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New Energy World IG
fuel cells & hydrogen for sustainability

U.S. Hydrogen and Fuel Cell Activities

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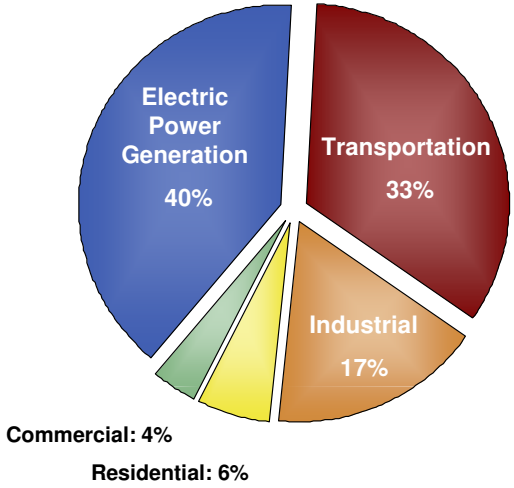
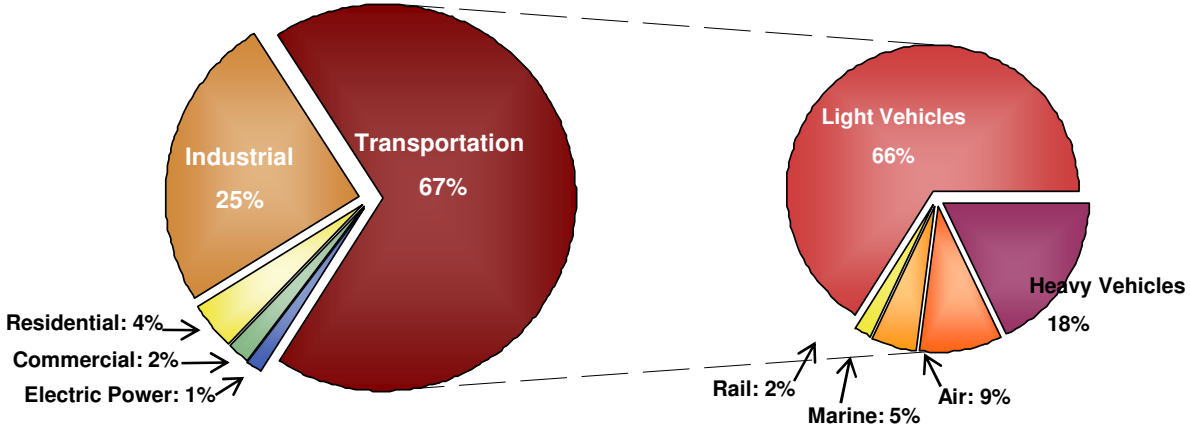
Drivers: *Climate Change & Oil Consumption*

U.S. CO_2 Emissions by Sector (2006)



U.S. Oil Consumption (2006)



Hydrogen offers benefits in the two largest energy sectors:

- **Transportation:** Use of hydrogen in fuel cell vehicles can reduce oil use and CO_2 emissions in the transportation sector
- **Power Generation:** Hydrogen can enable clean, reliable energy for stationary and portable power applications

H_2 & Fuel Cells — Where are we today?

H_2 & Fuel Cells for Transportation (in the U.S.):

> 200 fuel cell vehicles

> 20 hydrogen-fueled buses

> 60 fueling stations

Several carmakers (including GM, Honda, Daimler) have announced plans for increased deployments in the next few years.

Fuel Cells for Stationary Power and Niche-Markets

Fuel cells have become a cost-competitive option for

- Critical-load facilities
- Backup power
- Forklifts

H_2 Production & Delivery

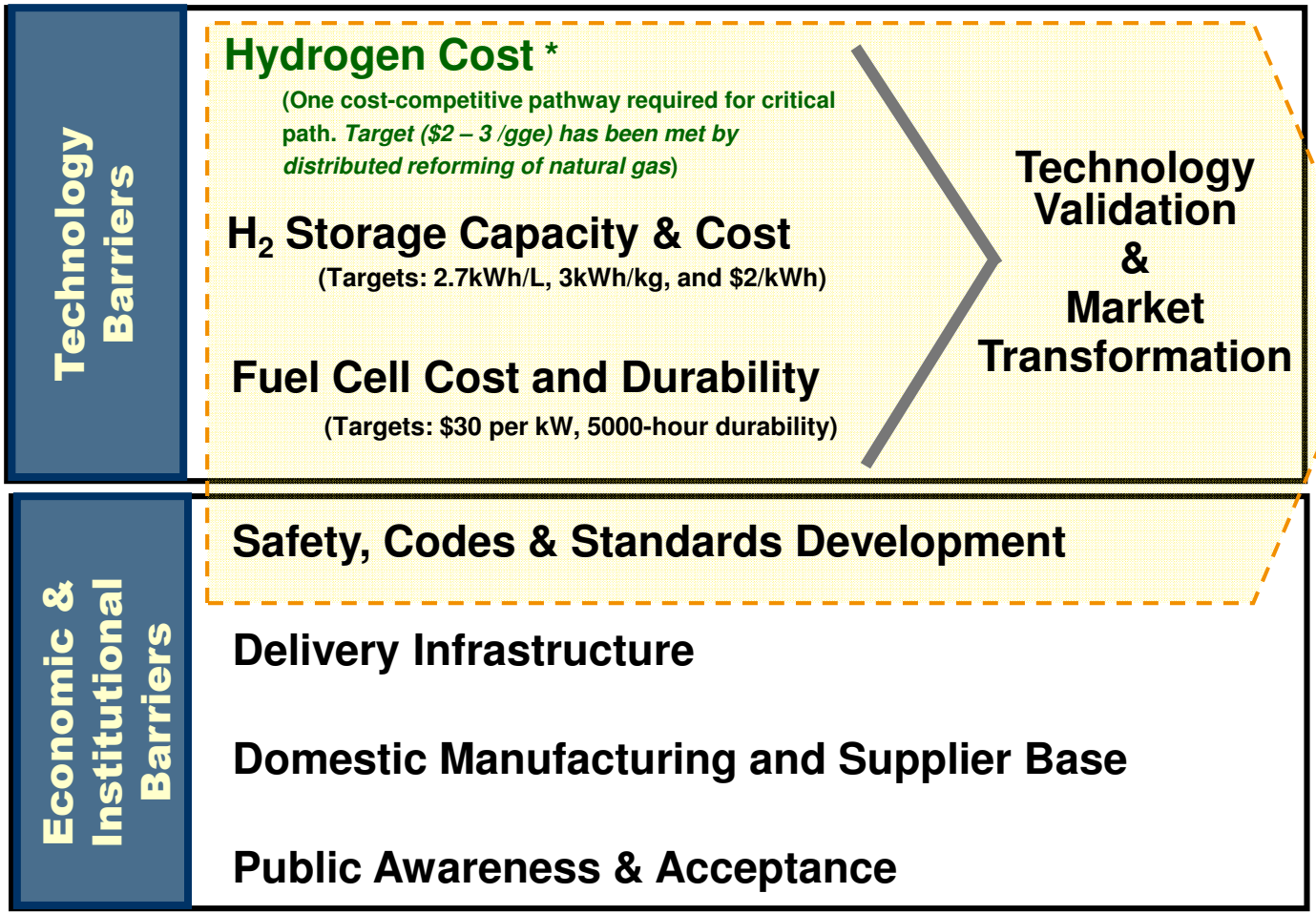
In the U.S., there are currently:

~19 million metric tons *of H_2 produced annually*

> 1000 miles *of H_2 pipelines*

Challenges and Barriers

U.S. hydrogen and fuel cell activities are structured to address the critical path barriers.



