*

The new Program is aligned with the Department's portfolio of technologies for nearer-term impact and improved energy efficiency using multiple fuels.



New Program Structure

The Program will refocus on technology-neutral Fuel Cell Systems R&D and Systems Analysis to prioritize research & quantify impacts/benefits.



New Directions — *Input on Targets*

Request for Information (RFI) on Targets for Combined Heat and Power (CHP) and Auxiliary Power Units (APUs)

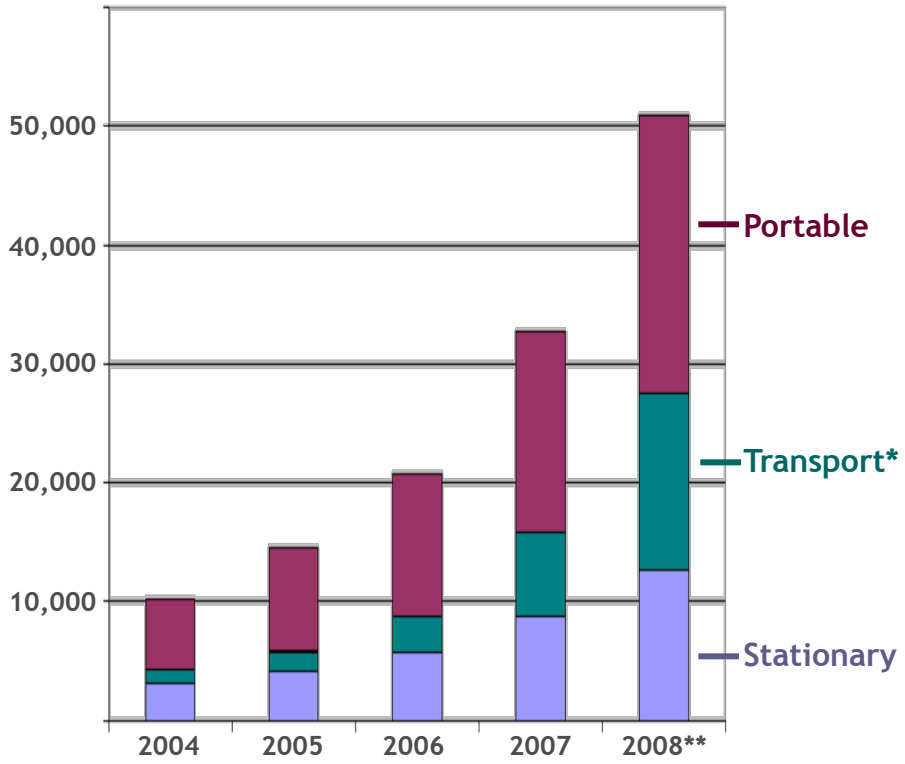
- **Opportunity for stakeholder and developer input**
- **Examples of information requested:**
  - ***Relevance of the proposed targets***
  - ***Recommendations for testing conditions and protocols***
  - ***Adequacy of target table explanations and/or need for additional supporting information***
  - ***Need for thermal cycling or on/off cycling durability targets***
  - ***Recommendations for additional targets***
  - ***Current status compared to targets & potential areas of R&D***

RFI to be posted online (www1.eere.energy.gov/hydrogenandfuelcells/)
Responses due June 30, 2009

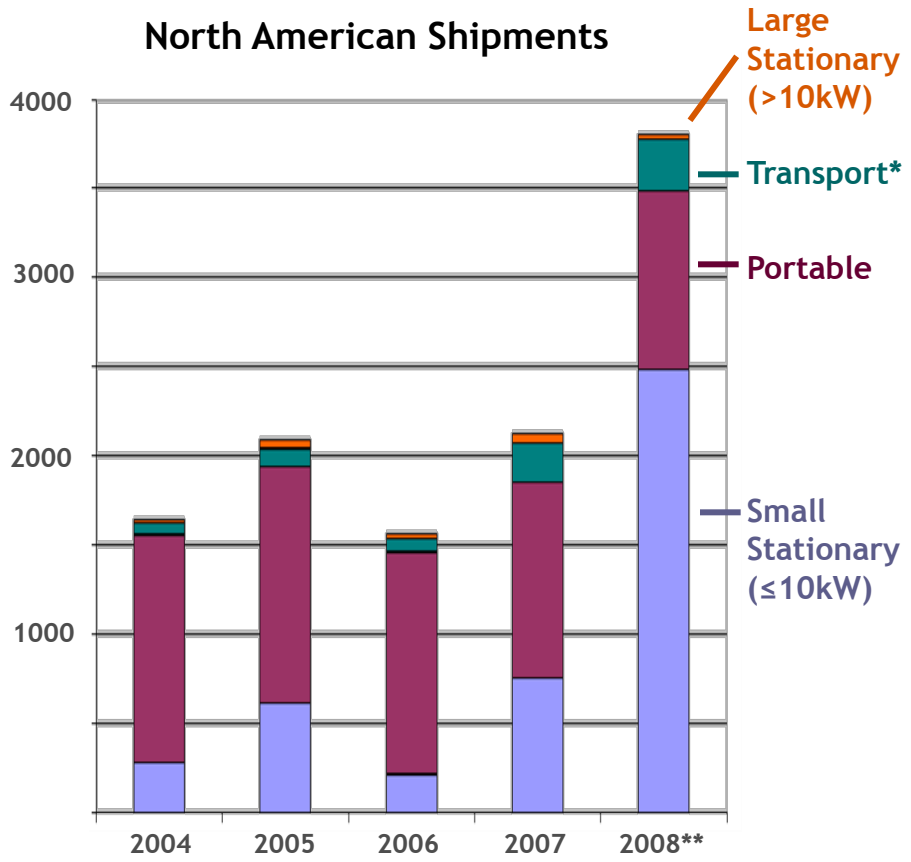
New Directions — *Growing Markets for Fuel Cells*

The fuel cell industry has seen growth of more than 50% annually over the past four years. Estimates show about 18,000 new units were shipped worldwide in 2008.

