

# ***U.S. Department of Energy Hydrogen Program Update***

***Presented to:***

***Hydrogen & Fuel Cell***

***Technical Advisory Committee***

***May 13, 2008***



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Program Manager**





# **FY 2009 Budget, Planned Activities, and Milestones**



# FY 2009 Budget in Brief

## The FY 2009 Budget Request:

### Increases funding for:

- Hydrogen Storage R&D
- Fuel Cell Stack Component R&D
- Distributed Energy Fuel Cell Systems
- Basic Science

### Moves / Reduces Funding for:

- **Technology Validation; Safety, Codes & Standards; and Education**
  - *Moved to Vehicle Technologies to leverage synergies within fuel cell, plug-in hybrid, and biofuel vehicle validation efforts*
  - *Funding for FCV Validation cut in half; impact on learning demo TBD*
- **Renewable Hydrogen Production and Manufacturing R&D**
  - *Funding deferred; not on critical path for 2015 technology readiness*
  - *Hydrogen from natural gas available economically; Program has met critical path target of \$3.00/gge; WTW CO<sub>2</sub> emissions in NG → H<sub>2</sub> FCVs 33 – 45% less than conventional vehicles*

### Results:

- Funding for EERE hydrogen technologies reduced from \$211.1M in FY08 to \$177.7M in FY09 Request
- A more balanced EERE portfolio of near-, mid-, and long-term solutions
- Increased focus in Hydrogen Program on 2015 critical path barriers



# Hydrogen Fuel Initiative Budget

*FY 2004 – FY 2009*

	Funding (\$ in thousands)					FY 2009 Request
	FY 2004 Approp.	FY 2005 Approp.	FY 2006 Approp.	FY 2007 Approp.	FY 2008 Approp.	
<b>HYDROGEN FUEL INITIATIVE</b>						
<b>EERE Hydrogen</b>	144,881	166,772	153,451	189,511	211,062	177,713*
<b>Fossil Energy (FE)</b>	4,879	16,518	21,036	21,513	21,773	11,430
<b>Nuclear Energy (NE)</b>	6,201	8,682	24,057	18,855	9,909	16,600
<b>Science (SC)</b>	0	29,183	32,500	36,388	36,388	60,400
<b>DOE Hydrogen TOTAL</b>	<b>155,961</b>	<b>221,155</b>	<b>231,044</b>	<b>266,267</b>	<b>279,132</b>	<b>266,143</b>
<b>Department of Transportation</b>	555	549	1,411	1,420	1,425	1,425
<b>Hydrogen Fuel Initiative TOTAL</b>	<b>156,516</b>	<b>221,704</b>	<b>232,455</b>	<b>267,687</b>	<b>280,557</b>	<b>267,568</b>

\* Includes \$146,213,000 in Hydrogen Technology and \$31,500,000 in Vehicle Technologies



# EERE Hydrogen Technologies Budget

## FY 2004 – FY 2009

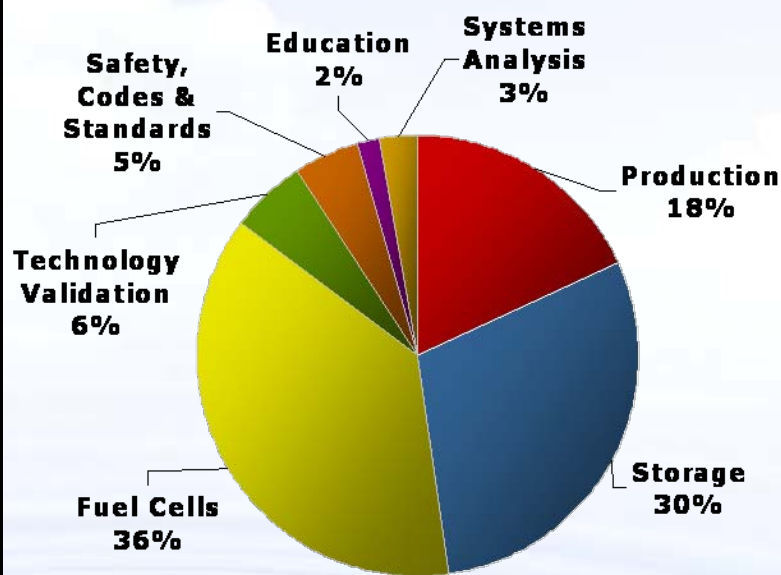
Activity	Funding (\$ in thousands)					
	FY 2004 Approp.	FY 2005 Approp.	FY 2006 Approp.	FY 2007 Approp.	FY 2008 Approp.	FY 2009 Request
Hydrogen Production & Delivery	10,083	13,303	8,391	33,702	39,636	0
Hydrogen Storage R&D	13,628	22,418	26,040	33,728	43,501	59,200
Fuel Cell Stack Component R&D	24,551	31,702	30,710	37,100	43,600	62,700
Technology Validation	15,648	26,098	33,301	39,413	29,727	15,000*
Transportation Fuel Cell Systems	7,317	7,300	1,050	7,324	7,927	6,600
Distributed Energy Fuel Cell Systems	7,249	6,753	939	7,257	7,630	10,000
Fuel Processor R&D	14,442	9,469	637	3,952	2,973	0
Safety, Codes & Standards	5,755	5,801	4,595	13,492	15,854	12,500*
Education	2,417	0	481	1,978	3,865	4,000*
Systems Analysis	1,429	3,157	4,787	9,637	11,395	7,713
Manufacturing R&D	0	0	0	1,928	4,954	0
Technical/Program Mgt. Support	395	535	0	0	0	0
Congressionally Directed Activities	41,967	40,236	42,520	0	0	0
<b>TOTAL</b>	<b>144,881</b>	<b>166,772</b>	<b>153,451</b>	<b>189,511</b>	<b>211,062</b>	<b>177,713</b>

\* Transferred to Vehicle Technologies in FY 2009



# DOE FY 2009 Budget Request for Hydrogen Technologies *(includes EERE, FE, NE, SC)*

Activity	Funding (\$ in thousands)					TOTAL
	EERE (HFCIT)	EERE (VT)	FE (coal)	NE (nuclear)	BES (science)	
Hydrogen Production			11,430	16,600	20,133	48,163
Hydrogen Storage	59,200				20,134	79,334
Fuel Cells	79,300				20,133	99,433
Technology Validation		15,000				15,000
Safety, Codes & Standards		12,500				12,500
Education		4,000				4,000
Systems Analysis	7,713					7,713
<b>TOTAL</b>	<b>146,213</b>	<b>31,500</b>	<b>11,430</b>	<b>16,600</b>	<b>60,400</b>	<b>266,143</b>





