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

U.S. Department of Energy Fuel Cell Technologies Program

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Fuel Cell Technologies Program

Energy Efficiency and Renewable Energy

United States Department of Energy

Washington, D.C.

18th World Hydrogen Energy Conference 2010

Essen, Germany

May 17, 2010

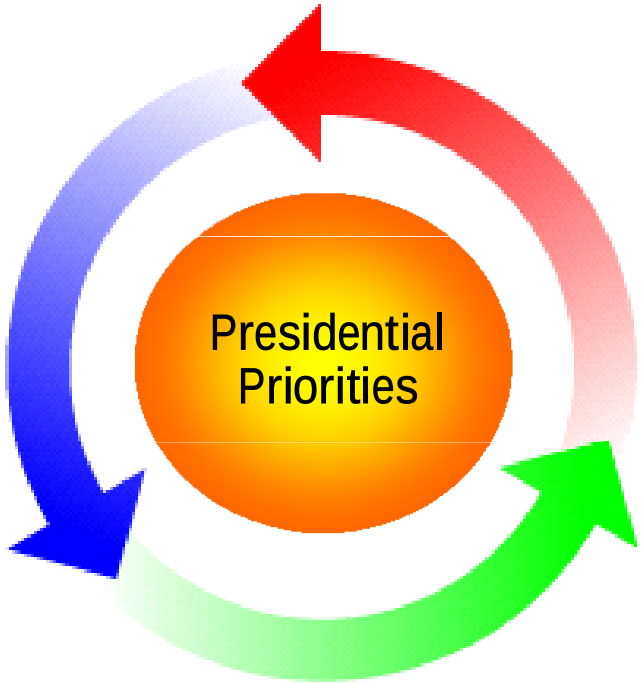
Advancing Presidential Priorities

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

Energy efficiency and renewable energy research, development, and deployment activities help the U.S. meet its economic, energy security, and environmental challenges concurrently.

Energy Security

- Deploy the cheapest, cleanest, fastest energy source – energy efficiency
- One million plug-in hybrid cars on the road by 2015
- Develop the next generation of sustainable biofuels and infrastructure
- Increase fuel economy standards



Economic

- Create green jobs through Recovery Act energy projects
- Double renewable energy generation by 2012
- Weatherize one million homes annually

Environmental

- Implement an economy-wide cap-and-trade program to reduce greenhouse gas emissions 80 percent by 2050
- Make the US a leader on climate change
- Establish a national low carbon fuel standard

U.S. DOE

President's National Objectives for DOE—Energy to Secure America's Future

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

- **Quickly Implement the Economic Recovery Package:** Create Millions of New Green Jobs and Lay the Foundation for the Future
- **Restore Science Leadership**: Strengthen America's Role as the World Leader in Science and Technology
- **Reduce GHG Emissions**: Drive emissions 20 Percent below 1990 levels by 2020
- **Enhance Energy Security:** Save More Oil than the U.S currently imports from the Middle East and Venezuela combined within 10 years
- **Enhance Nuclear Security**: Strengthen non-proliferation activities, reduce global stockpiles of nuclear weapons, and maintain safety and reliability of the US stockpile

First Principle:
Pursue material and cost-effective measures with a sense of urgency

From: Secretary Chu's presentation on DOE Goal's and Targets, 5/5/09

Executive Order 13514

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

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

Drivers for FCT Program

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

The mission of the U.S. DOE Fuel Cell Technologies Program is to enable the widespread commercialization of fuel cells, through applied R&D to overcome technical barriers and through efforts to reduce institutional and market barriers.

→ **This mission supports the broad national goals of:**

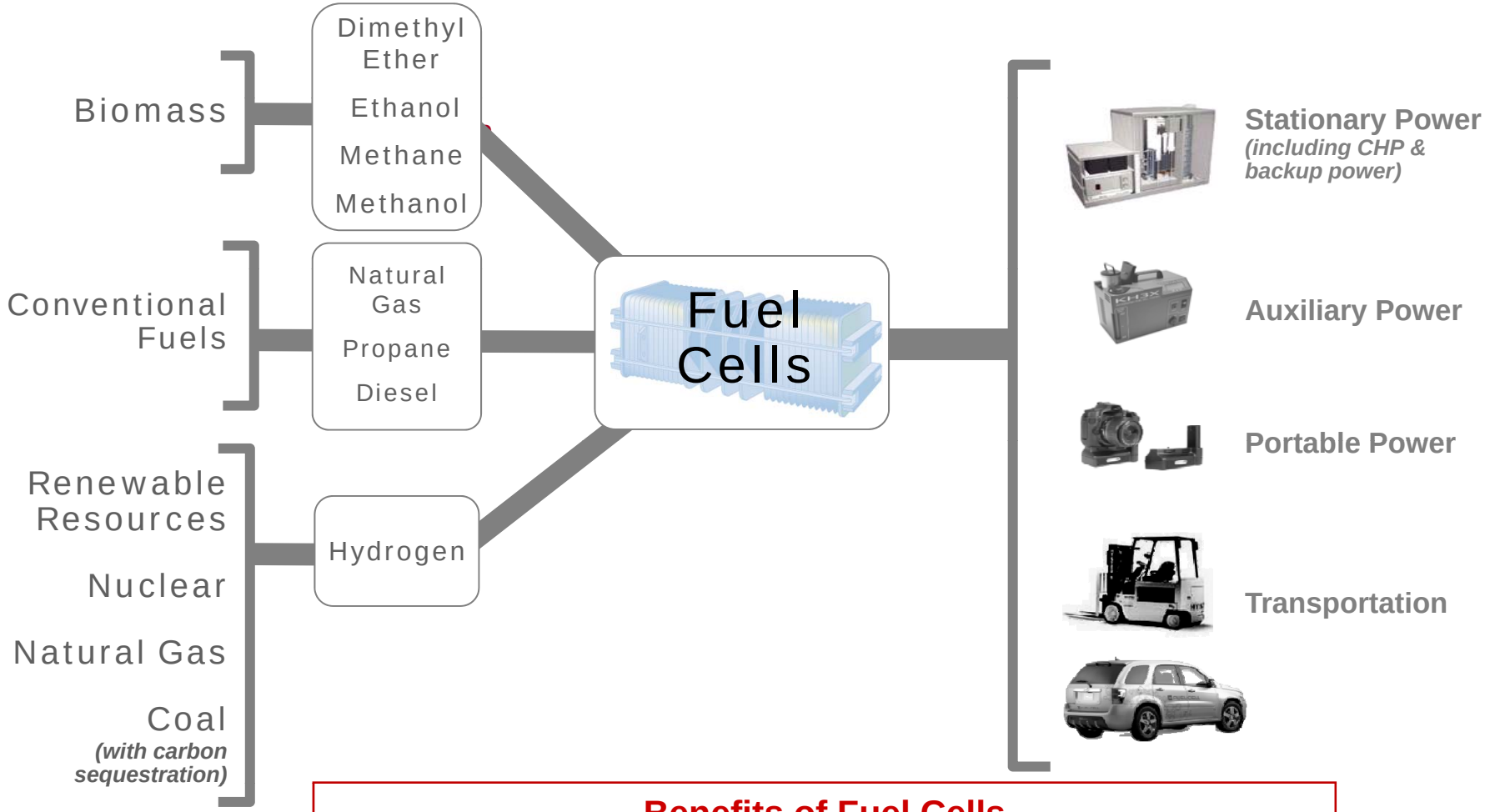
- **reducing petroleum use**
- **reducing greenhouse gas emissions, and air pollution**
- **developing a more diverse and efficient energy infrastructure**
- **creating high-skilled jobs in emerging technical fields**