Cumulative Shipments Worldwide



North American Shipments



* "Transport" includes specialty vehicles (e.g., forklifts) and auxiliary power units, which currently account for most of the sales in that sector.

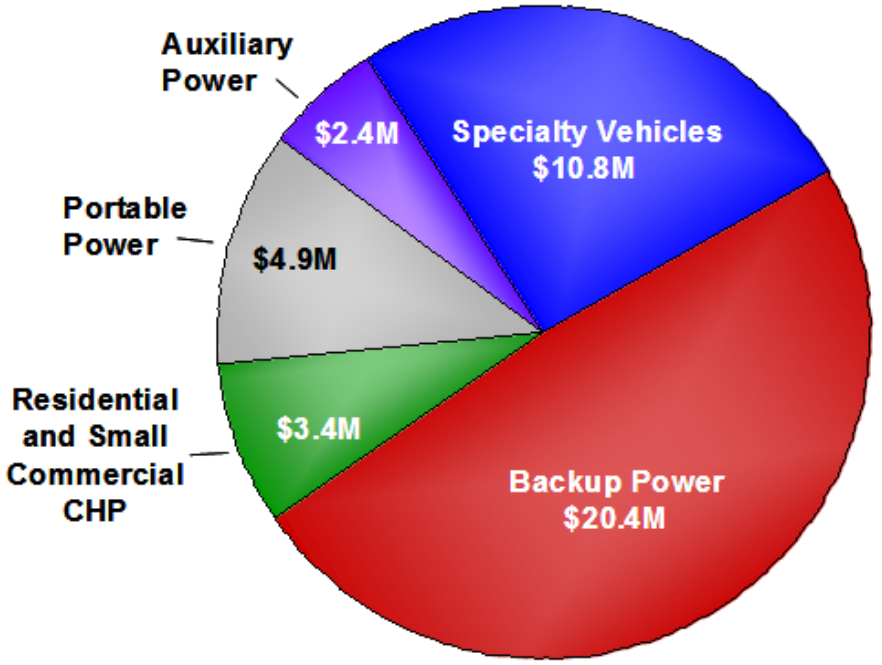
** 2008 numbers are preliminary estimates.

Source: Fuel Cell Today

Recovery Act Funding for Fuel Cells

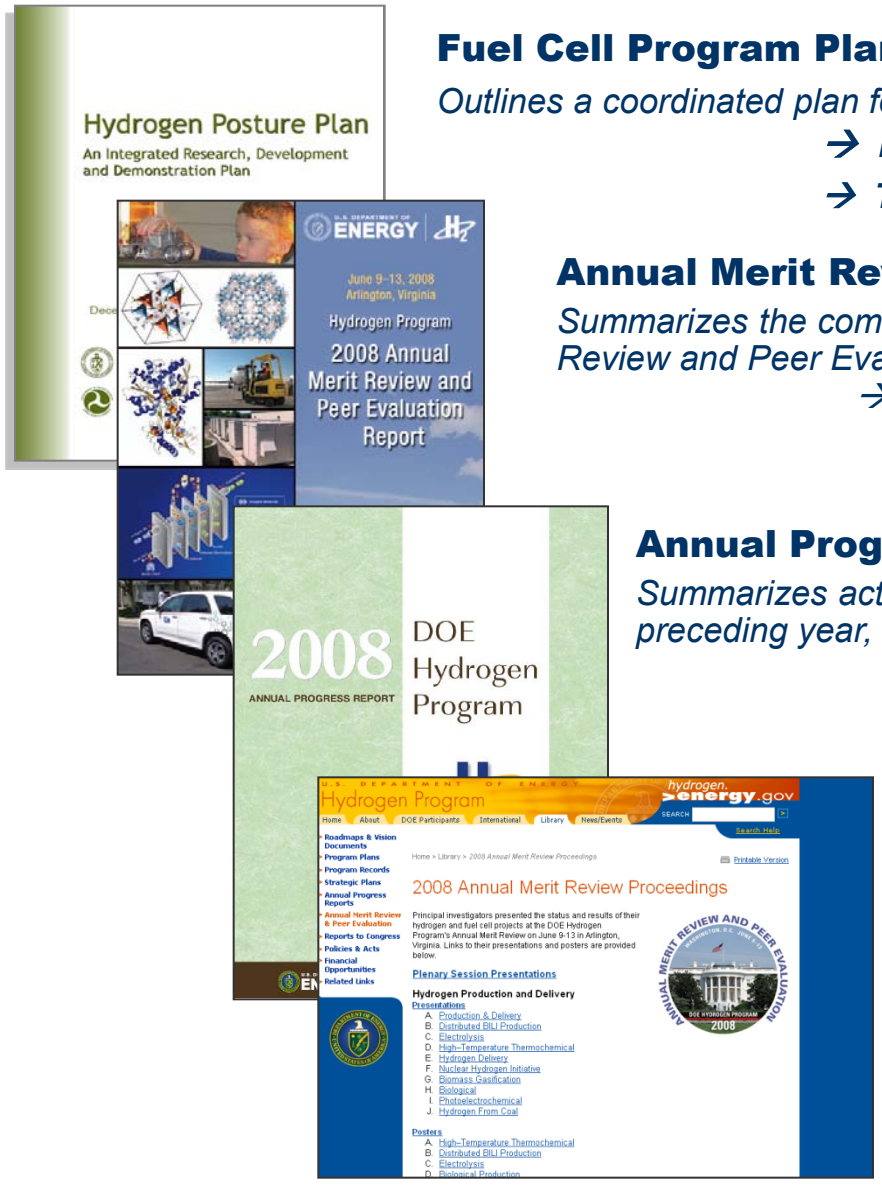
DOE announced $41.9 million from the American Recovery and Reinvestment Act to fund 13 projects to deploy more than 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

COMPANY	AWARD
Anheuser-Busch	$1.1 M
Delphi Automotive	$2.4 M
FedEx Freight East	$1.3 M
GENCO	$6.1 M
Jadoo Power	$1.8 M
MTI MicroFuel Cells	$2.4 M
Nuvera Fuel Cells	$1.1 M
Plug Power, Inc. (1)	$3.4 M
Plug Power, Inc. (2)	$2.7 M
PolyFuel, Inc.	$2.5 M
ReliOn Inc.	$8.6 M
Sprint Comm.	$7.3 M
Sysco of Houston	$1.2 M



Approximately $72.4 million in cost-share funding from industry participants—for a total of nearly $114.3 million.

