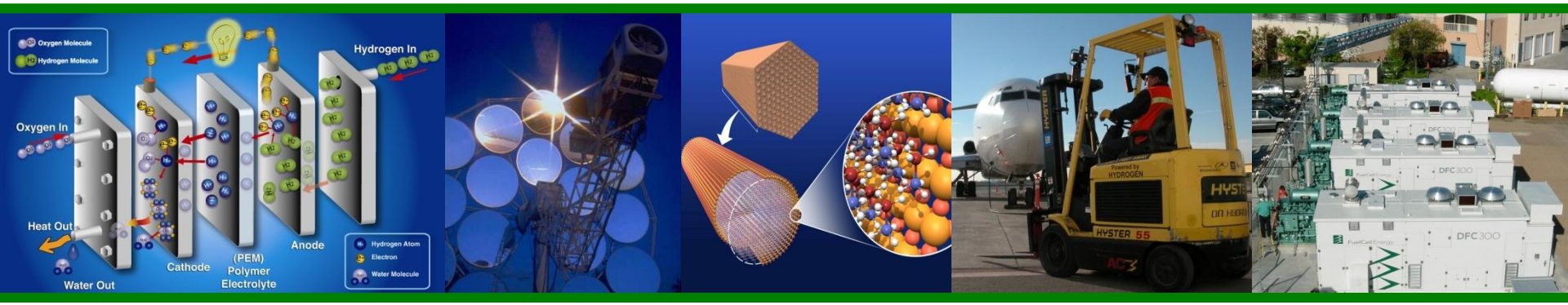
International Partnership for Hydrogen and Fuel Cells in the Economy



