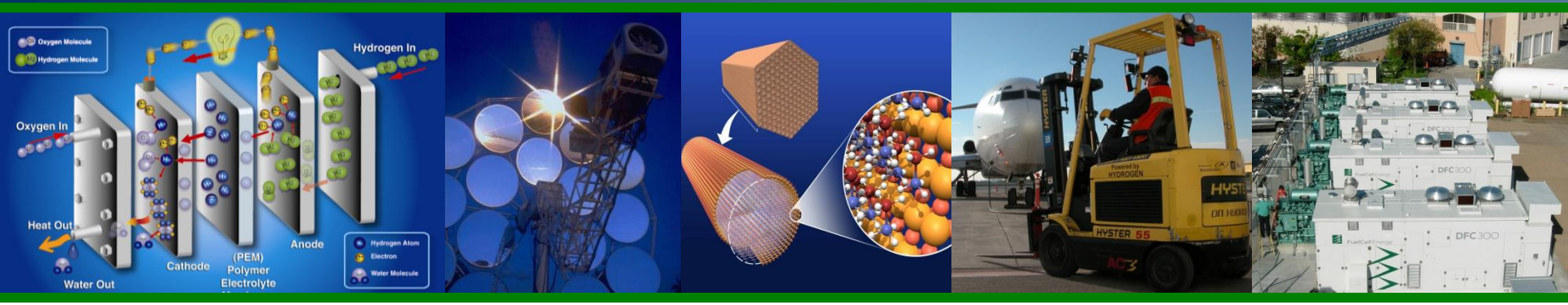
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Hydrogen and Fuel Cell Technologies Update

Dr. Sunita Satyapal

Program Manager

U.S. Department of Energy

Fuel Cell Technologies Program

Fuel Cell Seminar & Exposition

San Antonio, TX

October 19, 2010

Agenda

U.S. DEPARTMENT OF ENERGY

- Overview
  - RD&D Progress
  - Analysis & Key Publications
- Budget Update
- Next Steps
  - DOE Releases Program Plan for Stakeholder Input
  - Upcoming Workshops & Solicitations

Source: US DOE 10/2010

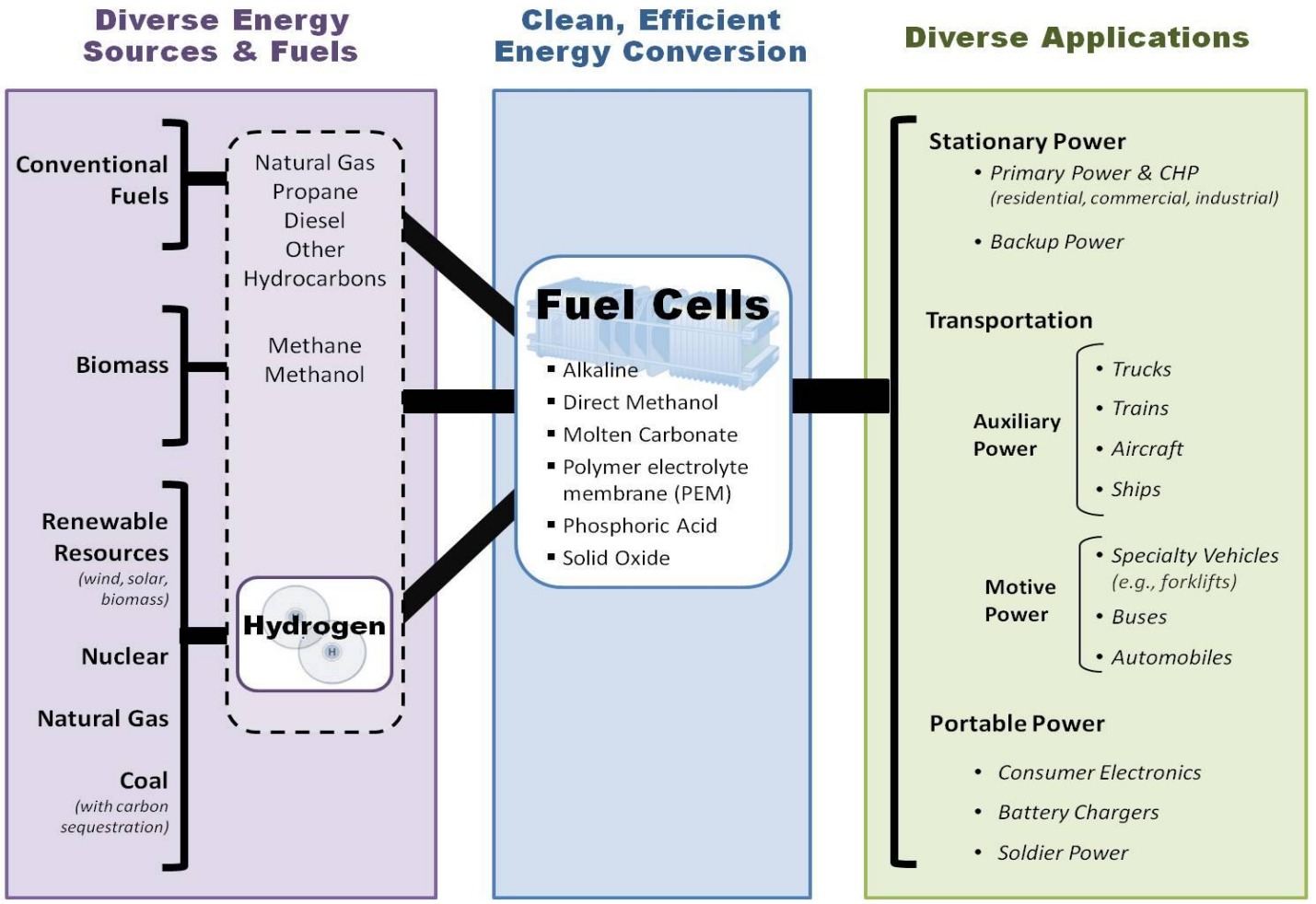
U.S. DEPARTMENT OF ENERGY

Key Examples

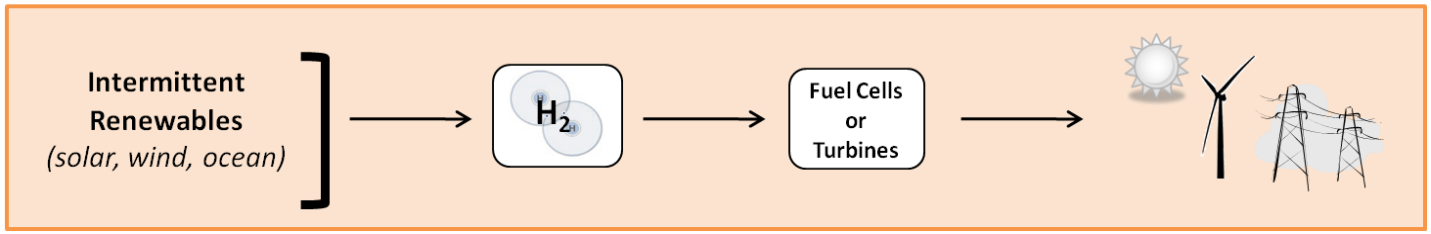
- ✓ **Double Renewable Energy Capacity by 2012**
- ✓ **Invest $150 billion over ten years in energy R&D to transition to a clean energy economy**
- ✓ **Reduce GHG emissions 83% by 2050**