For more information ...



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 2009***

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

→ ***To be released following the Annual Merit Review***

www.hydrogen.energy.gov/annual_review08_proceedings.html

www.hydrogen.energy.gov **www.hydrogenandfuelcells.energy.gov**

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 Group*
- **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

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***

Thank you

Additional Information

1- Budgets, Spending, and Participating Organizations

Hydrogen & Fuel Cell Budgets: *FY04 – FY10*

	Funding *($ in thousands)*						
	FY 2004 Approp.	FY 2005 Approp.	FY 2006 Approp.	FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Request
EERE Hydrogen/Fuel Cells	144,881	166,772	153,451	189,511	206,241	200,449	68,213
Fossil Energy (FE)	4,879	16,518	21,036	21,513	24,088	25,000*	16,400*
Nuclear Energy (NE)	6,201	8,682	24,057	18,855	9,668	7,500	0
Science (SC)	0	29,183	32,500	36,388	36,509	36,509	36,509**
DOE TOTAL	**155,961**	**221,155**	**231,044**	**266,267**	**276,506**	**269,458**	**121,122**
Department of Transportation (DOT)	555	549	1,411	1,420	1,425	1,800	1,800
TOTAL	**156,516**	**221,704**	**232,455**	**267,687**	**277,931**	**271,258**	**122,922**

*** Includes funding for R&D plus program direction. Fossil Energy also plans $58M for SECA in FY10.**
**** The Office of Science also plans ~$14M for Biological and Environmental Research in FY10.**