# EERE FY 2009 Budget Request

— Hydrogen remains a high EERE priority —

ACTIVITY	FY2007 Approp. (\$000)	FY2008 Approp. (\$000)	FY2009 Request (\$000)
Biomass and Biorefinery Systems	196,277	198,180	225,000
Vehicle Technologies	183,580	213,043	221,086*
Solar Energy	157,028	168,453	156,120
Hydrogen Technology	189,511	211,062	146,213
Building Technologies	102,983	108,999	123,765
Industrial Technologies	55,763	64,408	62,119
Weatherization & Intergovernmental Activities	281,731	282,217	58,500
Wind Energy	48,659	49,545	52,500
Geothermal Technology	5,000	19,818	30,000
Federal Energy Management Program	19,480	19,818	22,000
Hydropower	0	9,909	3,000
Congressionally Directed Activities	0	186,664	0
Program Direction	99,264	104,057	121,846
Program Support	10,930	10,801	20,000
Facilities & Infrastructure	107,035	76,176	13,982
Adjustments	0	-743	-738
<b>TOTAL EERE</b>	<b>1,457,241</b>	<b>1,722,407</b>	<b>1,255,393</b>

\* Includes \$31.5M for hydrogen activities in Technology Validation; Safety, Codes & Standards; and Education



# Hydrogen Program

## *FY 2009 Key Program Milestones/Activities*

### **PRODUCTION:**

- FOSSIL ENERGY: Validate prototype systems improvements for multi-gas separation processes
- NUCLEAR ENERGY: Gather data on operability and reaction rates from Sulfur-Iodine electrolysis experiment; design an experiment for the Hybrid Sulfur thermochemical cycle

### **STORAGE:**

- Demonstrate regeneration processes for chemical hydrogen storage and estimate their efficiency
- Make Go/No-Go decision on sorbents/carbon-based materials

### **FUEL CELLS:**

- Reduce cost of an automotive fuel cell system to \$60/kW (*at high volume*) in 2009, while increasing durability
- Improve efficiency of NG or propane fueled 5-250 kW stationary fuel cell systems to 36% at full power
- Initiate small-scale, stationary solid-oxide fuel cell projects

### **SYSTEMS ANALYSIS:**

- Complete a macro-system model of the fuel infrastructure and analyze the well-to-wheels hydrogen costs and greenhouse gas emissions profiles for various hydrogen pathways
- Complete H<sub>2</sub>A-type model for stationary power generation
- Continue analysis of resource needs, environmental impacts, and W2W analysis of emissions & energy use

***BASIC SCIENCE*** research will focus on *bio-inspired and solar hydrogen production, nanomaterials for hydrogen storage, and catalysis for fuel cells. It will emphasize the theory and modeling of the physical and chemical interactions of hydrogen with materials, nanostructured design, and novel synthesis.*





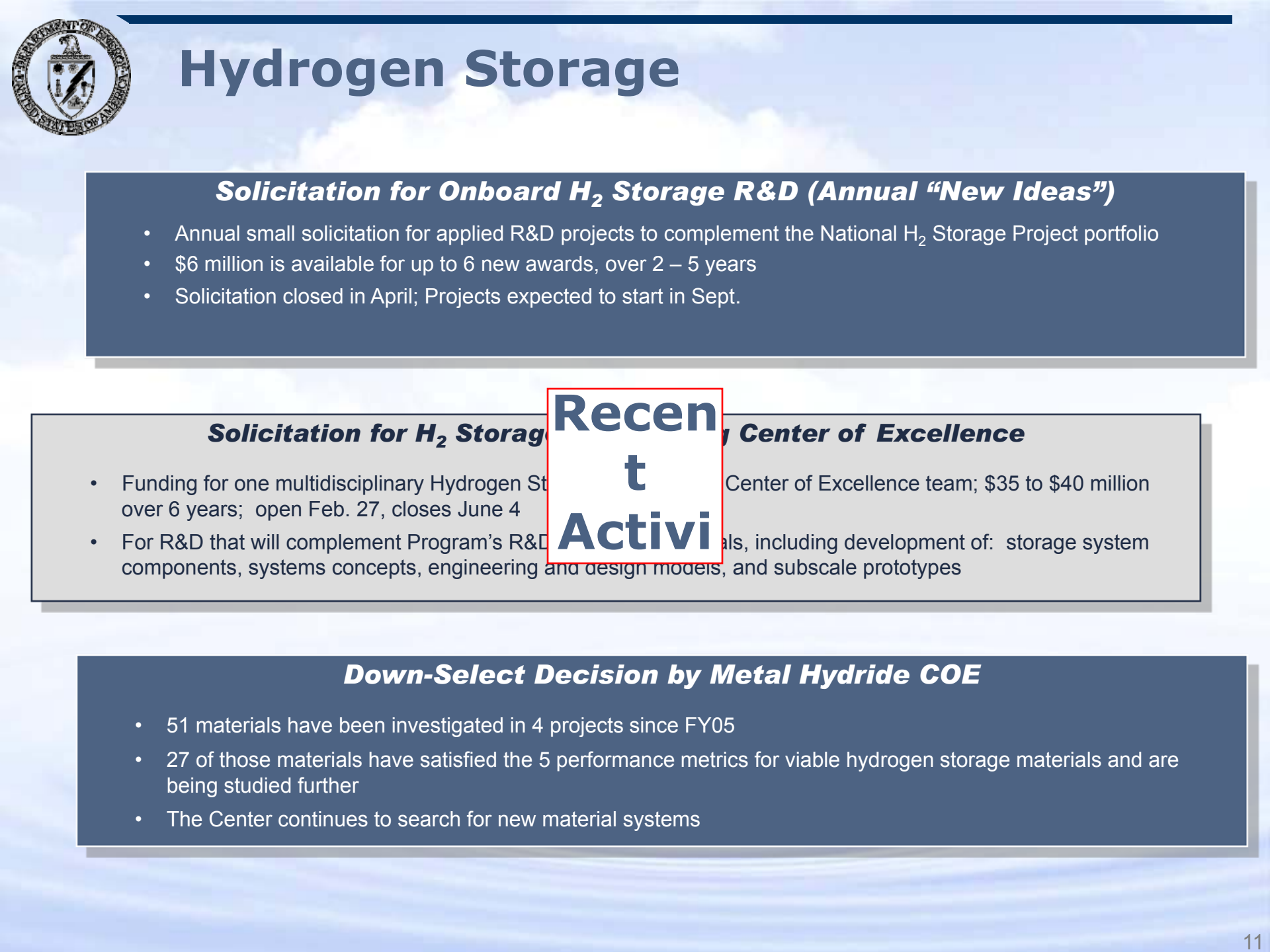
# Recent Activities/Progress



# Production & Delivery

## ***Selected New Projects in Electrolysis & Delivery***

- *Electrolysis (Giner, Avalence LLC)*
- *Hydrogen Compression (Concepts ETI, Mohawk)*
- *Hydrogen Tube Trailers (Lincoln Composites & LLNL)*
- *Hydrogen Liquefaction (Prometheus, Praxair)*