Fuel Cells: Addressing Energy Challenges

U.S. DEPARTMENT OF ENERGY



Energy Storage for Renewable Electricity



Key Challenges

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

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

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

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

Hydrogen Cost

Target: $2 – 4 /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**
- **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**

RD&D Progress

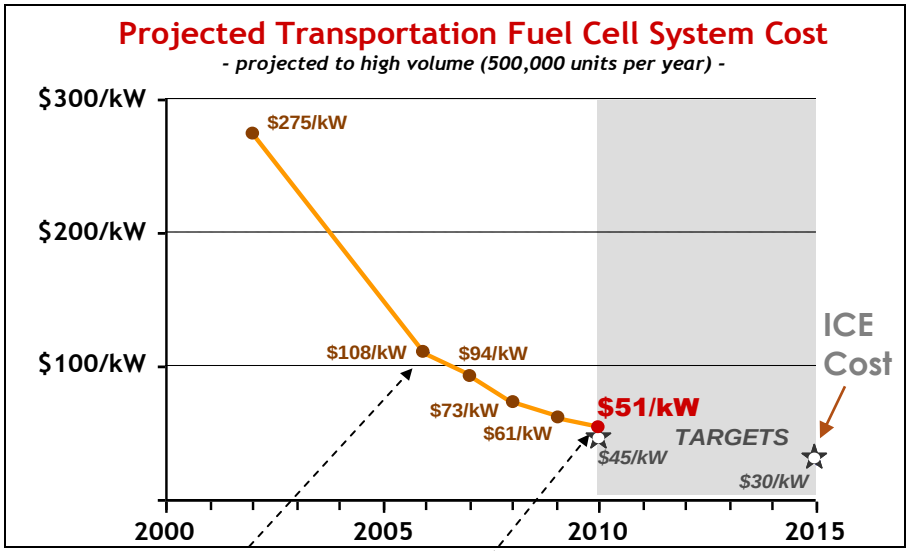
Fuel Cell R&D — *Progress: Cost*

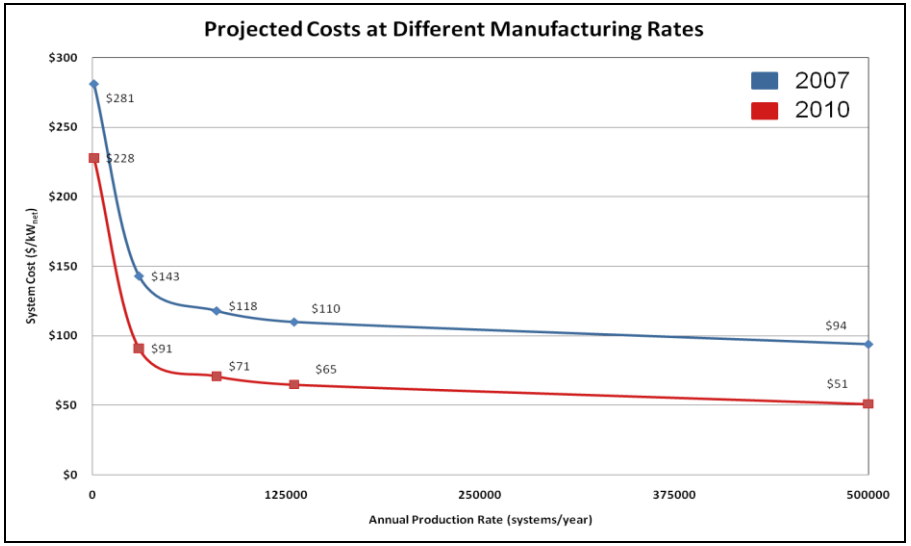
U.S. DEPARTMENT OF ENERGY

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

- ***More than 15% reduction since 2009***
- ***More than 80% reduction since 2002***
- ***2008 cost projection was validated by independent panel*****

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





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

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

Source: US DOE 10/2010

Hydrogen R&D

The projected high-volume cost of distributed hydrogen production technologies is beginning to approach targets. Low-volume/early market costs must be reduced. The competitive hydrogen threshold cost for 2020 is $2-4/gge.

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

NEAR TERM:

Distributed Production

- Natural Gas Reforming
- Ethanol Reforming
- Electrolysis

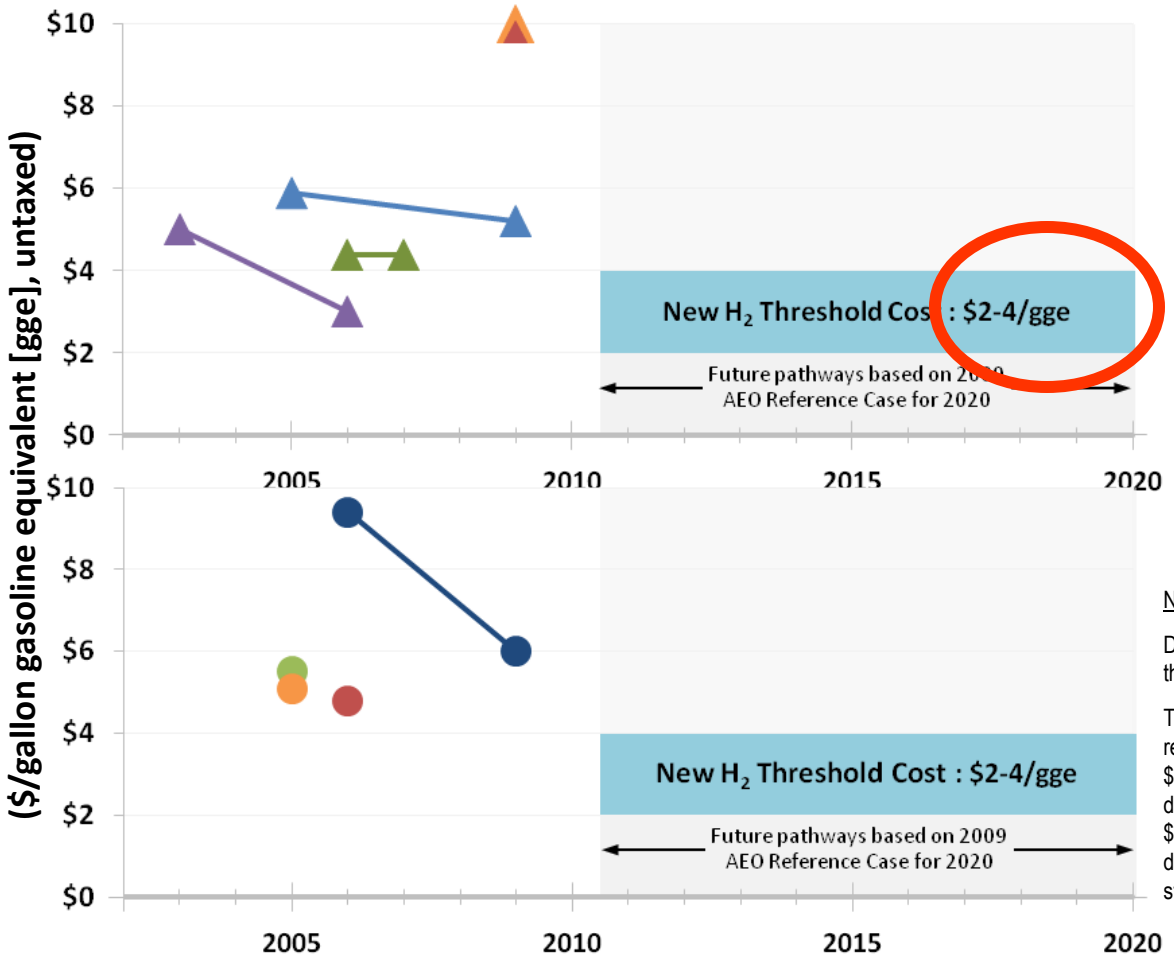
Low-volume (200 kg/day)