The key objective is to make fuel cells competitive with incumbent technologies and other advanced technologies in terms of lifecycle cost, performance, and market acceptance.

Fuel Cells: Addressing Economic, Energy, and Environmental Challenges

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

Diverse Energy Sources & Fuels → , Efficient Energy Conversion → Diverse Applications



Benefits of Fuel Cells

- **Efficiencies can be 60% (electrical) and 85% (with CHP)**
- **> 90% reduction in criteria pollutants**

U.S. DOE

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 FCs today are in stationary and portable power, APUs, 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, forklifts, and backup power.

Fuel Cells for Transportation

Worldwide, there are currently:

> 230 fuel cell vehicles

> 130 fuel cell buses

~ 200 fueling stations

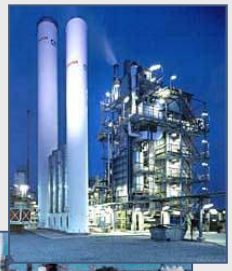
Several manufacturers - including Toyota, Honda, Hyundai, Daimler, GM, and Proterra (buses) - have announced plans to commercialize vehicles by 2015.

Production & Delivery of Hydrogen

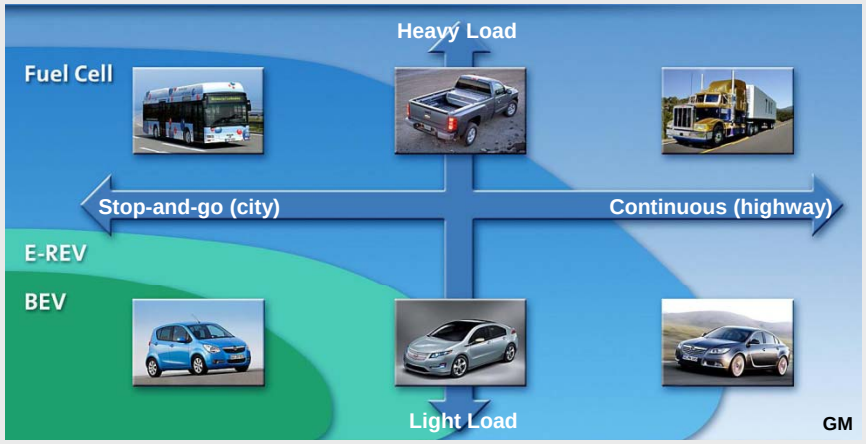
Worldwide, there are currently:

~50 million metric tons of H_2 produced annually

> 1900 miles of H_2 pipelines



The Role of Fuel Cells in Transportation



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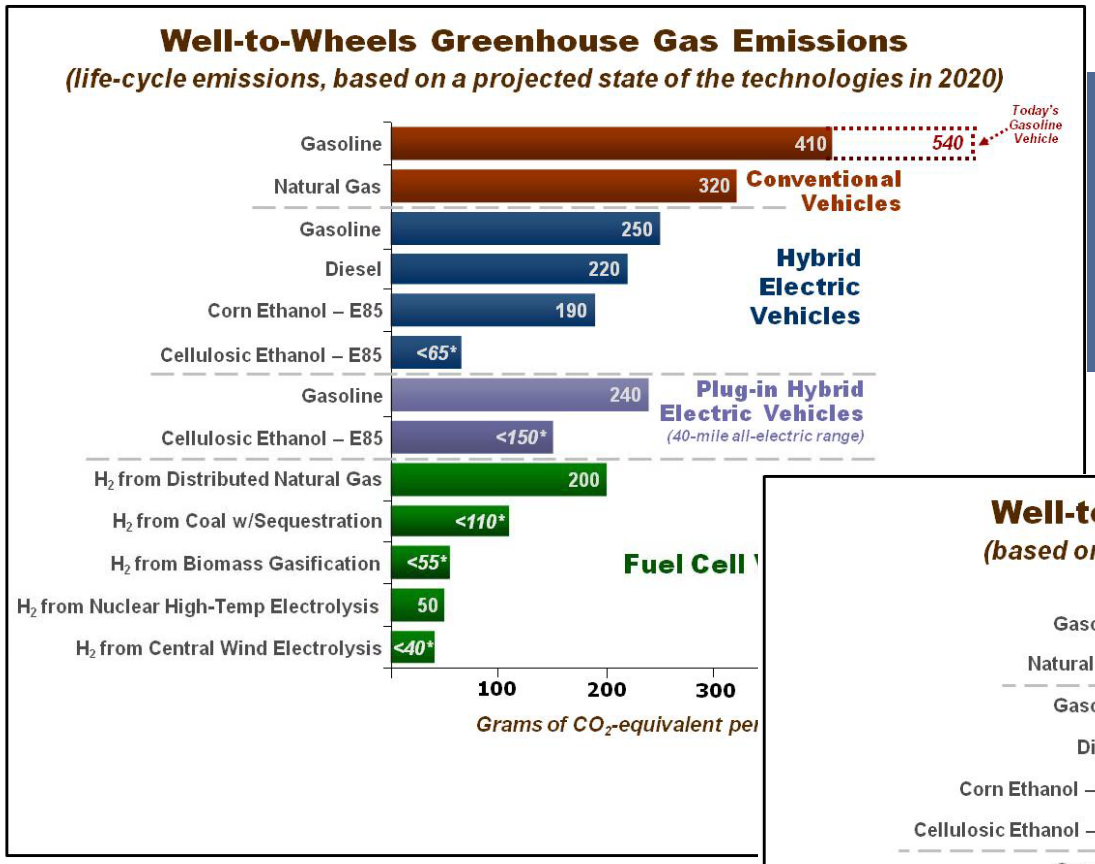
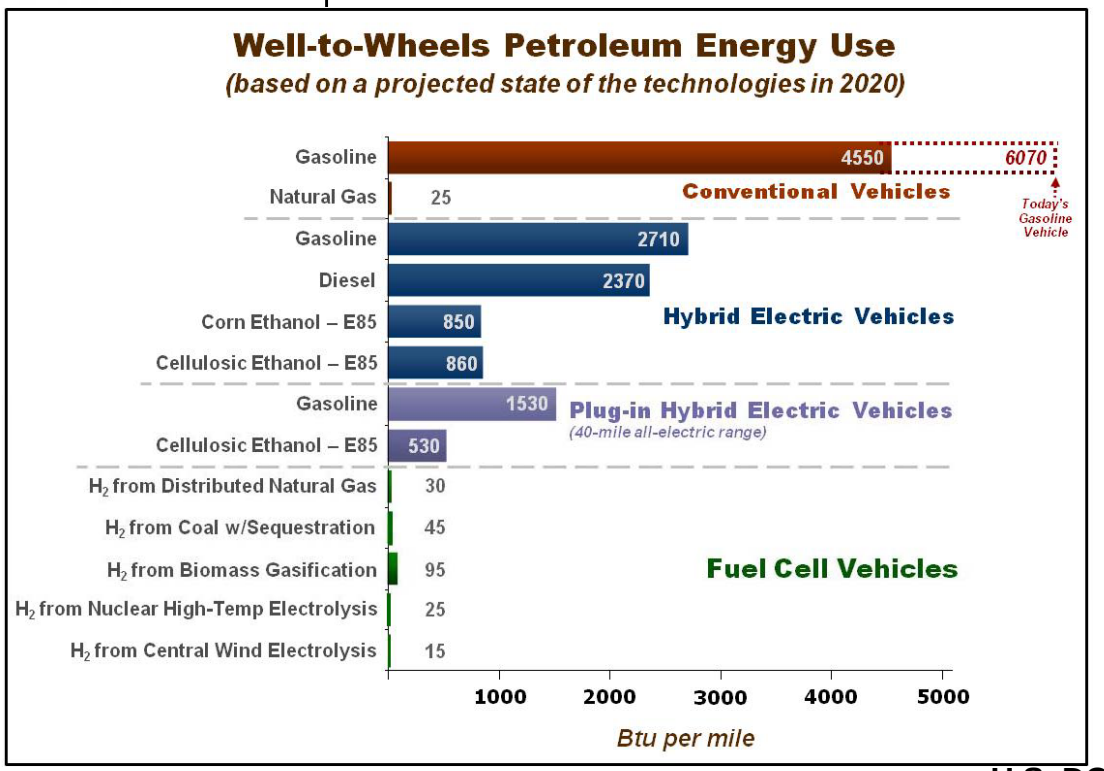
Benefits of electric vehicles – GHGs and Energy Use

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



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.

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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, 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

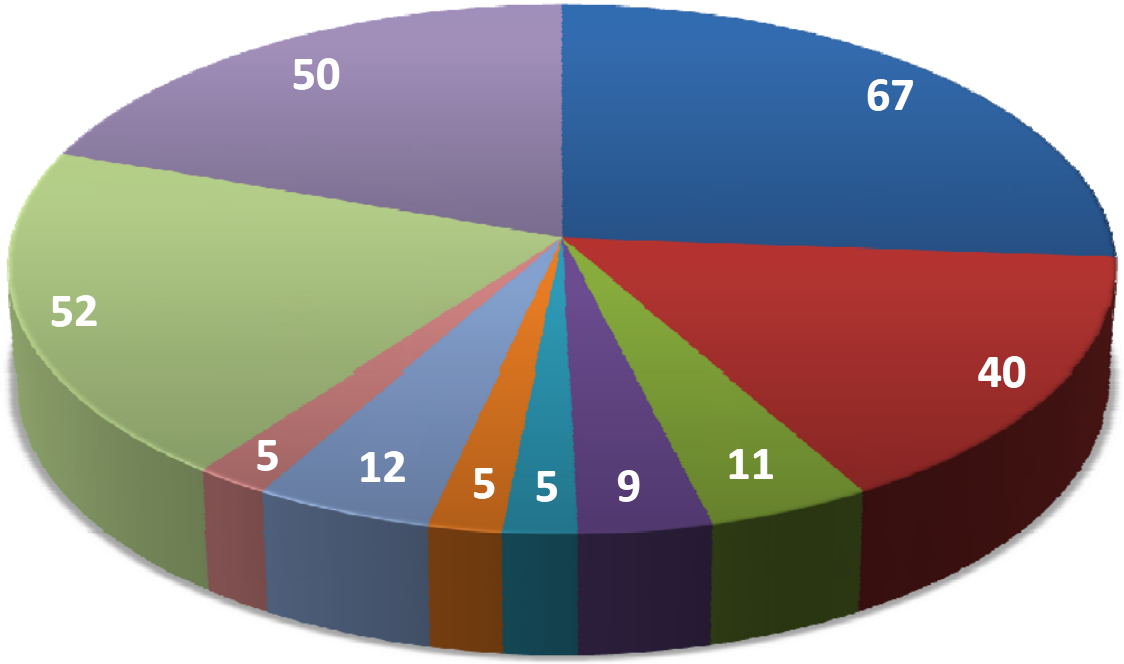
Assisting the growth of early markets will help to overcome many barriers, including achieving significant cost reductions through economies of scale.