Critical Path Barriers for FCV 2015 Technology Readiness Targets

Targets for stationary and portable power fuel cells have also been developed.

Strategic Partnerships & Key Collaborations

Strategic Partnerships

- FreedomCAR and Fuel Partnership
  - *DOE*
  - *U.S. Council for Automotive Research (Ford, GM, Chrysler)*
  - *Major energy companies (BP, Chevron, ConocoPhillips, ExxonMobil, Shell)*
  - *Utilities (Southern California Edison, DTE Energy)*
- International Partnership for the Hydrogen Economy (IPHE)

Key Collaborations

- Hydrogen Utility Group
- State/Local Governments
- Industry Associations
- Federal Interagency Partnerships
- International Energy Agency

Hydrogen Fuel Initiative Budget

FY2004- FY2009

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

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

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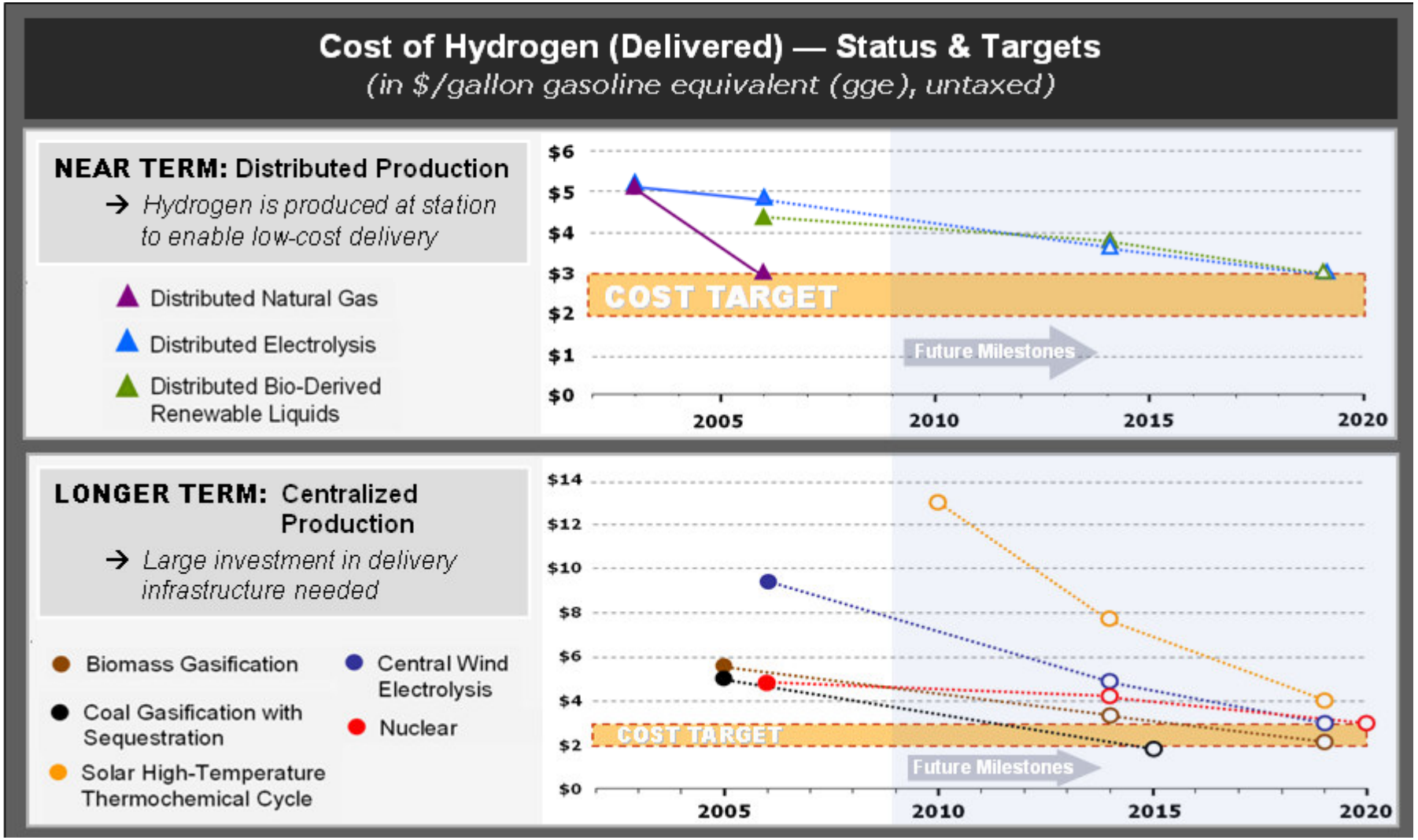
Progress

