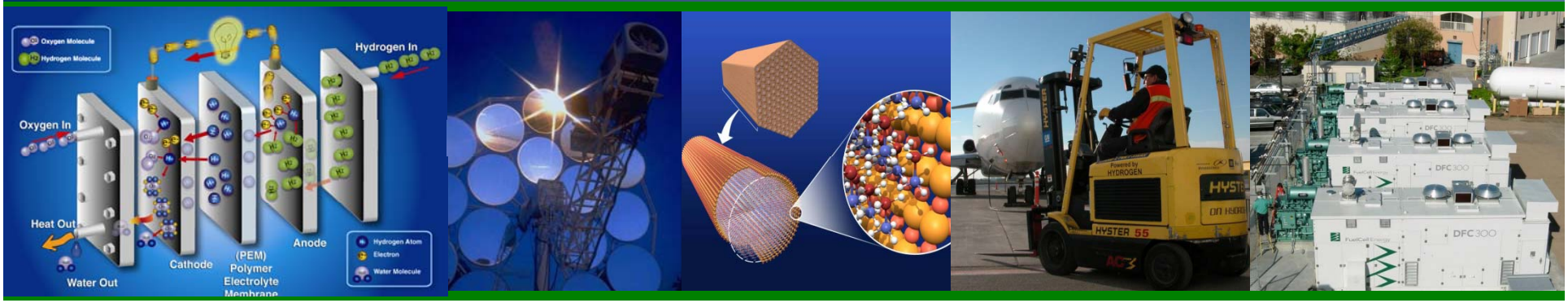
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



2010 Fuel Cell Project Kick-off

Dr. Dimitrios Papageorgopoulos

Fuel Cells Team Leader

U.S. Department of Energy

Fuel Cell Technologies Program

September 28, 2010

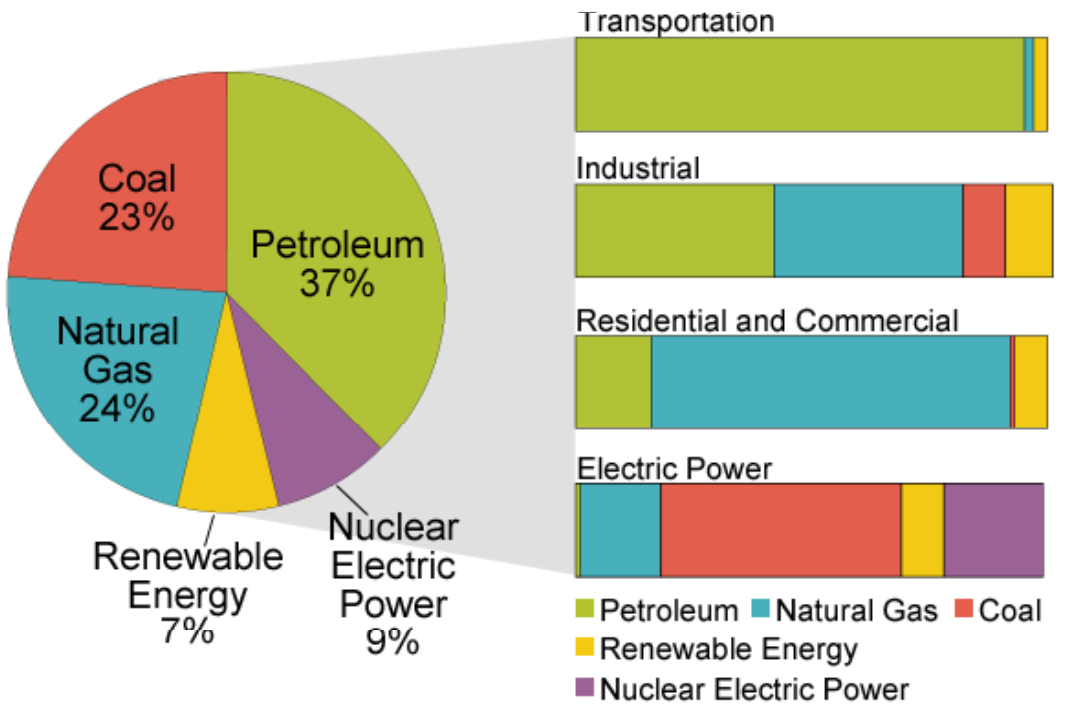
Administration's Clean Energy Goals

- ✓ 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

U.S. Energy Consumption

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

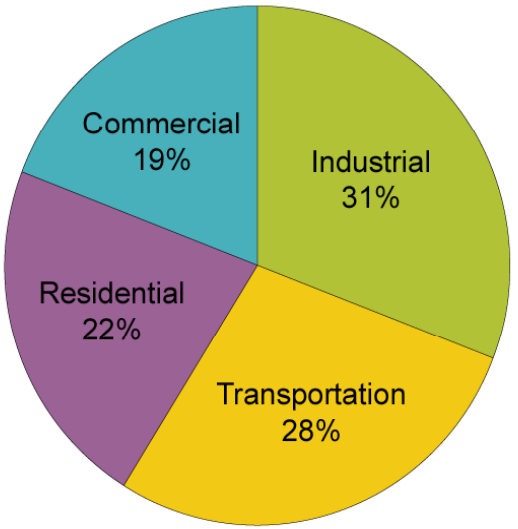
U.S. Primary Energy Consumption by Source and Sector



Total U.S. Energy = 99.3 Quadrillion Btu

Source: Energy Information Administration, *Annual Energy Review 2008,* Tables 1.3, 2.1b-2.1f.