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

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$)



- 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)

Total FY11 Budget Request $256 Million

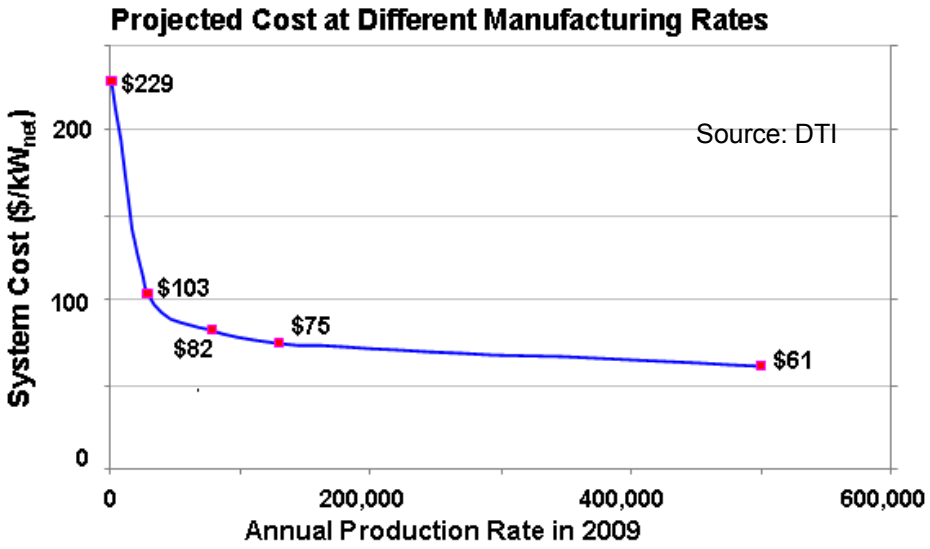
*NE request TBD, $5M represents FY10 funding
**SC Includes BES and BER

Fuel Cell R&D

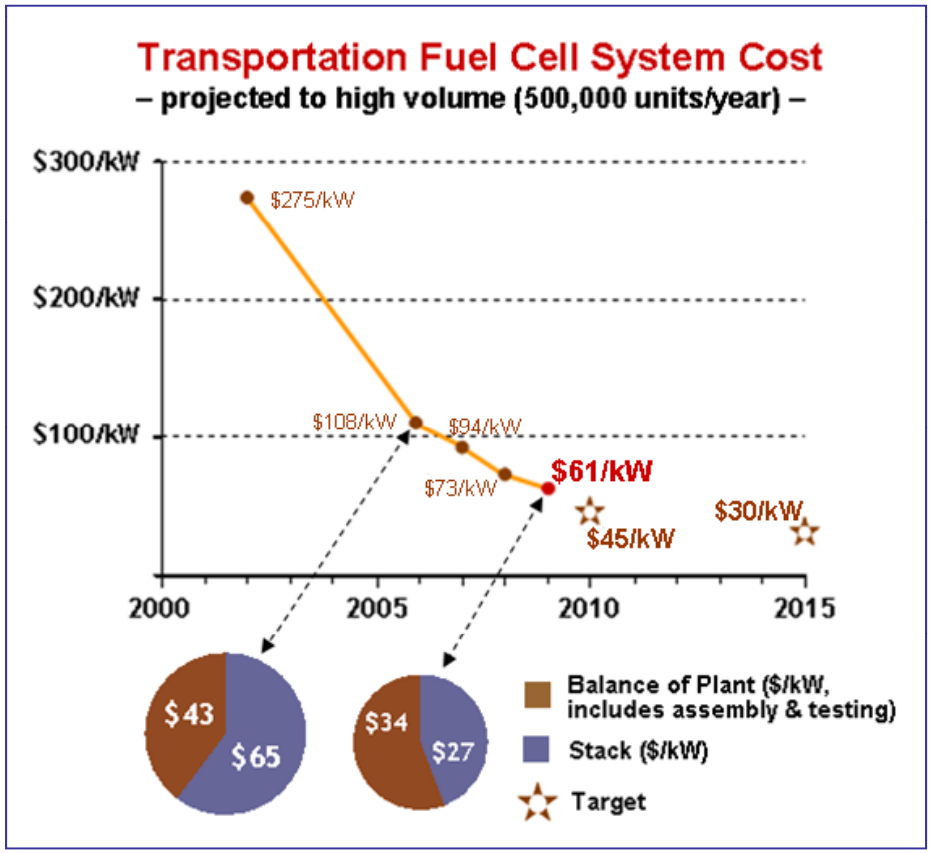
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The **projected** high-volume cost of **80-kW** transportation fuel cells has been reduced to $61/kW*

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



http://www.fuelcellseminar.com/assets/2009/GHT41-3_0930AM_James.pdf



*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.

