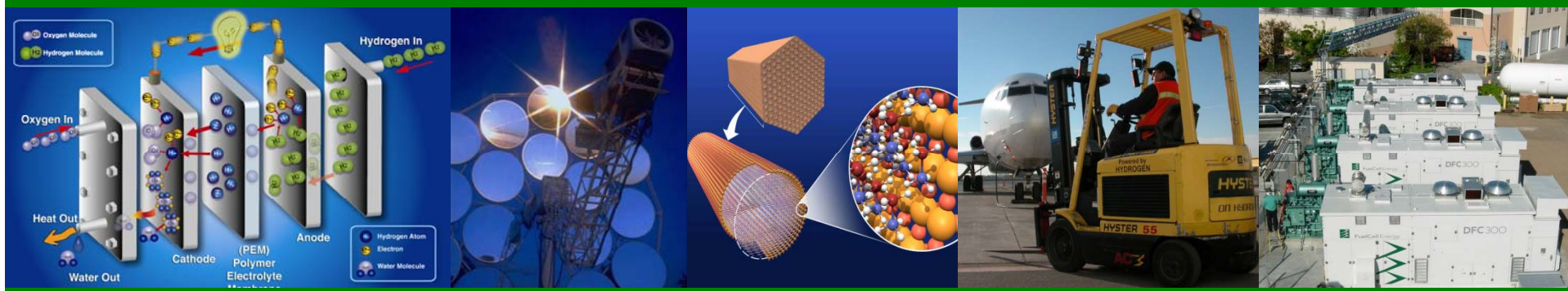




U.S. DEPARTMENT OF
ENERGY

Energy Efficiency &
Renewable Energy

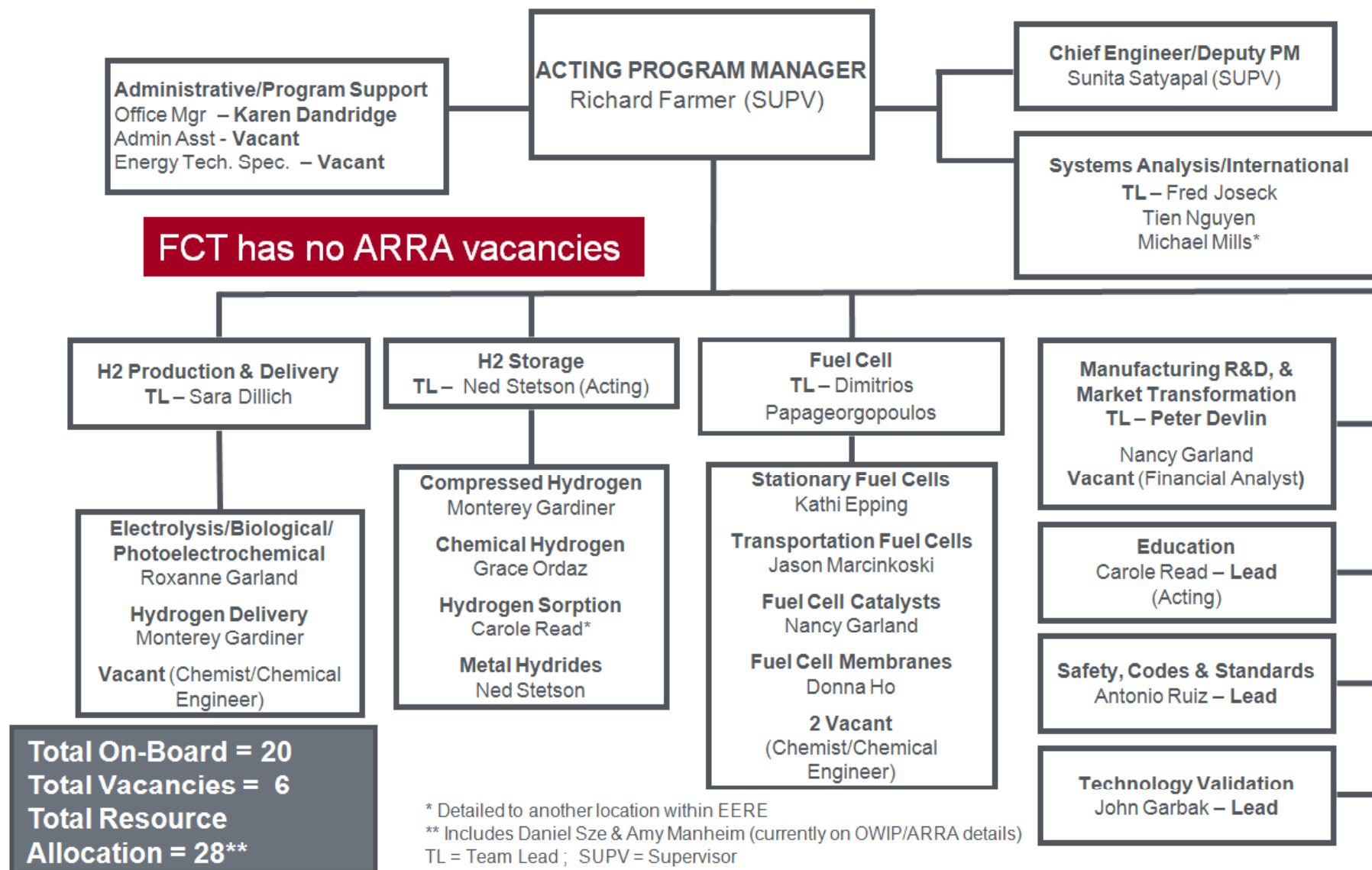


EERE R&D Program Update

Rick Farmer
Acting Program Manager

February 23, 2010

Organization Update



Funding priorities include fuel cell technologies for near- and long-term technologies, including stationary, transportation, and portable applications.

The FY 2011 Budget Request:

1. Reinstates hydrogen-related R&D

2. Creates new sub-programs for:

- ***Fuel Cell Systems R&D***
 - Consolidates four sub-programs: *Fuel Cell Stack Components R&D*, *Transportation Fuel Cell Systems*, *Distributed Energy Fuel Cell Systems*, and *Fuel Processor R&D*
 - Technology-neutral fuel cell systems R&D for diverse applications
- ***Hydrogen Fuel R&D***
 - Consolidates *Hydrogen Production & Delivery* and *Hydrogen Storage* activities
- ***Market Transformation***
 - Consolidates *Early Market Fuel Cells* (previously *Market Transformation*), *Safety Codes & Standards*, and *Education* activities