Hydrogen Production: Milestones & Progress

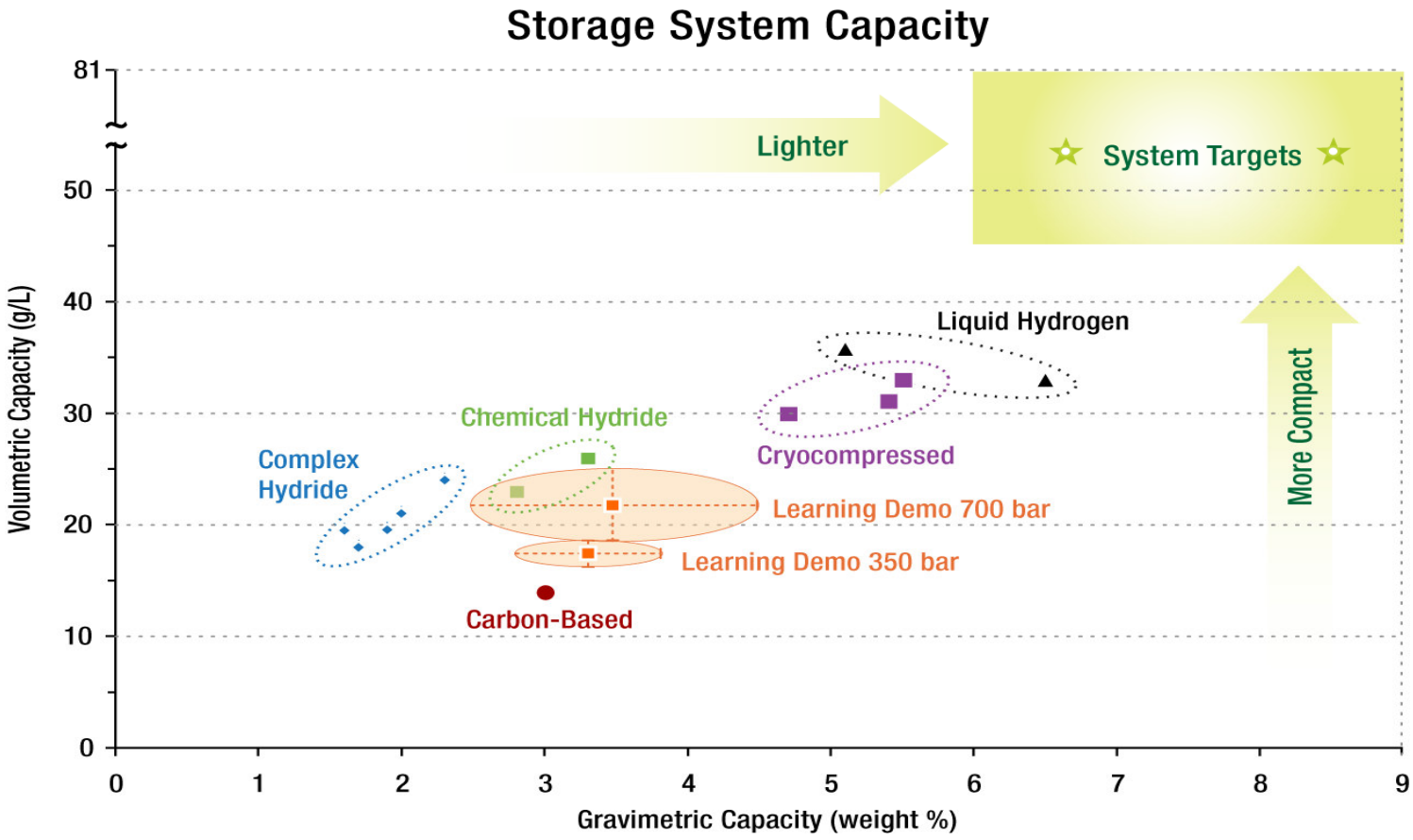
The Program has established milestones for R&D efforts in all production pathways, and reduced the cost in some areas.



Hydrogen Storage R&D

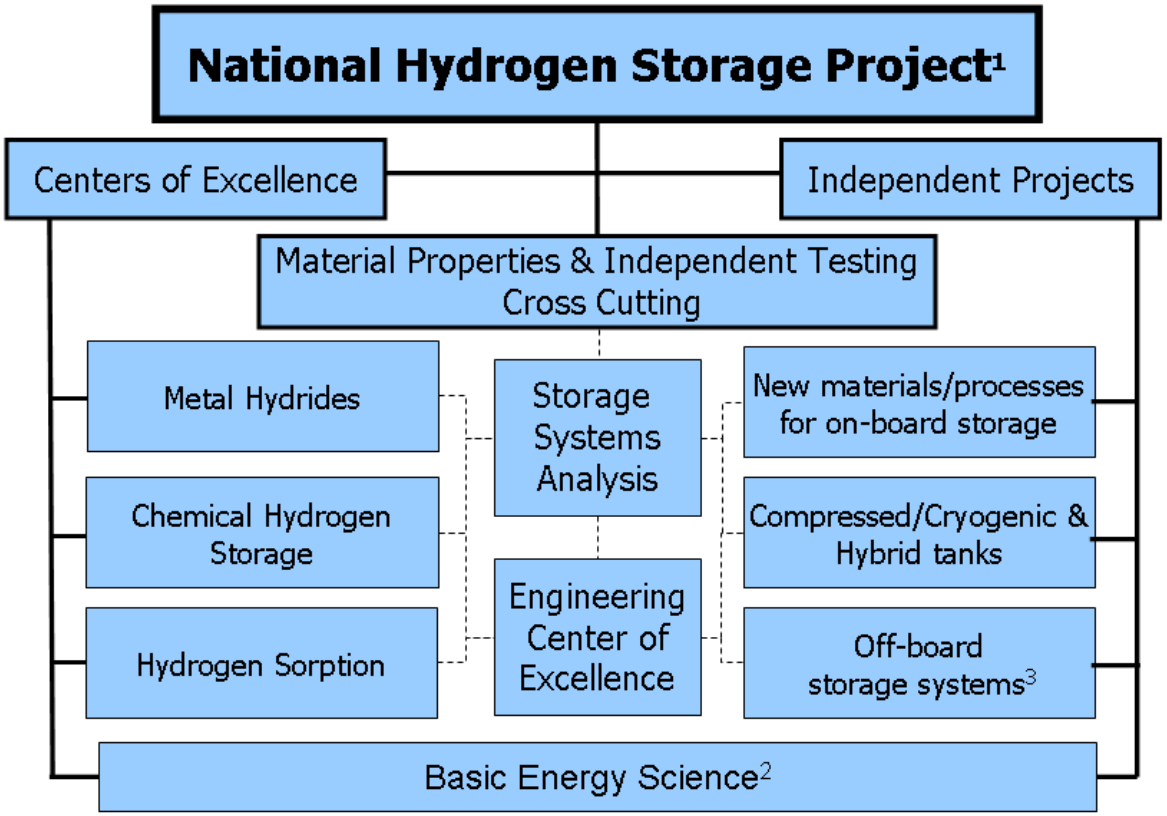
DOE targets are set to achieve > 300 mile driving range across different vehicle platforms, WITHOUT COMPROMISING passenger/cargo space, performance, or cost.

- → ***No currently available technology meets these targets.***
- → ***DOE Program is focused on materials R&D.***



Hydrogen Storage R&D

The National Hydrogen Storage Project is a balanced portfolio, involving ~48 universities, 15 companies, and 14 federal labs.



1. Coordinated by DOE Energy Efficiency and Renewable Energy, Office of Hydrogen, Fuel Cells and Infrastructure Technologies
2. Basic science for hydrogen storage conducted through DOE Office of Science, Basic Energy Sciences
3. Coordinated with Delivery Program element

Fuel Cell R&D

Fuel cell R&D is focused on light-duty vehicles and early market applications.

Light-Duty Vehicles

R&D for transportation fuel cells is focused on components rather than systems.