- Steam Methane Reforming
- H_2 from Combined Heat, Hydrogen, and Power Fuel Cell

LONGER TERM:

Centralized Production

- Biomass Gasification
- Central Wind Electrolysis
- Coal Gasification with Sequestration
- Nuclear



Updated to address gasoline cost volatility and range of vehicle assumptions

Notes:

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

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

Source: US DOE 10/2010

Technology Validation

U.S. DEPARTMENT OF ENERGY

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

RECENT PROGRESS

Vehicles & Infrastructure

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

Buses

- DOE is evaluating real-world bus fleet data (DOT collaboration)

– H_2 fuel cell buses have a 39% to 141% better fuel economy when compared to diesel & CNG buses

Forklifts

- Forklifts at Defense Logistics Agency site have completed more than 18,000 refuelings

Recovery Act

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

Source: US DOE 09/2010

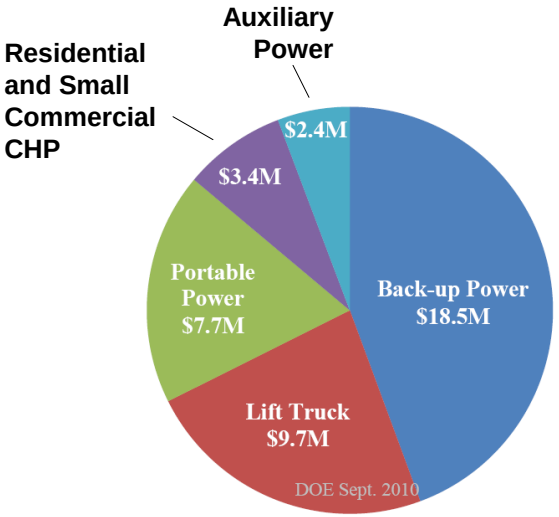
Recovery Act Fuel Cell Funding & Projects

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

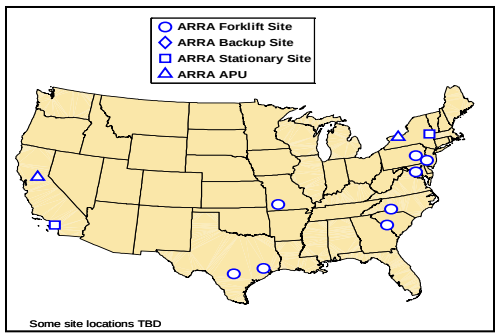
FROM the LABORATORY to DEPLOYMENT:

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



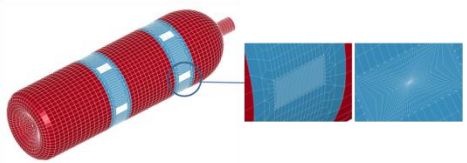
Approximately $54 million in cost-share funding from industry participants for a total of about $96 million.

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



Reporting deployment and performance metrics to inform goals and targets for FC RD&D.

Real-life field testing of portable power units by end users to improve future fuel cell designs



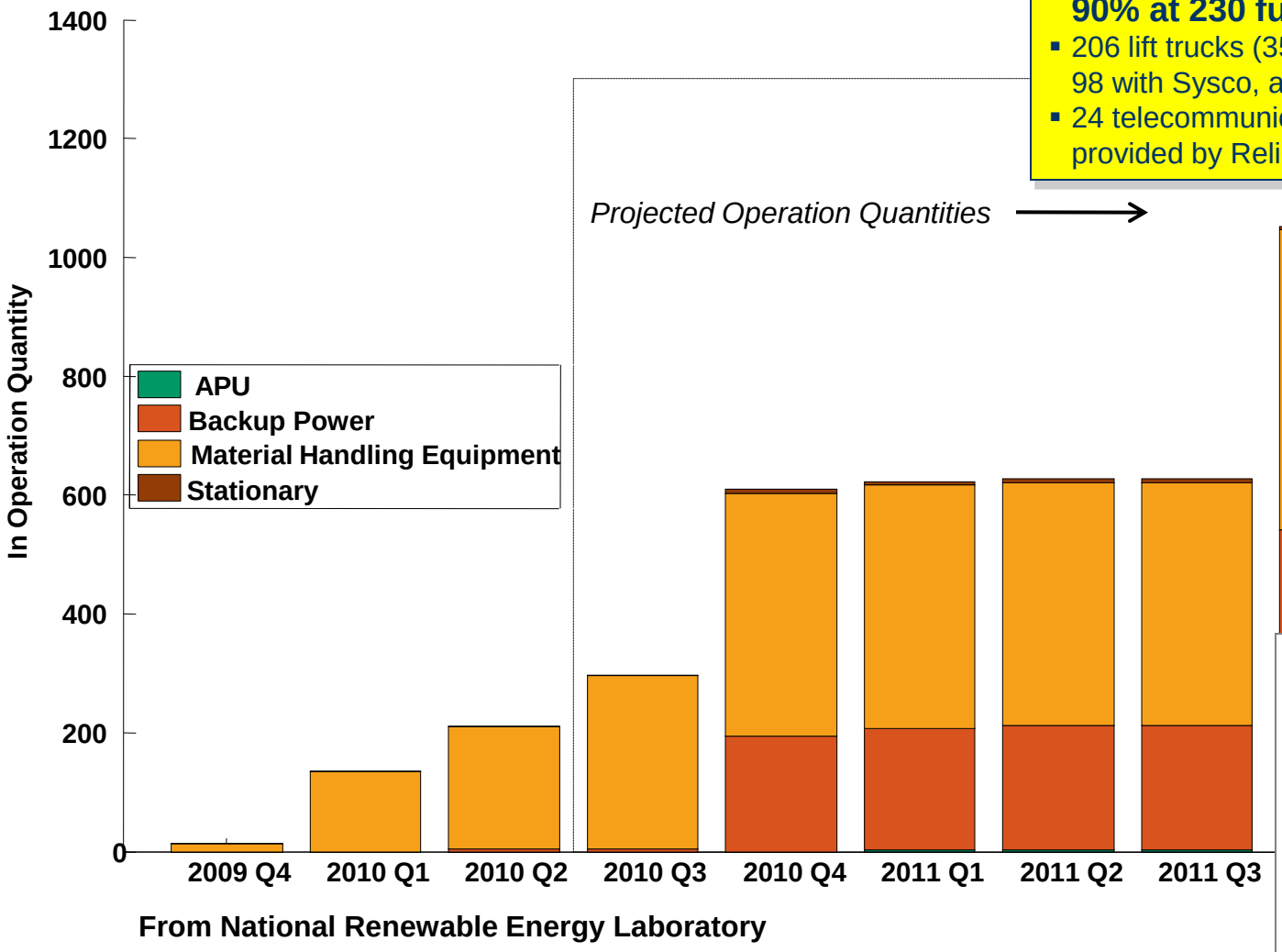
Partnering in studies of cyclic fatigue of steel tanks to provide technical basis for codes & standards development to enable commercial acceptance of fuel cell systems. Emphasizes importance of safety, codes & standards subprogram