# Hydrogen Storage

## ***Solicitation for Onboard H<sub>2</sub> Storage R&D (Annual “New Ideas”)***

- Annual small solicitation for applied R&D projects to complement the National H<sub>2</sub> Storage Project portfolio
- \$6 million is available for up to 6 new awards, over 2 – 5 years
- Solicitation closed in April; Projects expected to start in Sept.

## ***Solicitation for H<sub>2</sub> Storage Center of Excellence***

- Funding for one multidisciplinary Hydrogen Storage Center of Excellence team; \$35 to \$40 million over 6 years; open Feb. 27, closes June 4
- For R&D that will complement Program’s R&D goals, including development of: storage system components, systems concepts, engineering and design models, and subscale prototypes

**Recent  
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Activi**

## ***Down-Select Decision by Metal Hydride COE***

- 51 materials have been investigated in 4 projects since FY05
- 27 of those materials have satisfied the 5 performance metrics for viable hydrogen storage materials and are being studied further
- The Center continues to search for new material systems



# Fuel Cells

## ***New Fuel Cell Team Leader Position***

Announced March 17, closed April 25. Expect selection by July 25.

## ***Fuel Cell Cost Status Updated to \$94/kW***

- Based on analysis by DTI, for automotive system at high-volume manufacturing

## ***Fuel Cell Solicitation (~\$130M over 3 years)***

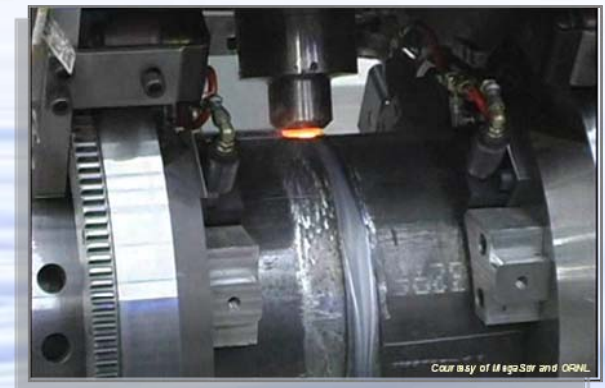
- **Request for Information**
  - ✓ Input on 10 technical topics and overall strategy
  - ✓ 36 entities responded (from industry, universities, national labs, state partnerships); 94 individual comments received
- **Pre-solicitation Workshop – 5 breakout groups**
  - ✓ Identified research gaps in *Catalysts & Supports; MEAs; Water Management*
  - ✓ Identified applications for *Early Market Demonstrations*
  - ✓ Identified key considerations and applications for *Solid Oxide Fuel Cells*
- **Status:** To be released on or before June 9



# Manufacturing R&D

## ***Selected New Manufacturing R&D Projects***

- ***7 awards for \$38M over 2 – 4 years***
- ***65/35 government/industry cost share***
- ***Projects will focus on:***
  - ***Novel fabrication methods for MEAs (GM)***
  - ***Low cost GDL manufacturing (Ballard)***
  - ***MEA and stack assembly processes (Rensselaer Polytechnic Institute, W. L. Gore)***
  - ***Stack conditioning and leak testing (UltraCell)***
  - ***Processes to make high-pressure carbon composite tanks (Quantum Technologies)***





# Technology Validation

- **Spring 2008 Report Released**



## **LATEST RESULTS:**

- **NUMBER of VEHICLES: 92**
  - **NUMBER of STATIONS: 15**
  - **EFFICIENCY: 53 – 58%**
  - **RANGE: 103 – 190 miles**
  - **FUEL CELL SYSTEM DURABILITY:**
    - **1900 hours, projected (~57,000 miles)**
    - **1200 hours, actual (~36,000 miles)**
- 
- **2nd Generation Vehicles Now in Operation**
  - **FY09 Planned Milestones:**
    - **2000-hour durability**
    - **250-mile range**
    - **\$3/gge demonstrated**



# Safety, Codes & Standards

## Permitting Compendium Released:

- Streamlines permitting process
- Designed to be a “one-stop shop” for permitting fueling stations
- Will be updated to include section on other hydrogen installations, such as stationary power sites (e.g., backup power for telecoms sites)

U.S. DEPARTMENT OF ENERGY  
Hydrogen Program

hydrogen.energy.gov  
SEARCH FUELING [input field] Search Help

### Hydrogen Fueling Station Codes and Standards

- Hydrogen Fueling Stations
- Permitting Process
- Codes & Standards Search
- Related Links
- Contacts

As the nation moves toward a hydrogen economy, key infrastructures must be developed to support the growing number of hydrogen-powered vehicles. One basic need is hydrogen fueling stations. These stations will provide the hydrogen to power America's vehicles, and economy, toward energy independence.

Today, more than 60 hydrogen fueling stations are operating throughout the United States. However, fewer than 20 are available for public use. In contrast, according to the U.S. Census Bureau, the United States has more than 121,000 gasoline fueling stations. If hydrogen-powered vehicles are to become an important, and common, technology of America's energy future, a vast network of public stations will be necessary to support them.

Although there is only a small number of hydrogen fueling stations today, national codes and standards have been developed to address their construction, operation, and maintenance. These codes and standards are necessary to ensure safe development and deployment, and many organizations are working to improve the existing codes and standards and address remaining gaps.

To support smoother, more efficient permitting of hydrogen fueling stations, the U.S. Department of Energy is working with codes and standards development organizations, code officials, national laboratories, and industry experts. Its goals are to identify and address hydrogen fueling station codes and standards issues, support the creation of relevant codes and standards, and provide up-to-date information to permitting officials.

Learn more about:

- Hydrogen fueling stations
- The hydrogen fueling station permitting process
- Hydrogen fueling station codes and standards

Printable Version

Although only a few hydrogen fueling stations are operating today, they will become more common in the future.

Search for Hydrogen Fueling Station Codes and Standards.