KEY TARGETS:

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

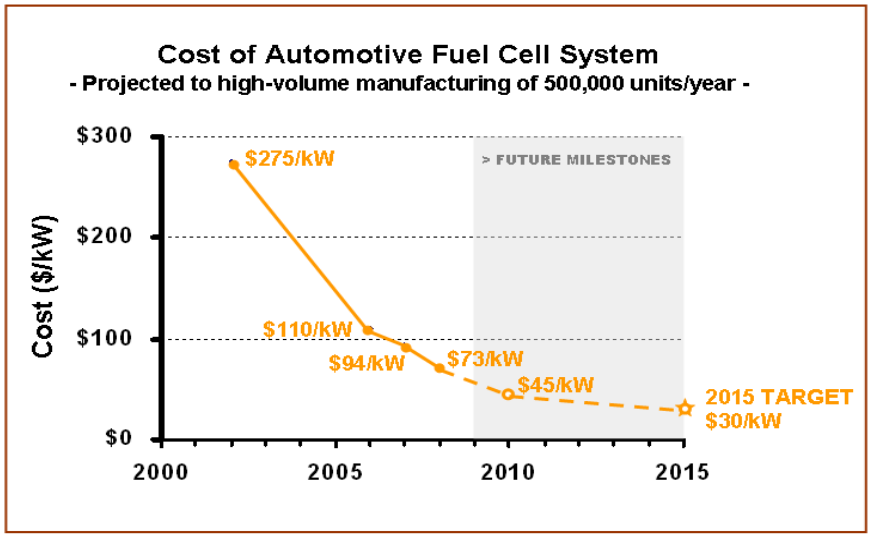
Early Market Applications

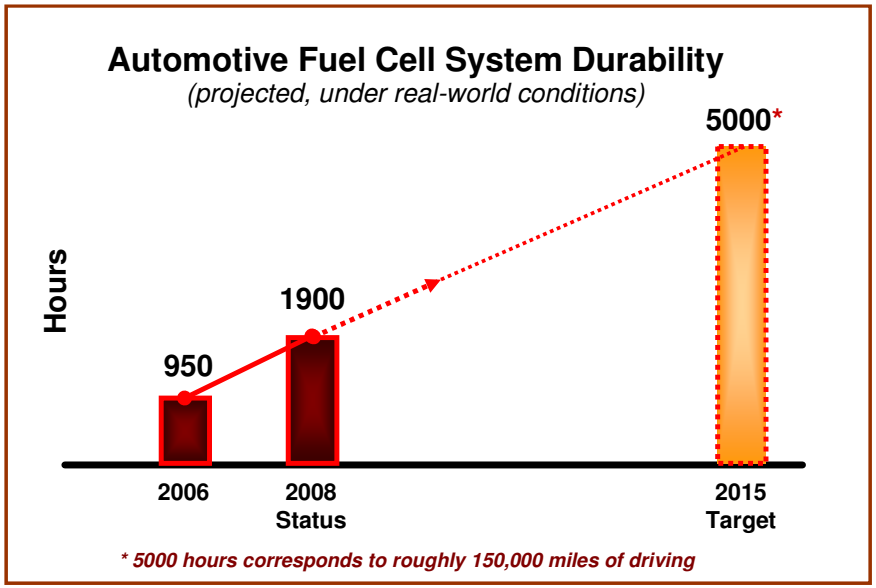
Early markets for stationary, backup power, and specialty applications will lower costs and grow the manufacturing base.

KEY TARGETS:

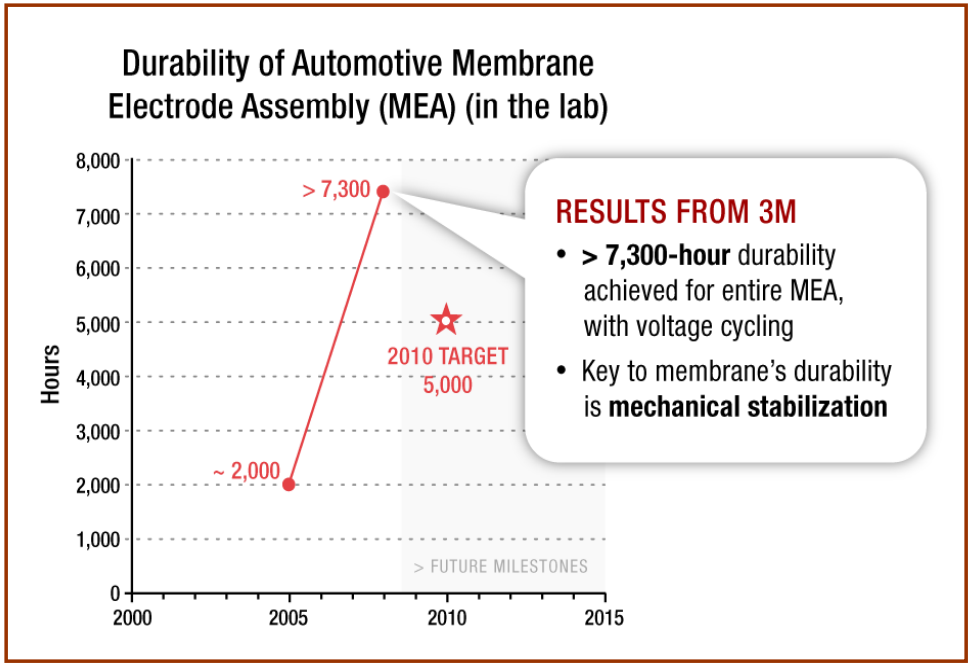
- **Distributed Power:** $750/kW and 40,000-hour durability (with 40% efficiency) by 2011
- **APUs:** Specific power of 100 W/kg and power density of 100 W/L by 2010
- **Portable Power:** Energy density of 1,000 W-h/L by 2010

Fuel Cell R&D





Steady progress is being made in reducing cost and increasing durability of automotive fuel cells.



Technology Validation – Vehicles

Technologies are validated & progress evaluated through learning demonstrations.
(four teams in 50/50 cost-shared projects)

DOE Vehicle/Infrastructure Demonstration

Verified performance in 122 fuel cell vehicles and 16 hydrogen stations:

- ***EFFICIENCY: 53 – 58%*** *(>2x higher than gasoline internal combustion engines)*
- ***RANGE: > 250 miles***
- ***FUEL CELL SYSTEM DURABILITY:***
  - ***1900 hours, projected (~57,000 miles)***
  - ***1700 hours, actual (~36,000 miles)***

DOT is demonstrating fuel cell buses and providing data to DOE for analysis

Eight buses in California, Massachusetts, New York, South Carolina, and Washington, DC

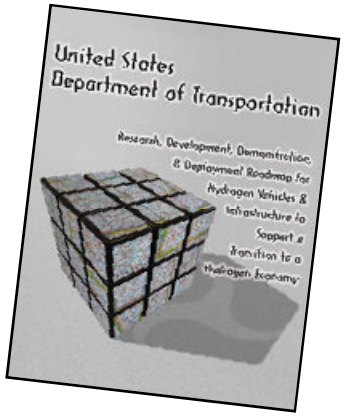
Department of Transportation Activities

Three principal areas of focus:

- Ensuring the safety of hydrogen as a fuel and commodity across all modes of transportation
- Leading the research, development, demonstration and deployment (RDD&D) of medium- and heavy-duty vehicles and their accompanying infrastructure, including buses, trucks, rail, marine, and aviation systems
- Guiding the RDD&D of a hydrogen infrastructure, including regulatory frameworks, pipeline best practices, and the integration of stationary power into DOT-regulated systems.