Share of Energy Consumed by Major Sectors of the Economy



Source: Energy Information Administration, *Annual Energy Review 2008.*

Fuel Cells: Addressing Energy Challenges

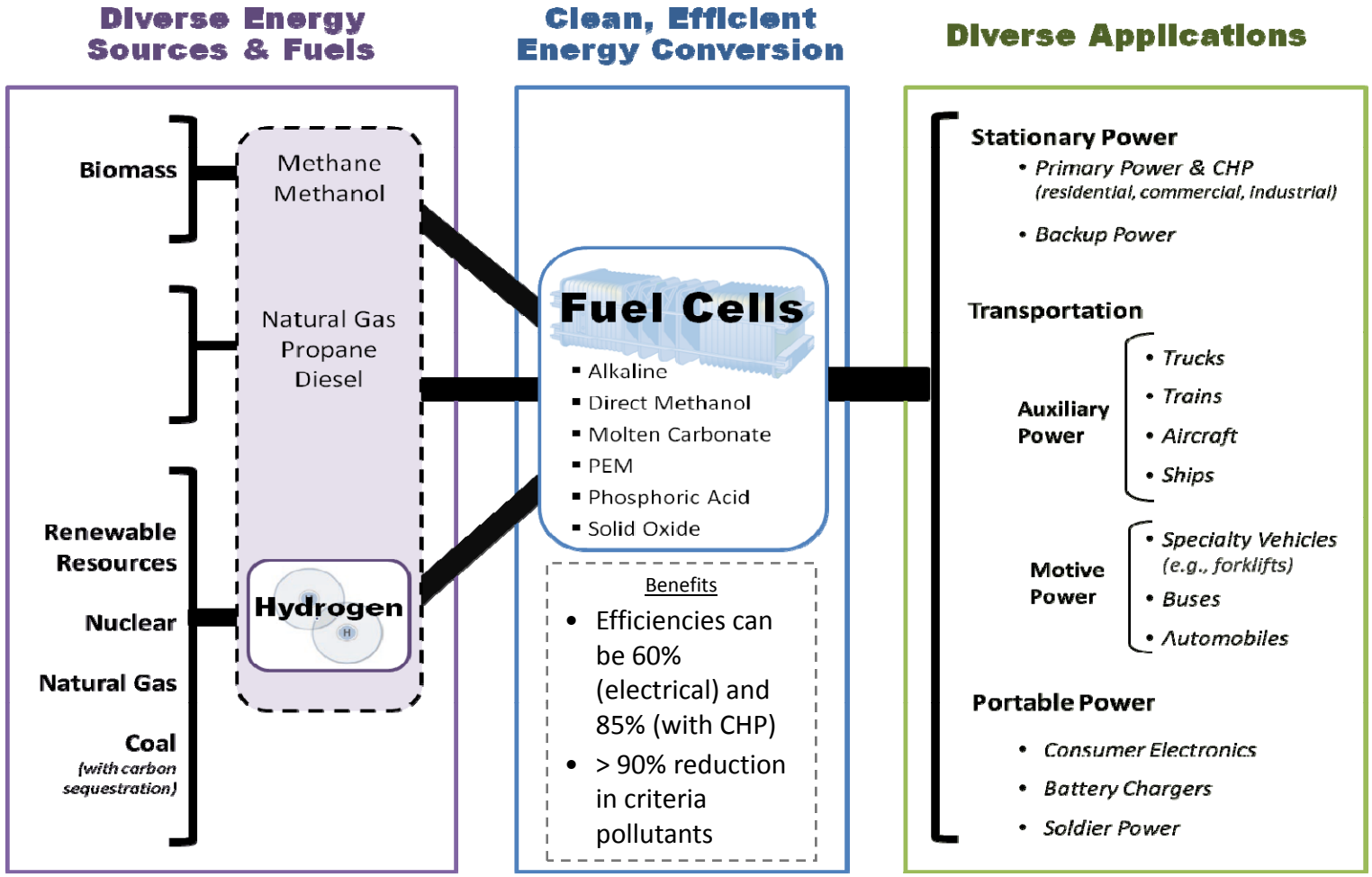
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Energy Efficiency and Resource Diversity

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

Greenhouse Gas Emissions and Air Pollution:

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



Source: US DOE
10/2010

Key Challenges

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

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

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

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

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

Hydrogen Cost

Target*: $2 – 3 /gge, (dispensed and untaxed)

Hydrogen Storage Capacity

Target: > 300-mile range for vehicles—without compromising interior space or performance

Technology Validation:

Technologies must be demonstrated under real-world conditions

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

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

* Targets and Metrics are being updated in 2010

Fuel Cells — *Where are we today?*

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

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

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

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

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

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

Fuel Cells for Transportation

In the U.S., there are currently:

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

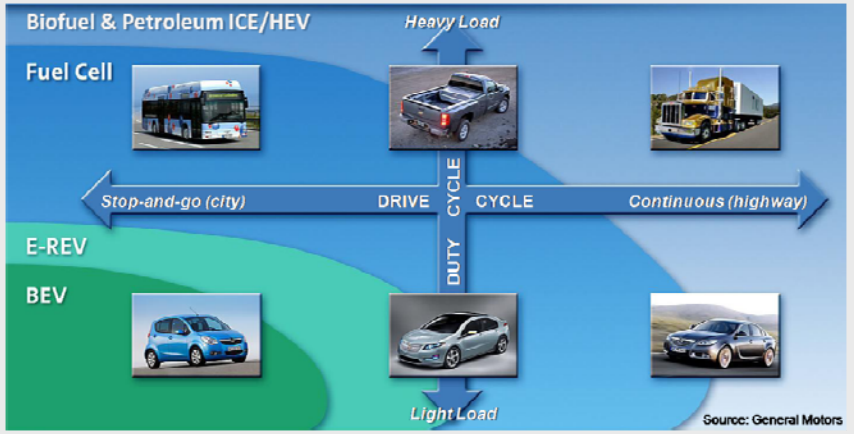
Several manufacturers—including Toyota, Honda, Hyundai, Daimler, GM, and Proterra (buses) — have announced plans to commercialize vehicles by 2015.