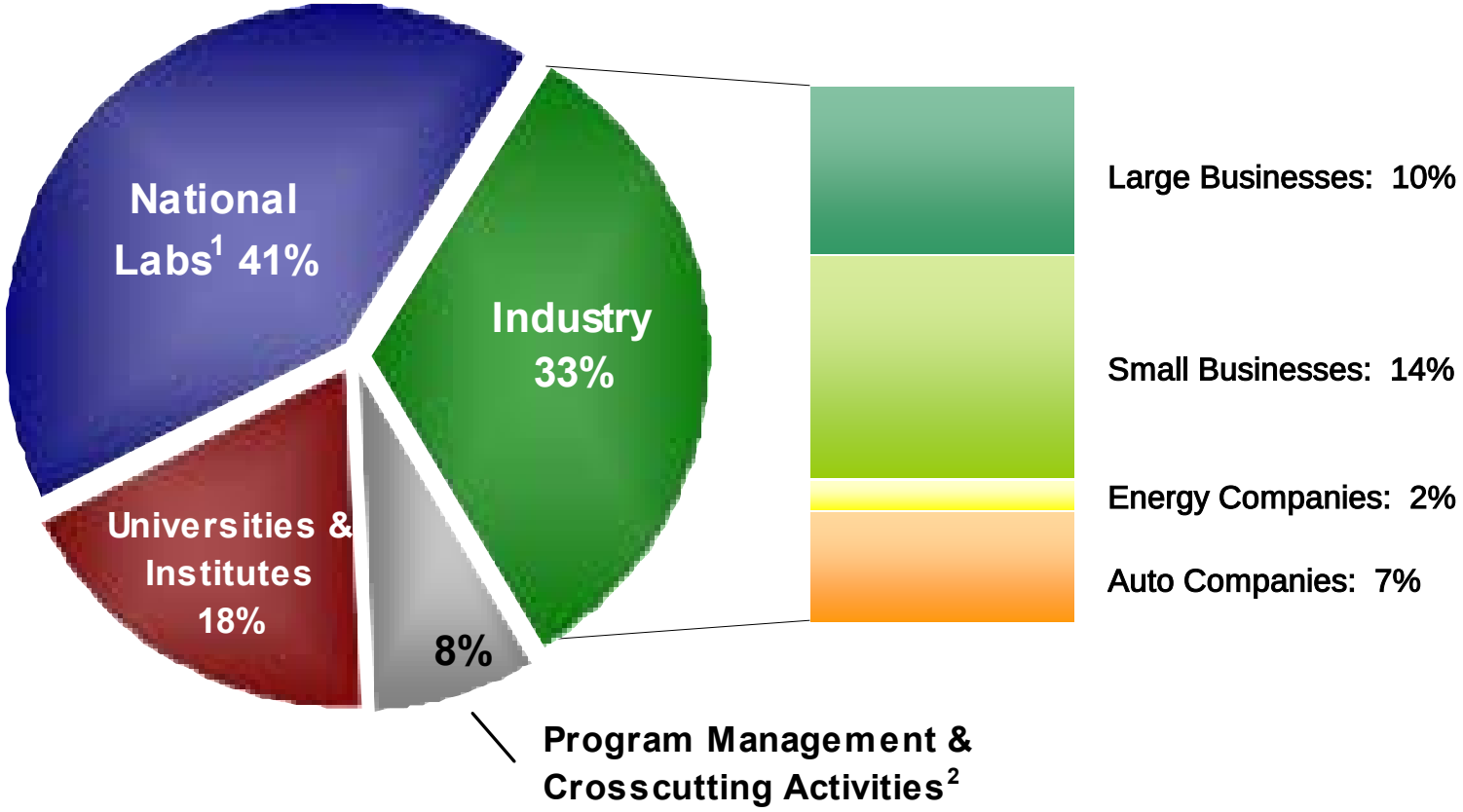
Budget — EERE Key Activities

EERE Hydrogen and Fuel Cells Budget *(in thousands)*				
Key Activity	**FY 2007** *appropriation*	**FY 2008** *appropriation*	**FY 2009** *appropriation*	**FY 2010** ***request***
Fuel Cell Systems R&D	**0**	**0**	**0**	**63,213**
Hydrogen Production & Delivery R&D	**33,702**	**38,607**	**10,000**	**0**
Hydrogen Storage R&D	**33,728**	**42,371**	**59,200**	**0**
Fuel Cell Stack Component R&D	**37,100**	**42,344**	**62,700**	**0**
Technology Validation	**39,413**	**29,612**	**14,789***	**0**
Transportation Fuel Cell Systems	**7,324**	**7,718**	**6,600**	**0**
Distributed Energy Fuel Cell Systems	**7,257**	**7,461**	**10,000**	**0**
Fuel Processor R&D	**3,952**	**2,896**	**3,000**	**0**
Safety, Codes & Standards	**13,492**	**15,442**	**12,500***	**0**
Education	**1,978**	**3,865**	**4,200***	**0**
Systems Analysis	**9,637**	**11,099**	**7,713**	**5,000**
Manufacturing R&D	**1,928**	**4,826**	**5,000**	**0**
Market Transformation	**0**	**0**	**4,747**	**0**
Total	**$189,511**	**$206,241**	**$200,449**	**$68,213**

* Under Vehicle Technologies Budget in FY 2009

FY 2008 Hydrogen Program - Spending Distribution

Total FY08 Budget: $279.1 M



*In FY 2008, **$191 million** in funding went to competitively selected projects, 76% of a total of $252 million in R&D project funding.*

[1] *"National Labs" includes DOE labs as well as other federal labs, such as NIST, JPL, etc.*

[2] *"Program Management & Crosscutting Activities" include various support activities, such as the Annual Merit Review, required EPACT studies and reports, etc.*

FY 09 Participating Organizations — *Fuel Cells*

Analysis & Testing
- ANL
- DTI
- TIAX
- LANL
- NIST
- ORNL

Catalysts & Supports
- 3M
- ANL
- BASF
- BNL
- LANL
- PNNL
- UTC Power

Distributed Energy Systems
- Acumentrics
- Bloo
- Intelligent Energy
- Materials & Systems Research
- Nanodynamics
- Plug Power
- University of South Carolina
- UTC Power

Fuel Processing
- Intelligent Energy

Hardware
- GrafTech Int'l, Ltd.
- ORNL
- UTC Power

Impurities
- Clemson University
- LANL
- University of Connecticut
- University of South Carolina

Membranes
- 3M
- Arizona State University
- Arkema
- Case Western Reserve U.
- Clemson University
- Colorado School of Mines
- FuelCell Energy
- Giner Electro Systems
- Kettering
- LBNL
- Penn State University
- University of Central Florida
- University of Southern Mississippi
- University of Tennessee
- Vanderbilt University
- Virginia Tech

Portable Power
- Lilliputian

Stack
- ANL
- Case Western Reserve U.

Transportation Systems
- ANL
- BTI
- Cummins
- Delphi
- Honeywell
- IdaTech
- PNNL
- Superprotonics

Water Transport
- CFD Research Corp.
- LANL
- Nuvera Fuel Cells
- Rochester Institute of Techn.

FY 09 Participating Organizations — *Hydrogen Production & Delivery*

Renewable Hydrogen Production

Distributed

ANL
H2Gen
Virent
NREL
Ohio State
PNNL

Centralized

Biological
UC Berkeley
J. Craig Venter Institute
NREL

Biomass Gasification
GTI, UTRC
LANL, NETL, NREL

Photoelectrochemical
UC Santa Barbara
Midwest Optoelectronics
MV Systems
NREL

Solar Thermochemical
University of Colorado
SAIC
ANL, NREL, SNL, SRNL

Crosscutting

Analysis
DTI
TIAX
NREL

Electrolysis
Arizona State
Avalence
Giner
NREL

Separations
Arizona State
BOC
HERA
Media & Process Technologies
ORNL
Pall Corporation
SNL
SRNL

Hydrogen Delivery

Analysis
ANL, NREL, PNNL

Pipelines
University of Illinois
Naturalhy
SECAT
ORNL, SNL, SRNL

Compression
Concepts ETI
Mohawk Innovative
ANL

Storage-Related
Lincoln Composites
LLNL, ORNL, SNL

Liquefaction
Gas Equipment Engineering
Praxair
Prometheus Energy

FY 09 Participating Organizations — *Hydrogen Production*

Nuclear Hydrogen Production

Technical Integration

Systems Analysis

- NREL
- SNL

Thermochemical System

System Definition

- UNLV
- INL

Sulfur-Based System

- Clemson University
- General Atomics
- INL
- SNL
- SRNL

Alternative Cycles

- Penn State
- ANL

Electrolytic System

HTE System

- Ceramatec
- Materials and Systems Research, Inc. (MSRI)
- ANL
- INL

System Interface & Supporting Systems

NGNP Interface

- UCLA
- University of Wisconsin
- INL
- SRNL

Fossil Hydrogen Production

- ANL
- Eltron Research, Inc.
- Media & Process Technology
- NETL
- Praxair
- Ohio State
- REB Research and Consulting
- Research Triangle Institute
- Southwest Research Institute
- University of Kentucky
- United Technologies Research Center
- Western Research Institute
- Worcester Polytechnic Institute

U.S. DEPARTMENT OF ENERGY

FY 09 Participating Organizations — *Hydrogen Storage*

Metal Hydride Center

National Lab:
- Sandia-Livermore

Industry:
- HRL Laboratories
- UTRC

Universities:
- CalTech
- Stanford
- Pittsburgh/Ga. Tech
- Hawaii/UNB
- Illinois
- Ohio State
- Nevada-Reno
- Utah

Federal Labs:
- BNL, JPL, NIST, ORNL, SRNL

Hydrogen Sorption Center

National Lab:
- NREL

Industry:
- Air Products

Universities:
- CalTech
- Duke U.
- Texas A&M
- Michigan
- North Carolina
- Penn State
- Rice