Guiding Document: The U.S. DOT Hydrogen Roadmap (2005)

Road 1: Safety Codes, Standards and Regulations
Road 2: Infrastructure Development and Deployment
Road 3: Safety Education, Outreach, and Training
Road 4: Medium- and Heavy-Duty Vehicle Development, Demonstration and Deployment



Technology Validation - Stationary

The Program is also demonstrating the integration of renewable power generation and hydrogen production.

DTE Energy *(ongoing)*

Hydrogen production using water electrolysis with on-site solar energy (Southfield, Michigan)

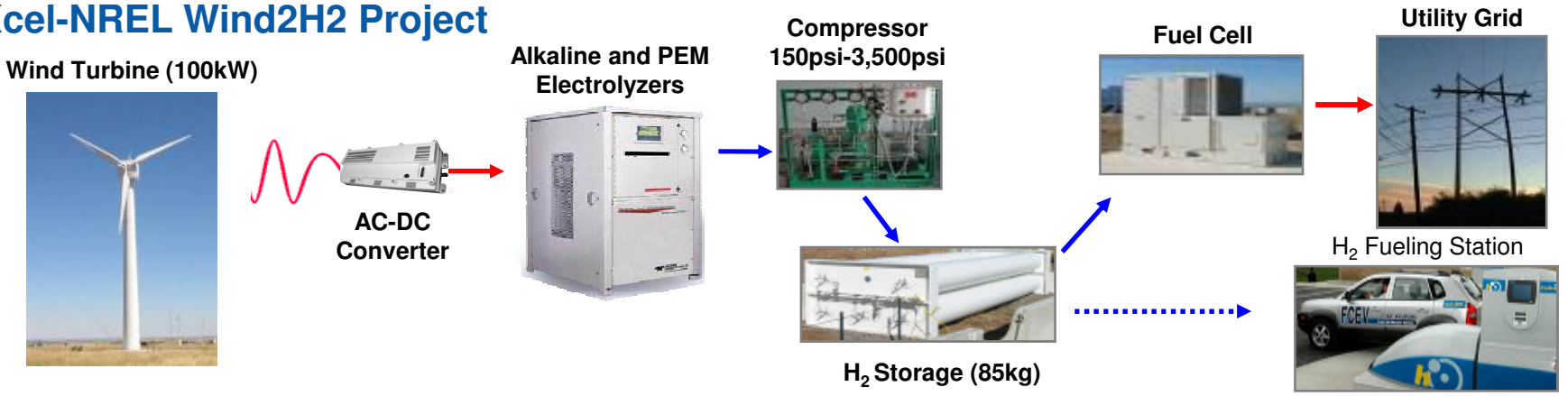
Xcel/NREL Wind/Hydrogen Project *(ongoing)*

Integrates electrolyzers and wind turbines to understand the benefits and impacts of adding hydrogen production facilities to the electric power grid (NREL wind site at Golden, Colorado)

Hawaii *(planned)*

Hydrogen production using curtailed wind and geothermal energy to generate electricity and to fuel hydrogen buses at national parks

Xcel-NREL Wind2H2 Project



Safety, Codes & Standards *and* Education

Safety, Codes & Standards

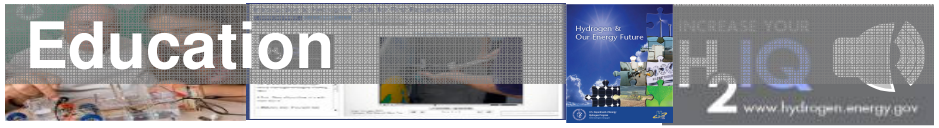
CHALLENGES

- Lack of technical data for C&S development; lack of domestic and international consistency; delayed adoption of approved C&S
- Difficult permitting processes
- H_2 safety information not widely available or accessible

PROGRESS

- Developed Technical Reference for Hydrogen Compatibility of Materials
- Developed Web-based Hydrogen Safety Best Practices Manual
- 22 hydrogen C&S published, 28 under preparation/review; progress toward an international fuel quality standard
- Published Hydrogen Fueling Station Permitting Compendium

Education



CHALLENGE

Lack of public awareness and understanding of hydrogen and fuel cell technologies

PROGRESS

- "Introduction to Hydrogen Safety for First Responders" (>6000 users since launch)
- Radio spots, podcasts, MySpace, Orlando Magic Collaboration
- 7 new projects for state & local gov't outreach, 5 university education projects
- Early market fact sheets & case studies
- Reached >6000 teachers through training workshops

Systems Analysis

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

OAK RIDGE National Laboratory

NREL Study: *Opportunities for H_2-Based Energy Storage for Electric Utilities*

→*H_2-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 reducing cost.*

→*Analysis also shows potential GHG emissions from a variety of early market applications*

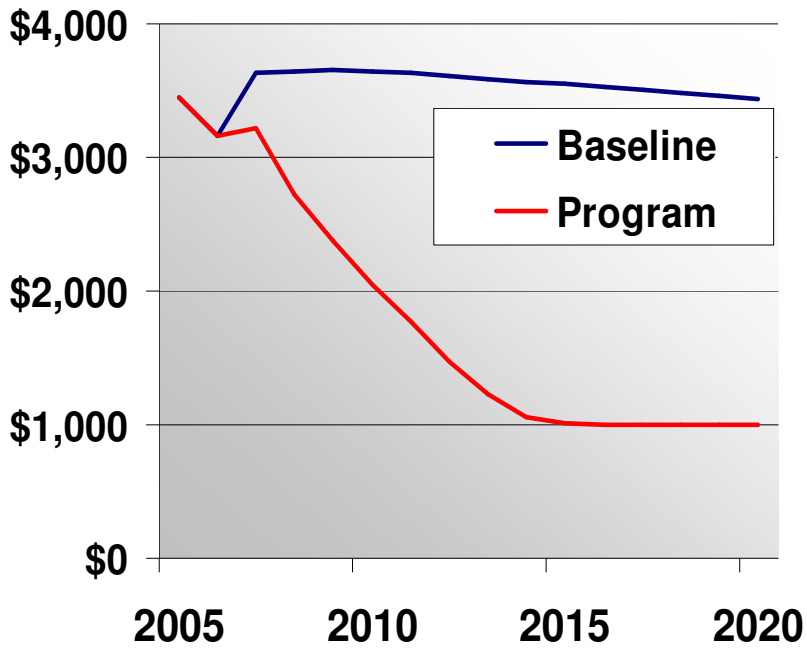
Market Transformation

The Program is facilitating the early adoption of hydrogen & fuel cell technologies.