[http://www.hydrogen.energy.gov/fueling\\_stations/](http://www.hydrogen.energy.gov/fueling_stations/)

## Progress toward Fuel Quality Standard:

- International Fuel Quality Specification (ISO 14687-2) approved and published March 1
- It is harmonized with SAE's "Hydrogen Specification Guideline for Fuel Cell Vehicles" (SAE J2719)
- The final version of ISO Fuel Quality Standard not due out until 2010

## Ongoing development of C&S

- 9 active US Codes and Standards Organizations working on hydrogen
- 22 C&S published, 10 of which are under revision
- 28 draft C&S under preparation/review
- 4 International C&S published, 13 under preparation/review

See [www.fuelcellstandards.com](http://www.fuelcellstandards.com)



# Education

## **Education Solicitation** (\$5M over 3 years)

- **Closed in January; projects to be announced on or before June 9**
- **Projects will address:** (1) State and Local Government Outreach (includes subtopics: “Hydrogen 101,” and State and Local Government Partnership Building); (2) Early Deployment and Education; (2) University Programs

## **Recent Activities & Progress**

### **Interim Survey**

- Began collecting data for survey to follow-up on baseline survey in 2004, to be published in FY09

### **First Responders & Code Officials**

- “Introduction to Hydrogen Safety for First Responders”
  - Upgraded course and began development of advanced course
  - >6000 users since launch
- Completed draft of “Introduction to Hydrogen for Code Officials”

### **Local Communities**

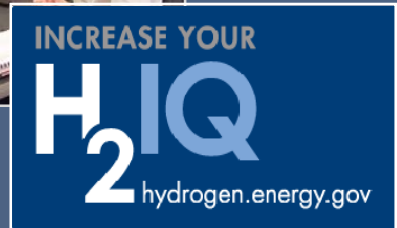
- Radio spots, podcasts, MySpace, Orlando Magic Collaboration

### **End-Users**

- Early market fact sheets, event outreach

### **Students**

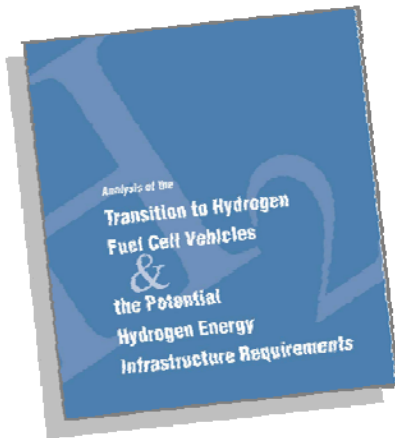
- Workshops, conference sessions, competitions
- New 2-week field testing unit for science classes; updated textbooks and databases







# Recent Systems Analysis Results



## **Hydrogen Transition Scenario Analysis Published by ORNL**

*Explores the requirements and impacts of potential market penetration scenarios for FCVs*

### **Key Findings:**

- Networks of fueling stations should be established in a limited number of urban centers (hydrogen clusters, not highways)
- Transition policies will be essential to overcome initial economic barriers
- Cost of these policies is not out of line with other policies that support national goals
- Cost-sharing & tax credits (2015 – 2025) would enable industry to be competitive in the marketplace by 2025
- With targeted deployment policies from 2012 to 2025, FCV market share could grow to 50% by 2030, and 90% by 2050

[http://cta.ornl.gov/cta/Publications/Reports/ORNL\\_TM\\_2008\\_30.pdf](http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2008_30.pdf)



## **NREL Study: Opportunities for H<sub>2</sub>-Based Energy Storage for Electric Utilities**

*→H<sub>2</sub>-based energy storage could be cost-competitive (in 2010 – 2020) with peak-power from NG generators*

### **Early Market Analysis:**

- Federal early adoption could have significant positive impact on industry*
- Analysis also shows potential GHG emissions from a variety of early market applications*



# Market Transformation

## ***Interagency Task Force Meeting***

*(details in briefing by C. Cooper)*

***Continued focus on Federal Government's role as early adopter***

### **Key topics:**

- Impacts of federal deployment
- Growing needs for power reliability for federal agencies
- Fuel cell financing

## ***Loan Guarantee Program***

- **Established in Title XVII of EPACT.** Program has identified 10 categories of eligible projects, including hydrogen fuel cell technology for residential, industrial, or fuel cell applications
- **First round:** \$4B for FY 2007; this includes Bridgeport Fuel Cell Park, LLC (*will be largest single-site installation of FCs in the world*)
- **Second round:** Will include up to \$10B for renewable energy, energy efficiency, and electricity transmission projects; RFI closed May 2; solicitation expected in June

## *Current Status of Work with Federal Early Adopters*

### *Confirmed Projects*

- DLA forklift deployments: 90+ fuel cell forklifts at 4 sites
- FAA backup power for communications towers: 20 – 30 sites



### *Planned Projects*

- DOE: Fuel cell data center at Germantown facility
- USDA: Backup power for critical headquarters operations
- National Science Foundation: Electrolyzer for McMurdo Station, Antarctica
- National Park Service:
  - Hydrogen ICE bus for VIP tours of Washington, D.C.
  - 2 ICE buses at Hawaii Volcanoes Nat'l Park
- DOD-Air Force: Hydrogen ICE bus at Hickam AFB, Hawaii





# International Activities



## **IPHE Focus Areas/Actions:**

- Agreement on 4 priorities:
  1. *Accelerating market penetration & early adoption of H<sub>2</sub>, FC & infrastructure*
  2. *Policy and regulatory actions to support widespread deployment*
  3. *Raising profile w/policy-makers and public*
  4. *Monitoring relevant technology dev't*
- Global IPHE Project
- “State of the Nation” document
- Outreach
- Fuel cell cost analysis comparison
- List of commercially available products
- List of demo projects in IPHE countries
- Brief for policy-makers

## **IEA – Hydrogen Implementing Agreement**



- 21 Member countries plus EC
- Currently implementing tasks 18 – 25; 2 new ones proposed
- US participates in all current tasks
- Portfolio and membership expanding (Greece & Turkey recently joined)

## **IEA - Advanced Fuel Cells Implementing Agreement**

- 17 member countries; six current tasks
- Current phase ends in 2008; writing plan for next phase (2009 – 2012)
- Executive Committee met in Tokyo in Feb. to address new plan