Source: US DOE 10/2010

ARRA Fuel Cell Deployments

U.S. DEPARTMENT OF ENERGY

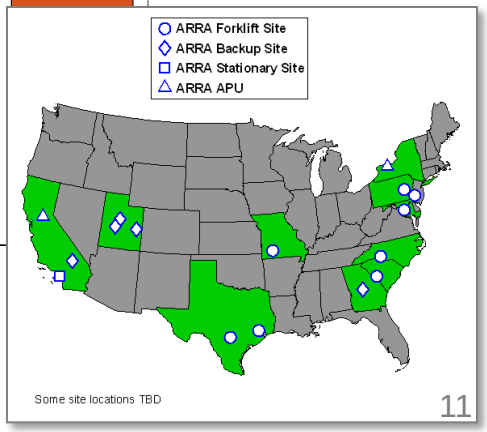
DOE ARRA-funded Early Market Fuel Cell Installations
(actual and projected)



From National Renewable Energy Laboratory

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

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



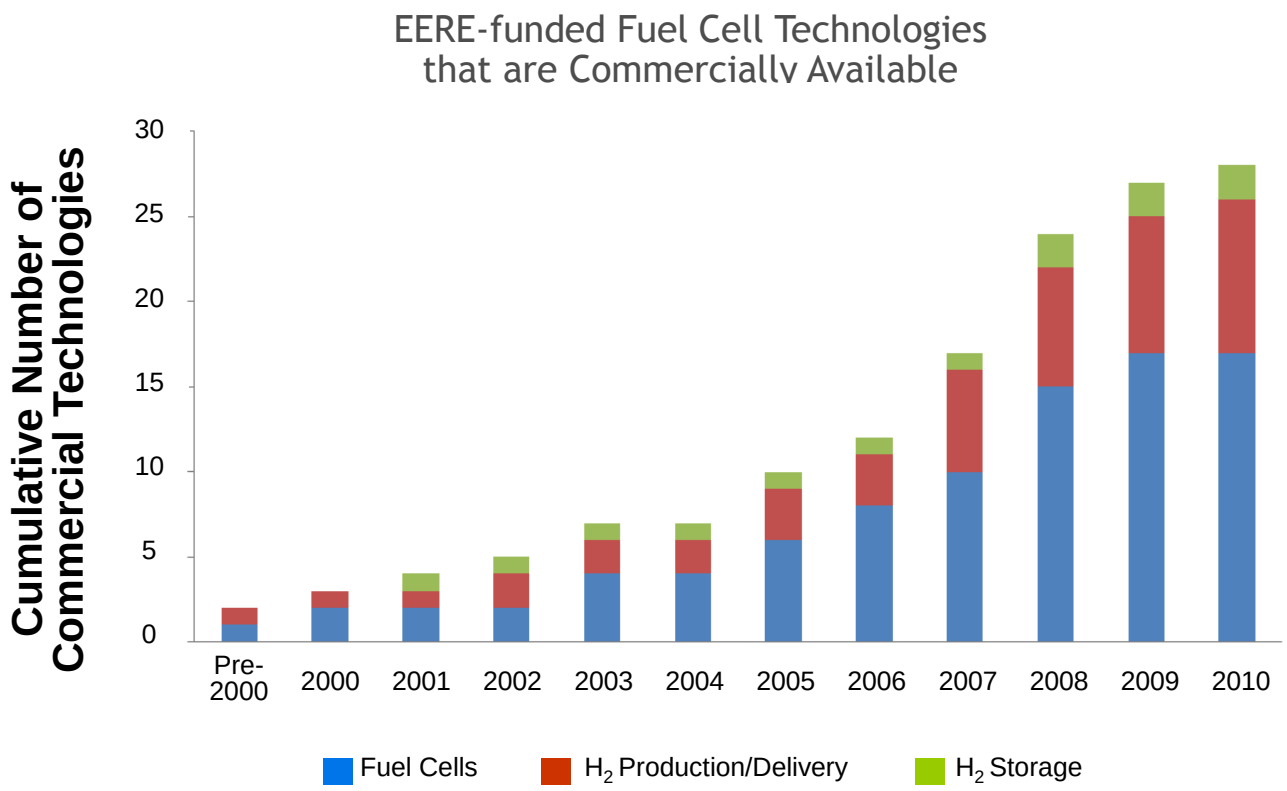
Source: US DOE 09/2010

Assessing the Program-*Commercializing Technologies*

U.S. DEPARTMENT OF ENERGY

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

Accelerating Commercialization



198 PATENTS resulting from EERE-funded R&D:

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

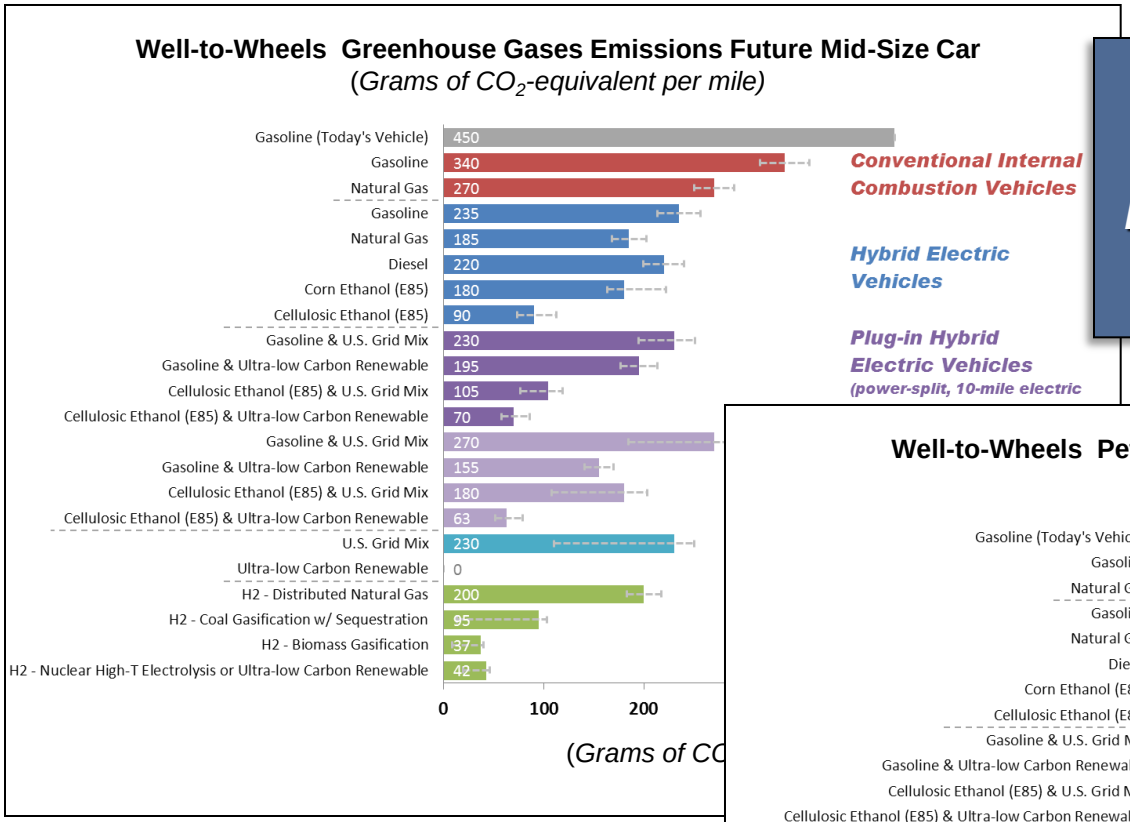
60% are actively used in:

1) Commercial products
2) Emerging technologies
3) Research

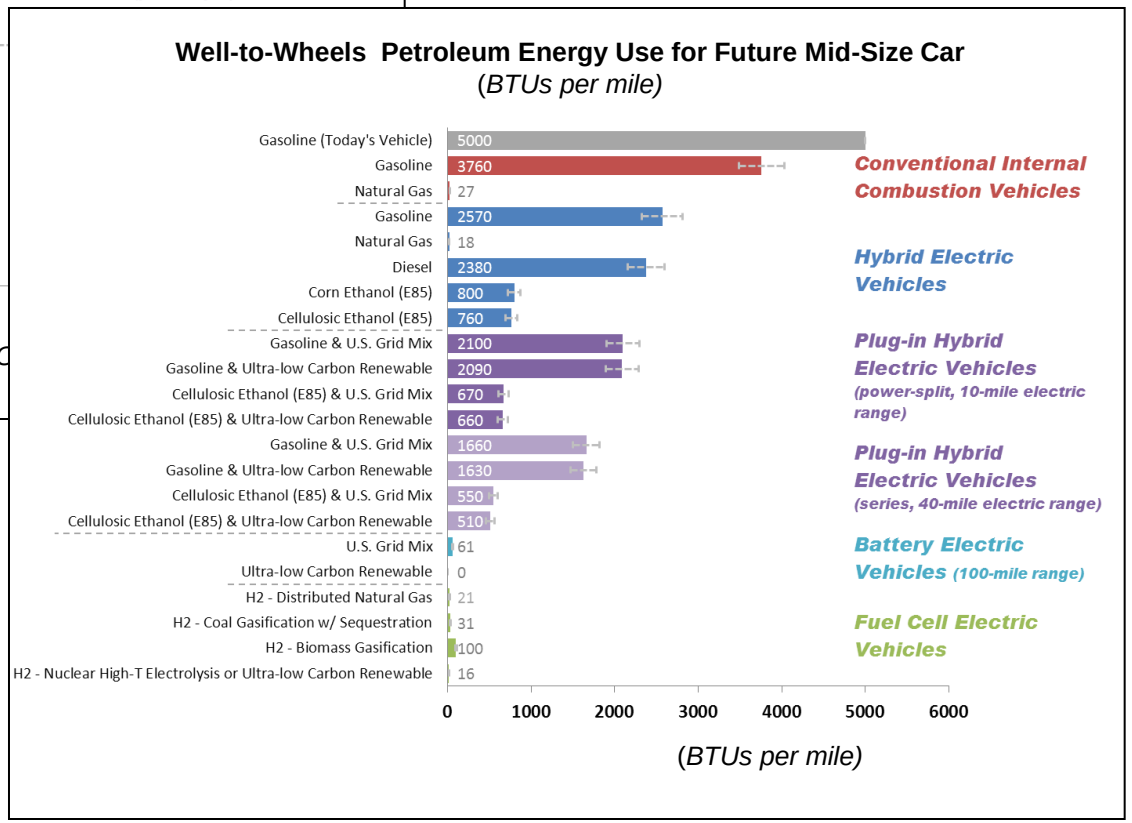
Completed Fuel Cell Market Report provides an overview of market trends and profiles for select fuel cell companies

Source: US DOE 09/2010

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



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



Analysis details to be published October, 2010

Assumptions at: http://hydrogen.energy.gov/program_records.html

Notes:

For a projected state of technologies in 2035-2045.