U.S. DOE

KEY OBJECTIVE: **Reduce the cost of hydrogen (delivered & untaxed) to $2 – 3 per gge (gallon gasoline equivalent)**

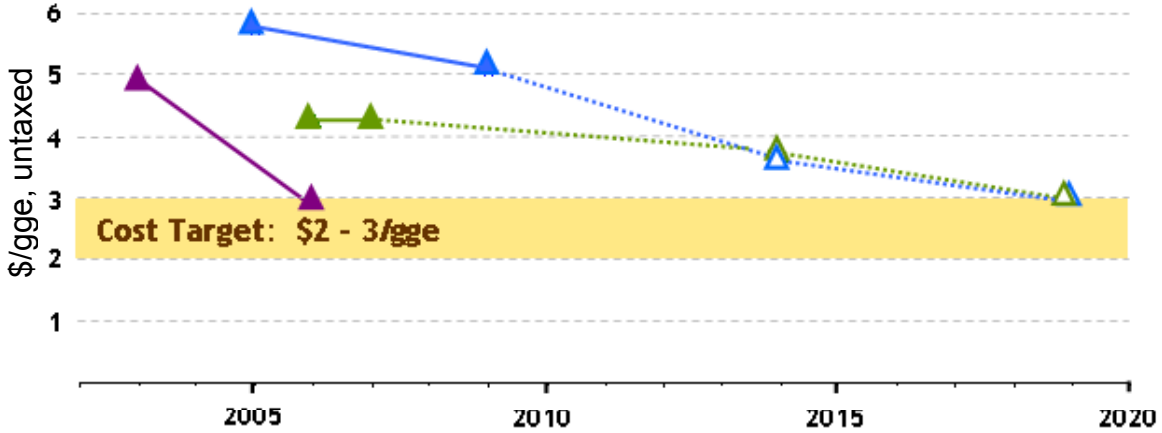
Projected* High-Volume Cost of Hydrogen (Delivered) — Status & Targets

NEAR TERM:

Distributed Production

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

Hollow triangles (△) represent targets

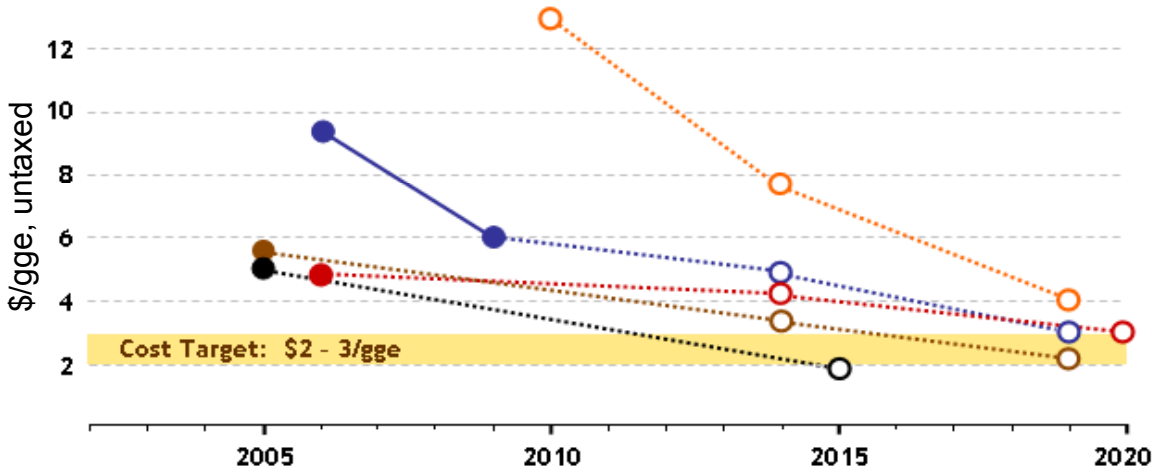


LONGER TERM:

Centralized Production

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

Hollow circles (○) represent targets



* **Distributed production** status and targets assume station capacities of 1,500 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.

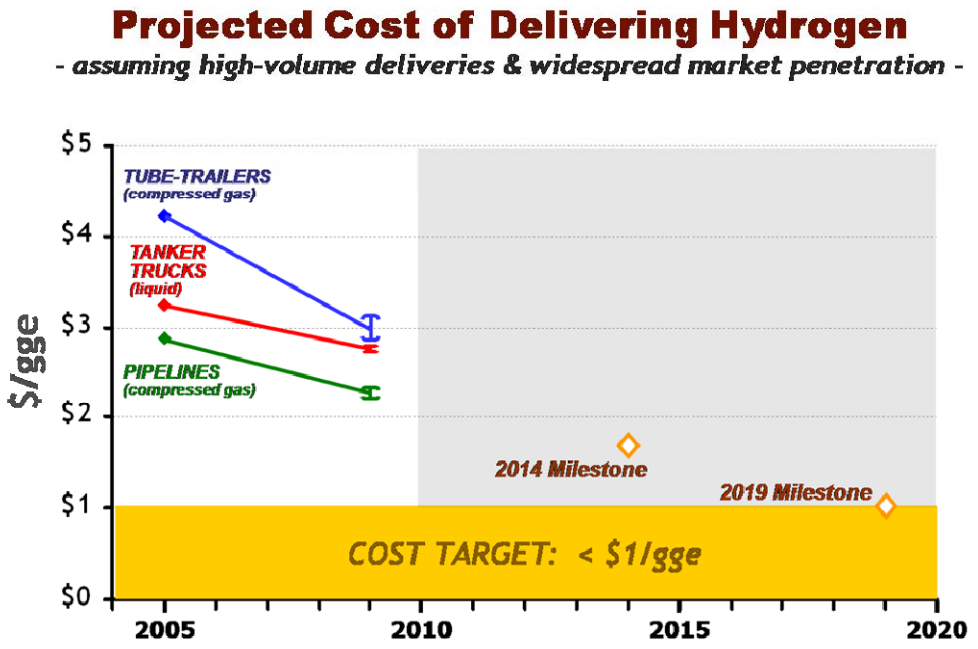
KEY OBJECTIVE - Reduce the cost of delivering hydrogen to < $1/gge

PROGRESS

~30% reduction in tube-trailer costs

>20% reduction in pipeline costs

~15% reduction in liquid hydrogen delivery costs



Assumptions: Sacramento, with 20% market penetration; 147 stations (1000 kg/day per station); plant 62 miles from city gate; 10 days off-peak storage (geologic storage for tube-trailers and pipelines, liquid storage for tanker-trucks). Costs include all processes from the production site through dispensing (for 350-Bar onboard storage), expressed in 2005 dollars. **Model:** HDSAM (www.hydrogen.energy.gov/h2a_delivery.html). **Date:** January 2010.