## **Joint IPHE – IEA Infrastructure Workshops:**

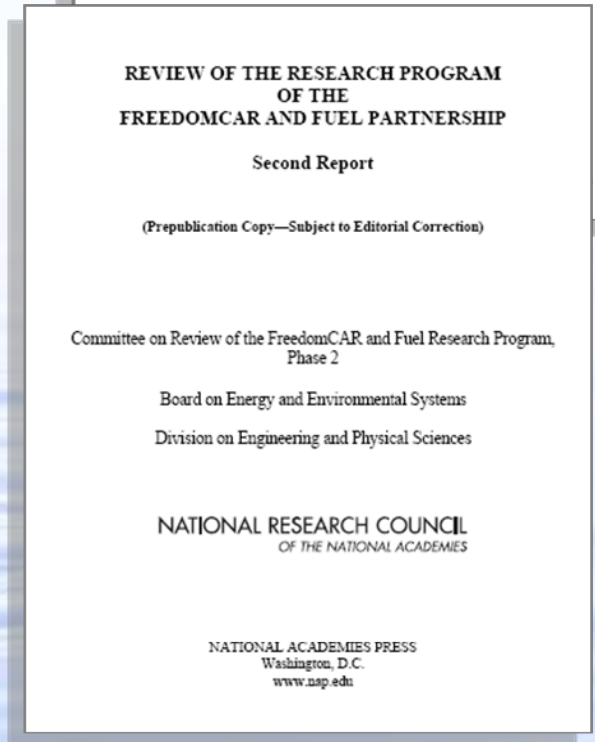
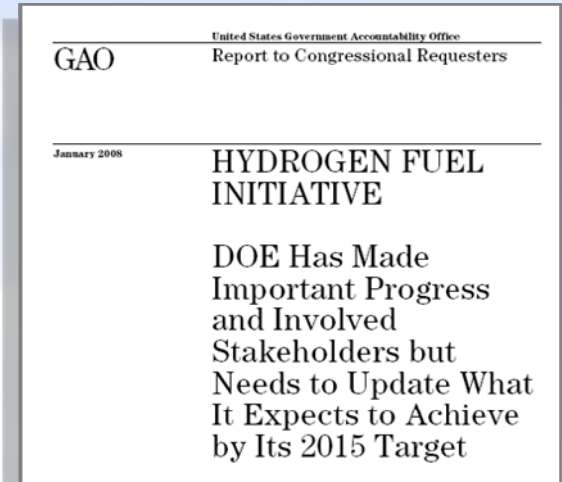
### **“Building the Hydrogen Economy: An Infrastructure Strategy”**

- 3 workshops held in 2007
- 2 main goals: Summarize analysis and lessons learned; develop vision and pathways forward



# External Review/Strategic Input

- **GAO Report on the Hydrogen Fuel Initiative:** Released in January 2008
  - *“DOE has effectively involved industry in designing and reviewing its hydrogen R&D program ...”*
- **NAS Review of FreedomCAR Partnership — Phase II: Completed April 2008**
  - *“The FreedomCAR and Fuel Partnership is well planned, organized, and managed. It is an excellent example of an effective industry/government cooperative effort.”*
  - *“The Executive Steering Group ... should establish a high-level planning group to develop a strategic plan appropriate for the next phase of the nation’s collaborative R&D program for vehicle and fuels technology.”*
  - *“There has been significant progress in most areas since the Phase 1 Report, and the committee commends management on its thorough and generally receptive responses to the recommendations in that report.”*





# R&D Progress



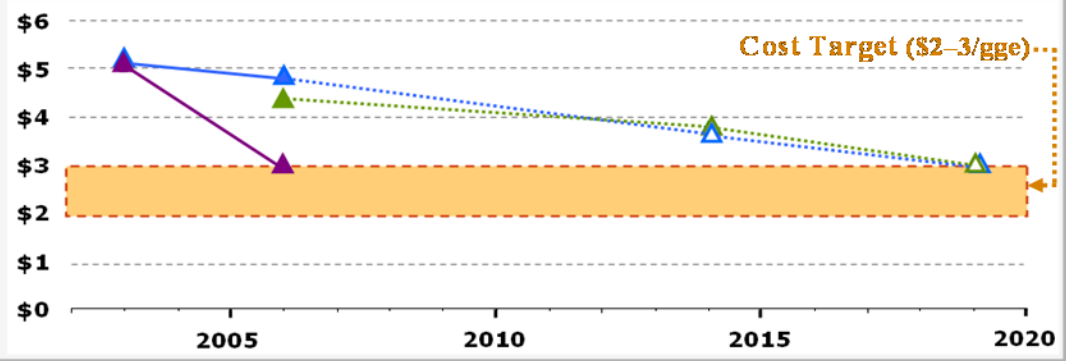
# Hydrogen Production Progress

*The Program has reduced the cost of producing hydrogen from multiple pathways*

## Cost of Hydrogen (Delivered) — Status & Targets (in \$/gallon gasoline equivalent (gge), untaxed)

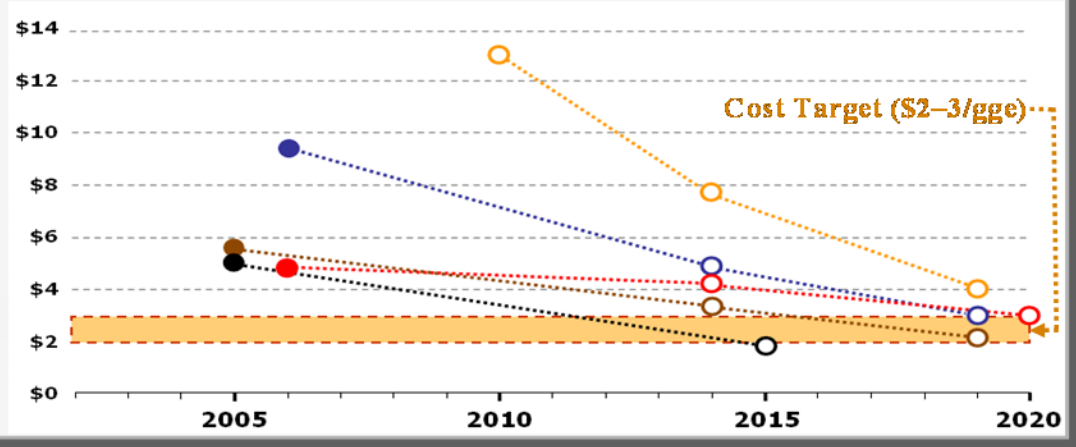
**NEAR TERM: Distributed Production**  
 → Hydrogen is produced at station to enable low-cost delivery

- ▲ Distributed Natural Gas
- ▲ Distributed Electrolysis
- ▲ Distributed Bio-Derived Renewable Liquids