Production & Delivery of Hydrogen

In the U.S., there are currently:

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

The Role of Fuel Cells in Transportation

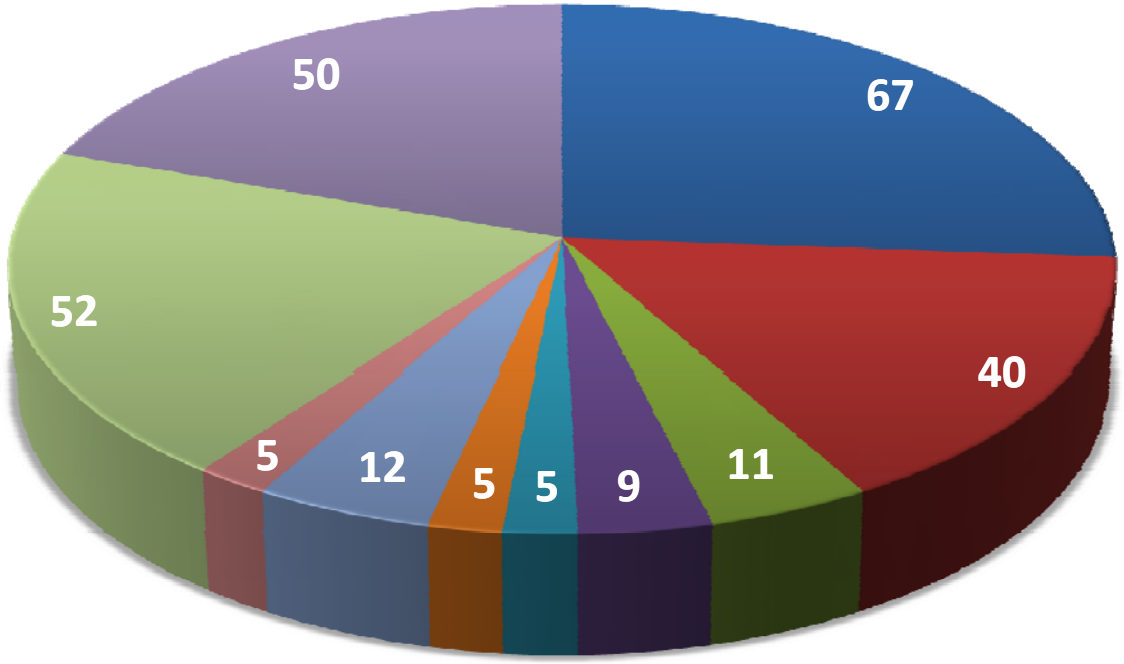


Source: US DOE 10/2010

Total DOE FY11 Budget Request

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable 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 request TBD, $5M represents FY10 funding
**SC Includes BES and BER

Budget

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

FY 2010 Emphasis

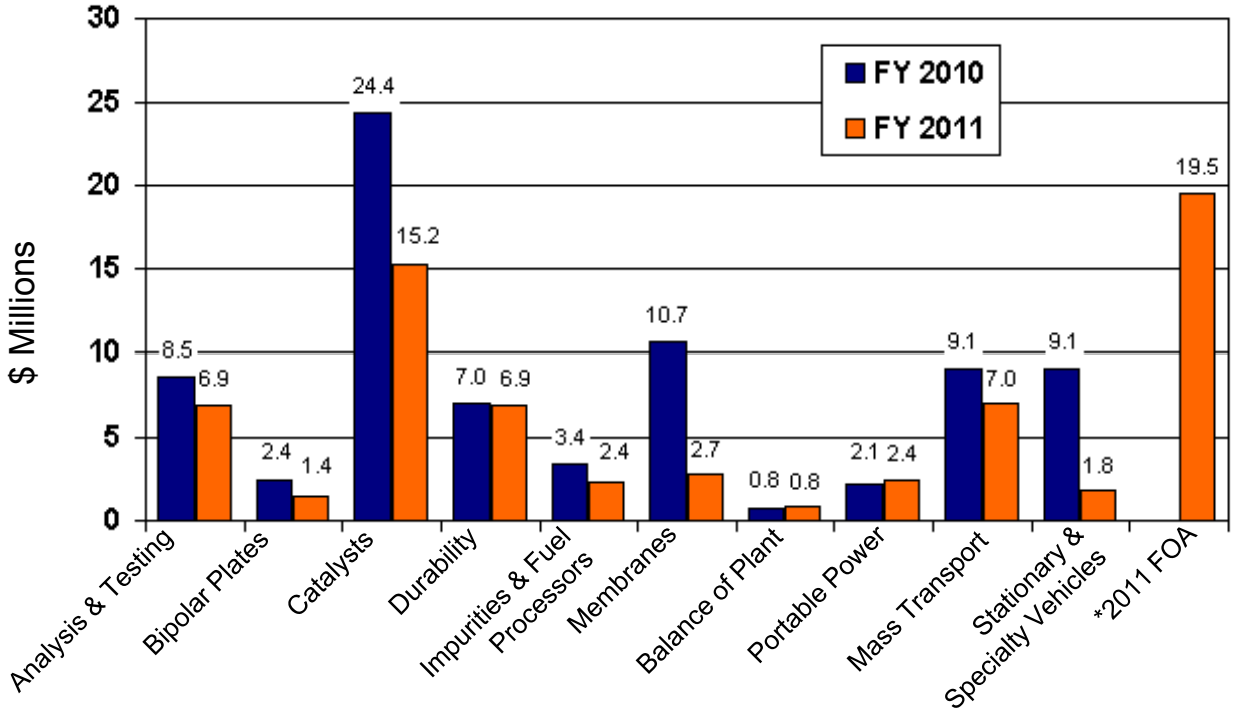
R&D of materials, stack components, balance-of-plant subsystems, and integrated fuel cell systems targeting lower cost and enhanced durability