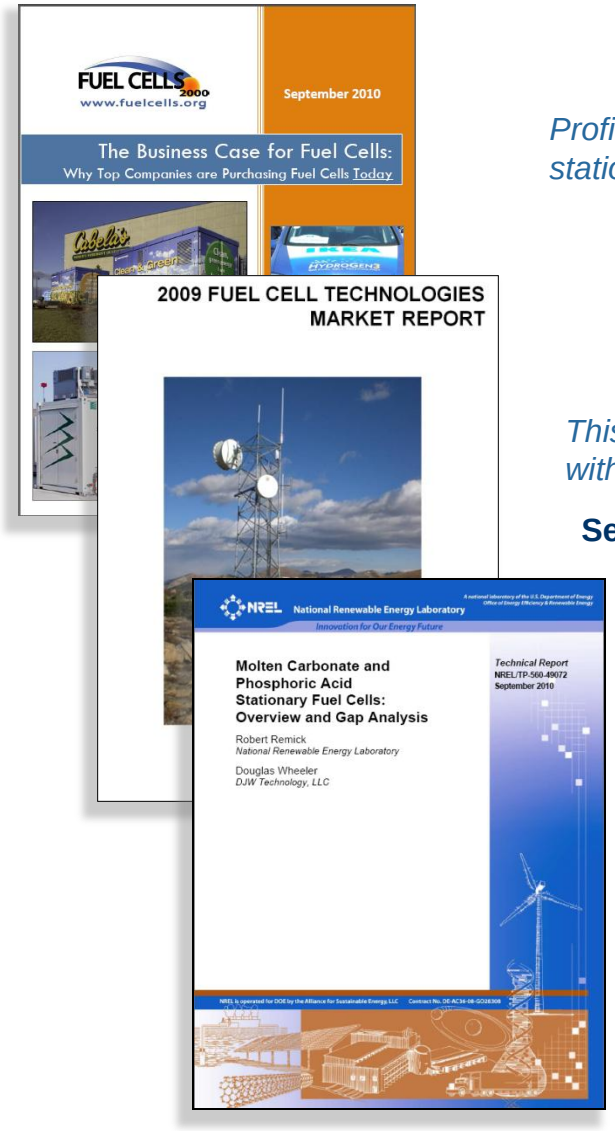
Ultra-low carbon renewable electricity includes wind, solar, etc.

Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning.

Global warming potential of primary fuels excluded.

Source: US DOE 10/2010

Key Reports Recently Published



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

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

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

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

2009 Fuel Cell Technologies Market Report

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

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

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

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

By NREL and DJW Technology, LLC

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

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

Fuel Cell Today 2009 Market Analysis

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

October 2010

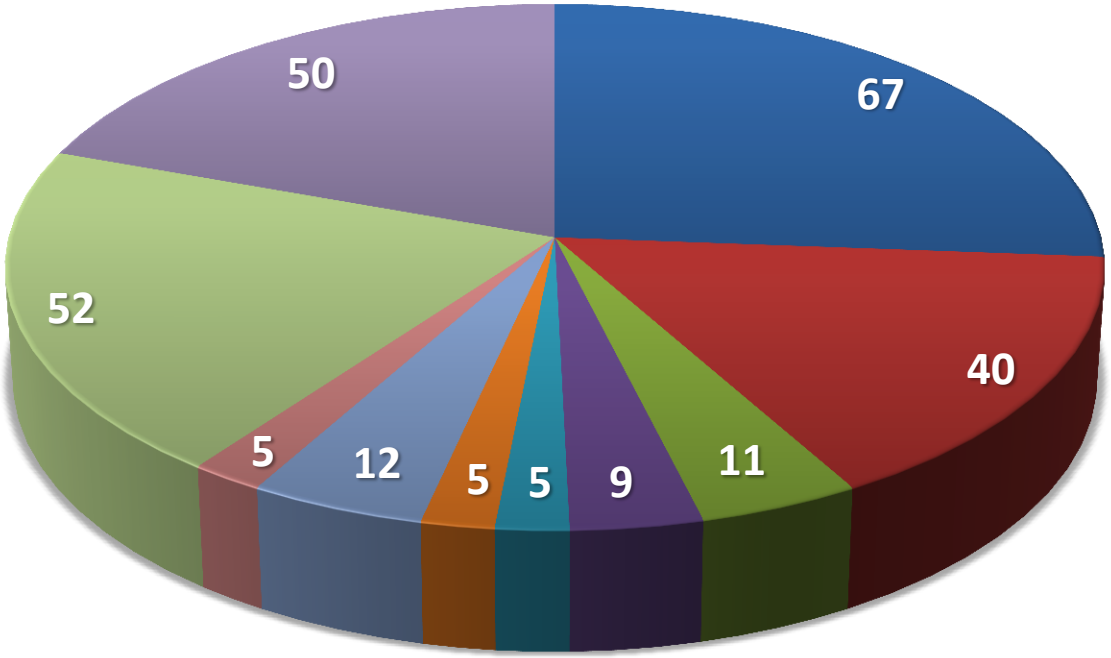
Source: US DOE 10/2010

FY 2011 Budget Update

Total DOE FY11 Budget Request

U.S. DEPARTMENT OF ENERGY

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



Total FY11 Budget Request $256 Million

Applied RD&D (EERE)
- Fuel Cell Systems R&D
- Hydrogen Fuel R&D
- Technology Validation
- Market Transformation and Safety, Codes & Standards
- Systems Analysis
- Manufacturing R&D

Other DOE
- Fossil Energy (FE)
- Nuclear Energy (NE)*
- Basic Science (SC)**

- SECA - MW SOFC (FE)

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

Source: US DOE 09/2010

DOE EERE H_2 & Fuel Cells Budgets

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

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

Source: US DOE 10/2010

Next Steps

Upcoming Workshops and Solicitations

Program Plan Released

An integrated strategic plan for the research, development, and demonstration activities of DOE's Hydrogen and Fuel Cells Program

- **Update to the Hydrogen Posture Plan (2006)**
- **Addresses previous reviews (e.g. GAO, HTAC, NAS, etc.)**