3. Defers funding for

- ***Education***
- ***Early Market Fuel Cells*** (previously *Market Transformation*)

EERE H₂ & Fuel Cells Budgets

Funding (\$ in thousands)				
Key Activity	FY 2008	FY 2009 ⁴	FY 2010	FY 2011 Request
Fuel Cell Systems R&D¹	-	-	-	67,000
Fuel Cell Stack Component R&D	42,344	61,133	62,700	-
Transportation Systems R&D	7,718	6,435	3,201	-
Distributed Energy Systems R&D	7,461	9,750	11,410	-
Fuel Processor R&D	2,896	2,750	171	-
Hydrogen Fuel R&D²	-	-	-	40,000
Hydrogen Production & Delivery R&D	38,607	10,000	15,000	-
Hydrogen Storage R&D	42,371	57,823	32,000	-
Technology Validation	29,612	14,789⁵	13,097	11,000
Market Transformation³	0	4,747	15,026	9,000
Safety, Codes & Standards	15,442	12,238 ⁵	8,839	-
Education	3,865	4,200 ⁵	2,000	-
Systems Analysis	11,099	7,520	5,556	5,000
Manufacturing R&D	4,826	4,480	5,000	5,000
Total	\$206,241	\$195,865	\$174,000⁶	\$137,000

¹ Fuel Cell Systems R & D includes Fuel Cell Stack Component R&D, Transportation Systems R&D, Distributed Energy Systems R&D, and Fuel Processor R&D

² Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D

³ Market Transformation will fund only Safety, Codes and Standards in FY 2011

⁴ FY 2009 Recovery Act funding of \$42.967M not shown in table

⁵ Under Vehicle Technologies Budget in FY 2009

⁶ Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

DOE H₂ & Fuel Cells Budgets: FY07 – FY11

	Funding (\$ in thousands)							
	FY 2004 Approp.	FY 2005 Approp.	FY 2006 Approp.	FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Approp.	FY 2011 Request
EERE Hydrogen & Fuel Cells	144,881	166,772	153,451	189,511	206,241	195,865	174,000 ²	137,000
Fossil Energy (FE)¹	4,879	16,518	21,036	21,513	21,773	26,400	~26,400	12,000 ³
Nuclear Energy (NE)	6,201	8,682	24,057	18,855	9,668	7,500	5,000	TBD
Science (SC)	0	29,183	32,500	36,388	36,484	38,284	~38,284	~38,000 ⁴
DOE TOTAL	155,961	221,155	231,044	266,267	276,481	268,049	~243,684	TBD

¹ All FE numbers include funding for program direction.

² Includes SBIR/STTR funds to be transferred to the Science Appropriation; other years shown exclude this funding.

³ Includes coal to hydrogen and other fuels. FE also plans \$50M for SECA in FY11.

⁴ Estimated funding for hydrogen- and fuel cell-related projects; exact funding to be determined. The Office of Science also plans ~\$14M for hydrogen production research in the Office of Biological and Environmental Research in FY11.

EERE Budget: FY08 – FY11



Energy Efficiency &
Renewable Energy

Funding (\$ in thousands)				
Activity	FY 2008	FY 2009 *	FY 2010	FY 2011 Request
Biomass and Biorefinery Systems	195,633	214,245	220,000	220,000
Building Technologies	107,382	138,113	222,000	230,698
Federal Energy Management Program	19,818	22,000	32,000	42,272
Geothermal Technology	19,307	43,322	44,000	55,000
Hydrogen Technology	206,241	164,638	174,000	0
Hydrogen and Fuel Cell Technologies	0	0	0	137,000
Water Power	9,654	39,082	50,000	40,488
Industrial Technologies	63,192	88,196	96,000	100,000
Solar Energy	166,320	172,414	247,000	302,398
Vehicle Technologies	208,359	267,143	311,365	325,302
Weatherization & Intergovernmental Activities	282,217	516,000**	270,000	385,000
Wind Energy	49,034	54,370	80,000	122,500
Facilities & Infrastructure	76,176	76,000	19,000	57,500
Program Support	10,801	18,157	45,000	87,307
Program Direction	104,057	127,620	140,000	200,008
Congressionally Directed Activities	186,664	228,803	292,135	0
RE-ENERGYSE	0	0	0	50,000
Adjustments	-743	-13,238	-	-
Total	\$1,704,112	\$2,156,865	\$2,242,500	\$2,355,473

* SBIR/STTR funding transferred in FY 2009 was \$19,327,840 for the SBIR program and \$2,347,160 for the STTR program.

** Includes \$250.0 million in emergency funding for the Weatherization Assistance Grants program provided by P.L. 111-6, "The Continuing Appropriations Resolution, 2009."

Key Challenges

The program has identified key challenges facing the widespread commercialization of fuel cells.

TECHNOLOGY REQUIREMENTS

Fuel Cell Cost & Durability

Cost must be reduced & durability improved.

	Status	2015 Target
Transportation	\$61/kW, >2000 hrs	\$30/kW, 5000 hrs
Stationary Power	~\$713/kW, ~20,000 hrs	\$750/kW, 40,000 hrs

APUs and Residential CHP: Status and Targets are under review and will be finalized in 2011.

Hydrogen Cost

Cost of producing and delivering H₂ from zero or near-zero carbon sources must be reduced.

	Status	2015 Target
Total Cost of Hydrogen (delivered & dispensed)	\$3–\$12/gge	\$2–\$3/gge
Delivery (includes storage & dispensing)	\$2.30–\$3.30/gge	<\$1/gge

Hydrogen Storage Capacity & Cost

Compact, lightweight, and low-cost storage systems must be developed.

	Status	2015 Target
Volumetric Capacity	15–50g/L	40g/L
Gravimetric Capacity	3.0–6.5 wt%	5.5 wt%
Cost	\$8–\$23/kWh	\$4 (under consideration for revision)

Technology Validation

Technologies must be demonstrated under real-world conditions

Market Transformation

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

Cost of Key Early Market FCs

	Status	Target
Backup Power & Lift Truck Power	~\$3500/kW	~\$1000/kW
CHP System	~\$5500/kW	~\$3000/kW

ECONOMIC & INSTITUTIONAL REQUIREMENTS

Safety, Codes & Standards Data must be collected to enable development of codes & standards; domestic and international codes & standards must be made more consistent; and best-practices for the safe handling and use of hydrogen need to be established.