- Develop improved fuel cell catalysts and membrane electrolytes
- Characterize and optimize transport phenomena improving MEA and stack performance
- Optimize fuel cells and systems for early market applications
- Develop innovative concepts leading to a new generation of fuel cell technologies

Applications include: transportation, combined heat and power (CHP), auxiliary power units (APUs), direct methanol fuel cells for portable power, and backup power for critical infrastructure.

FY 2010 Budget Plan Industry - $31.5M, National Labs - $40.2M, University - $5.7M

FY 2010
APPROPRIATION = $77.4M
FY 2011
***REQUEST* = $67M**



*FOA subject to approval / appropriations

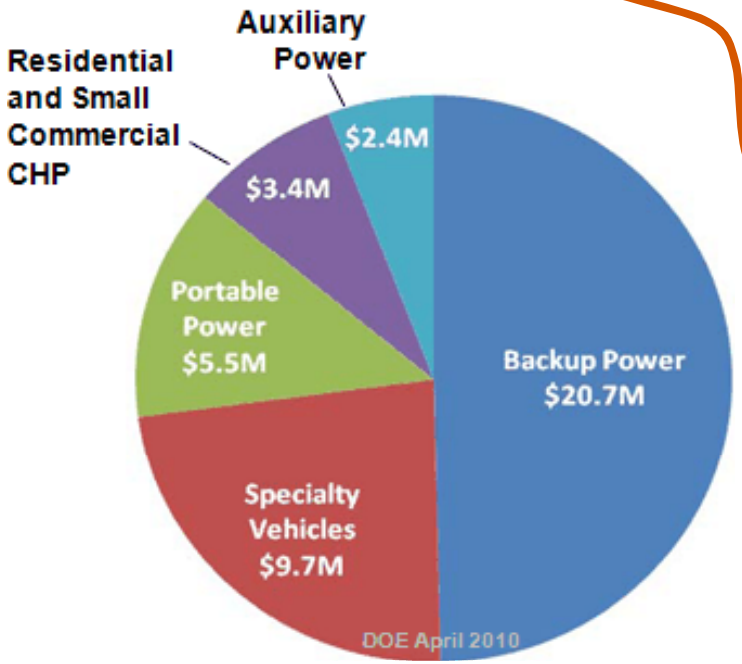
Recovery Act Funding for Fuel Cells

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

DOE announced more than $40 million from the American Recovery and Reinvestment Act to fund 12 projects, which will deploy up to 1,000 fuel cells — to help achieve near term impact and create jobs in fuel cell manufacturing, installation, maintenance & support service sectors.

FROM the LABORATORY to DEPLOYMENT:

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



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

Source: US DOE 09/2010

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

Fuel Cell R&D - *Metrics*

U.S. DEPARTMENT OF ENERGY

Fuel Cell R&D is focused on a broad range of applications, using a variety of technologies and fuels.

KEY TARGETS:

Distributed Power*:

- $750/kW by 2011
- 40,000-hour durability by 2011
- 40% efficiency by 2011

Transportation:

- $45/kW by 2010; $30/kW by 2015*
- 5,000-hour durability by 2015
- 60% efficiency

APUs:

- Specific power of 40 W/kg by 2015
- Power density of 35 W/L by 2015

Portable Power*:

- Energy density of 1,000 W-h/L by 2013

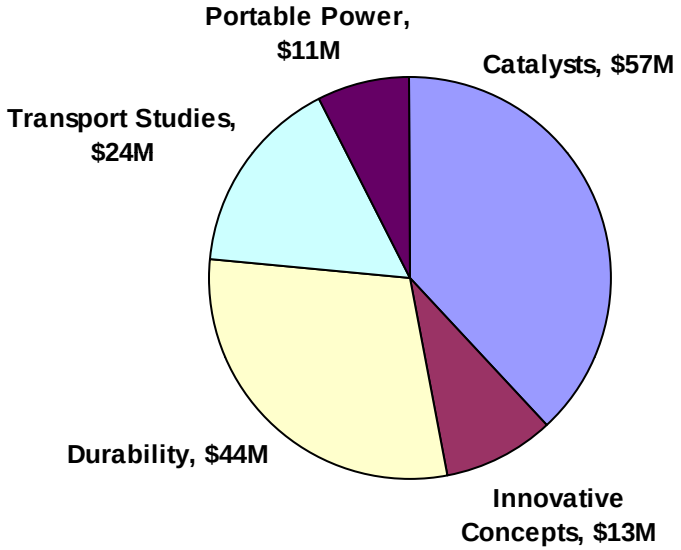
Performance metrics being tracked will help form materials handling and backup power targets

*Targets are currently under review

Source: US DOE 09/2010

New Fuel Cell Projects

9 new R&D projects kicked off in 2010, in addition to 28 from 2009
Total award of $150M



New projects will:

- **Develop improved fuel cell catalysts**
- **Enhance fuel cell durability**
- **Characterize transport phenomena**
- **Optimize fuel cells for early market applications**
- **Develop innovative concepts leading to a new generation of fuel cell technology**