Federal Labs:
- ANL, LLNL, NIST, ORNL

Chemical Hydrogen Storage Center

National Labs:
- Los Alamos
- Pacific Northwest

Industry:
- Rohm & Haas
- U.S. Borax

Universities:
- Penn State
- Alabama
- California-Davis
- Missouri-Columbia
- Pennsylvania
- Oregon
- Washington

Federal Labs:
- INL

Engineering Storage Center

National Lab:
- Savannah River

Industry:
- Ford
- General Motors
- Lincoln Composites
- UTRC

Universities:
- Oregon State

Federal Labs:
- JPL
- LANL
- NREL
- PNNL

Independent Projects

Industry

Air Products and Chemicals, Inc.; Gas Technology Institute; H2 Technology Consulting LLC; Quantum Technologies; TIAX; UOP; UTRC

Universities & Institutes

Alfred U.; Hydrogen Education Foundation; Michigan Tech; Missouri – Columbia; Northwestern; Penn State; Purdue; Southwest Research Institute; SUNY – Syracuse; U. of Arkansas; UC Berkeley; UCLA; UC Santa Barbara; University of Connecticut; UPenn/Drexel

Federal Labs

ANL; SRNL; LANL; LLNL; ORNL; SNL

FY 09 Participating Organizations — *Technology Validation; Manufacturing R&D; Safety, Codes & Standards*

Technology Validation/ Learning Demonstration Teams

Lead: General Motors Corp.
Partner: Shell Hydrogen

Lead: Chevron
Partner: Hyundai-Kia Motor Co.
Additional Team Member: UTC

Lead: Chrysler, Daimler
Partner: BP

Lead: Ford Motor Company
Partner: BP

Data collection and analysis: NREL

Manufacturing R&D

Ballard Material Products, Inc.
BASF
LBNL
NIST
NREL
PNL
Quantum Technologies
Rensselaer Polytechnic Institute
UltraCell Corporation
WL Gore & Associates

Safety, Codes & Standards

LANL
LLNL
NIST
NREL
PNNL
ORNL
SNL
U.S. Dept. of Transportation

FY09 Participating Organizations — *Education, Systems Analysis, Market Transformation*

Education

State Governments and State-based Organizations

- CT Center for Advanced Technology
- Ohio Fuel Cell Coalition
- SC Hydrogen and Fuel Cell Alliance
- VA Dept of Mines, Minerals & Energy

Universities

- California State University – LA
- Humboldt State University
- The Lawrence Hall of Science at UC-Berkeley
- Michigan Technological University
- University of Central Florida
- University of North Dakota

Industry

- Carolina Tractor & Equipment Company
- The Media Network
- Opinion Research Corporation

Federal Labs

- NREL
- ORNL
- PNNL

Other Organizations

- Automotive X Prize
- Clean Energy States Alliance
- Houston Advanced Research Center
- Hydrogen Education Foundation
- The National Energy Education Development Project
- Technology Transition Corporation

Systems Analysis

- ANL
- Energy & Environmental Analysis, Inc.
- LLNL
- NREL
- ORNL
- PNNL
- RCF Economic & Financial Consulting, Inc.
- SNL
- UC Davis

Market Transformation

- Anheuser-Busch
- FedEx Freight East
- GENCO
- Jadoo Power
- MTI MicroFuel Cells Inc.
- Nuvera Fuel Cells
- PolyFuel, Inc.
- Plug Power, Inc.
- ReliOn, Inc.
- Sprint Comm
- Sysco of Houston

FY09 Participating Organizations — *Basic Energy Sciences*

Category A: Novel H2 Storage

Ames Laboratory
BNL
Carnegie Institute of Washington, CSM
Florida International University
Georgia Tech & Louisiana Tech
LBNL
MIT
Northwestern U.
ORNL
PNNL
Rutgers U.
Southern Illinois
SRNL
Stanford Linear Accelerator Ctr.
U. of Missouri
U. of Missouri – Rolla
U. of Georgia
U. of California
U. of Pennsylvania
U. of South Florida
Washington U.

Category B: Membranes

Cal Tech
Carnegie Mellon
Case Western Reserve U.
Clemson U.
Cornell U.
LANL
LBNL
Lehigh U.
PNNL
RPI
UNC
U. of Penn.
U. of Rochester
U. of Tennessee
U. of Utah
Vanderbilt

Category C: Catalyst Design at Nanoscale

ANL
Arizona State
BNL
Cornell
Georgetown U.
Johns Hopkins
MIT
Ohio State
ORNL
PNNL
Purdue
Stanford Linear Accelerator Ctr.
Texas A&M
Texas Tech
Tufts
UC Santa Barbara
U. of Delaware
U. of Illinois
U. of New Mexico
U. of Pittsburg
U. of Virginia
U. of Wisconsin
U. of Wyoming

Category D: Solar & Bio-Inspired Production

BNL
Cal Tech
Colorado State U.
LANL
LBNL
Nanoptek Corp.
NREL
Ohio State
Penn State
PNNL
Princeton
Purdue
SUNY – Stony Brook
UC Santa Cruz
U. of Alabama - Tuscaloosa
U. of Arizona
U. of Colorado
U. of Georgia
U. of Hawaii,
UNC
U. of Oklahoma
U. of Pennsylvania
U. of Washington
Virginia Tech

Category F: Core Projects

ANL
Cal Tech,
Colorado State
Cornell
Georgia Tech
LBNL
Nanoptek Corp.
NC State
Northwestern
Notre Dame Radiation Lab
NREL
Ohio State
Penn State
Princeton
SNL
Stanford Linear Accel. Ctr.
UC Berkeley
UCLA
U. of Georgia
U. of Houston
U. of Michigan
U. of Minnesota
U. of Nebraska
U. of Pennsylvania
U. of Texas
U. of Utah
U. of Wisconsin
Washington State U.

