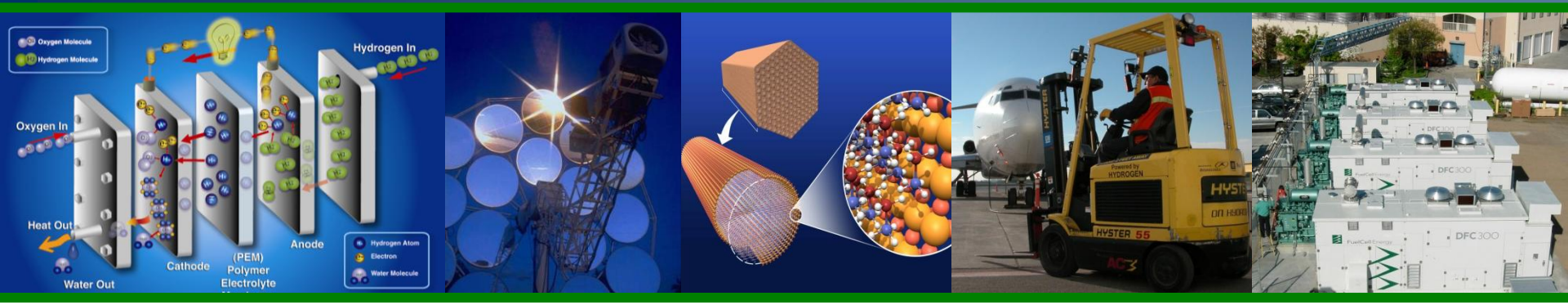
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



Overview of Hydrogen and Fuel Cell Activities

Dr. Sunita Satyapal

Chief Engineer & Deputy Program Manager

Fuel Cell Technologies Program

United States Department of Energy

Military Energy and Alternative Fuels Conference

March 17-18, 2010

San Diego, CA

Outline

1. Overview, Challenges & Technology Status
2. DOE Program Activities and Progress
3. Market Transformation

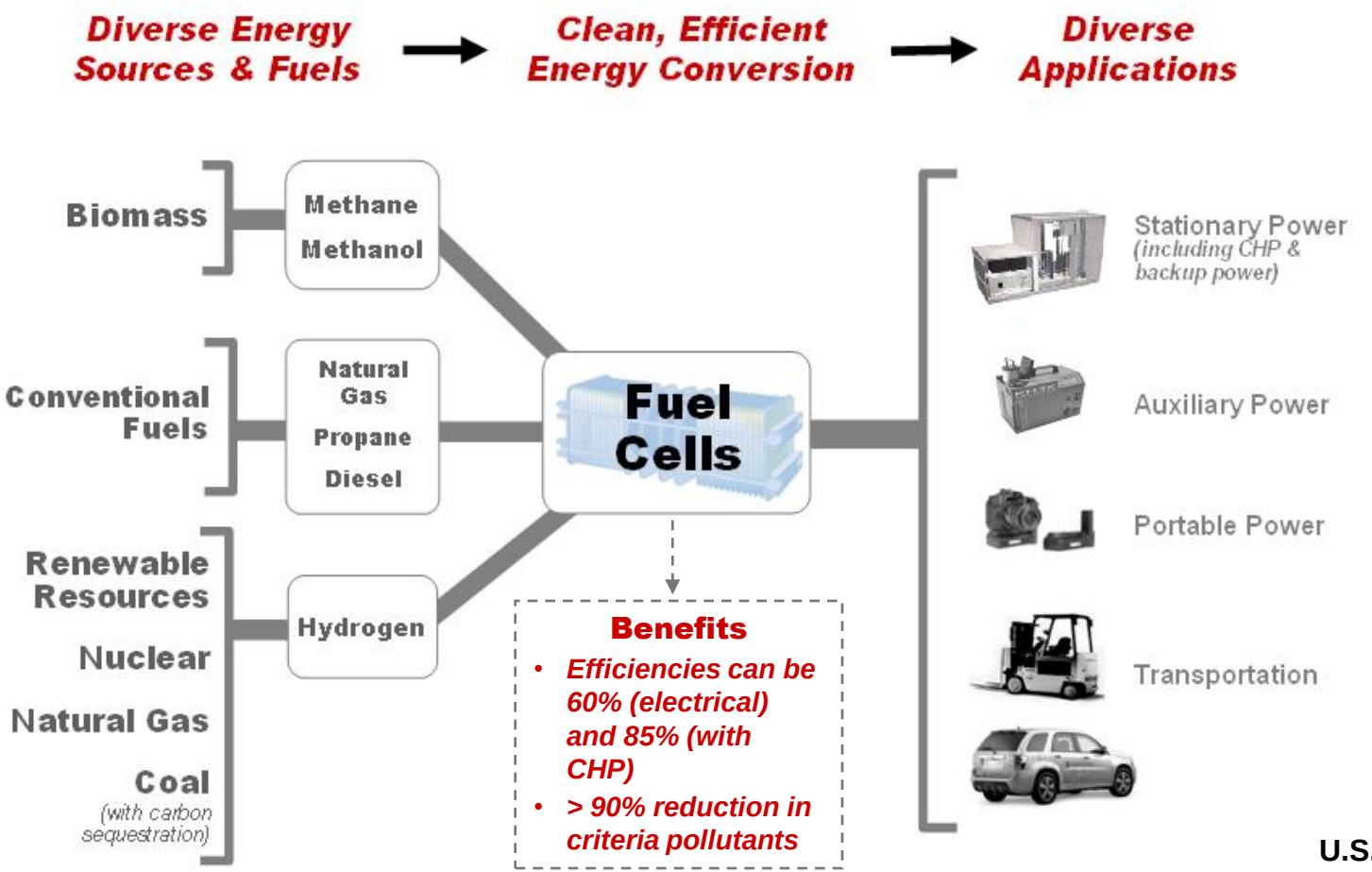
Fuel Cells: Addressing Energy Challenges

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.*



U.S. DOE

Executive Order 13514

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

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

Examples:

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

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

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

Fuel Cells — *Where are we today?*

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

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

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

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

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

Fuel Cells for Transportation

In the U.S., there are currently:

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

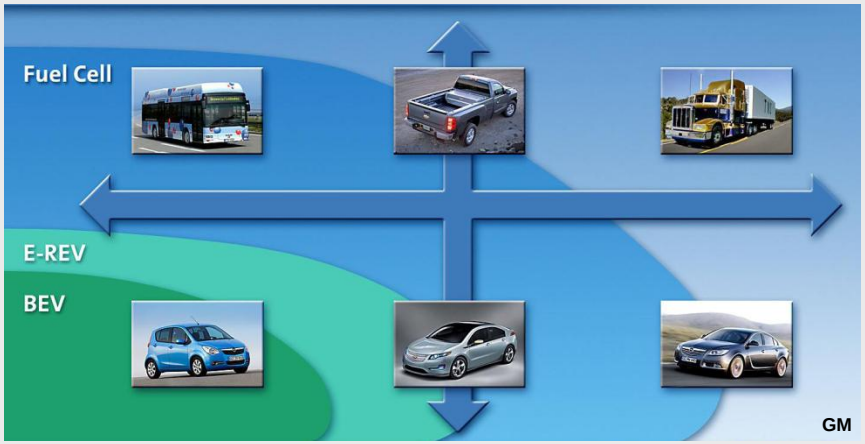
Several manufacturers—including Toyota, Honda, Hyundai, Daimler, GM, and Proterra (buses) — have announced plans to commercialize vehicles by 2015.