Projects led by stakeholders in industry, universities, and national labs

Industry

3M
Arkema
Ballard Power Systems
DuPont
Giner Electrochemical Systems
General Motors
Ion Power
Nuvera Fuel Cells
Plug Power
TreadStone
UTC Power
Versa Power Systems
W.L. Gore & Associates

Universities

Illlinois Institute of Technology
Northeastern University
Univ. of North Florida
Univ. of Hawaii
Univ. of South Carolina

National Labs

Argonne
Brookhaven
Los Alamos
Lawrence Berkeley
National Renewable Energy Lab
Sandia

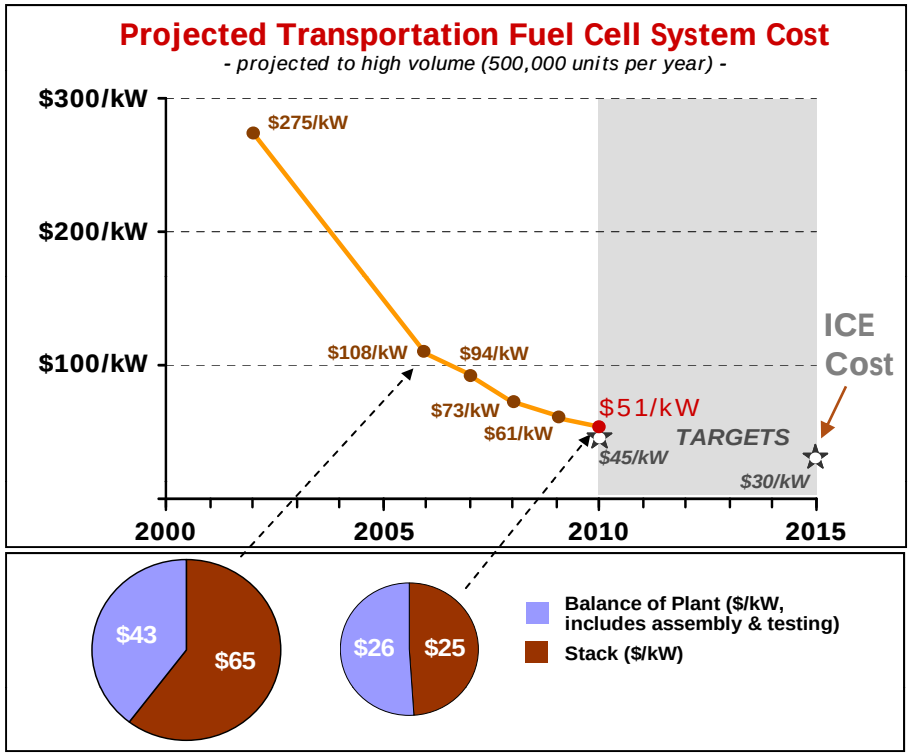
Fuel Cell R&D — *Progress: Cost*

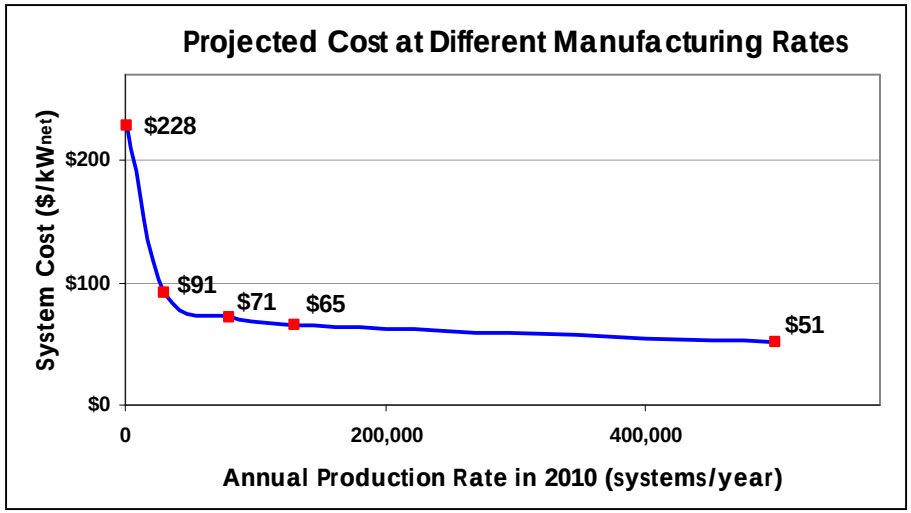
U.S. DEPARTMENT OF ENERGY

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).**

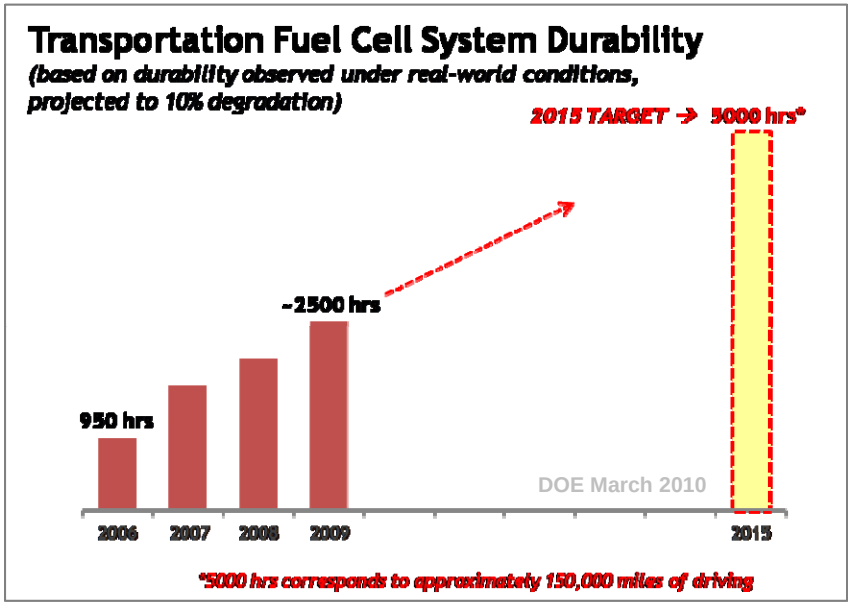
****Panel found $60 – $80/kW to be a "valid estimate": http://hydrogendoedev.nrel.gov/peer_reviews.html**