H₂ Supply & Delivery Infrastructure The high investment risk of developing refueling infrastructure in absence of strong demand must be mitigated.

Manufacturing Cost & Supplier Base High initial manufacturing costs must be overcome and the manufacturing and supplier base must be expanded.

Public Awareness & Acceptance Public awareness and understanding of the technologies must be strengthened, especially among code and safety officials, policy makers, and potential early adopters.

NOTE: All costs are projected to high-volume manufacturing and production.

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

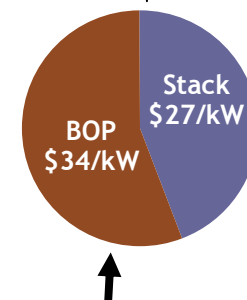
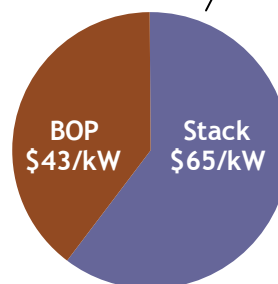
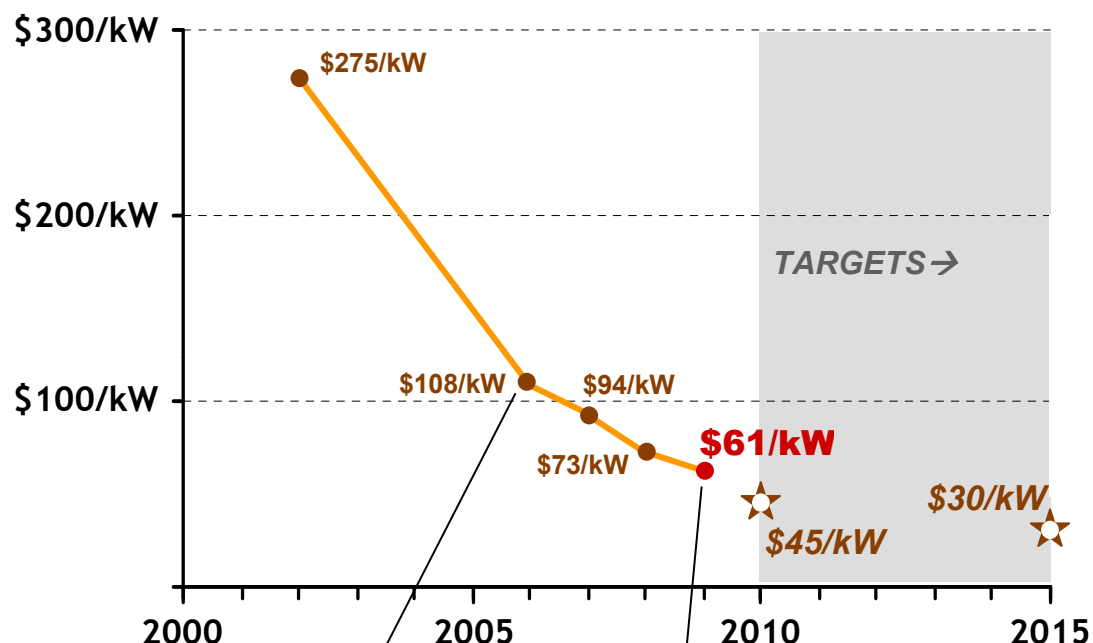
- **More than 35% reduction in the last two years**
- **More than 75% reduction since 2002**
- **2008 cost projection was validated by independent panel****

*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

Projected Transportation Fuel Cell System Cost

- projected to high volume (500,000 units per year) -



As stack costs are reduced, balance-of-plant components are responsible for a larger % of costs (BOP costs shown here include system assembly & testing).

Continue R&D of fuel cell systems for stationary, portable, and transportation applications, using multiple technologies (*including PEM, solid-oxide, and alkaline fuel cells*) and a variety of fuels (*including hydrogen, diesel, natural gas, and bio-derived renewable fuels*).