U.S. Country Update

IPHE Steering Committee Meeting

Michael Mills

Advisor – International Program

Energy Efficiency and Renewable Energy

U.S. Department of Energy

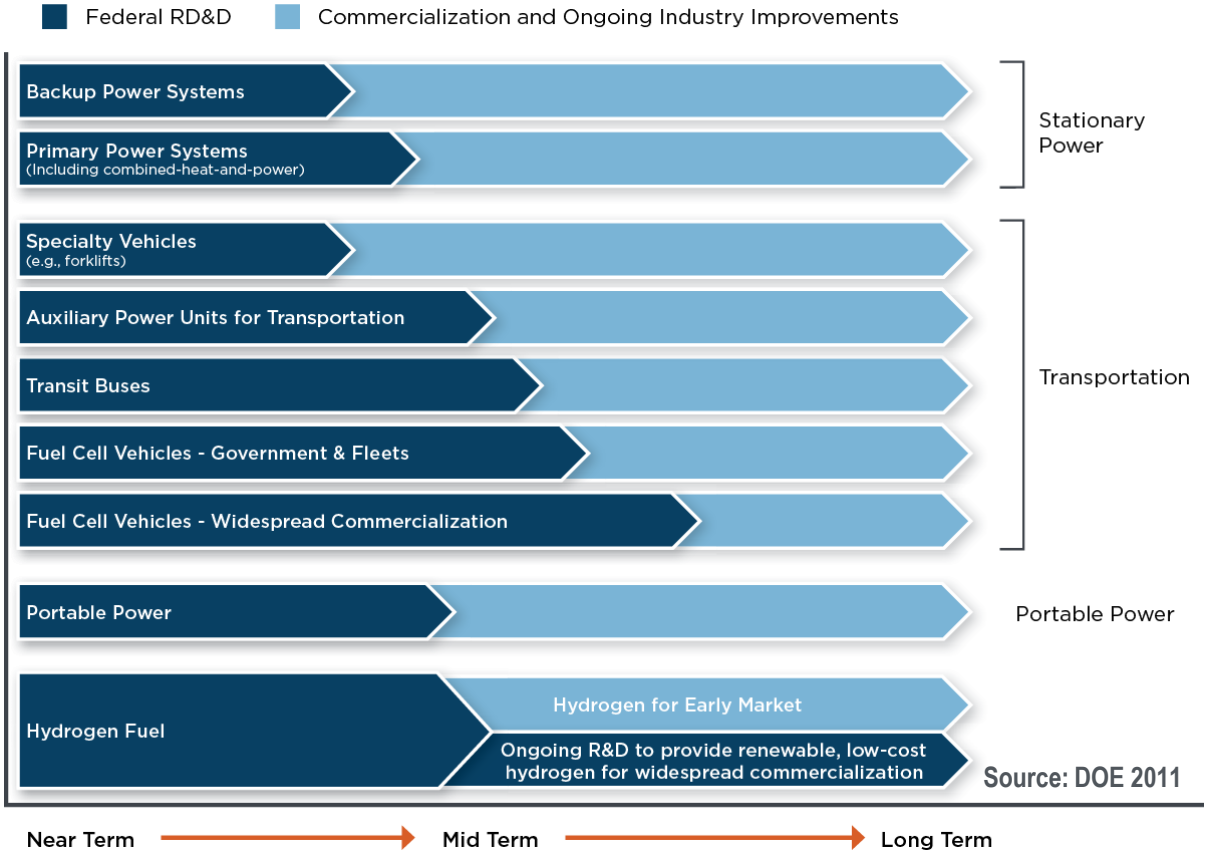
May 3, 2012

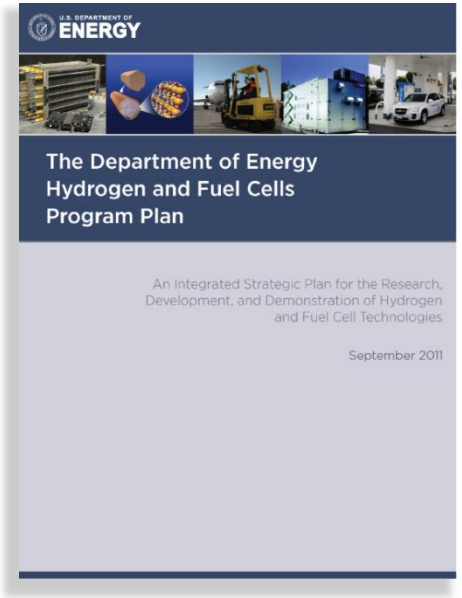
Cape Town, South Africa

DOE Program Plan Released

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

An integrated strategic plan for the research, development, and demonstration activities of DOE's Hydrogen and Fuel Cells Program: Includes Stationary, Portable and Transportation Fuel Cells





Update to the Hydrogen Posture Plan (2006)

Program efforts are planned to transition to industry as technologies reach commercial-readiness.