Production & Delivery of Hydrogen

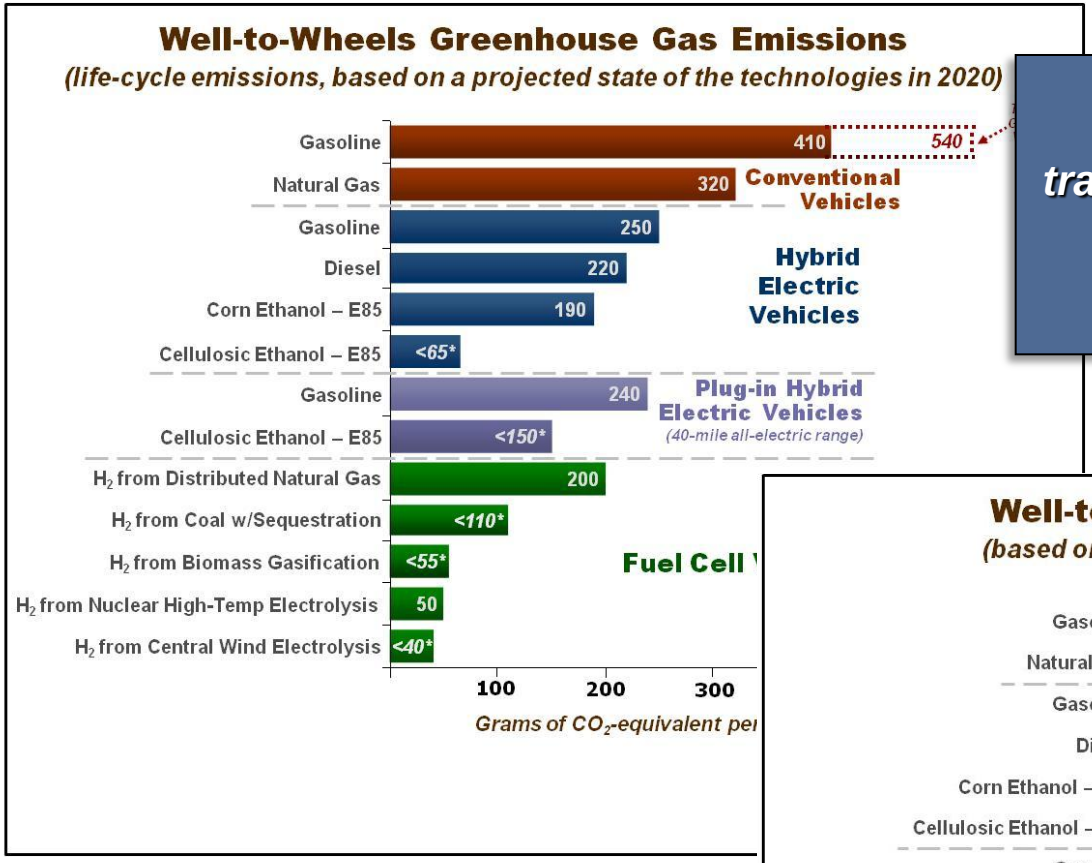
In the U.S., there are currently:

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

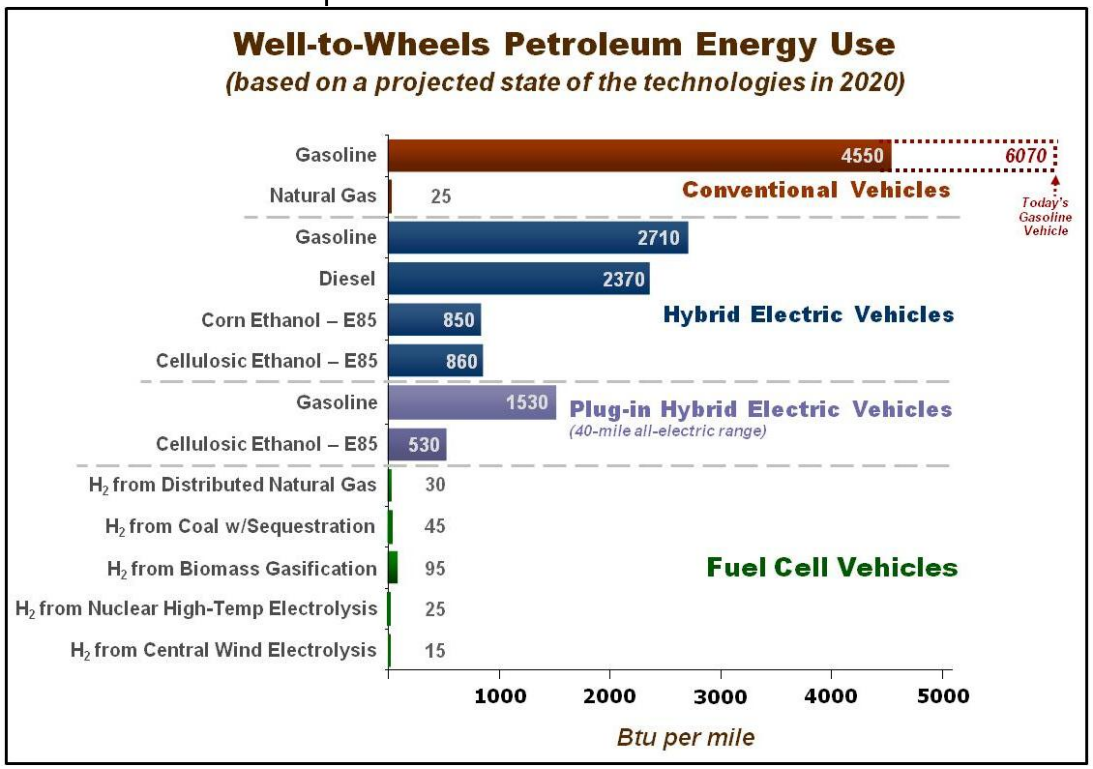
The Role of Fuel Cells in Transportation



Systems Analysis — *Examples of Benefits*



Analysis shows portfolio of transportation technologies will reduce greenhouse gas emissions and oil consumption.



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

Key Challenges

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

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

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

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

Hydrogen Cost

Target: $2 – 3 /gge, 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.

U.S. DOE

***Metrics available/under development for various applications**

Fuel Cell R&D — *Progress*

We've reduced the projected high-volume cost of fuel cells to $61/kW*

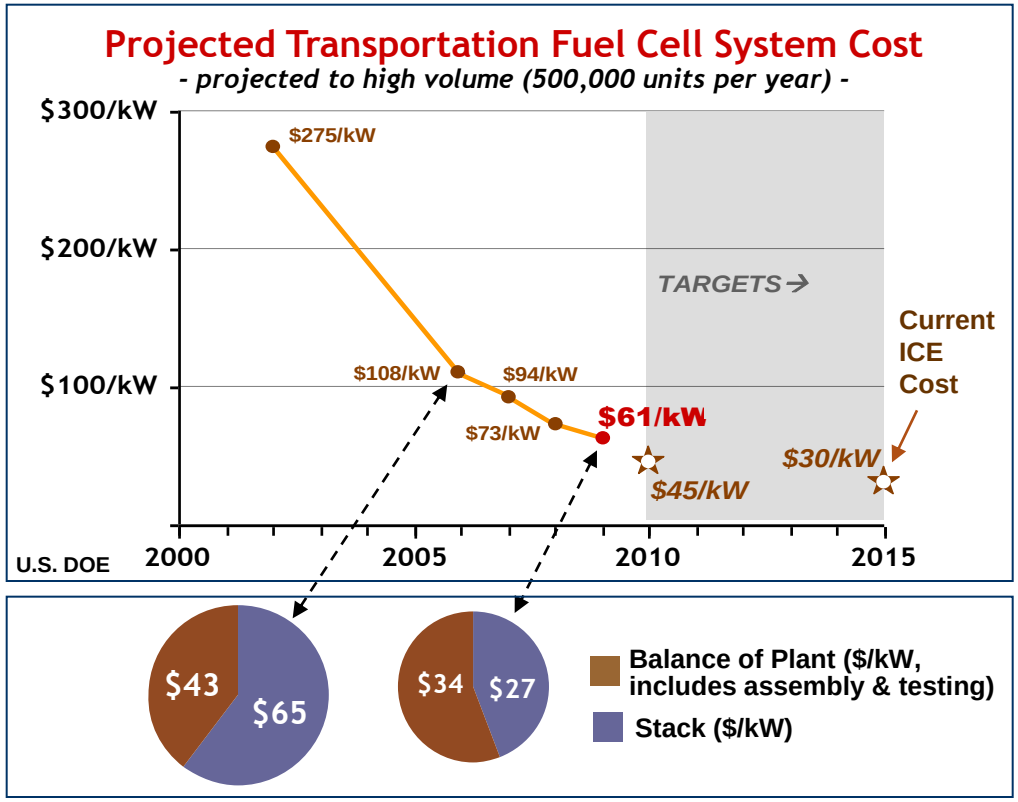
- *More than 35% reduction in the last two years*
- *More than 75% reduction since 2002*
- ***2008 cost projection was validated by independent panel*****