Additional Information

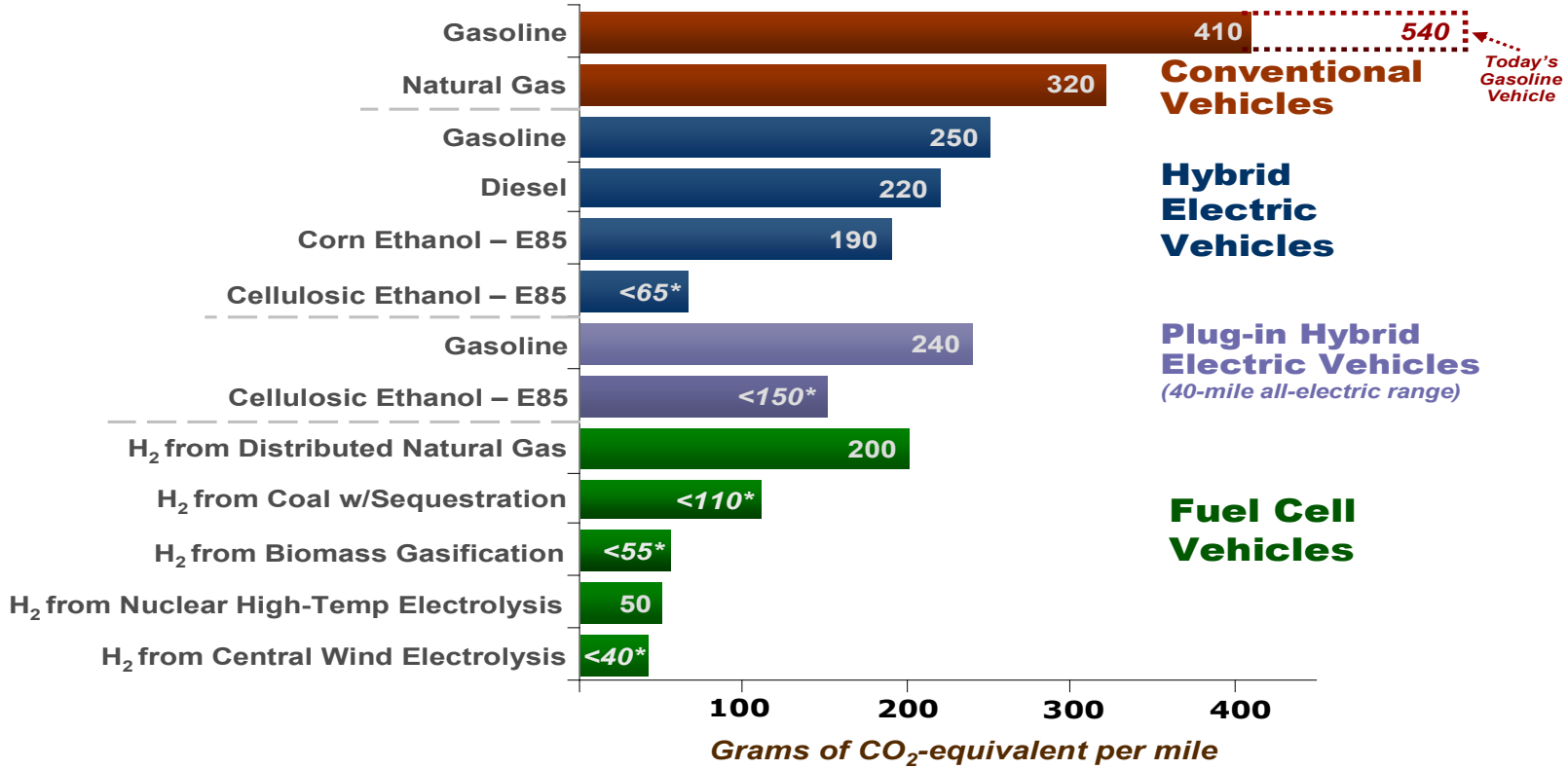
2 – Well to Wheels Analysis and Technology Status

Systems Analysis: *Greenhouse Gas Emissions*

Hydrogen and fuel cells are part of DOE's portfolio of technologies to reduce emissions of greenhouse gases by light-duty vehicles.