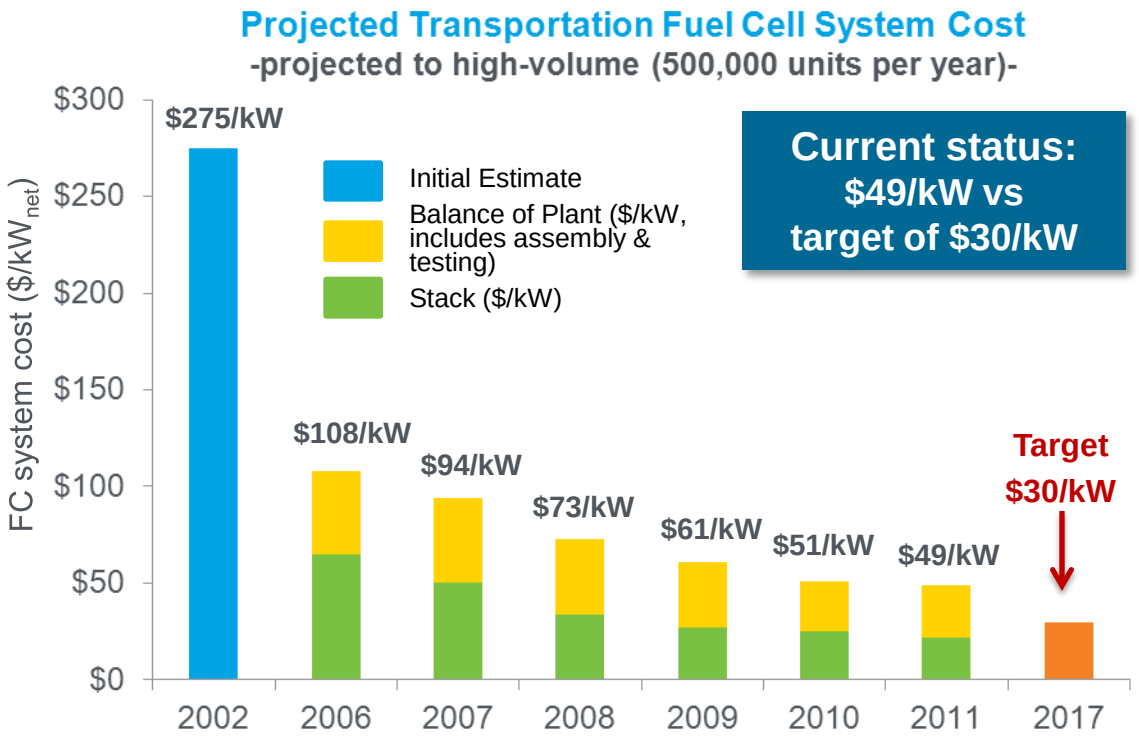
Released September 2011

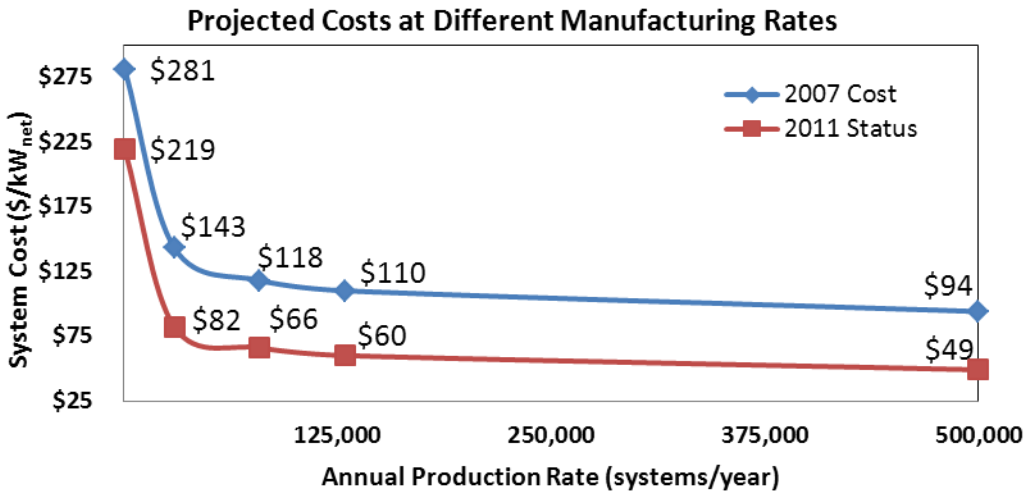
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/program_plan2011.pdf

Progress – Fuel Cells

Projected high-volume cost of fuel cells has been reduced to $49/kW (2011)*

- ***More than 30% reduction since 2008***
- ***More than 80% reduction since 2002***