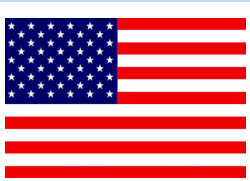
OBJECTIVES

- Assist federal agencies in promoting fuel cell use across the U.S. government to meet the requirements of:
  - EPACT 2005 Sec. 782 and 783
  - Executive Order 13423
- Increase sales & manufacturing volumes of fuel cells to achieve economies of scale
- Support national infrastructure and domestic supplier base development
- Improve user confidence in fuel cell reliability by collecting operations data

Estimated Impact of Gov't Acquisitions on FC Stack Costs *(in $/kW)*



Source: David Greene, ORNL; K.G. Duleep, Energy & Environmental Analysis, Inc.



Collaboration with JTI

Past Successes

- EU participation in 2008 DOE Hydrogen Merit Review
- Jointly funded, competitively selected project on stationary fuel cells
- Round-robin testing of hydrogen and fuel cell technologies
- Collaborative projects, include HyWays-IPHE systems analysis project and safety, codes & standards efforts

Proposed Activities

- Continue collaboration via IPHE and IEA
- JTI participation in 2009 Hydrogen Program Annual Merit Review
- Exchange of information on projects, R&D plans, and analytic tools
- Reciprocal peer review of projects
- Solicitations open to US and EU entities
- Exchange visits by researchers from laboratories and universities
- Joint participation in international projects

Summary

- Steady progress is being made; consistent budgets are key.
- Partnerships are critical to success.
- Government must go beyond R&D to facilitate commercialization.

We congratulate the EU on the launch of the JTI and look forward to continued collaboration.

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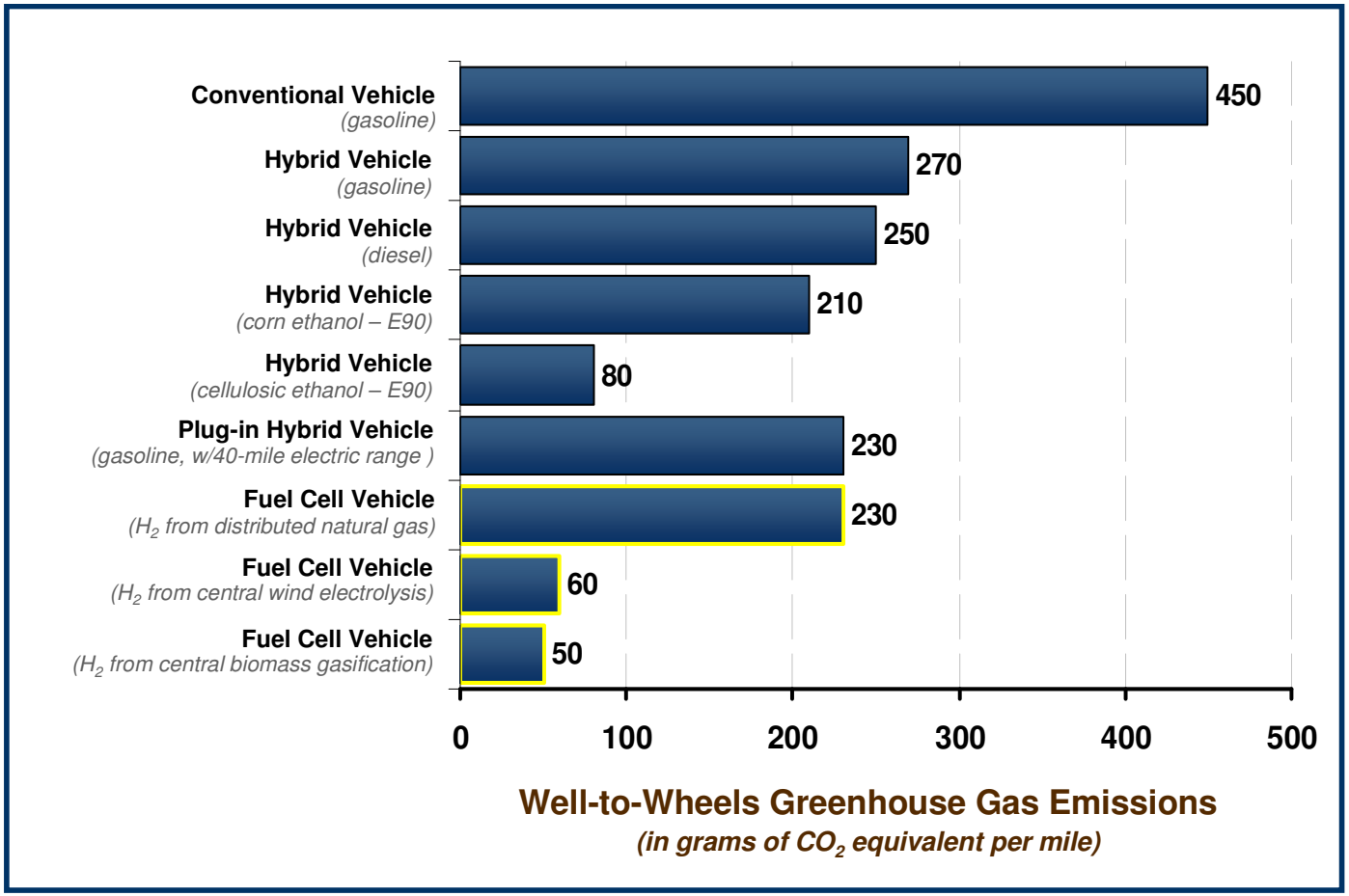
Additional Information