Cost reductions enabled by:

- New materials for tube trailers
- Advanced liquefaction processes
- Replacing steel with fiber reinforced polymer for pipelines

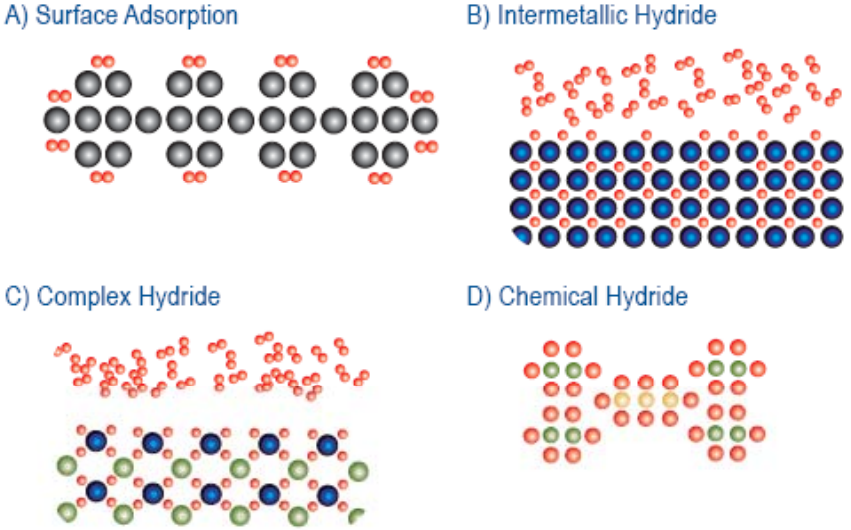
Hydrogen Storage R&D

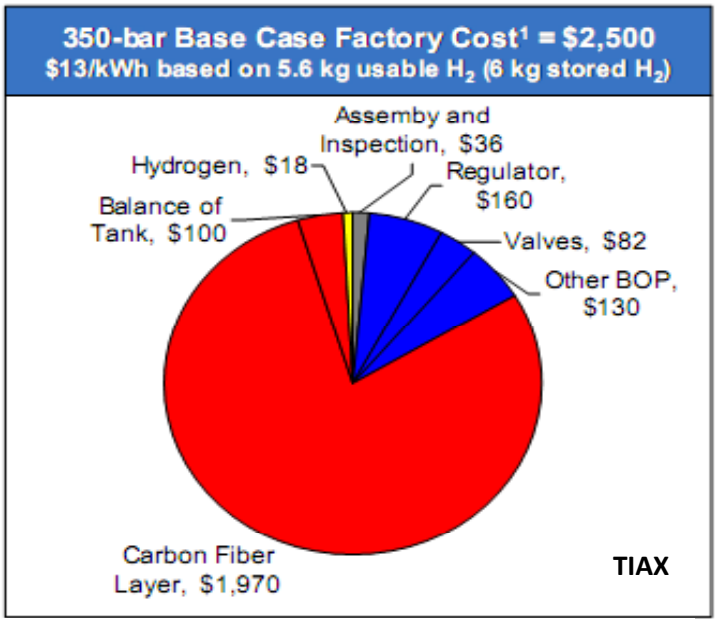
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE has focused on materials R&D and has identified several promising new materials - resulting in significant capacity improvements since 2004.

Compressed gas storage offers a near-term option for initial vehicle commercialization

- Cost of composite tanks is challenging
- > 75% of the cost is projected to be due to the carbon fiber layer
- Additional analysis is needed to better understand costs at lower volumes





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

Materials discovery research is still needed for long-term, advanced materials-based storage technologies

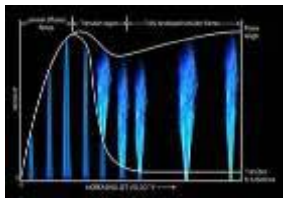
U.S. DOE

Safety, Codes & Standards *and* Education

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

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

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

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

- **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**

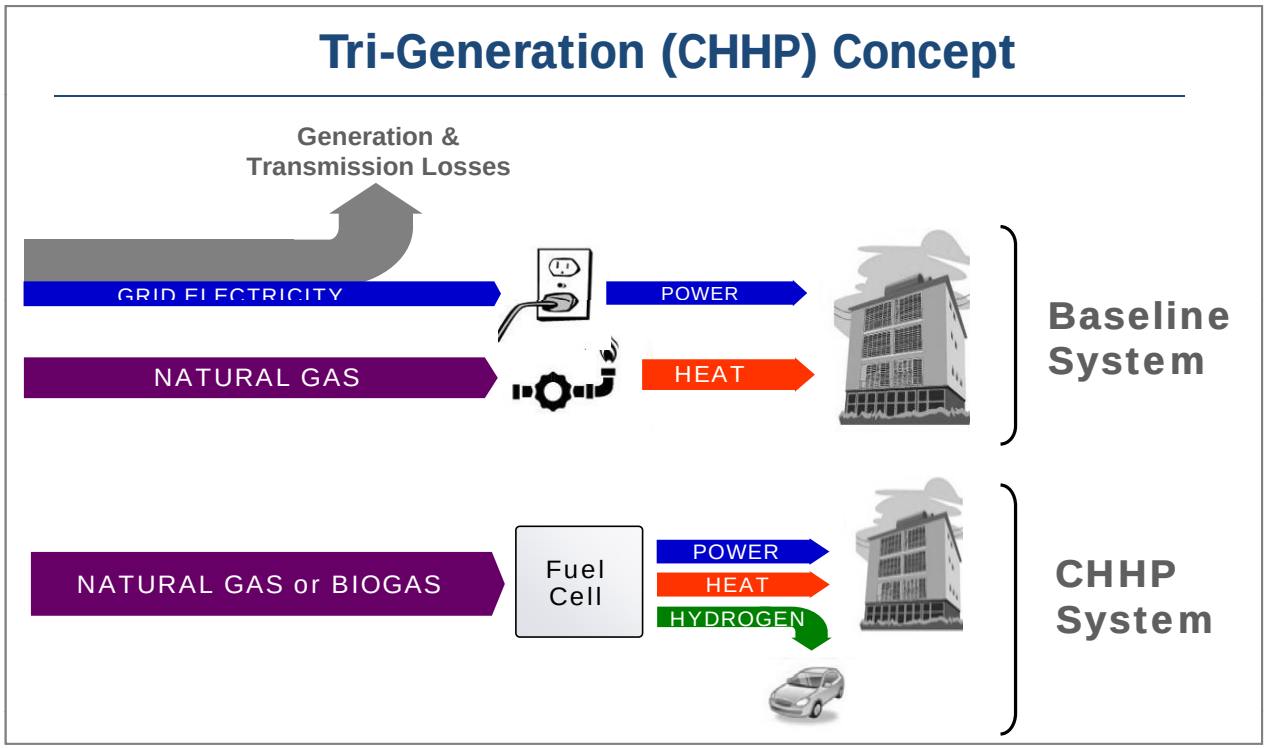
We are also demonstrating stationary fuel cells and evaluating real-world forklift and bus fleet data (DOD and DOT collaboration).