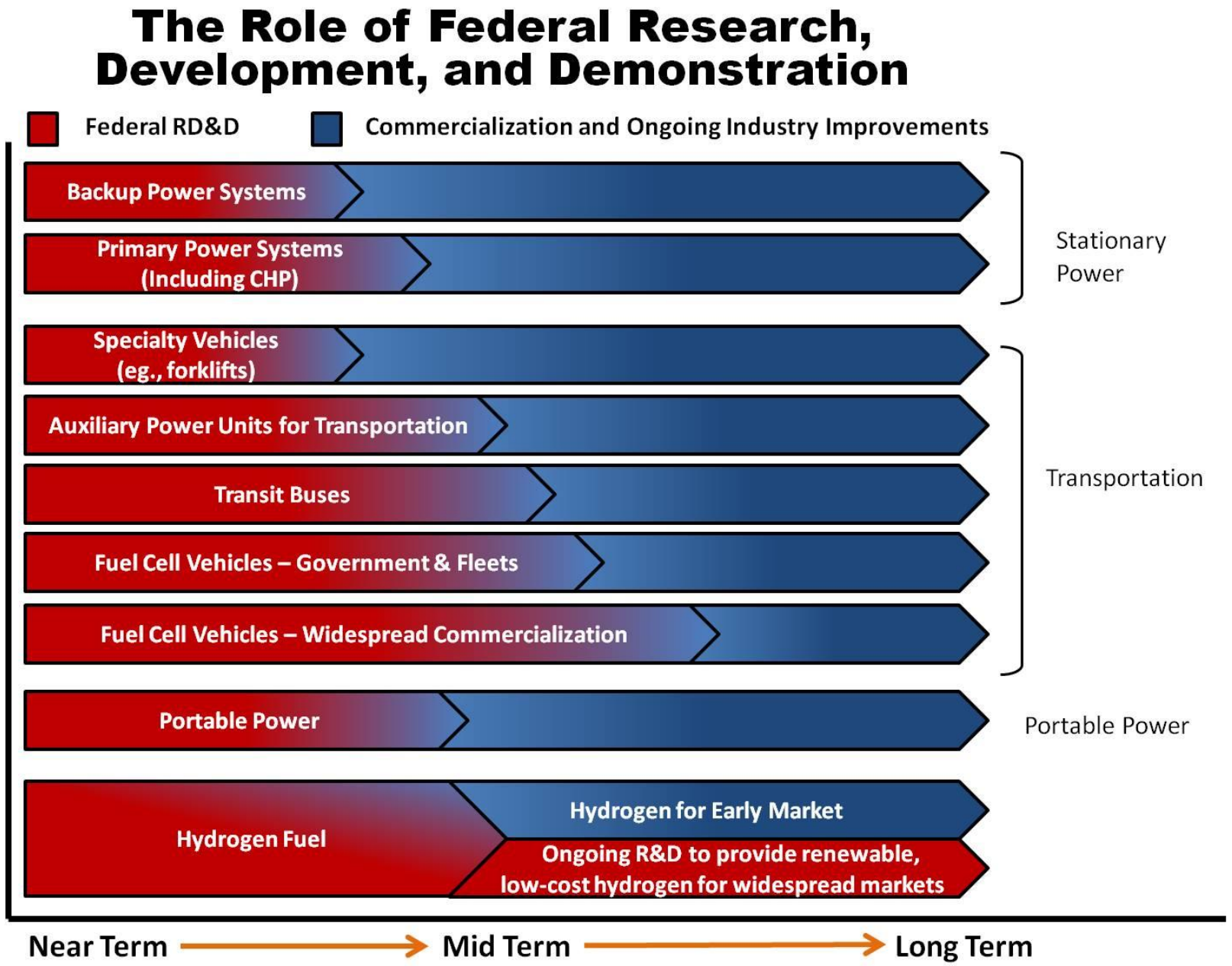
Draft available for stakeholder and public comment:
DOEH2ProgramPlan@ee.doe.gov
Until 11/30/2010

http://www1.eere.energy.gov/hydrogenandfuelcells/

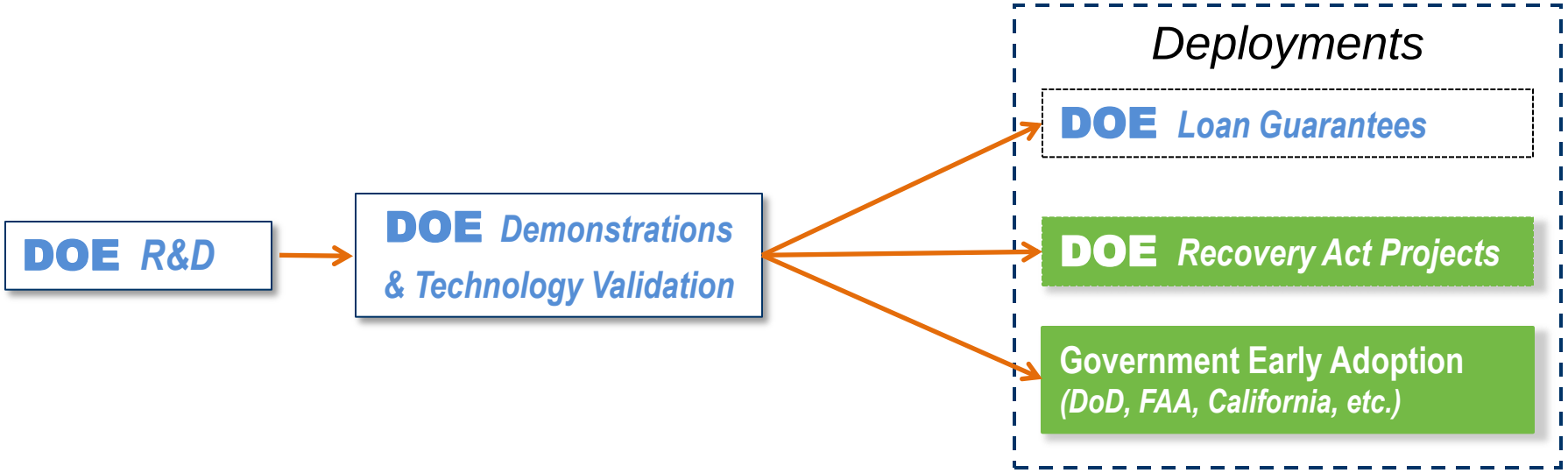
Multi-year RD&D Plan to be revised FY11

Source: US DOE 10/2010

Program Plan includes Portfolio



Example of RD&D to Deployments



Project Example:

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

What more can Government do to accelerate commercialization?

Source: US DOE 10/2010

Recent Federal Grants and Tax Credits

U.S. DEPARTMENT OF ENERGY

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

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

Source: US DOE & US Treasury10/2010

Executive Order 13514

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

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

Examples:

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

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

Source: US DOE 08/2010

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

Market Transformation

RFI: Fuel Cell Commercialization Topics

Need ideas for “turn key” approaches to finance, procure, install and operate fuel cells for stationary power on Federal facilities and utility scale hydrogen energy storage from renewables.

Need information and recommendations for installing and operating fuel cell powered airport Ground Support Equipment.

Need stakeholder responses by mid December 2010

Source: US DOE 10/2010

Upcoming Workshops

U.S. DEPARTMENT OF ENERGY

Hydrogen Production, Delivery, and Storage

Production

- PEC workshop on EERE/BES Partnerships (TBD)
- Biological workshop on EERE/BES Partnerships (TBD)
- STCH discussion of down-select report and future directions (TBD)

Delivery

- Joint storage and delivery interface discussion with industry partners currently interested in refilling station design compatible with advanced storage concepts (TBD)

Storage

- Workshop to develop roadmap for lower cost compressed H_2 storage activities (Q2, FY 2011)
- Workshop to identify key R&D issues for cryo-compressed H_2 storage (Q2, FY 2011)
- Follow-up workshops on hydrogen sorbents (TBD)
- Workshops on interface issues between the infrastructure and on-board storage (TBD)
- Workshops to develop roadmap/strategies for future storage materials R&D

Education

- Stakeholder updated roadmap workshop planned in October

Manufacturing

- Stationary Manufacturing R&D FY11 (TBD)

Fuel Cells

- Reversible fuel cells (TBD)
- AFC workshop: Status, prospects and R&D needs (TBD)

Safety, Codes and Standards

- Insurability of Hydrogen and FC Technologies (Spring-Summer 2011)
- Collaborative Safety R&D (March 2011, Japan)
- Assessment of Sensor Technology and Targets (Summer-Fall 2011)
- FC Systems and Components Certification and Qualification (Nov 5, 2010, SNL, CA)