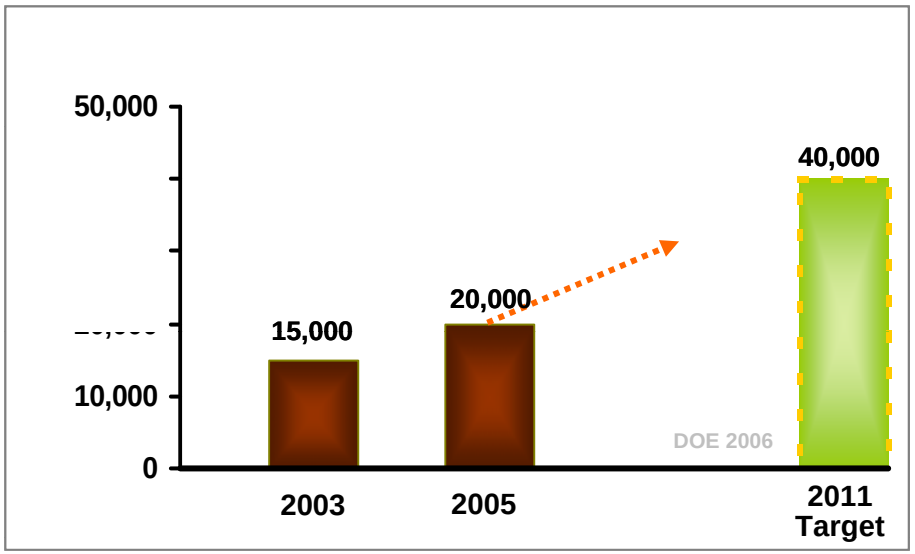
Source: US DOE 09/2010

Fuel Cell R&D – *Progress: Durability*

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

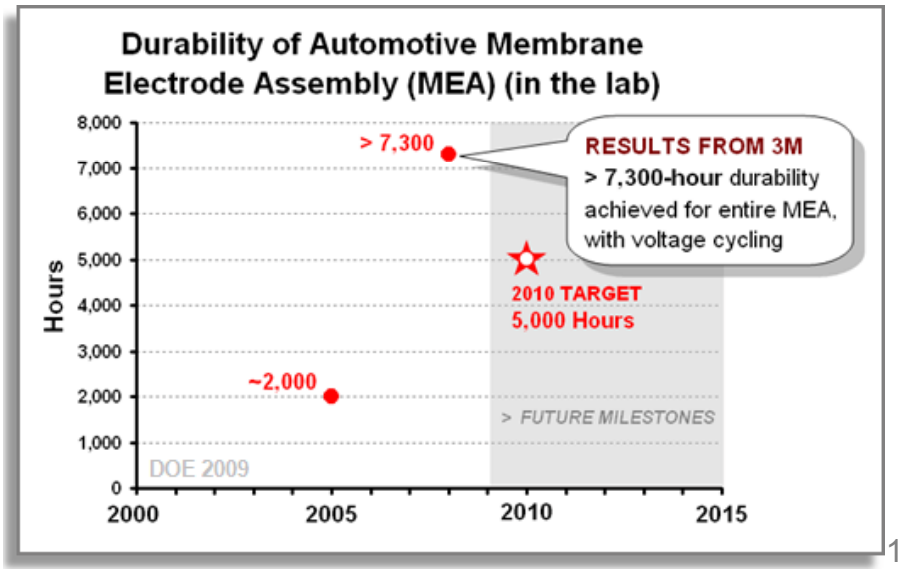
We've greatly increased durability—including more than doubling the demonstrated durability of transportation fuel cells.





Demonstrated >7,300-hour durability →

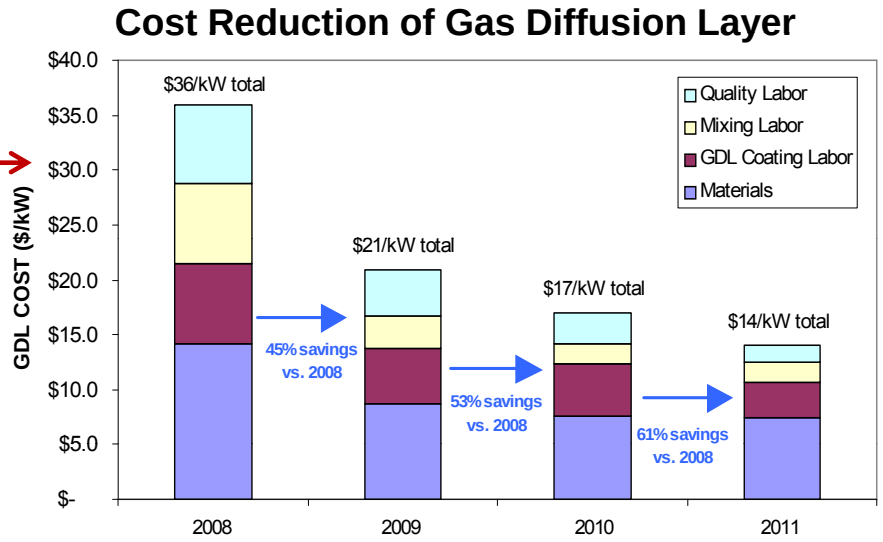
This exceeds our target for MEA durability, in single-cell testing—and has the potential to meet the 2010 target for MEAs in a fuel cell system