**LONGER TERM: Centralized Production**  
 → Large investment in delivery infrastructure needed

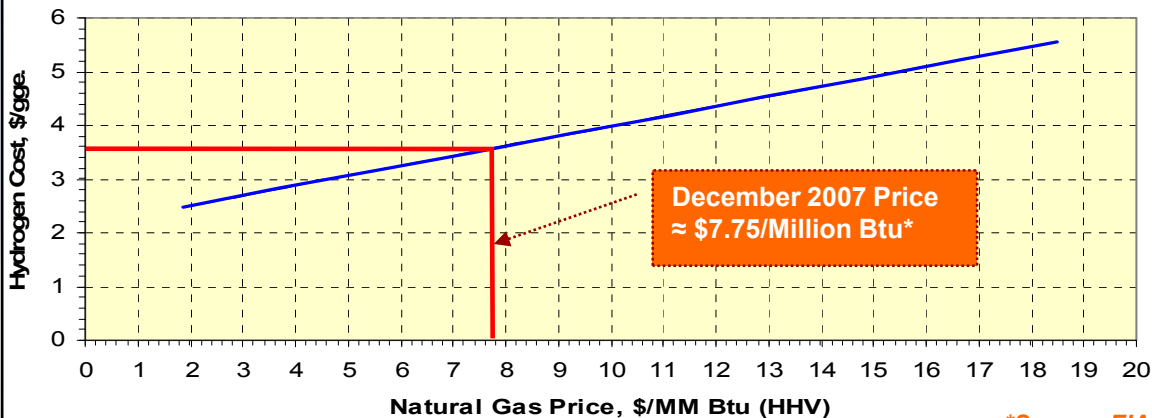
- Biomass Gasification
- Coal Gasification with Sequestration
- Solar High-Temperature Thermochemical Cycle
- Central Wind Electrolysis
- Nuclear





# Progress on the Critical Path: *Hydrogen can be produced cost-competitively with gasoline*

Hydrogen Production Cost from Distributed Natural Gas Versus Sensitivity to Natural Gas Price



\*Source: EIA

**Current cost of H<sub>2</sub> from natural gas:**

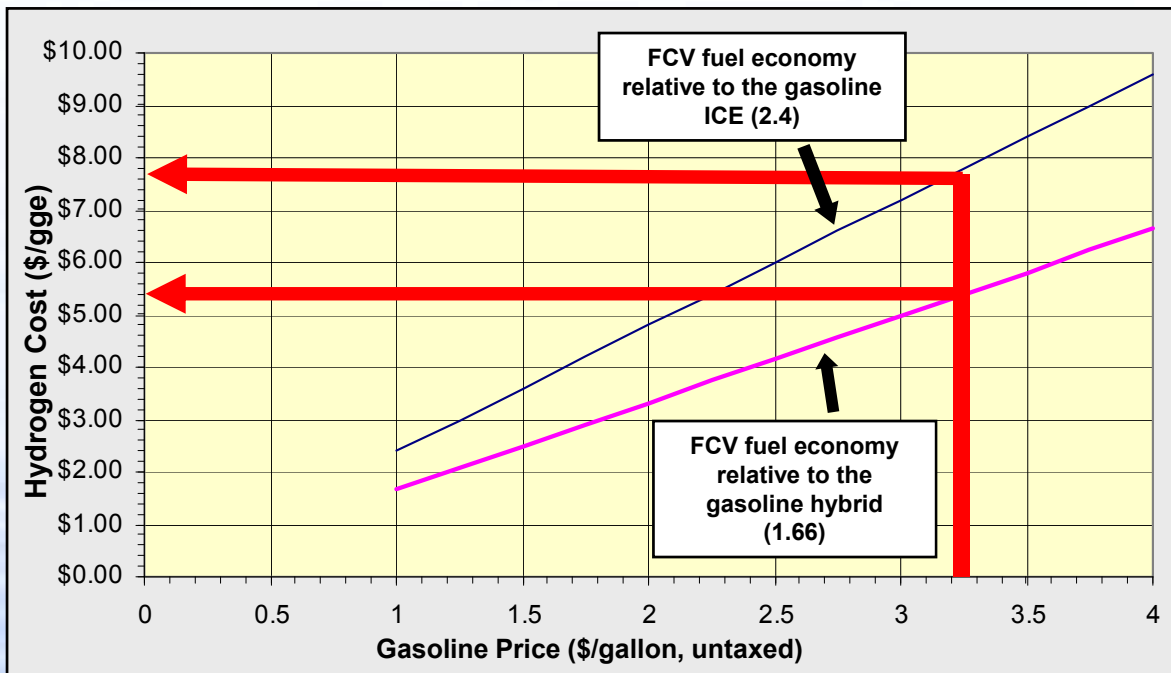
**~\$3.55/gge**

**Cost analysis based on:**

- Combination of best available research results
- Projected to 500 units/year

**Based on current gasoline price of \$3.25/gallon (untaxed) —**

- **At \$7.80/gge:** Hydrogen is cost-competitive (on cents-per-mile basis) with gasoline used in conventional ICE vehicles.
- **At \$5.40/gge:** Hydrogen is cost-competitive (on cents-per-mile basis) with gasoline used in hybrid-electric vehicles.