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

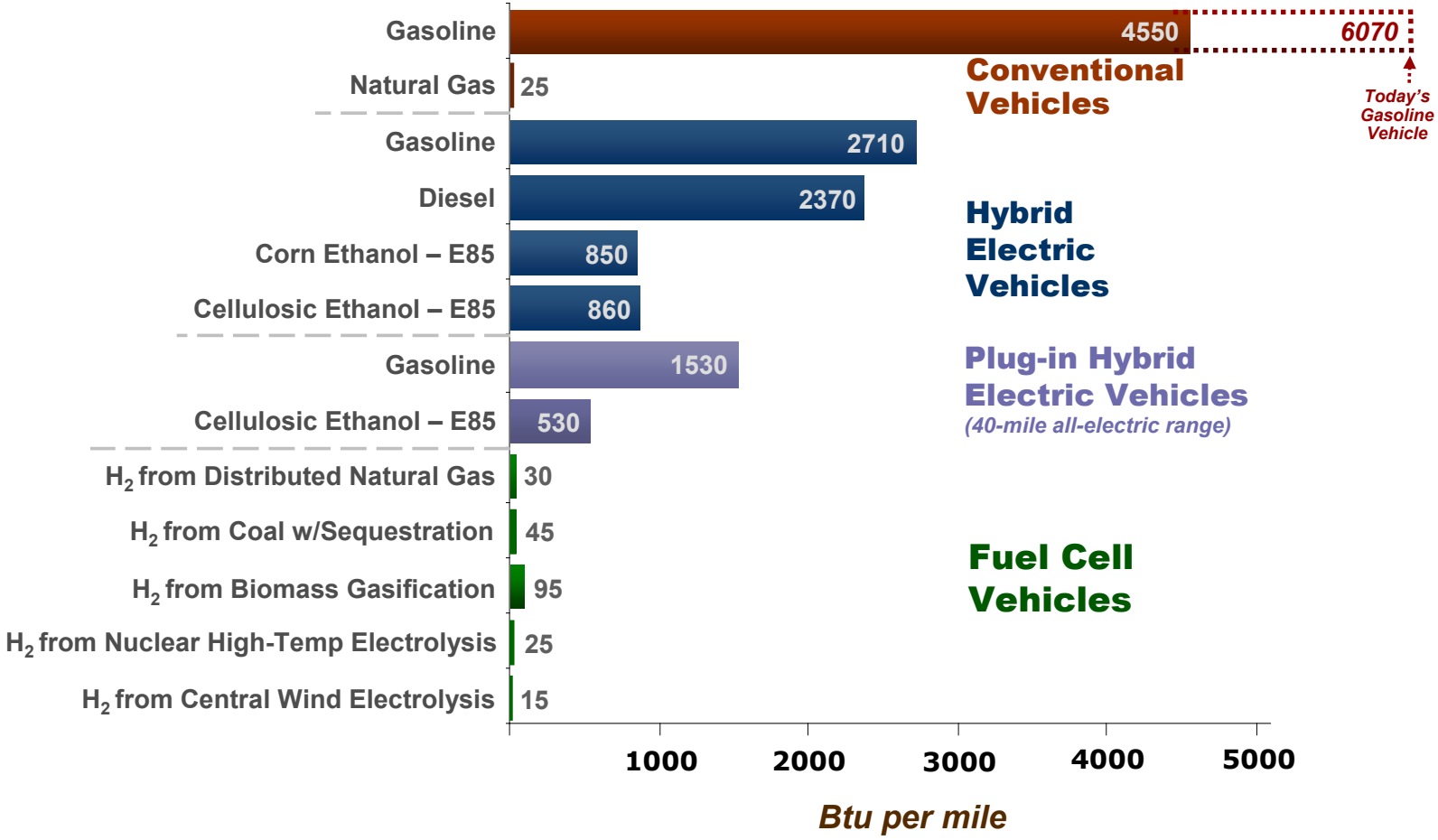
Hydrogen Program Record #9002, www.hydrogen.energy.gov/program_records.html

Systems Analysis: *Petroleum Use*

Hydrogen and fuel cells are part of DOE's portfolio of technologies to reduce the use of petroleum by light-duty vehicles.

Well-to-Wheels Petroleum Energy Use

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



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

Targets and Status

KEY H_2 STORAGE TARGETS	350 bar	700 bar	Materials-based*	Liquid H_2
System Gravimetric Density (TARGET = 5.5 wt%)	2.8 - 3.8%	2.5 - 4.4%	3%	5.1 - 6.5%
System Volumetric Density (TARGET = 40 g/L)	17 - 18 g/L	18 - 25 g/L	14 - 19 g/L	22 - 36 g/L
System Cost (TARGET = $2/kWh)	~ $15.5/kWh	~$23/kWh	~$15.6/kWh	~$8/kWh**

KEY FUEL CELL (AUTO) TARGETS	Status
Durability (TARGET = 5,000 hrs)	1,977 hrs
Cost (TARGET = $30/kW)	$73/kW
Efficiency at 25% Rated Power (TARGET = 60%)	59%

* For modeled adsorbent system. ** Does not include liquefaction cost; 10.1 kg H_2 system. Fuel cell and storage costs are projections for 500,000 units/year.

KEY H_2 PRODUCTION & DELIVERY TARGETS	Distr. NG	Distr. Bio-derived Liquids	Distr. Electrolysis	Central Wind Electrolysis	Central Biomass Gasification/ Pyrolysis	Solar High-temp. Electrochemical
Cost [TARGET = $2 - 3/gge (delivered) at the pump]	$3/gge	$4.4/gge	$4.8/gge	$5.9/gge @ plant gate	<$2/gge @ plant gate	.....

KEY H_2 DELIVERY TARGETS	Pipeline to Station (350 bar)	Pipeline & Truck to Station	Liquid Truck to Station
Cost [Target < $1/gge, from point of production to point of use]	$3/gge	$5/gge	$3.2/gge

H = High (significant challenge) M/H = Medium/High M = Medium L = Low (minimal challenge)

Additional Information

4 – Program Partnerships

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 Group*
- **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

International Partnership for the Hydrogen Economy

- International project reviewers here at the Annual Merit Review
- Sponsoring Global Student Competition (Germany, 2010)
- Published new Demonstration and Deployment Map on Web site *(www.iphe.net)*
- Released final report on IEA-IPHE Infrastructure Workshops
- Working on "Hydrogen & Fuel Cells for the 21st Century" — a policy brief and technology status update for IPHE countries

International Energy Agency – Implementing Agreements

- Advanced Fuel Cell Implementing Agreement extended five years—to 2013
- Hydrogen Implementing Agreement extended five years—to 2014. New tasks include:
  - Market transformation task
  - R&D task for renewable production of H_2 using sunlight

Additional Information

5 – Recovery Act and Award Details

American Recovery & Reinvestment Act

Energy-Related Funding Includes:

- $16.8 B for Energy Efficiency and Renewable Energy
- $2.0 B for DOE Office of Science (including $400 M for the Advanced Research Projects Agency)
- $3.4 B for Fossil Energy R&D
- $4.5 B for Electricity Delivery & Energy Reliability (Smart Grid)
- $6.0 B for Loan Guarantee Program
- $5.6 B for GSA (includes high performance green federal buildings and fleets)
- $300 M for DoD Energy research, including fuel cells

New Recovery Act Projects

Deploying Fuel Cells for Specialty Vehicles

Anheuser-Busch (St. Louis, MO)	**$1.1 million**	***23 fuel cells in class-1 lift trucks***
FedEx Freight East (Harrison, AR)	**$1.3 million**	***35 fuel cells in class-1 lift trucks***
GENCO (Pittsburgh, PA)	**$6.1 million**	***156 fuel cells in 6 fleets of class-1 and -3 lift trucks***
Nuvera Fuel Cells (Billerica, MA)	**$1.1 million**	***Supplement a fuel cell forklift fleet with 10 fuel cell power packs and a hydrogen fueling system***
Sysco of Houston (West Houston, TX)	**$1.2 million**	***90 fuel cells in class-3 pallet trucks***