Source: US DOE 09/2010

RECENT ACCOMPLISHMENTS

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



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

Technology Validation
2010 Vehicles Progress & Accomplishments

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

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

RECENT ACCOMPLISHMENTS

Vehicles & Infrastructure

- Fuel cell durability
  - 2,500 hours projected (nearly 75K miles)
- Over 2.8 million miles traveled
- Over 114 thousand total vehicle hours driven
- Fuel cell efficiency 53-59%
- Vehicle Range: ~196 – 254 miles
- Over 134,000 kg- H_2 produced or dispensed*
- 152 fuel cell vehicles and 24 hydrogen fueling stations have reported data to the project

Buses

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

Forklifts

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

Recovery Act

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

* Not all hydrogen produced is used in vehicles

Early Market Deployments
Interagency Collaboration

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

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

RECENT DEPLOYMENTS

Warner-Robins, GA -	20 forklifts
Susquehanna, PA -	40 forklifts
Fort Louis, WA -	19 forklifts
Los Alamitos, CA -	PAFC 200kW Prime Power Fuel Cell
National Labs -	3 Ford H_2 ICE Bus

UPCOMING PROJECTS

Hawaii Installation

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

South Carolina Landfill Gas

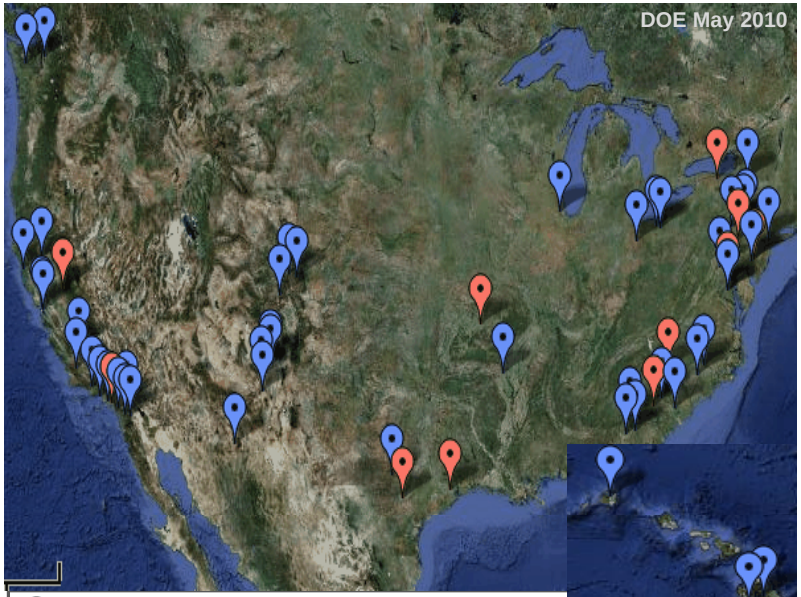
Landfill gas reformation generates H_2 that powers onsite material handling equipment

Ford H_2 ICE Bus Deployments

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

CERL Backup Power

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



Market Transformation fuel cell deployments

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

Source: US DOE 10/2010

Collaborations

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

Federal Agencies

- DOC
- DOD
- DOEd
- DOT
- EPA
- GSA
- DOI
- DHS
- NASA
- NSF
- USDA
- USPS

– *Interagency coordination through staff-level Interagency Working Group (meets monthly)*

– *Assistant Secretary-level Interagency Task Force mandated by EPACT 2005.*

Universities

~ 50 projects with 40 universities

International

- **IEA Implementing agreements – 25 countries**
- **International Partnership for the Hydrogen Economy – 16 countries, 30 projects**

DOE Fuel Cell Technologies Program*

– ***Applied RD&D***

– ***Efforts to Overcome Non-Technical Barriers***

– ***Internal Collaboration with Fossil Energy, Nuclear Energy and Basic Energy Sciences***

Industry Partnerships & Stakeholder Assn's.

- **FreedomCAR and Fuel Partnership**
- **National Hydrogen Association**
- **U. S. Fuel Cell Council**
- **Hydrogen Utility Group**
- **~ 65 projects with 50 companies**

State & Regional Partnerships

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

National Laboratories

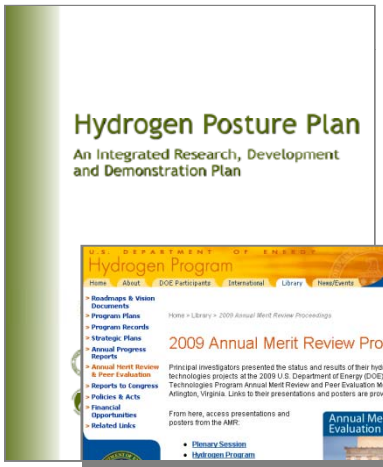
National Renewable Energy Laboratory P&D, S, FC, A, SC&S, TV
Argonne A, FC, P&D
Los Alamos S, FC, SC&S
Sandia P&D, S, SC&S
Pacific Northwest P&D, S, FC, A
Oak Ridge P&D, S, FC, A
Lawrence Berkeley FC, A
Lawrence Livermore P&D, S
Savannah River S, P&D
Brookhaven S, FC