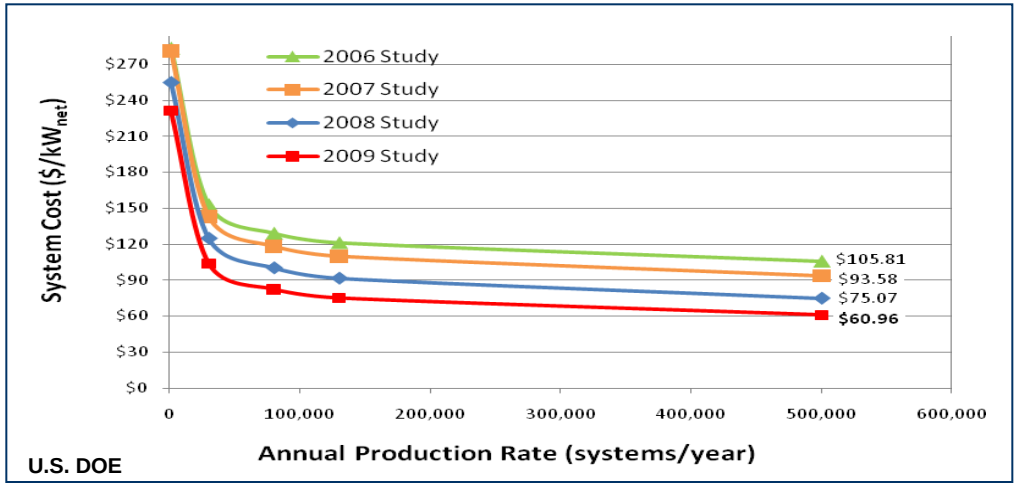
We've more than doubled durability in the last few years

- *More than 7,300 hrs with single cell, exceeding 5,000 hr target*

**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 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 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

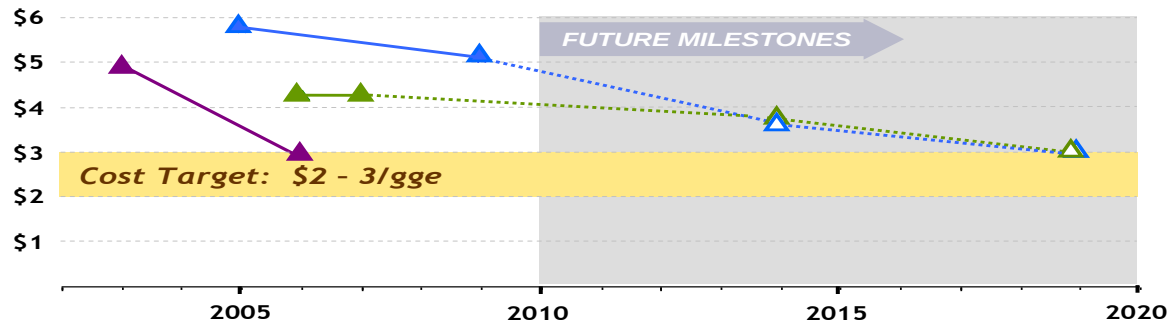
($/gallon gasoline equivalent [gge], untaxed)

U.S. DOE

NEAR TERM:

Distributed Production

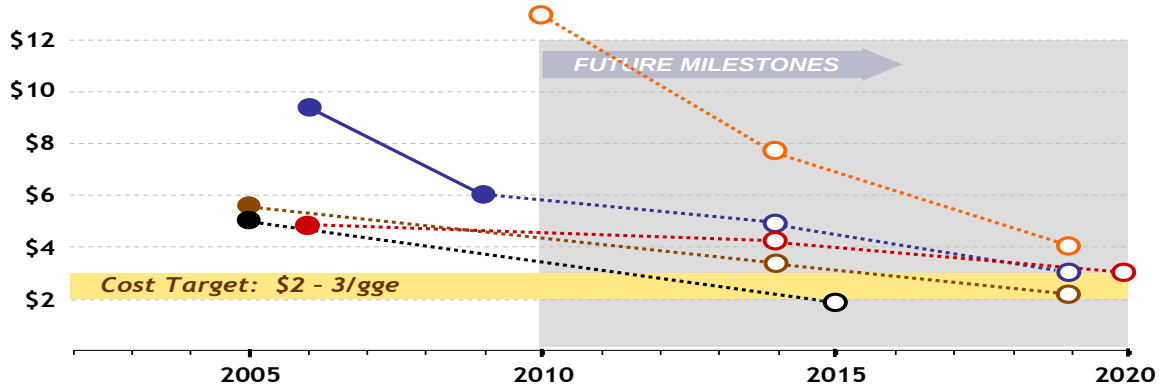
- Natural Gas Reforming
- Bio-Derived Renewable Liquids
- Electrolysis



LONGER TERM:

Centralized Production

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



* **Distributed production** status and targets assume station capacities of 1500 kg/day, with 500 stations built per year.
Centralized production values assume the following plant 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. Values for the status of centralized production assume $3/gge delivery cost, the while targets shown assume delivery cost targets are met ($1.70/gge in 2014 and <$1/gge in 2019).