Benefits of Fuel Cell Vehicles

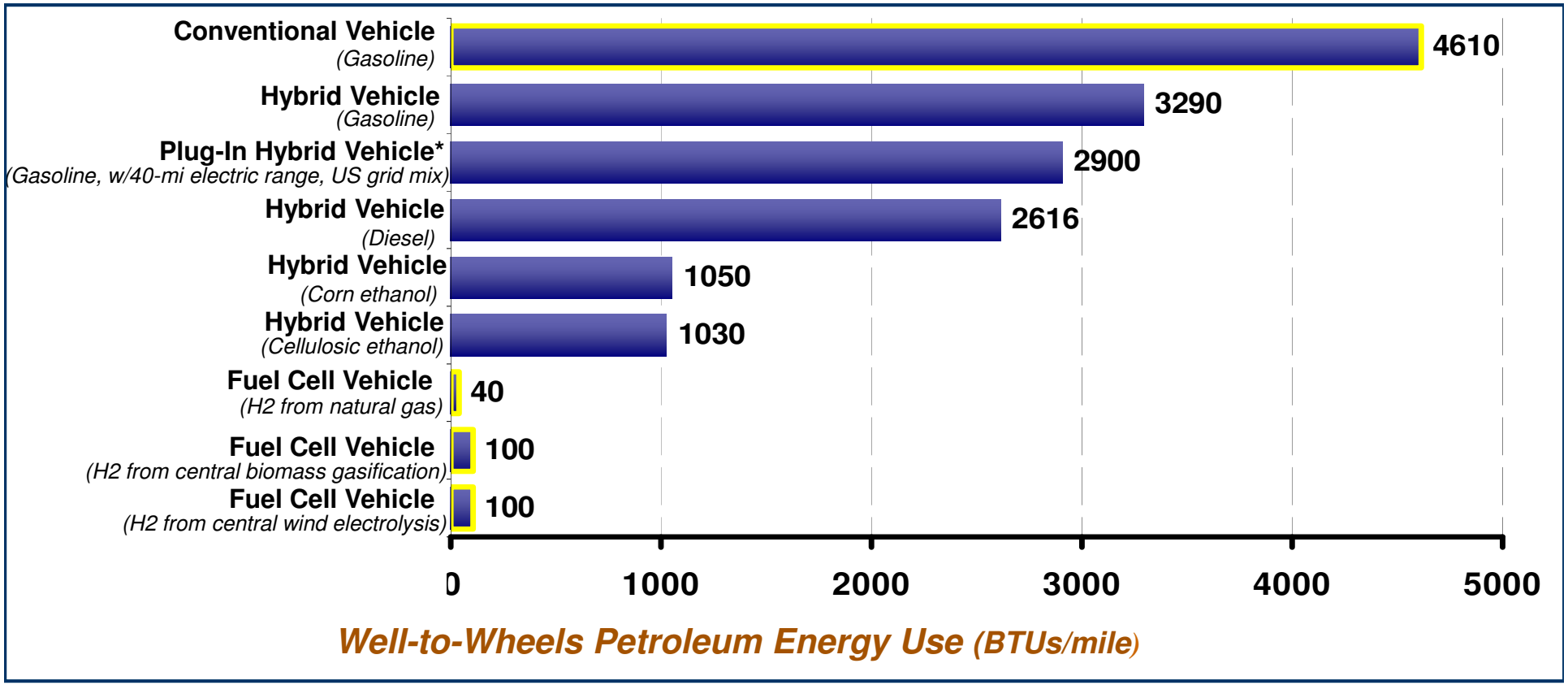
Well-to-wheels analysis* shows that use of hydrogen — from a variety of sources — would reduce greenhouse gas emissions.



**Analysis based on technologies expected to be available in 2015, except for central hydrogen production pathways, which are based on delivery infrastructure expected in 2030.*

Benefits of Fuel Cell Vehicles

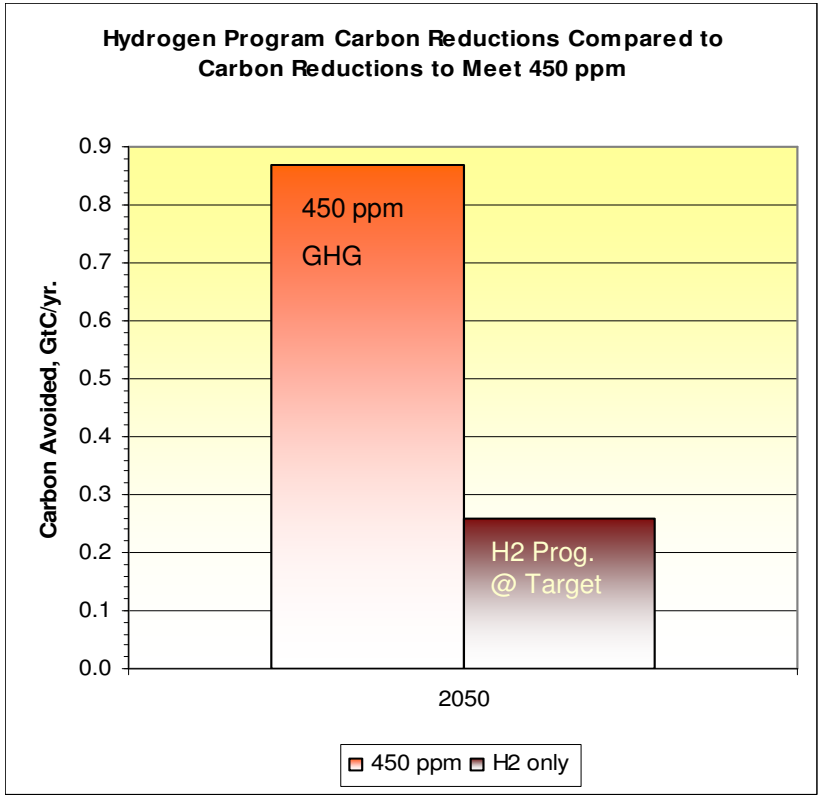
Well-to-wheels analysis* shows that use of hydrogen — <u>from a variety of sources</u> — would reduce petroleum consumption.

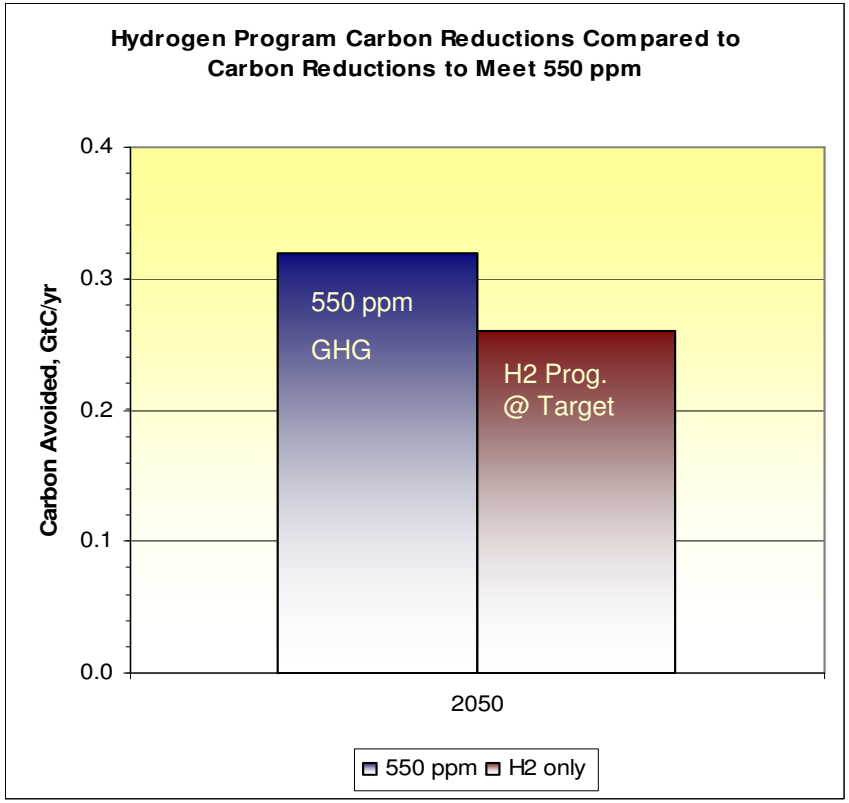


**Analysis based on technologies expected to be available in 2015, except for central hydrogen production pathways, which are based on delivery infrastructure expected in 2030. Plug-in hybrid*

Impact of Hydrogen Program on Carbon Reducations

Carbon reduction benefits of ~0.26 giga tonnes per year in 2050 by Program achieving goals.