The Program is increasing emphasis on:

- Science & engineering at the cell level
- Integration and component interactions at the systems level
- Balance-of-plant components (such as water transport, sensors, and air compression)

Key R&D areas (*core technologies*):

- **Catalysts.** New approaches will increase activity and utilization of current PGM and PGM-alloy catalysts as well as non-PGM catalyst approaches.
- Develop **high-temperature membranes** that will allow better catalyst utilization, reduce the negative effects of impurities, and decrease the size of the cooling system.
- Develop improved **bipolar plates, seals, and gas diffusion layers.**
- Develop **transport models** and in-situ and ex-situ experiments to provide data for model validation.
- Identify **degradation mechanisms** and develop approaches to mitigate their effects.
- Investigate and quantify **effects of impurities** on fuel cell performance.
- **Durability & accelerated stress-testing**—determine their correlation with real-world degradation.

Applications—examples of systems R&D in FY 2011

- **Portable Power.** Focus on materials improvements for direct-methanol fuel cells.
 - Reduce anode & cathode catalyst loading, while improving catalytic activity and durability.
 - Improve membranes, to reduce crossover and increase proton conductivity.
- **Auxiliary Power.** Develop FC systems for heavy duty trucks, as an alternative to main-engine idling.
 - Develop SOFC APUs, in coordination with FE's SOFC effort.
 - Address conductivity, catalyst performance, and chemical degradation issues.
 - Test SOFC hardware for potential application on heavy-duty trucks.

Progress: Hydrogen Production R&D

The Program is developing technologies to produce hydrogen from clean, domestic resources at reduced cost.

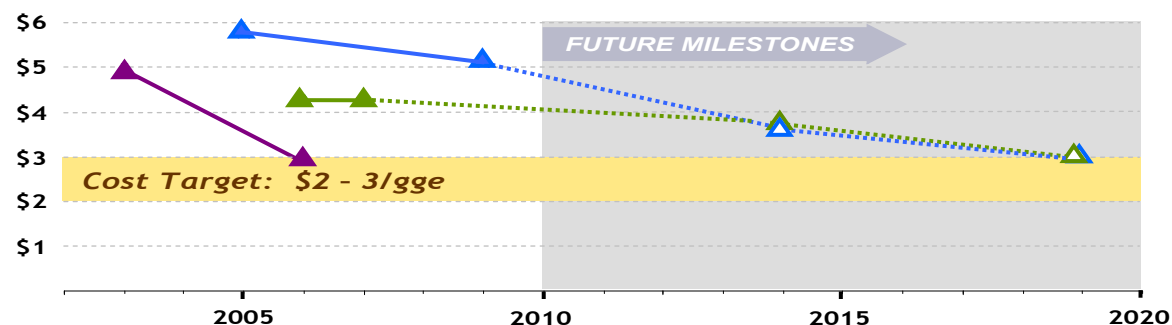
KEY PRODUCTION OBJECTIVE: Reduce the cost of hydrogen (delivered & untaxed) to \$2 – 3 per gge (gallon gasoline equivalent)

Projected* High-Volume Cost of Hydrogen (Delivered) — Status & Targets (\$/gallon gasoline equivalent [gge], untaxed)

NEAR TERM:

Distributed Production

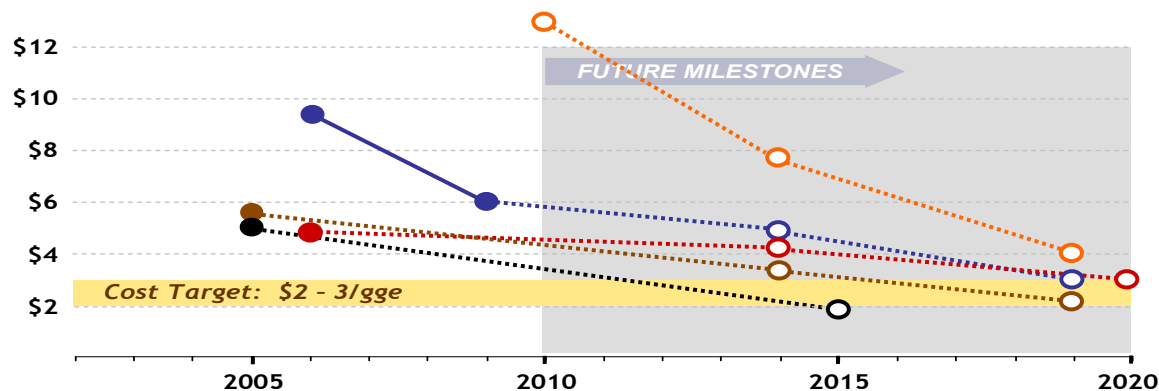
- ▲ Natural Gas Reforming
- ▲ Bio-Derived Renewable Liquids
- ▲ Electrolysis