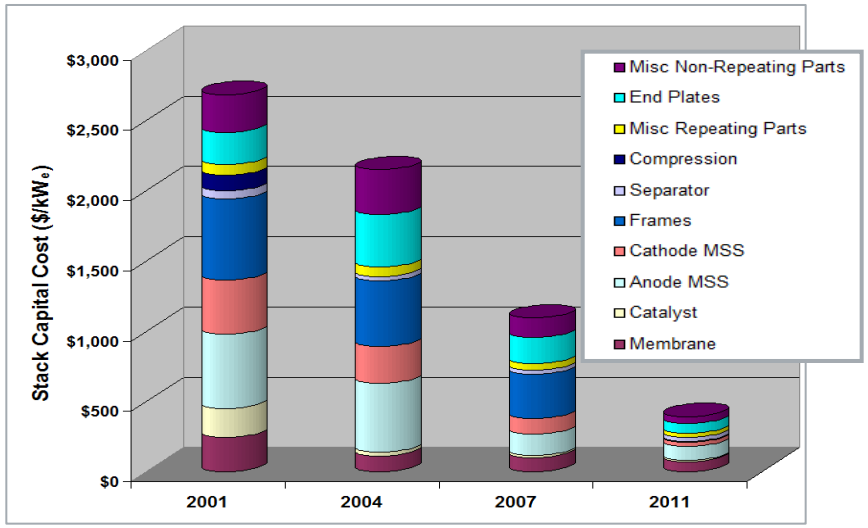


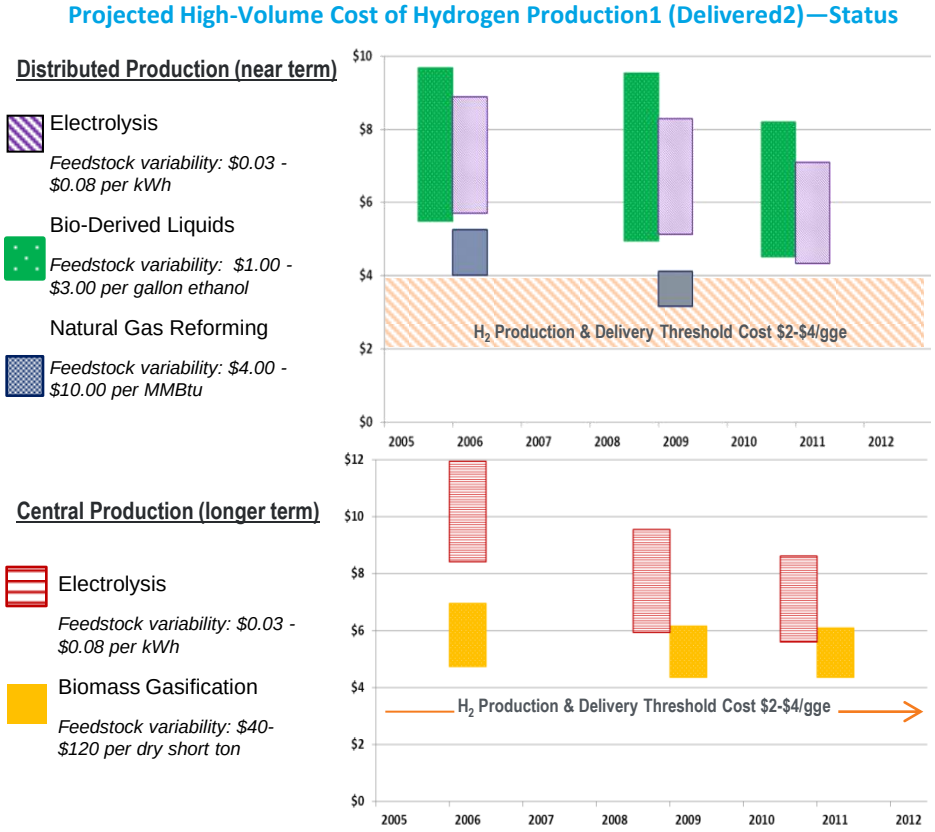


***Based on projection to high-volume manufacturing (500,000 units/year).** The projected cost status is based on an analysis of state-of-the-art components that have been developed and demonstrated through the DOE Program at the laboratory scale. Additional efforts would be needed for integration of components into a complete automotive system that meets durability requirements in real-world conditions.*

Reduced cost of H_2 production (multiple pathways)

- Reduced electrolyzer stack costs by greater than 80% since 2001 through design optimization and manufacturing innovations (Giner Electrochemical Systems)





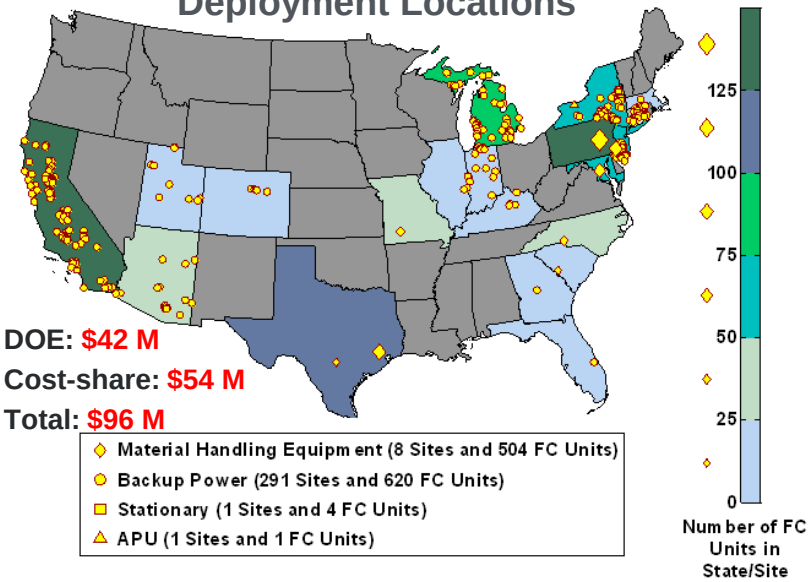
- **Compressed H_2 tanks can achieve >250 mile range**
- **Validated a vehicle that can achieve 430 mile range (with 700 bar Type IV tanks)**
- **Developed and evaluated more than 400 material approaches experimentally and millions computationally**