Manufacturing R&D

GOAL: Develop and demonstrate technologies and processes that will:

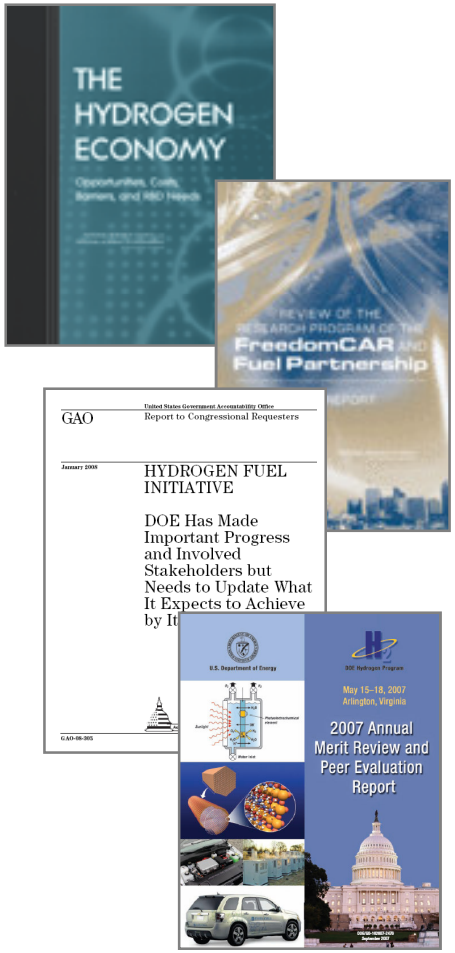
- ***Reduce cost of components and systems for hydrogen production, storage, and fuel cells***
- ***Grow the domestic supplier base***

OBJECTIVES

- Lower fuel cell manufacturing cost to:
  - $30/kW Mobile
  - $400/kW Stationary
- Reduce cost of carbon composite high pressure storage tanks
  - $2/kW hr

External Evaluation/Advisory Input

External reviews have found that the Program is well-managed and has effectively engaged stakeholders; the Program has made good progress; and significant challenges remain.



National Academies — Establishes committees of leading experts to provide independent advice to the government

Government Accountability Office — An investigative arm of Congress charged with auditing and evaluating government programs and activities

Hydrogen & Fuel Cells Technical Advisory Committee — Experts from industry, academia, and other federal agencies provide technical and programmatic advice to DOE

Annual Merit Review and Peer Evaluation — More than 150 technical experts review the DOE Hydrogen Program's projects for their merit and contribution to Program goals

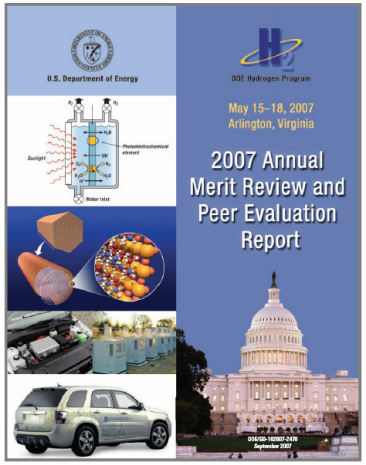
Ongoing Stakeholder Input

Technology-Focused Workshops help the Program determine its role in particular areas, develop detailed R&D plans, and establish technical targets. Several are held each year.

Examples of past workshops:

- Hydrogen Storage Materials (2002)
- Basic Energy Sciences Workshop (2003)
- Fuel Purity Specifications (2004)
- Hydrogen Transition Analysis (2006)
- Bio-derived Liquids to Hydrogen (2007)
- Fuel Cell Pre-Solicitation (2008)

The Solicitation Process allows the Program to competitively select the best proposals from the most qualified teams, based on the input of independent reviewers. This involves an initial Request for Information (RFI), followed by a pre-solicitation workshop, followed by the final solicitation announcement.



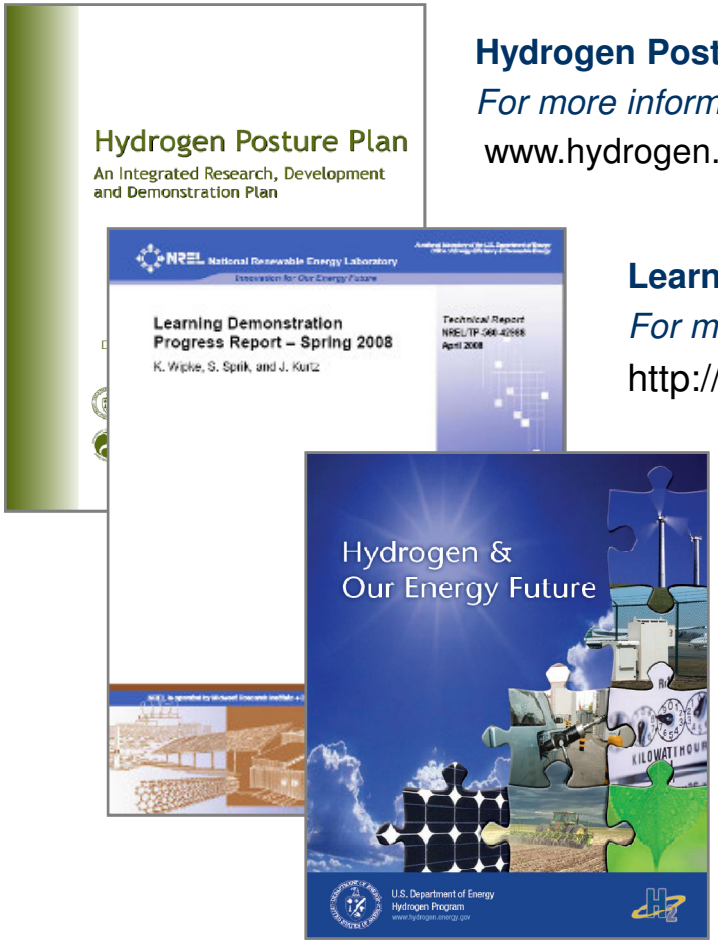
Annual Merit Review & Peer Evaluation

Technical experts—from industry, academia, and the national labs—review the DOE Hydrogen Program's projects for their merit and contribution to Program goals. The FY 2008 Merit Review included:

- More than 1000 registered attendees
- 300 projects, in oral and poster presentations
- Nearly 200 reviewers

Questions?

For more information visit: www.hydrogen.energy.gov



Hydrogen Posture Plan

For more information on the Hydrogen Program

www.hydrogen.energy.gov/roadmaps_vision.html

Learning Demonstration Progress Report

For more information on the vehicle/infrastructure demonstration

http://www.nrel.gov/hydrogen/pdfs/42986.pdf

Hydrogen Overview Book

For more information on hydrogen and fuel cell technologies

www1.eere.energy.gov/hydrogenandfuelcells/education/h2iq.html