Systems Analysis

- Infrastructure workshop on station cost identification and identification of R&D gaps (TBD)
- Workshop tentatively planned for NHA (Feb 2011)

Source: US DOE 10/2010

First-ever customer-focused panel conducted by the Fuel Cell Seminar

- **Wednesday, October 20, 2010 at 8:00am**

  Panelists to include:

  - Mr. Harry S. Pettit, Pepperidge Farm, Inc.
  - Mr. J. D. Van Wyhe, PG&E
  - Ms. Elizabeth A. Moore, Defense Distribution Depot Warner Robins
  - Mr. Scott Kliever, Sysco Houston, Inc.
  - Mr. Gary Lunz, Crown Equipment Corporation

Providing Primary, Back Up, and Motive Power

Contact: Pete Devlin, DOE

Pepperidge Farm | PG&E | Crown | Sysco

Source: US DOE 10/2010

Topic 3: Hydrogen and Fuel Cells

- **Subtopic 3a – Reducing the Cost of High Pressure Hydrogen Storage Tanks**
- **Subtopic 3b – Fuel Cell Balance-of-Plant**
- **Subtopic 3c – Hydrogen Odorant Technology**
- **Subtopic 3d – Demonstration of Alternative-Fuel Cells as Range Extenders for Battery-Powered Airport Ground Support Equipment (GSE)**
- Subtopic 3e – Other: Should address one of the four subtopics (a-d). However, the proposal can take an approach that is not specified in the subtopic description but that will still meet the technical targets, goals or objectives, which are referenced in the description.

Closes on **11/15/2010**

http://science.doe.gov/sbir/Solicitations/FOA_2011_Phase_I.pdf

Source: US DOE 10/2010

Source: US DOE 10/2010

New Solicitations Planned

- Fuel Cell R&D
  - To be released before end of 2010
- Additional Solicitations Planned
  - Cost analysis (stationary fuel cells, storage)
  - Hydrogen fuel R&D (e.g. production, storage)
  - Market transformation

(subject to appropriations)

Source: US DOE 10/2010

Source: US DOE 10/2010

2011 Hydrogen Student Design Contest

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

Challenging university-level, multidisciplinary, student teams to plan and design a Residential Hydrogen Fueling System

The Hydrogen Education Foundation's Hydrogen Student Design Contest
www.HydrogenContest.org
Sponsored by the U.S. Department of Energy

Registration and abstract submissions extended, due:

November 1, 2010

For more information and to register, please visit:

http://www.hydrogencontest.org/

Prizes:

- Expenses-paid trip to present at 2011 National Hydrogen Association (NHA) Hydrogen Conference and Expo, February 13-16 in Washington, DC
- Priority consideration for summer internships at participating sponsor organizations; and more…

Current Registration:

- 36 teams registered from 16 countries including the U.S. Australia, Canada, China, Czech Republic, Iceland, India, Indonesia, Japan, Latvia, Malaysia, Morocco, Spain, Turkey, UK, Ukraine

Supported by: Proton Energy Systems

U.S. DEPARTMENT OF ENERGY

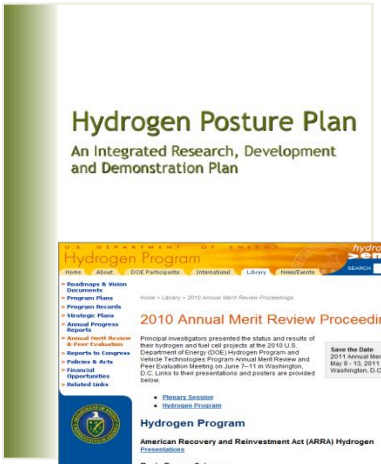
Source: US DOE 10/2010

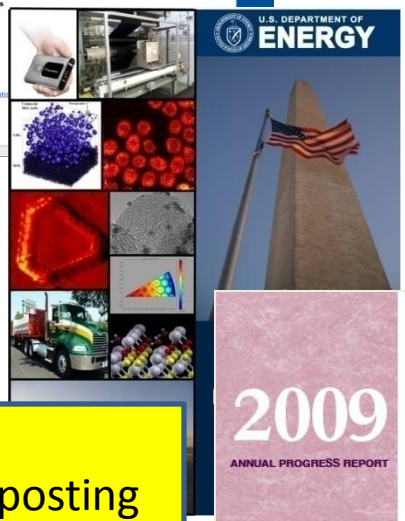
Summary

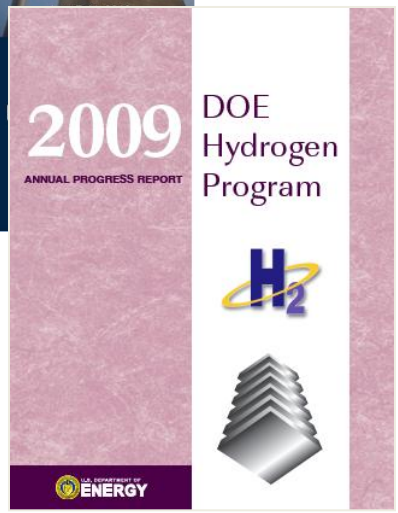
- Hydrogen and fuel cells are part of a diverse portfolio of RD&D activities within DOE and address stationary, portable and transportation applications.
- RD&D has resulted in significant progress - future work is still needed and will continue.
- DOE continues to solicit input from stakeholders on approaches to accelerate progress and enable widespread commercialization.

Source: US DOE 10/2010

Key Program Documents







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 & Peer Evaluation Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- **Latest edition released June 2010**

www.hydrogen.energy.gov/annual_review10_proceedings.html

Annual Merit Review & Peer Evaluation Report

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

- **To be released 2010**

www.hydrogen.energy.gov/annual_review09_report.html

Annual Progress Report

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

- **To be released 2010**

www.hydrogen.energy.gov/annual_progress.html

DOE job posting planned (check website/ USAjobs)

Next Annual Review: May 9 – 13, 2011

Washington, D.C.

http://annualmeritreview.energy.gov/

Source: US DOE 10/2010

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Collaborations

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 Hydrogen & Fuel Cells in the 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**
- **U. S. Fuel Cell Council**
- **National Hydrogen Association**
- **Hydrogen Utility Group**
- **~ 65 projects with 50 companies**

State & Regional Partnerships

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

National Laboratories

National Renewable Energy Laboratory P&D, S, FC, A, SC&S, TV, MN
Argonne A, FC, P&D
Los Alamos S, FC, SC&S
Sandia P&D, S, SC&S
Pacific Northwest P&D, S, FC, SC&S, A
Oak Ridge P&D, S, FC, A
Lawrence Berkeley FC, A
Lawrence Livermore P&D, S
Savannah River S, P&D
Brookhaven S, FC
Idaho National Lab P&D

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

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

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

Source: US DOE 10/2010

Thank you

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hydrogenandfuelcells.energy.gov