LONGER TERM:

Centralized Production

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



* Distributed production status and targets assume station capacities of 1500 kg/day, with 500 stations built per year.

Centralized production values assume the following plant capacities: biomass gasification—155,000 to 194,000 kg/day; central wind electrolysis—50,000 kg/day; coal gasification—308,000 kg/day; nuclear—768,000 kg/day; and solar high-temperature thermochemical—100,000 kg/day. Values for the status of centralized production assume \$3/gge delivery cost, the while targets shown assume delivery cost targets are met (\$1.70/gge in 2014 and <\$1/gge in 2019).

Progress: Hydrogen Delivery R&D

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

KEY OBJECTIVE

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

PROGRESS

We've reduced the projected cost of hydrogen delivery

~30% reduction in tube-trailer costs

>20% reduction in pipeline costs

~15% reduction liquid hydrogen delivery costs

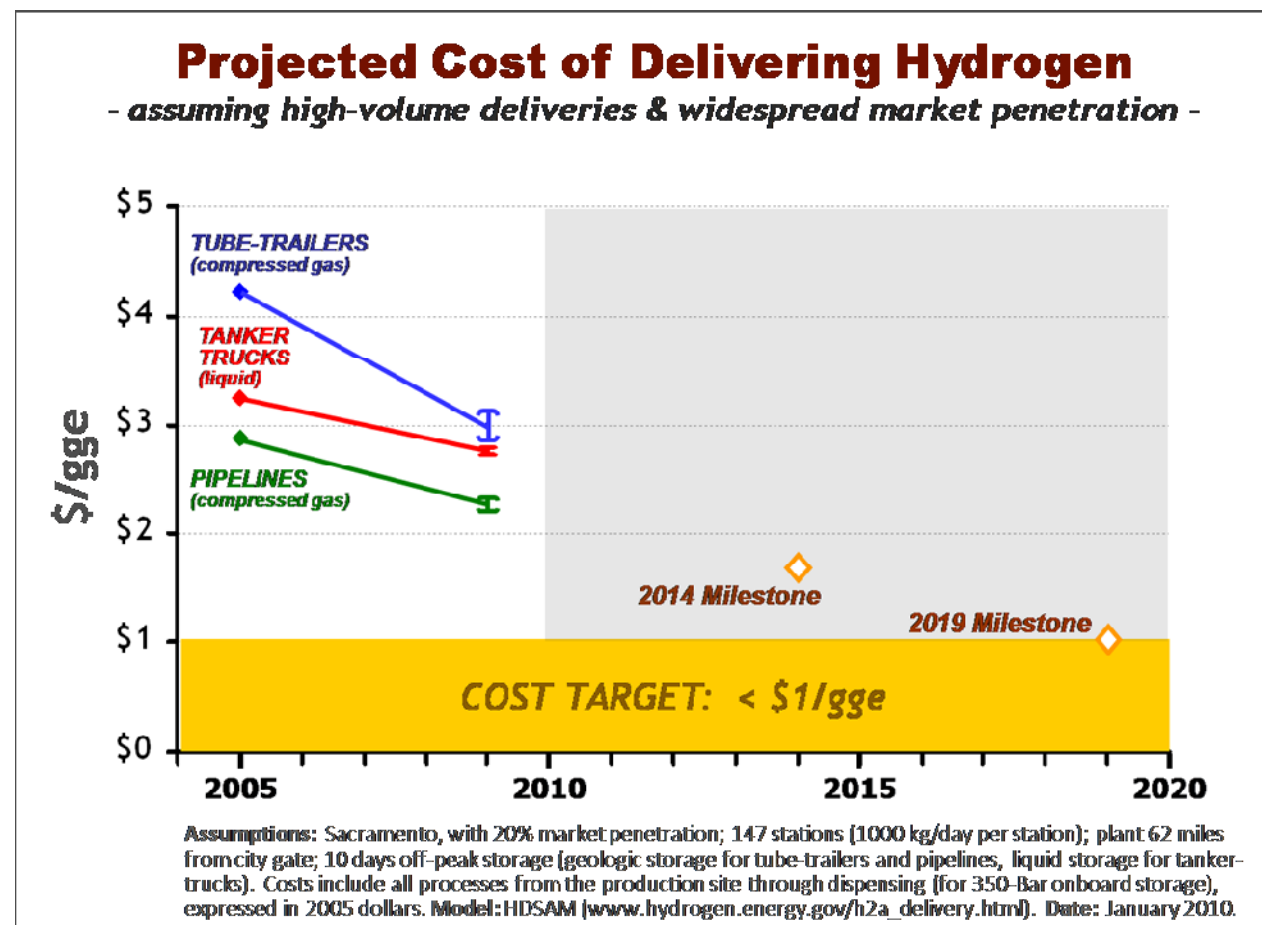


Figure 1 is a scatter plot showing the relationship between observed H₂ material capacity (wt %) and H₂ sorption/release temperatures. The y-axis represents "Observed H₂ Material Capacity, weight %" ranging from 0 to 16. The x-axis has two scales: "H₂ sorption temperature (°C)" from -200 to 0 (blue) and "Temperature for observed H₂ release (°C)" from 0 to 400 (red). The plot is divided into three regions: "sorbents" (blue, left), "chemical hydrides" (orange, middle), and "metal hydrides" (red, right). A vertical dashed line at 0°C separates sorption and release temperatures. A white arrow points to a "DOE system targets" box, indicating that material capacity must exceed system targets. Various materials are plotted, including MOFs, carbides, and various hydrides, with some labeled as "new mat'ls for FY2009".

Focuses on materials research and technology to address key challenges to hydrogen production, delivery, and storage, and to enable low-cost, carbon-free hydrogen fuels from diverse renewable pathways.

→ Request focuses on continuing funding to existing projects.