Hydrogen Delivery R&D

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

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

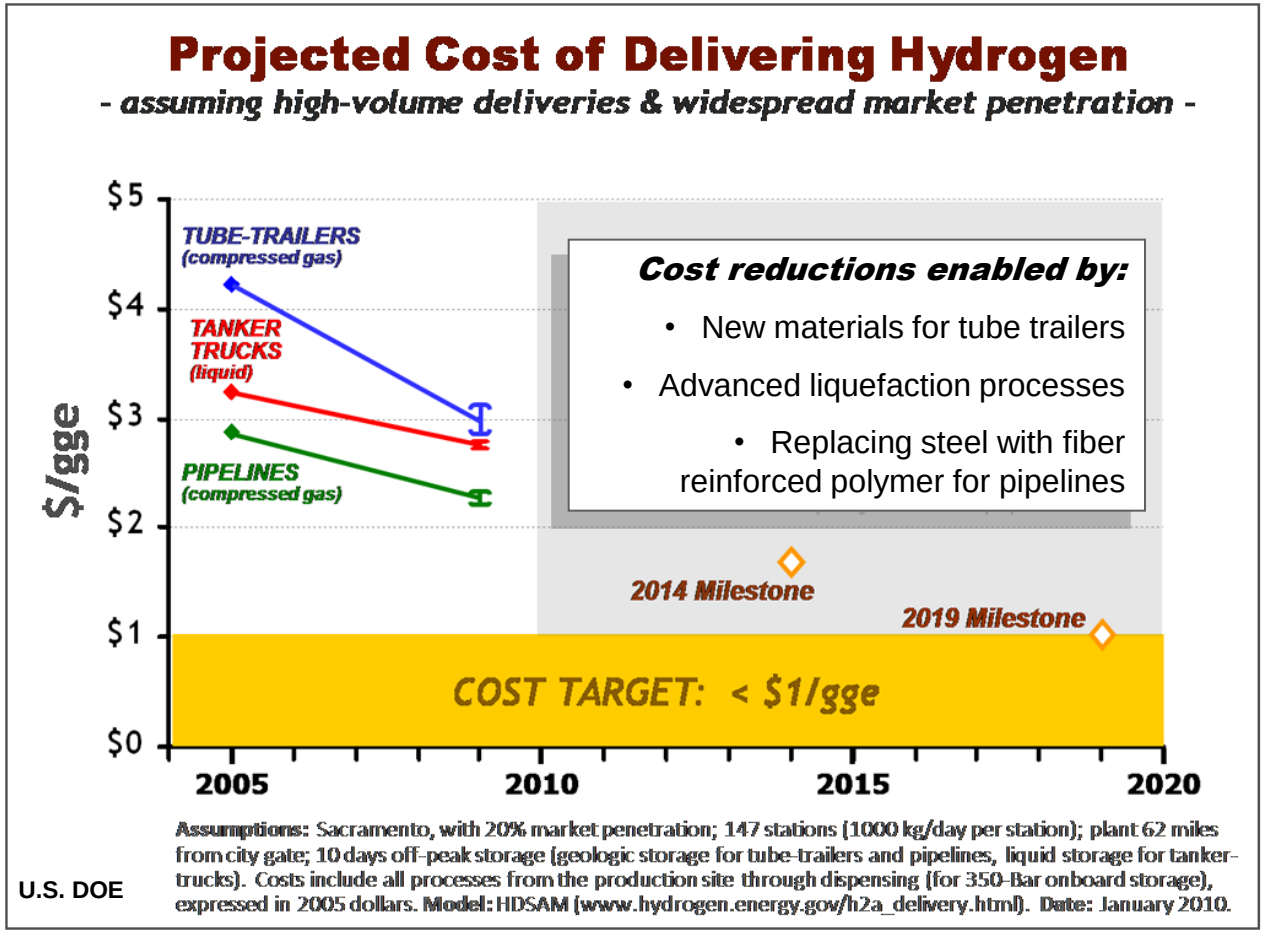
KEY OBJECTIVE

Reduce the cost of delivering hydrogen to < $1/gge

PROGRESS

We've reduced the projected cost of hydrogen delivery

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



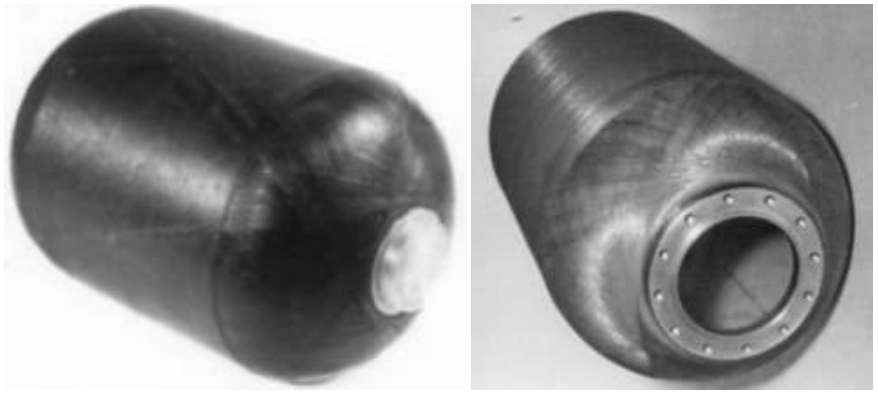
Hydrogen Storage R&D

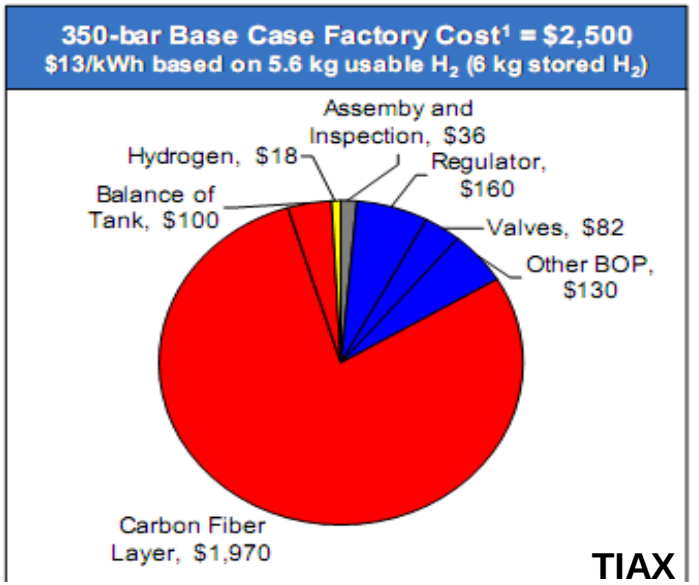
DOE has focused on materials R&D and has identified several promising new materials— providing more than 50% improvement in capacity since 2004.

KEY OBJECTIVE

> 300-mile driving range in all vehicle platforms, without compromising passenger/ cargo space, performance, or cost

- **High pressure tanks are viable for early market penetration and have already demonstrated > 300 mile range (e.g. 430 miles) with excellent performance & safety.**
- **Developed & evaluated > 350 materials for low pressure storage**





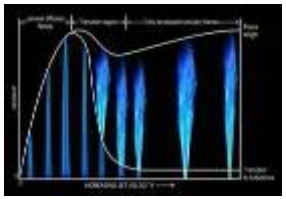
[1] Cost estimate in 2005 USD. Includes processing costs.

Future work is required to reduce cost while maintaining capacity and performance.

Safety, Codes & Standards *and* Education

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 held permitted workshops that reached >250 code officials

Growing number of C&S published (primary building & fire codes 100% complete)

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

Technology Validation

The Program is demonstrating key technologies to validate their performance in integrated systems, under real-world conditions.

DOE Vehicle/Infrastructure Demonstration

Four teams in 50/50 cost-shared projects with DOE Vehicle Technologies Program

- 140 fuel cell vehicles and 20 fueling stations demonstrated
- More than 2.3 million miles traveled
- More than 115,000 kg of hydrogen produced or dispensed*
- Analysis by NREL shows:
  - **Efficiency: 53 – 58%** (>2x higher than gasoline internal combustion engines)
  - **Range: ~196 – 254 miles**
  - **Fuel Cell System Durability:**

    ~ 2,500 hrs (~75,000 miles)

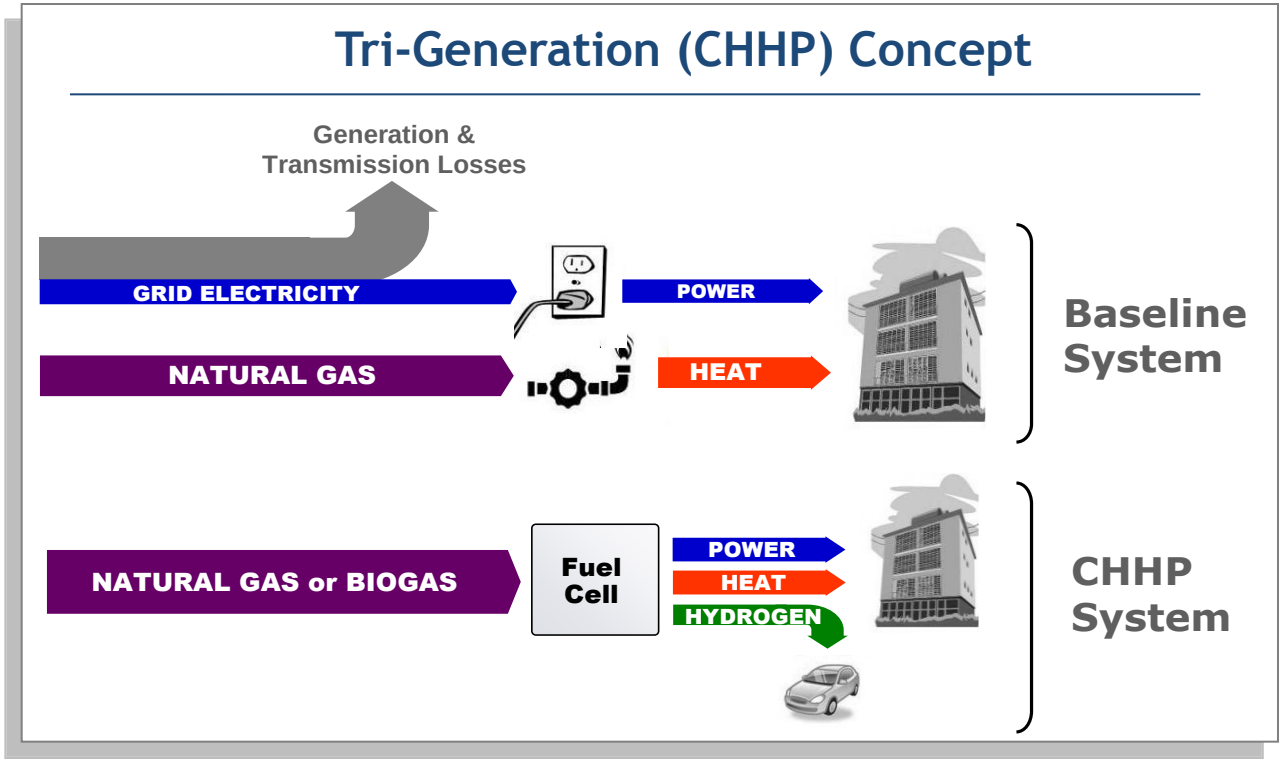
**includes hydrogen not used in the Program's demonstration vehicles*

We are also demonstrating stationary fuel cells and evaluating real-world forklift and bus fleet data (DOD and DOT collaboration).