Recovery Act and Market Transformation Spur Deployments

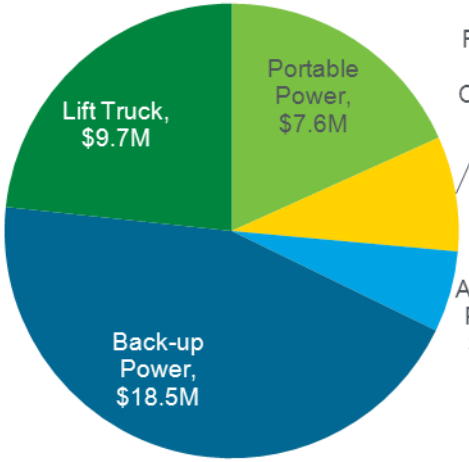
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Deployments help ensure continued technology utilization growth and catalyze market penetration while providing data and lessons learned.

Deployment Locations



DOE: $42 M
Cost-share: $54 M
Total: $96 M



ARRA Deployment Status – December 2011

Fuel Cell Application	Operational Fuel Cells	Total Fuel Cells Planned
Backup Power	607	539
Material Handling	504	504
Stationary	0	6
APU	0	3
Total	**1,111**	**> 1,000**

NREL ARRA Data Collection Snapshot

ARRA Material Handling Equipment Data	As of 12/31/2011
Hydrogen Dispensed	99,650 kg
Hydrogen Fills	>148,250
Hours Accumulated	>959,880 hrs

The initial investment of 400 DOE-funded lift trucks has led to MORE THAN 3,000 ADDITIONAL fuel cell lift trucks planned or installed with NO DOE funding.