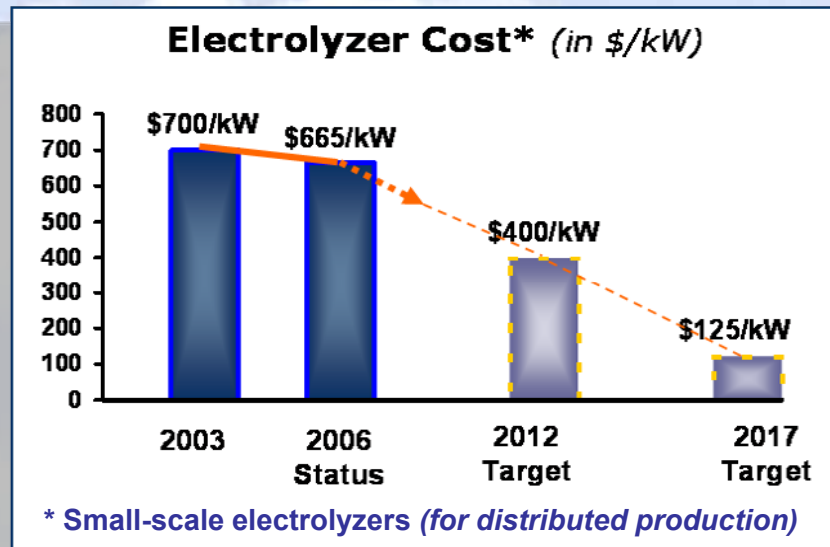






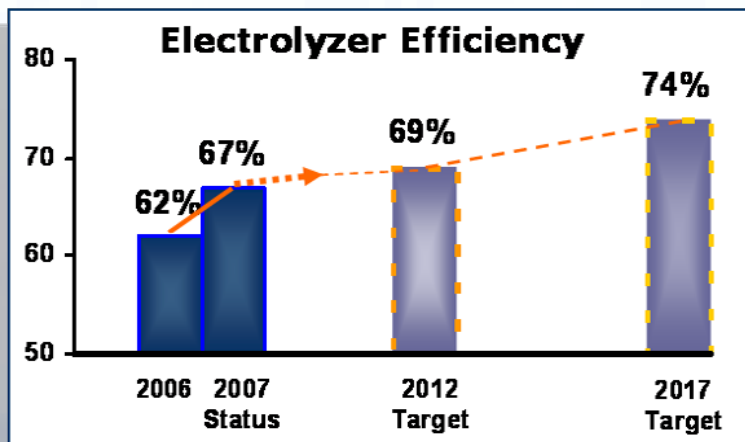
# Hydrogen Production Progress

The capital cost of electrolyzers is being reduced

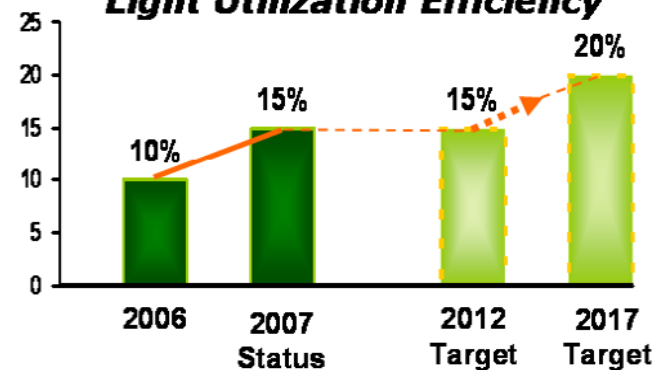


Progress is being made in biological production

The energy efficiency of electrolyzers is being improved



### Biological Production: Light Utilization Efficiency

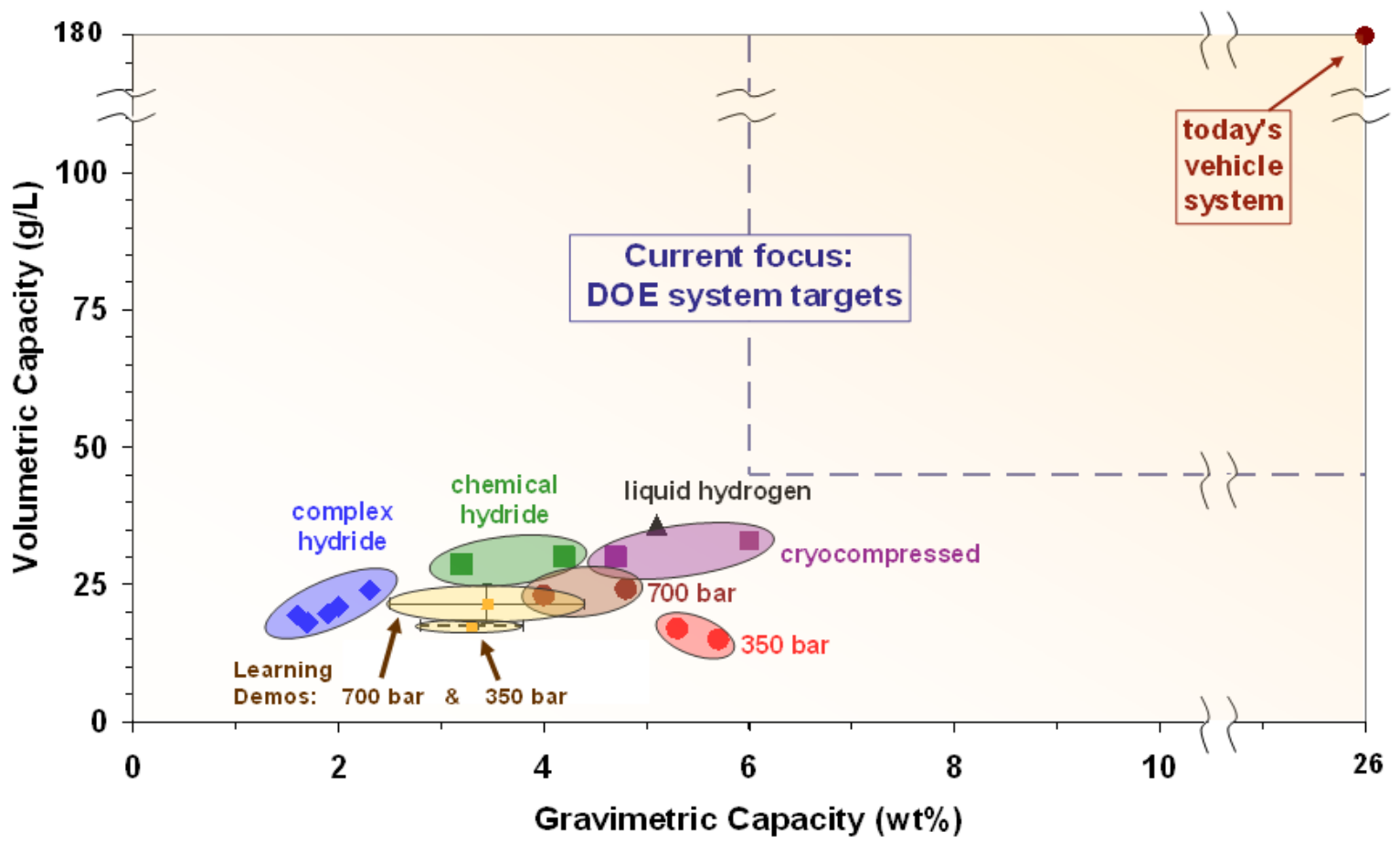




# Hydrogen Storage

## Storage Remains a Challenge

### Storage **SYSTEM\*** Capacity — Status vs. Targets

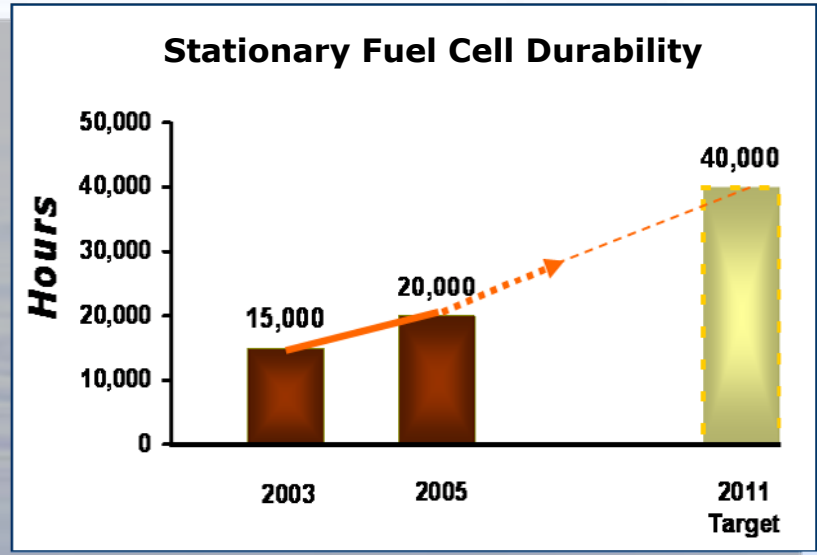
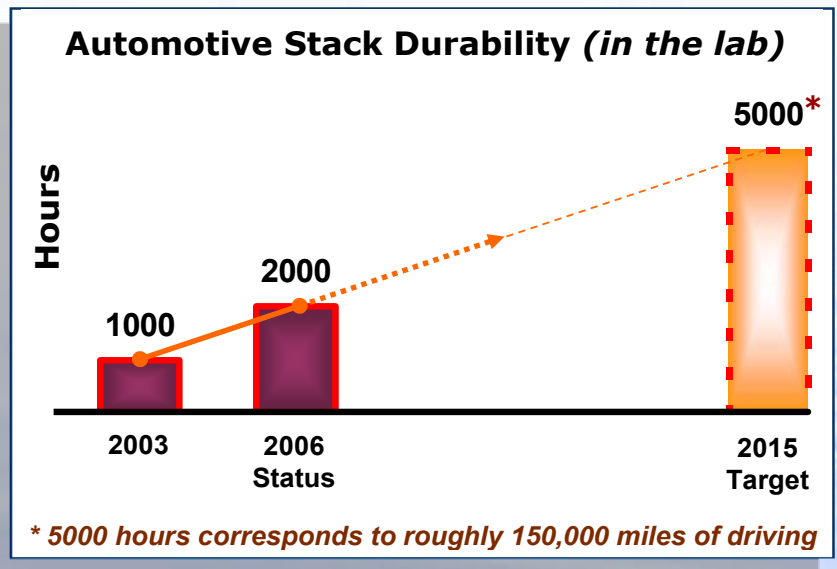
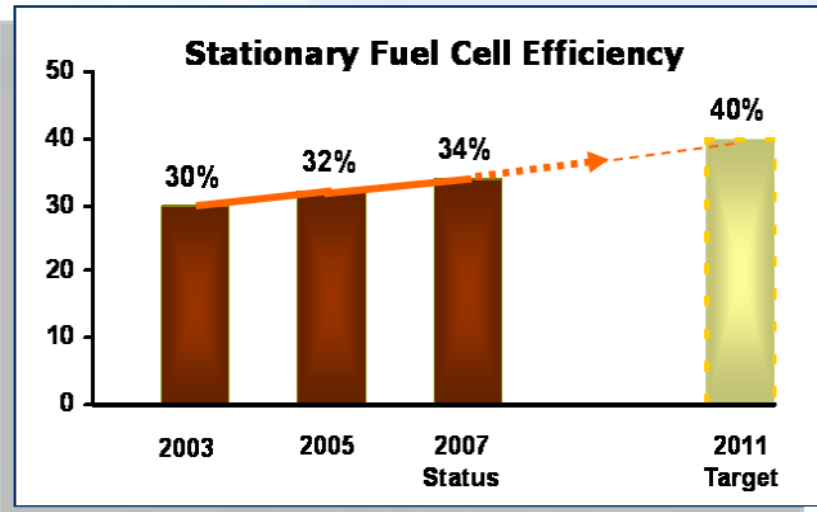
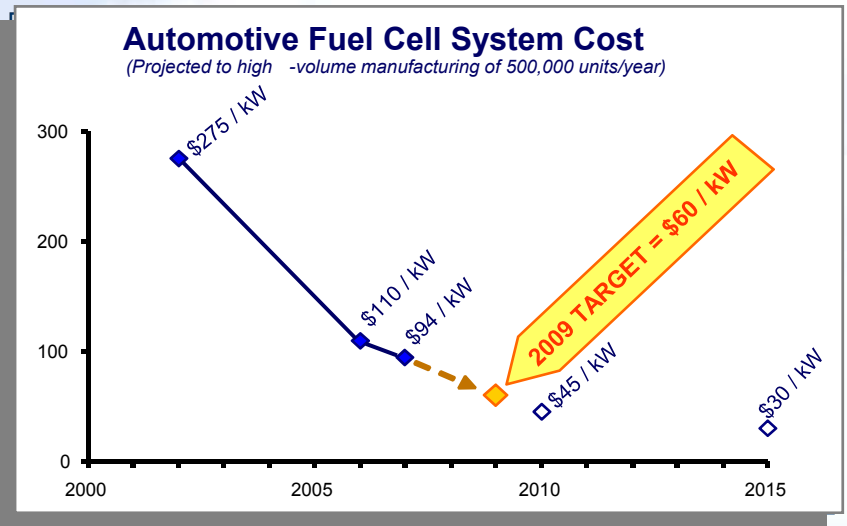


\* System capacity estimates include materials, tanks, and balance of plant



# Fuel Cells — Automotive & Stationary

*Steady Progress in Cost, Efficiency, and Durability*





# 2008 Annual Merit Review

*Each year hydrogen and fuel cell projects funded by DOE's Hydrogen Program are evaluated during the Annual Merit Review and Peer Evaluation Meeting.*

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*June 9 – 13, 2008*

**Crystal Gateway Marriott Hotel**  
**Arlington, Virginia**

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Hydrogen and fuel cell principal investigators representing the offices of **Energy Efficiency and Renewable Energy**, **Fossil Energy**, **Nuclear Energy**, and **Science** will present their project status and results in oral and poster presentations.

**[www.hydrogen.energy.gov](http://www.hydrogen.energy.gov)**