Technology Validation — *Tri-Gen Highlight*

We are participating in a project to demonstrate a combined heat, hydrogen, and power (CHHP) 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 can:

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

Public-Sector Partners:

South Coast Air Quality Management District

California Air Resources Board

Examples of Early Market Applications

Fuel Cells for Backup Power ...

- Provide longer continuous run-time, greater durability than batteries
- Require less maintenance than batteries or generators
- *May provide substantial cost-savings* over batteries and generators

A 1-kW fuel cell system has been providing power for this FAA radio tower near Chicago for more than three years.

(Photo courtesy of ReliOn)

Fuel Cells for Material Handling Equipment ...

- Allow for rapid refueling — much faster than changing-out or recharging batteries
- Provide constant power without voltage drop
- Eliminate need for space for battery storage and chargers
- *May provide substantial cost-savings* over battery-powered forklifts

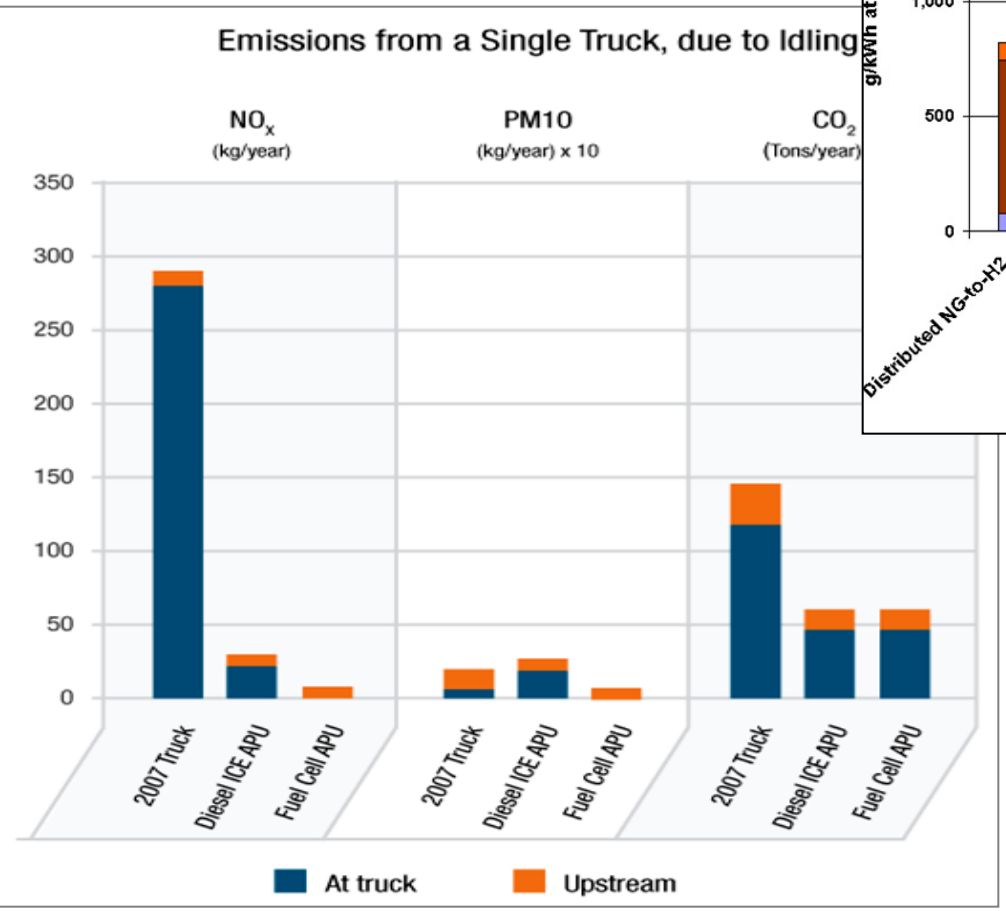
Photo courtesy of Hydrogenics

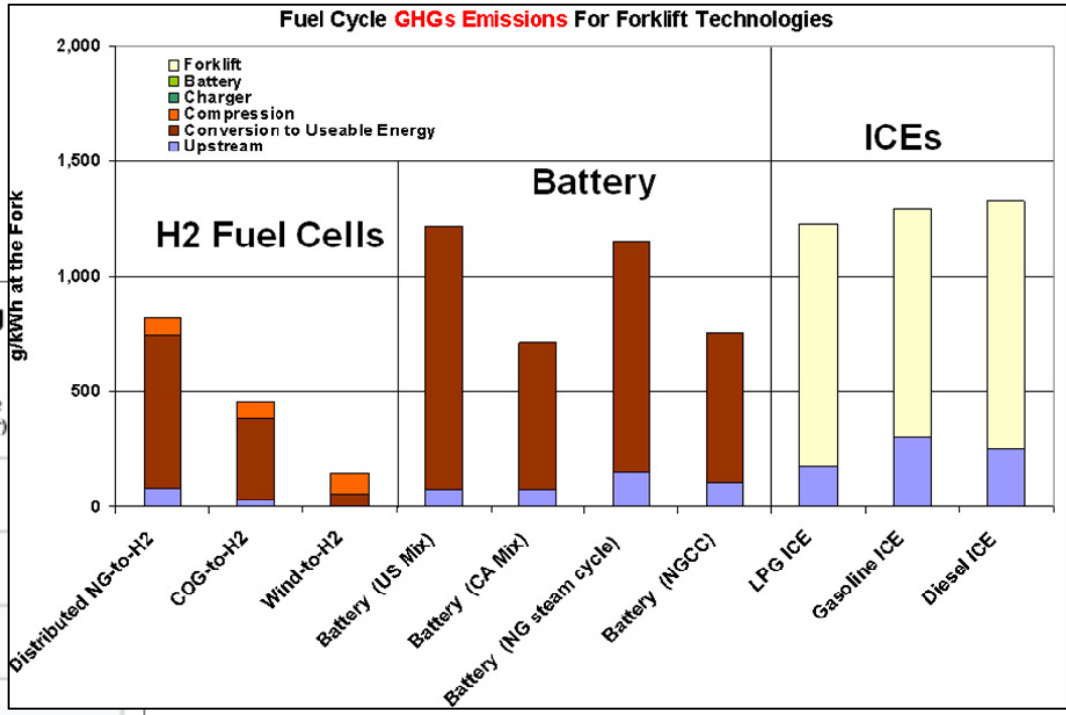
Fuel Cells for Data Centers ...