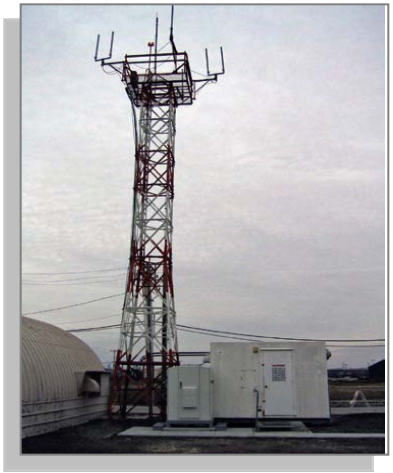
TOTAL: $10.8 million

Advantages of Fuel Cells for Specialty Vehicles:

- Allow for rapid refueling — much faster than changing-out or recharging batteries *(refueling with hydrogen takes about one minute, while battery changes can take 20 – 45 minutes, and recharging can take anywhere from 2 to 16 hours)*
- Provide constant power without voltage drop
- Eliminate space requirements of batteries & chargers
- *Can provide substantial cost-savings* over battery-powered forklifts (more than 50% reduction in lifecycle costs for a 3-kW pallet truck)

New Recovery Act Projects

Deploying Fuel Cells for Back-up Power



Plug Power (Latham, NY)	**$2.7 million**	• *Up to 275 kW at government sites*
ReliOn Inc. (Spokane, WA)	**$8.6 million**	• *25 sites in utility communications network* • *180 installations for telecommunications network*
Sprint (Reston, VA)	**$7.3 million**	• *1- to 10-kW fuel cells for state/local first responders*
Jadoo Power (Folsom, CA)	**$1.8 million**	• *Evaluation of environmental and cost benefits of using 1-kW fuel cell, as opposed to gas/diesel generators and batteries*
TOTAL:	**$20.4 million**	

Advantages of Fuel Cells for Backup Power:

- **Provide longer continuous run-time, greater durability than batteries** *(Battery systems usually run 4 – 8 hrs, and have to be replaced every 3 – 5 years, while fuel cell runtime is limited only by storage capacity, and they could last 15 years or more, depending on amount of actual use.)*
- **Require less maintenance than batteries or generators** *(estimated routine maintenance of 2 hours per year for fuel cells and 8 hours/year for batteries and generators)*
- **Can be remotely monitored**
- **Can provide substantial cost-savings over battery-generator systems** *(nearly 25% reduction in lifecycle costs for a 5-kW, 52-hour backup power system)*

New Recovery Act Projects

Demonstrating PEM Fuel Cells for Residential and Small Commercial CHP

ADVANTAGES of FUEL CELLS for CHP…

- **Up to 85% overall efficiency**
- **25 – 35% reduction in emissions from household energy use**
- **Zero emissions**
- **Low noise and vibration**
- **Low O&M requirements, less down-time**
  - ***100x more reliable than the average power supply for data centers—three seconds of down time per year versus an average of five minutes.***
- **Less variation in efficiency across variable loads**

Plug Power, Inc. (Latham, NY)	$3.4 million	*5-kW stationary CHP systems*

Plug Power's GenSys Blue, for residential and small commercial applications

New Recovery Act Projects

Deploying Fuel Cells for Portable Power

MTI MicroFuel Cells (Albany, NY)	$2.4 million	• *1 W consumer electronics power pack*
PolyFuel, Inc. (Mountain View, CA)	$2.5 million	• *Portable power system for mobile computing*
TOTAL:	$4.9 million	

Deploying Fuel Cells for Auxiliary Power

Delphi Automotive (Troy, MI)	$2.4 million	• *3 – 5 kW SOFC APU for heavy-duty class 8 trucks*

Additional Information

6 – Funding Opportunities and Recent Tax Incentives

Recovery Act Opportunities

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

TAX CREDITS IN THE RECOVERY ACT	
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.**

Funding Opportunities *(non-Recovery Act)*

Loan Guarantee Program

- Loan guarantees for renewable energy, energy efficiency, & electricity transmission projects (up to $10B).

State Energy Program Competitive Activities

- Topics are Advanced Building Energy Codes and Utility-Scale Clean Energy Capacity; offered by EERE's Weatherization and Intergovernmental Program; closes July 10, 2008 (~$7.5M).

SBIR/STTR

- DOE SBIRs:
  - Annual solicitations on a wide variety of topics
  - 2010 Solicitation subtopics to be released in the Fall
- DoD SBIR topic: "Extraction of Atmospheric CO_2 and Conversion to Liquid Hydrocarbon Fuel" *(The Army is seeking ways to produce fuel from CO2 and water in the atmosphere. Water will be used to provide the hydrogen needed for the conversion process);* closes June 17.

Department of Defense

- Defense Logistics Agency—two Broad Agency Announcements expected in the next two months for deployment of material handling equipment (funding TBD by 2010 budget)
- Office of Naval Research and DOE to conduct a joint project on hydrogen for renewable energy storage (funding TBD)

H-Prize

- First round ($1 million pilot award, for onboard storage materials) will open in spring 2009—award expected in September 2010.

H-Prize – Energy Independence and Security Act of 2007

- **Goal:** Demonstrate advancement for an on-board storage material exceeding performance targets
- **Administering Entity:** Pilot administered by Hydrogen Education Foundation, in partnership with SCRA
- **Announcement:** H-Prize criteria, eligibility requirements and registration procedures announced in the Federal Register **Spring, 2009.** ***Registration to submit a proposal must occur within 6 months of Federal Register posting.***
- **Award:** The pilot award of $1 Million Prize expected in **September 2010**
  - Administering entity is raising cost share to augments funds for future prizes

(Opens w/Federal Register Notice)