Production R&D key focus areas for FY 2011:

Bio-derived liquid reforming—improve materials and processes and further develop aqueous-phase reforming.

Electrolysis—reduce capital cost of PEM and alkaline electrolyzers.

→ Production R&D, ongoing work: *Existing projects in longer-term centralized production will continue (including **solar thermochemical**, **photoelectrochemical**, and **biological**).*

Delivery R&D key focus areas for FY 2011:

Development of **glass-fiber composites**, and **novel concepts for hydrogen delivery**.

Storage R&D key focus areas for FY 2011:

Storage **Materials Centers of Excellence** will terminate in FY 2010.

Engineering Center of Excellence will continue, with limited work on materials.

Continue development of new analytical models and tools to help quantify GHG, criteria pollutants and petroleum use reduction benefits. Identify research, environmental, and economic gaps for various applications, such as material handling, CHP, and stationary and portable power.

The *Systems Analysis* Subprogram will focus on:

- Developing models for program analysis, using cost, performance, yield and environmental information from independent reviews and research projects.
- Providing support and input to all program elements, such as go/no-go decisions and risk analysis.
- Assessing market penetration, job creation, and opportunities for fuel cell applications in the near term—material handling, back-up power, and residential CHP markets.
- Ensure analysis consistency and transparency by updating and maintaining analysis portfolio and information databases.

Key analysis areas:

- **Environmental benefits of utilizing renewable fuels**—benefits of using landfill gas, biogas, and extraneous gas for stationary fuel cells will be assessed on a well-to-wheels basis.
- **Cross-cutting analysis of tradeoffs and synergies among regions**—looking at infrastructure and resource availability.
- **Market studies**—assessment of opportunities for early market applications of fuel cells and resulting impacts on job growth.
- **Effects of a federal fuel cell acquisition program**—on cost reduction and job creation.