- Provide high-quality, reliable, grid-independent on-site critical load power
- Improve the effectiveness of data center power use by 40%, with combined heat-and-power (for cooling and heating)
- Produce no emissions
- Have low O&M requirements
- Can be remotely monitored

Examples of Benefits- Forklifts & APUs

Fuel Cells can provide significant emissions reductions in forklift and APU applications





U.S. DOE

Forklift Comparison

Green Text = *Advantage*

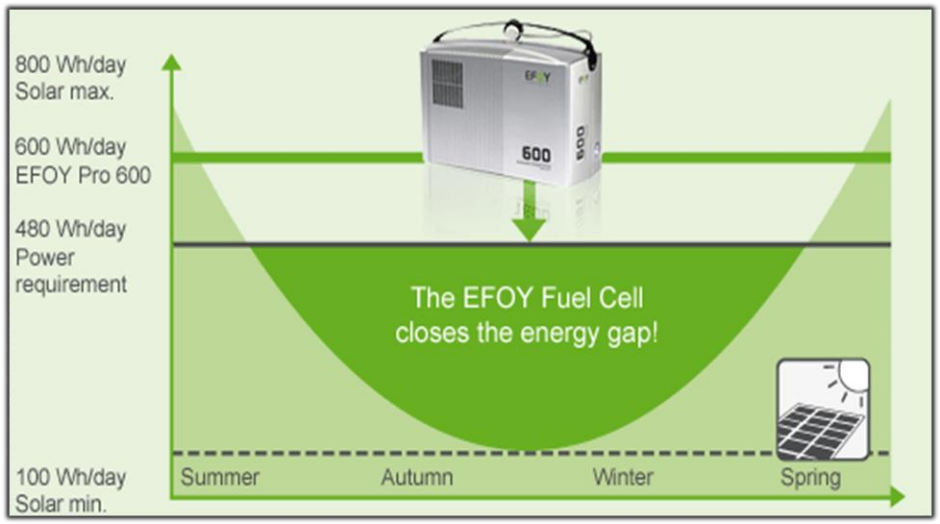
	3-kW PEM Fuel Cell-Powered Pallet Trucks*	3-kW Battery-powered (2 batteries per truck)*
Total Fuel Cycle Energy Use *(total energy consumed per kWh delivered to the wheels)*	**~12,000 Btu/kWh**	>14,000 Btu/kWh
Fuel Cycle Greenhouse Gas Emissions *(in g CO_2 equivalent)*	**820 g/kWh**	1200 g/kWh
No Emissions at Point of Use	✓	✓
Quiet Operation	✓	✓
Wide Ambient Operating Temperature Range	✓	
Constant Power Available over Shift	✓	
Routine Maintenance Costs	**$720/year**	$3,600/year
Time for Refueling/Changing Batteries	**3 – 10 minutes/day**	30 – 90 minutes/day *(for battery change-outs)* 8-hours *(for battery recharging & cooling)*
Cost of Fuel/Electricity	$4,380/year	**$1,307/year**
Labor Cost of Refueling/Recharging	**$274/year**	$8,213/year
Net Present Value of Capital Costs	**$16,684** ($23,835 w/o incentive)	$17,654
Net Present Value of O&M costs (including fuel)	**$52,241**	$127,539
Net Present Value of Total Costs of System	**$68,925** (**$76,075** w/o incentive)	$145,193

Sources: *Full Fuel-Cycle Comparison of Forklift Propulsion Systems*, Argonne National Laboratory, October 2008; *Identification and Characterization of Near-term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets*, Battelle Memorial Institute, April 2007; and forklift manufacturer industry information collected by the National Renewable Energy Laboratory.

Additional Examples – FC Applications

FC Battery Chargers

- Flexibility
- Long run times
- Grid independent
- Quiet
- Light weight
- Reduced down time
- Enables & complements intermittent renewables



FC Soldier Power

- Light weight
- Efficient
- Quiet
- Low heat
- Design flexibility

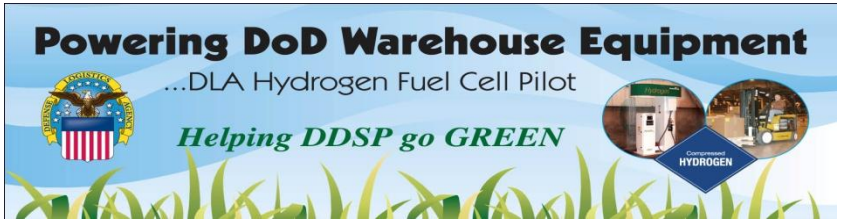
72 hour mission example

Source: USFCC, DOD

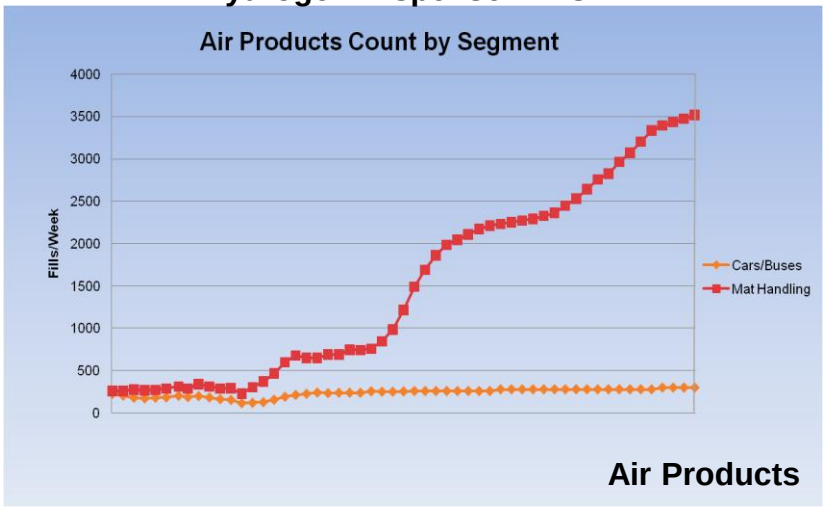
Potential Opportunities – Gov't Leadership

Examples

- DLA: material handling equipment and H2ICE shuttle buses
- FAA: ground support equipment and backup power
- APTO: ground support equipment and H2ICE shuttle buses
- Army incl. CERL/TARDEC: backup power, waste to energy, and H2ICE shuttle buses
- NPS: renewably generated backup power and H2ICE shuttle buses
- ONR/USMC: utility scale renewable hydrogen generation and H2ICE shuttle buses
- NASA: backup power and H2ICE shuttle buses



Hydrogen Dispenser Fills

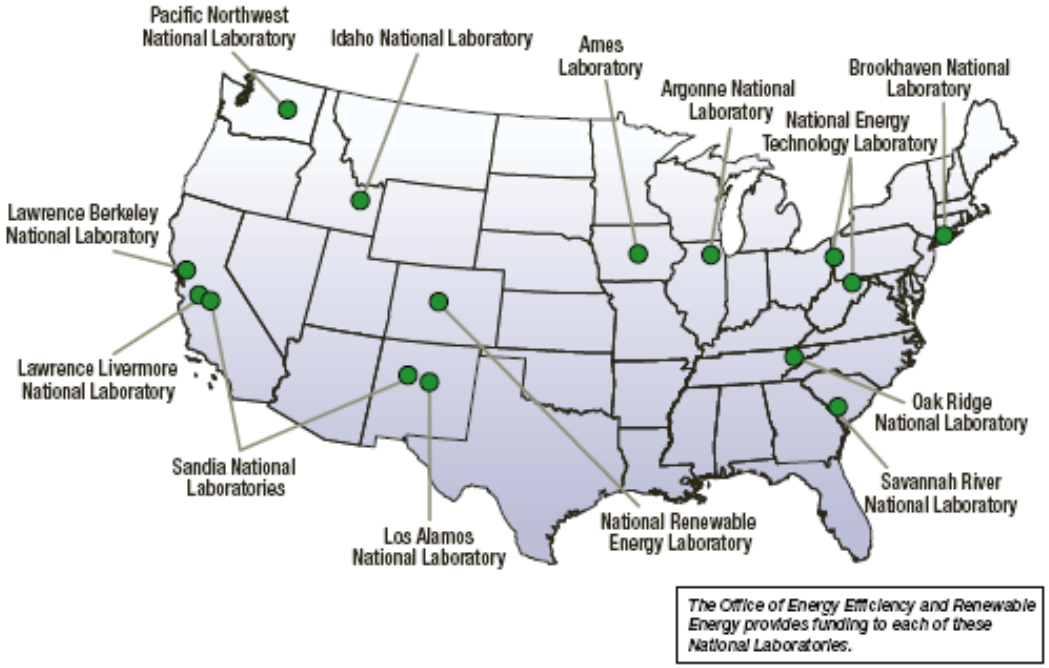


DLA, DDSP – First of several 15,000 fills/yr sites

DOE National Laboratory Projects

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

DOE intends to lead by example by deploying fuel cells at its facilities, and the Program has begun to identify opportunities.