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

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

Source: US DOE 10/2010

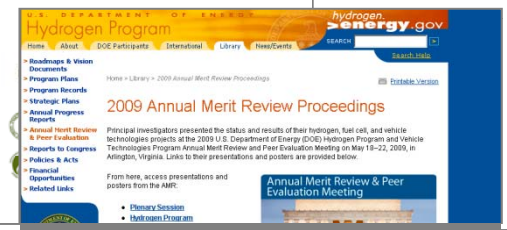
Key Program Documents



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***

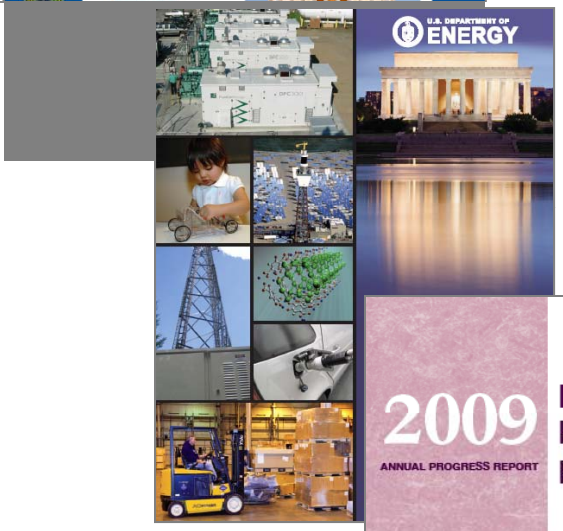


Annual Merit Review Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- → ***Latest edition released June 2010***

www.hydrogen.energy.gov/annual_review10_proceedings.html

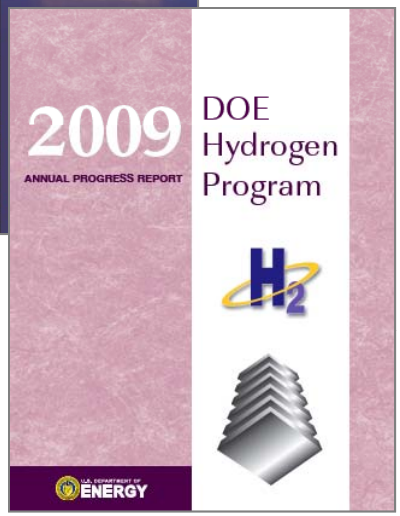


Annual Merit Review & Peer Evaluation Report

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

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

www.hydrogen.energy.gov/annual_review08_report.html



Annual Progress Report

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

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

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 9 – 13, 2011

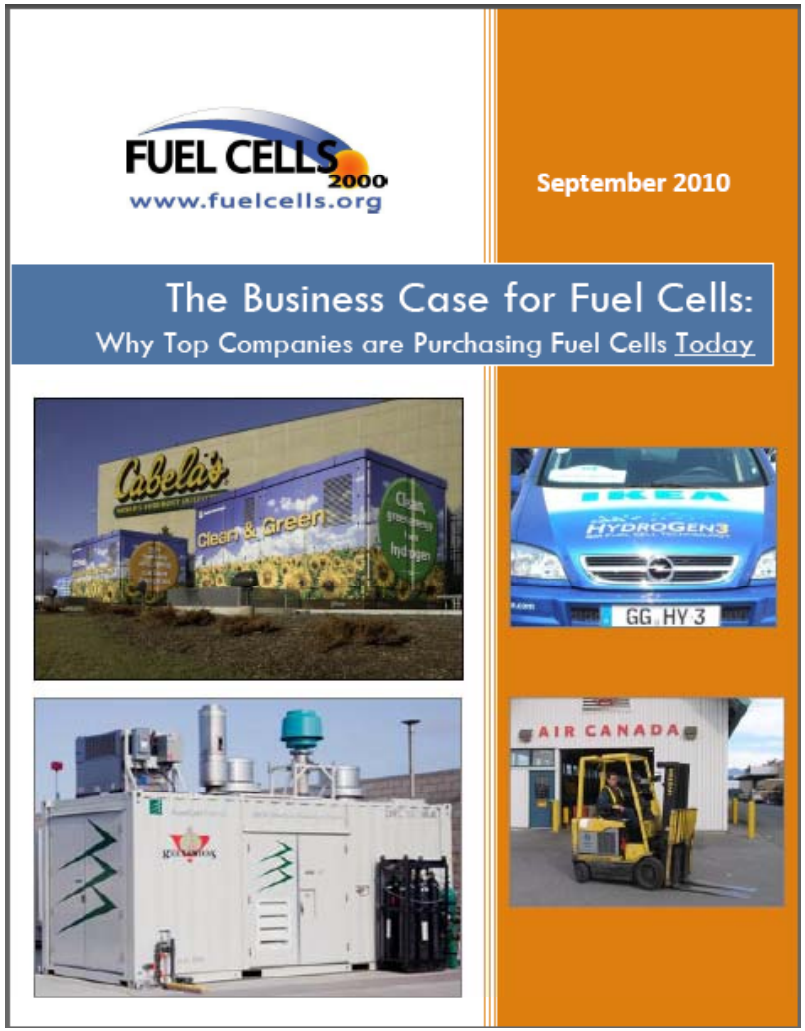
Washington, D.C.

http://annualmeritreview.energy.gov/

Source: US DOE 09/2010

New Report Just Released

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



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

By FuelCells2000
http://www.fuelcells.org

38 companies profiled in the report, cumulatively, have ordered, installed or deployed:

- **more than 1,000 fuel cell forklifts;**
- **58 stationary fuel cell systems totaling almost 15MW of power;**
- **more than 600 fuel cell units at telecom sites.**

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

Source: US DOE 09/2010

Thank you

Dimitrios.Papageorgopoulos@ee.doe.gov

hydrogenandfuelcells.energy.gov