This new sub-program works to eliminate non-technical barriers by: facilitating the development of safe practices, and codes and standards; raising public awareness; and stimulating the market and industry by providing financial assistance for demonstrating fuel cells in early-market applications.

FY 2011 Plans:

- Maintain critical safety-related activities and support the development of codes and standards to enable the widespread adoption of hydrogen and fuel cell technologies.
- Facilitate the development of computational fluid dynamics models to support the risk assessment activities for fueling, production infrastructure, and transportation of alternative fuels in tunnels, garages, and other confined spaces.
- Quantify the effects of fuel contaminants on fuel cell system components to support development of fuel quality standards, and develop analytical methods to quantify the effect of fuel purity on cost.
- Provide training for firefighters and fire department training coordinators, law enforcement personnel, and emergency medical technicians, as well as code officials, fire marshals, city planners, \state government representatives, and other fuel cell users.

→ Funding for Education and early market activities has been deferred in 2011 in order to focus on critical safety, codes, and standards issues.

→ Market Transformation received \$42M in Recovery Act funds, so no additional funds for deployments are requested in FY 2011. The Program will assess the impact and benefits of Recovery Act funds and determine potential future needs.

Continue early-market-application data collection and conduct limited validation activities to address fuel cell systems used in stationary power applications, mass-transit, and light-duty vehicles.

FY 2011 Activities

- **Hydrogen Learning Demonstration.** DOE will fulfill its commitment to the Hydrogen Learning Demonstration activities, scheduled to be completed by the end of 2011.
- **Other Activities.** Demonstration projects will continue with data collection and operation of backup power systems and specialty vehicles; collaboration with DOT on the Fuel Cell Bus Program will continue; and support for CHHP (*combined heat, hydrogen, and power*) demonstration will continue (in collaboration with the California Air Resources Board and the South Coast Air Quality Management District).

Manufacturing R&D will continue to develop processes and technologies to enable low-cost, high-volume manufacturing of hydrogen and fuel cell technologies. Near-term activities will encompass R&D of technologies critical to an early start-up of high-volume commercialized products.

FY 2011 Activities

Develop improved processes/technologies for manufacturing:

- Membrane-electrode assemblies and gas diffusion layers for fuel cells
- Distributed production systems and components
- Vessels for hydrogen storage and dispensing

Production & Delivery

- Workshop on hydrogen liquefaction needs to support vehicle introduction: May 5, 2010 at NHA conference in Long Beach, CA
- Workshop on high pressure compressed hydrogen tank and dispensing needs: TBD

Fuel Cells

- Workshop on bus targets and gaps: TBD
- Pre-solicitation meeting (BOP, MEA/stack, component integration, other innovative concepts); March 16-17, 2010, Denver, CO

Market Transformation

- Hydrogen 101 Workshop with NHA: May 3, 2010, Long Beach, CA

Safety, Codes & Standards

- NHA Codes & Standards: May 2010, Long Beach, CA
- Insurance workshop: TBD
- NASA-DOE tank safety workshop: TBD

Systems Analysis

- IPHE Infrastructure workshop Feb 25-26, 2010, Sacramento, CA

Objective: To identify key challenges and opportunities for market implementation, and potential next steps for government and industry.

Details

- Workshop scheduled for February 25-26 in Sacramento, CA
 - Participants include industry and international representatives
 - Overview presentations on infrastructure plans in the U.S., German, Japan and South Korea
 - Breakout sessions to discuss business case and barriers.
- Preliminary Online Focus Group completed with fuel retailers
 - Lessons learned from experiences with ethanol and biodiesel
 - Reactions to proposed business cases
- Pre-workshop webinar held February 17 (Presentation from Joan Ogden)
- Results to be published on DOE and IPHE websites.



Key Program Documents

Hydrogen Posture Plan

An Integrated Research, Development and Demonstration Plan

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 early 2010*

Annual Merit Review Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

→ *Latest edition released June 2009*

www.hydrogen.energy.gov/annual_review09_proceedings.html

Annual Merit Review & Peer Evaluation Report

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

→ *Latest edition released October 2009*

www.hydrogen.energy.gov/annual_review08_report.html

Annual Progress Report

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

→ *Latest edition published November 2009*

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: June 7 – 11, 2010

Washington, D.C.

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