Goals:

- Deploy fuel cells and quantify benefits at lab facilities
- Develop DOE lab fuel cell expertise across the country

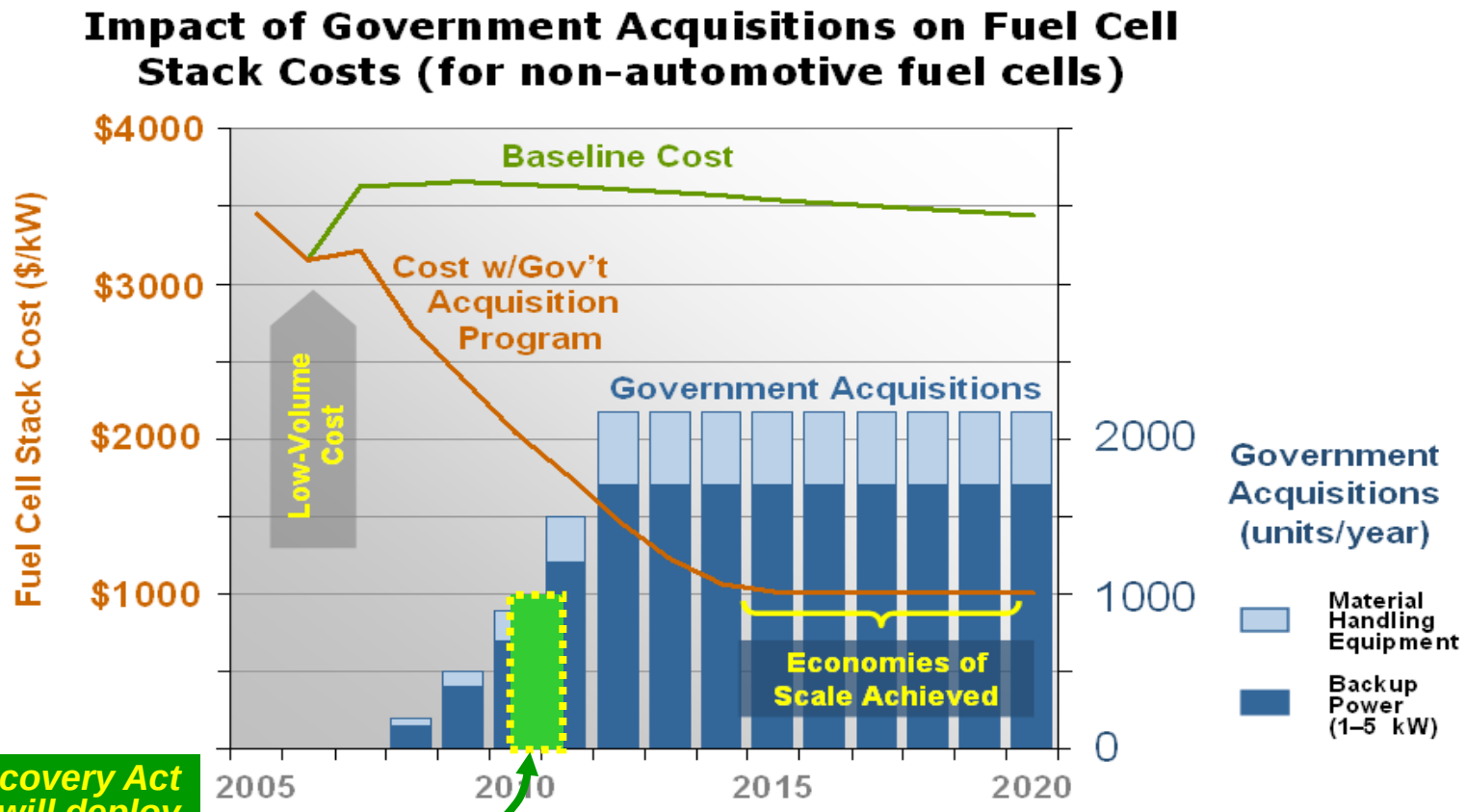
Ideal sites:

- Require consistent, reliable, quiet power
- Would combine FC installation with planned projects.

- ***8 feasibility studies are underway to identify potential fuel cell deployment projects at the following 7 locations: Argonne National Laboratory, National Renewable Energy Laboratory (2 studies), Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Sandia National Laboratory, Thomas Jefferson National Accelerator Facility, and the Y-12 Site Office***

Market Transformation

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



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

Source: ORNL

U.S. DOE

We are facilitating the adoption of fuel cells across government and industry:

- **100 fuel cells are being deployed, through interagency agreements.**
- **More interagency agreements under development.**

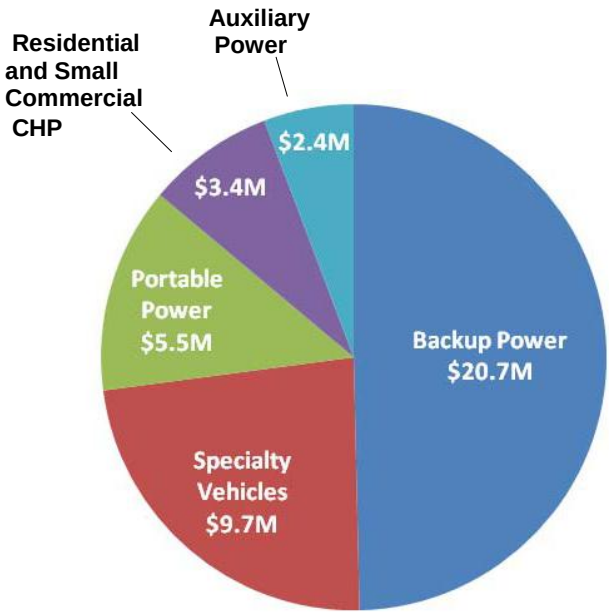
Recovery Act Deployments

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

DOE announced ~$40 million from the American Recovery and Reinvestment Act to fund 12 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:

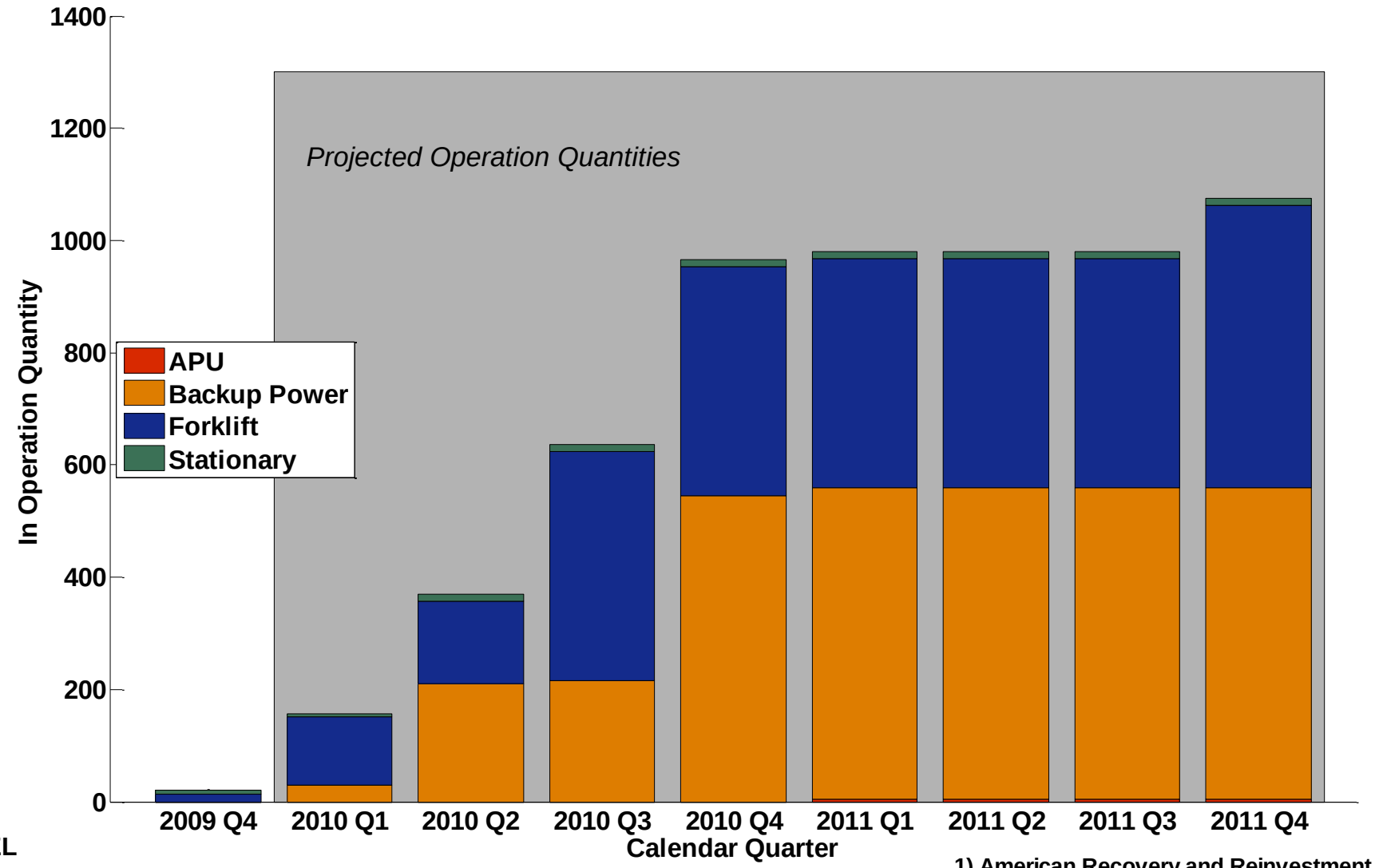
DOE funding has supported R&D by all of the fuel cell suppliers involved in these projects.