Technology Validation - *Tri-Generation*

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

U.S.DOE is participating in a project to demonstrate a combined heat, hydrogen, and power (CHHP) system using biogas from wastewater treatment plant at the Orange County Sanitation District in Fountain Valley, CA.

- **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 late FY10.**



CHHP 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

U.S. DOE

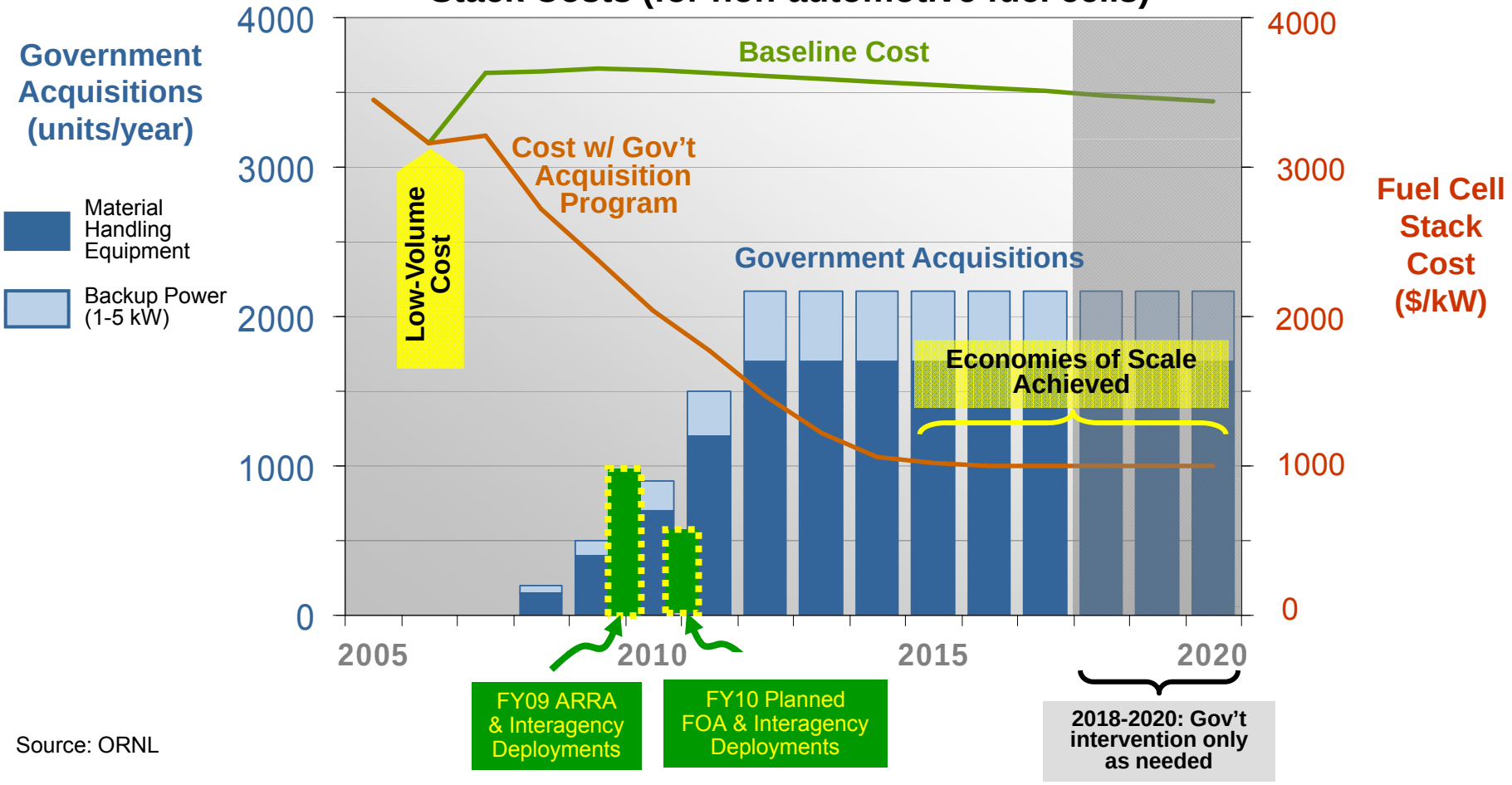
Market Transformation

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

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

Key Market Transformation Goals: Enable cost reductions from ~$3500/kW to ~$1000/kW for backup power and lift-truck power and from ~$5500/kW to ~$3000/kW for CHP systems

Impact of Government Acquisitions on Fuel Cell Stack Costs (for non-automotive fuel cells)



Source: ORNL

U.S. DOE

FY07 – FY10 Federal Deployments

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

DOE is facilitating the adoption of fuel cells across the U.S. federal government.