Approximately $51 million in cost-share proposed by industry participants—for a total of nearly $93 million.

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

ARRA Fuel Cell Deployment Estimates



NREL

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1) American Recovery and Reinvestment Act

Preliminary estimates. DOE will continue to update status as units are delivered

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

Key Partnerships & 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 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**

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 Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- → ***Latest edition released June 2009***

www.hydrogen.energy.gov/annual_review09_proceedings.html

Annual Merit Review & Peer Evaluation Report

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

- → ***Latest edition released October 2009***

www.hydrogen.energy.gov/annual_review08_report.html

Annual Progress Report

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

- → ***Latest edition published November 2009***

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: June 7 – 11, 2010

Washington, D.C.

http://annualmeritreview.energy.gov/

Thank you

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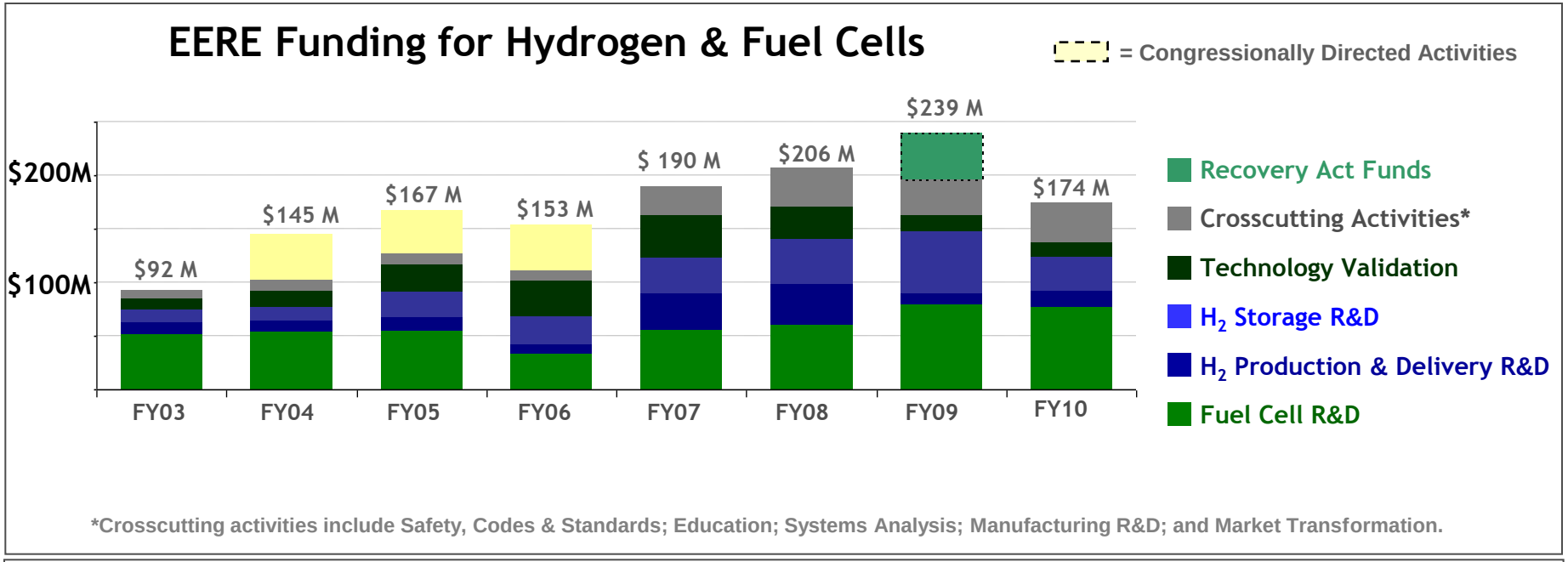
http://www.eere.energy.gov/hydrogenandfuelcells

Additional Information

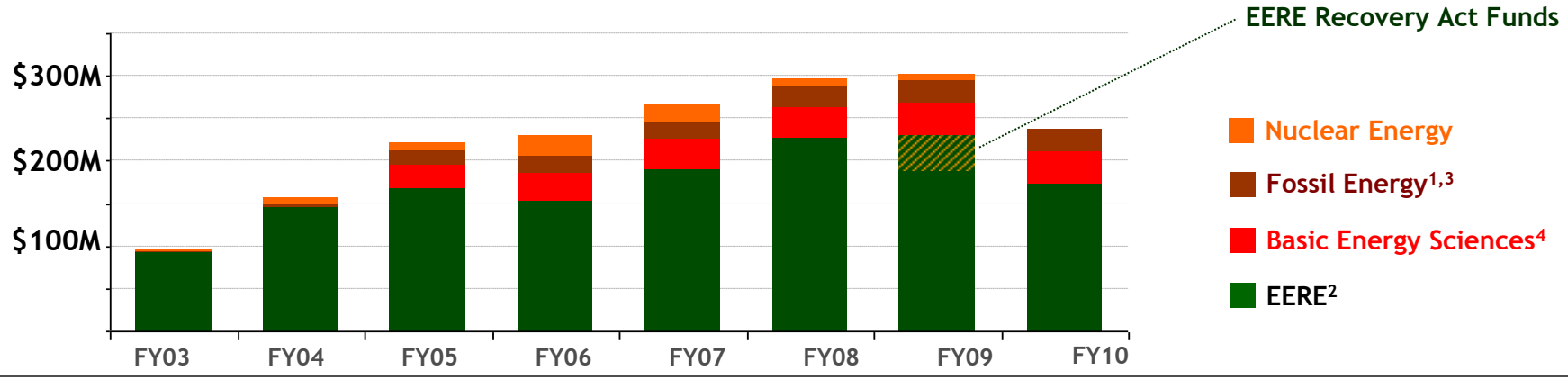
DOE Funding History for Fuel Cells

EERE Funding for Hydrogen & Fuel Cells



*Crosscutting activities include Safety, Codes & Standards; Education; Systems Analysis; Manufacturing R&D; and Market Transformation.

DOE Funding for Hydrogen & Fuel Cells



[1] All FE numbers include funding for program direction.

[2] FY09 and FY10 include SBIR/STTR funds to be transferred to the Science Appropriation; previous years shown exclude this funding.

[3] FY10 number includes coal to hydrogen and other fuels. FE also plans $50M for SECA in FY10.

[4] FY10 shows estimated funding for hydrogen- and fuel cell–related projects; exact funding to be determined. The Office of Science also plans ~$14M for hydrogen production research in the Office of Biological and Environmental Research in FY10.

Examples of Policies Promoting Fuel Cells

Some tax credits affecting fuel cells were 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.**