FY2007 - DOE works with the Defense Logistics Agency to deploy 40 forklifts at DDSP warehouse

- 7000 refuelings in seven months (milestone reached this summer)

FY2008 - 4 interagency agreements to deploy >40 backup power fuel cells

- FAA – 25 fuel cells (telecommunications infrastructure)
- Fort Jackson, South Carolina – 10 fuel cells (Telecommunications Center, Energy Monitoring and Control Facility, Emergency Services Center)
- Los Alamitos Joint Forces Training Base, CA – 4 fuel cells (Fire Station)
- Marine Corps Logistics Base Barstow, CA – 4 fuel cells (Fire Station)

FY2009 - Army-CERL Broad Agency Announcement to deploy up to 87 fuel cells for backup power at 13 locations across the country announced 11/13/09

- Argonne National Laboratory, IL
- Cheyenne Mountain Air Force Station, CO
- Aberdeen Proving Ground, MD
- Fort Bragg, NC
- Fort Hood, TX
- Fort Irwin, CA
- Ohio National Guard
- Picatinny Arsenal, NJ
- NASA Ames Research Center, CA
- Marine Corps Air Ground Combat Center 29 Palms, CA
- U.S. Military Academy at West Point, NY
- Fort Richardson, AK
- National Park Service Fort Sumter, SC

FY2010 - 10 Feasibility Studies Underway

- Argonne National Laboratory, IL
- Lawrence Livermore National Laboratory/ Sandia National Laboratories
- National Renewable Energy Laboratory (2 studies)
- Oak Ridge National Laboratory
- Pacific Northwest National Laboratory
- Sandia National Laboratories
- Thomas Jefferson National Accelerator Facility
- Y-12 Site Office
- Fort Shafter, HI - Office of Naval Research
- Los Alamos National Laboratory

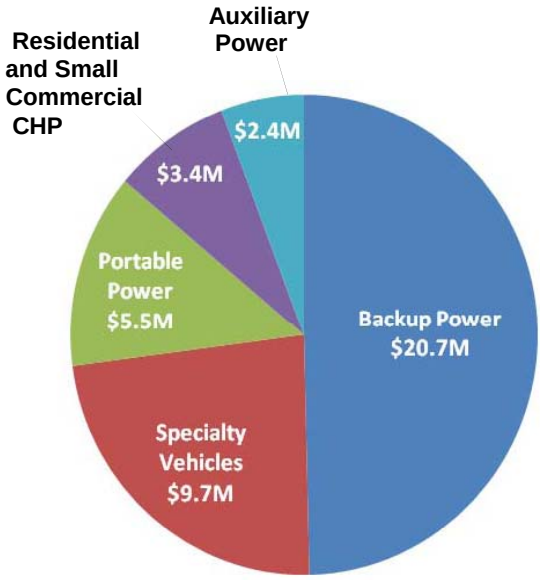
Recovery Act Deployments

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 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 $51 million in cost-share proposed by industry participants—for a total of nearly $91 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

Key Partnerships & 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)

– Interagency Task Force mandated by EPACT 2005; representatives at the Assistant Secretary-level.

Universities

~ 50 projects with 40 universities

International

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

DOE Fuel Cell Technologies Program*

– ***Applied RD&D***

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

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

Industry Partnerships & Stakeholder Assns.

- **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, FC, 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**

Examples of Policies Promoting Fuel Cells

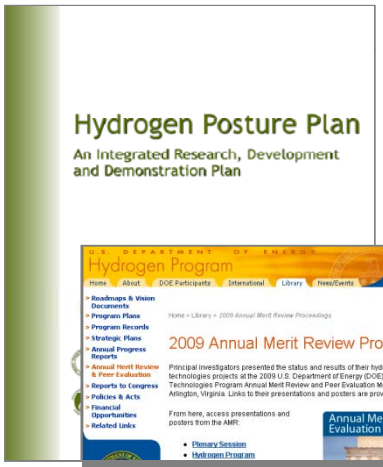
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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 cap in EPACT 2005 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.**
Fuel Cell Investment Tax Credit	**Increases the investment tax credit to 30%, up to $3,000/kW for business installations, and extends the credit from 2008 to 2016.**

Key Program Documents

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



Fuel Cell Program Plan

Outlines overarching plan for fuel cell activities in the Department of Energy

→ ***Replacement for current* Hydrogen Posture Plan**

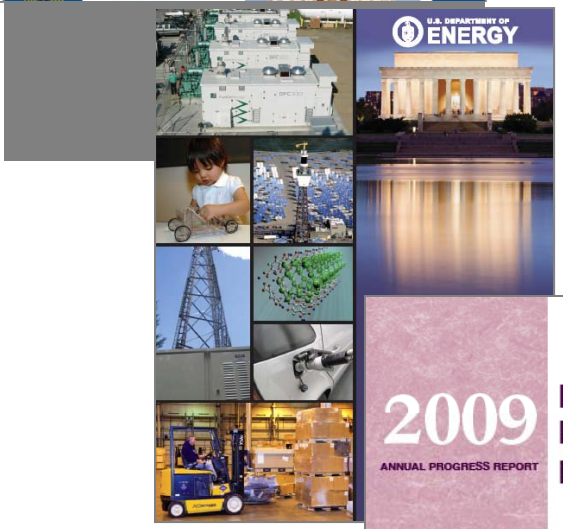
→ ***To be released in 2010***

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

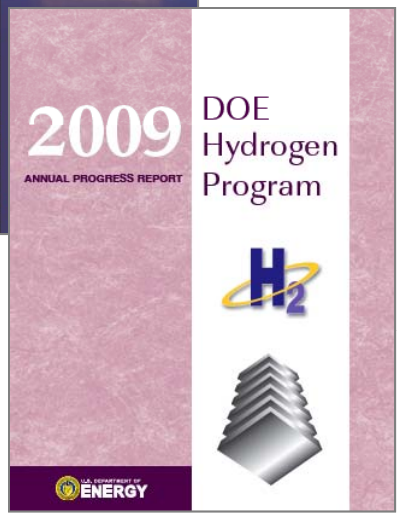


Annual Merit Review & Peer Evaluation Report

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

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