Validation of an Integrated Energy Station

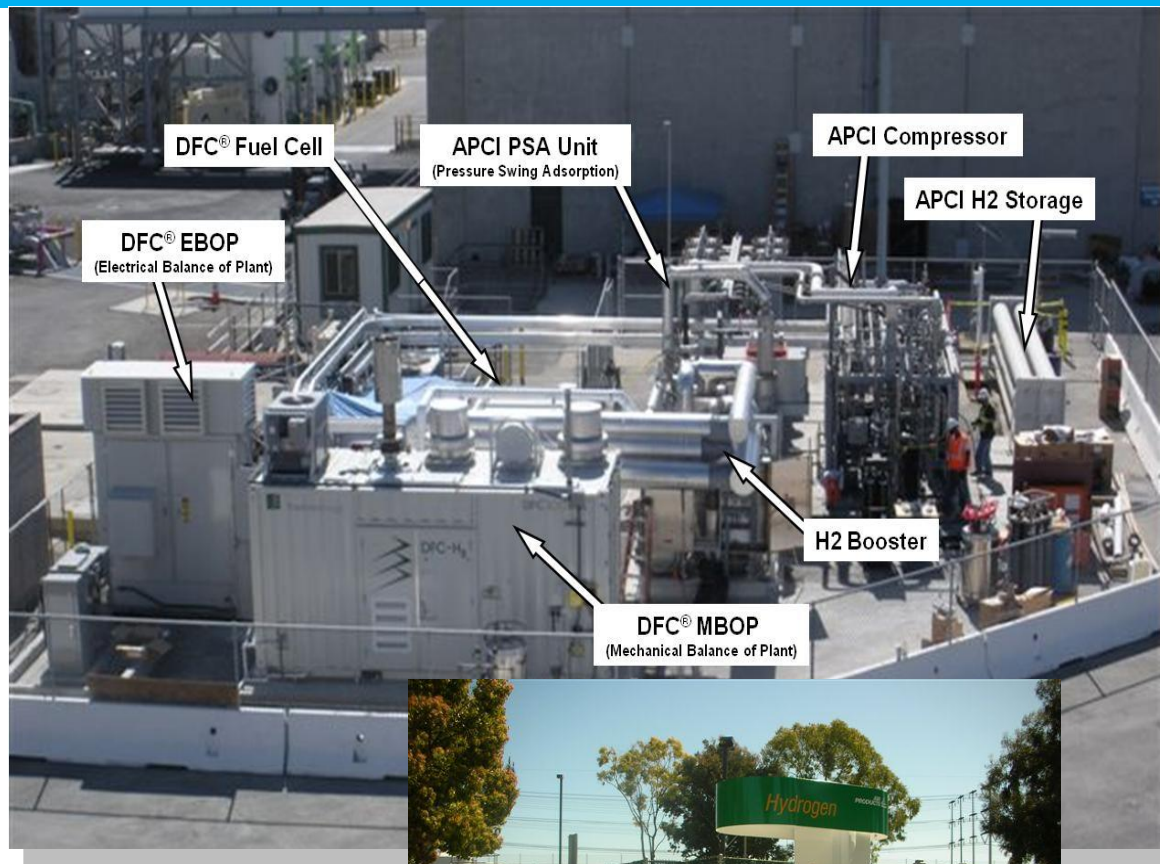
U.S. DEPARTMENT OF ENERGY

"Energy Department Applauds World's First Fuel Cell and Hydrogen Energy Station in Orange County" (Co-funded by DOE, CA and industry)

AIR PRODUCTS

FuelCell Energy

- ✓ **March 2011- first vehicle refueling**
- ✓ **June 2011- began operation on ADG (anaerobic digester gas)**
- ✓ **Exported > 1 GWh electricity**
  - Generates ~250 kW of electricity
- ✓ **Produced > 5,700 kg H2**
  - ~100 kg/day hydrogen capacity (350/700 bar), enough for 25-50 vehicles.
- ✓ **To operate 3 years (31 May 2014)**



- ❖ **Fueled with Orange County municipal wastewater gas**
- ❖ **54% efficiency coproducing H_2 and electricity**

Funding Partners: CARB, SCAQMD and DOE

Progress – Technology Validation

Demonstrations are essential for validating technologies in integrated systems.

Real-world Validation

Vehicles & Infrastructure

- >180 fuel cell vehicles and 25 hydrogen fueling stations
- Over 3.7 million miles traveled
- Over 146 thousand total vehicle hours driven
- 2,500 hours (nearly 75K miles) durability
- 5 minute refueling time (4 kg of hydrogen)
- Vehicle Range: ~196 – 254 miles (430 miles on separate FCEV)

Buses (with DOT)

- H_2 fuel cell buses have a 42% to 139% better fuel economy when compared to diesel & CNG buses

Forklifts

- Over 130,742 total refuelings since 2009

National Lab Data Collection and Analysis Process

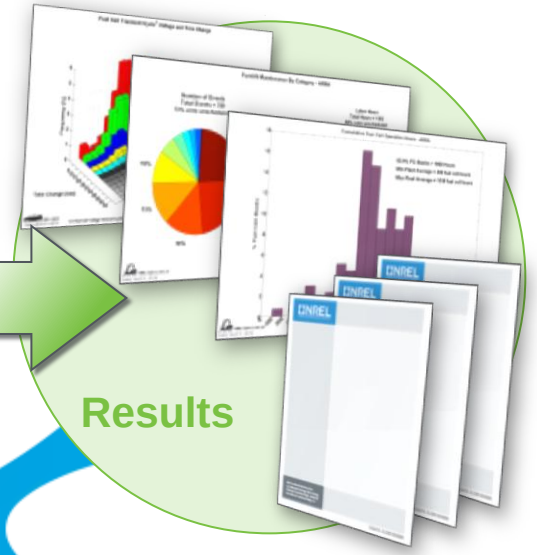
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Bundled data (operation & maintenance/safety) delivered to NREL quarterly

Internal analysis completed quarterly

HSDC

NREL's Hydrogen Secure Data Center



DDPs

CDPs

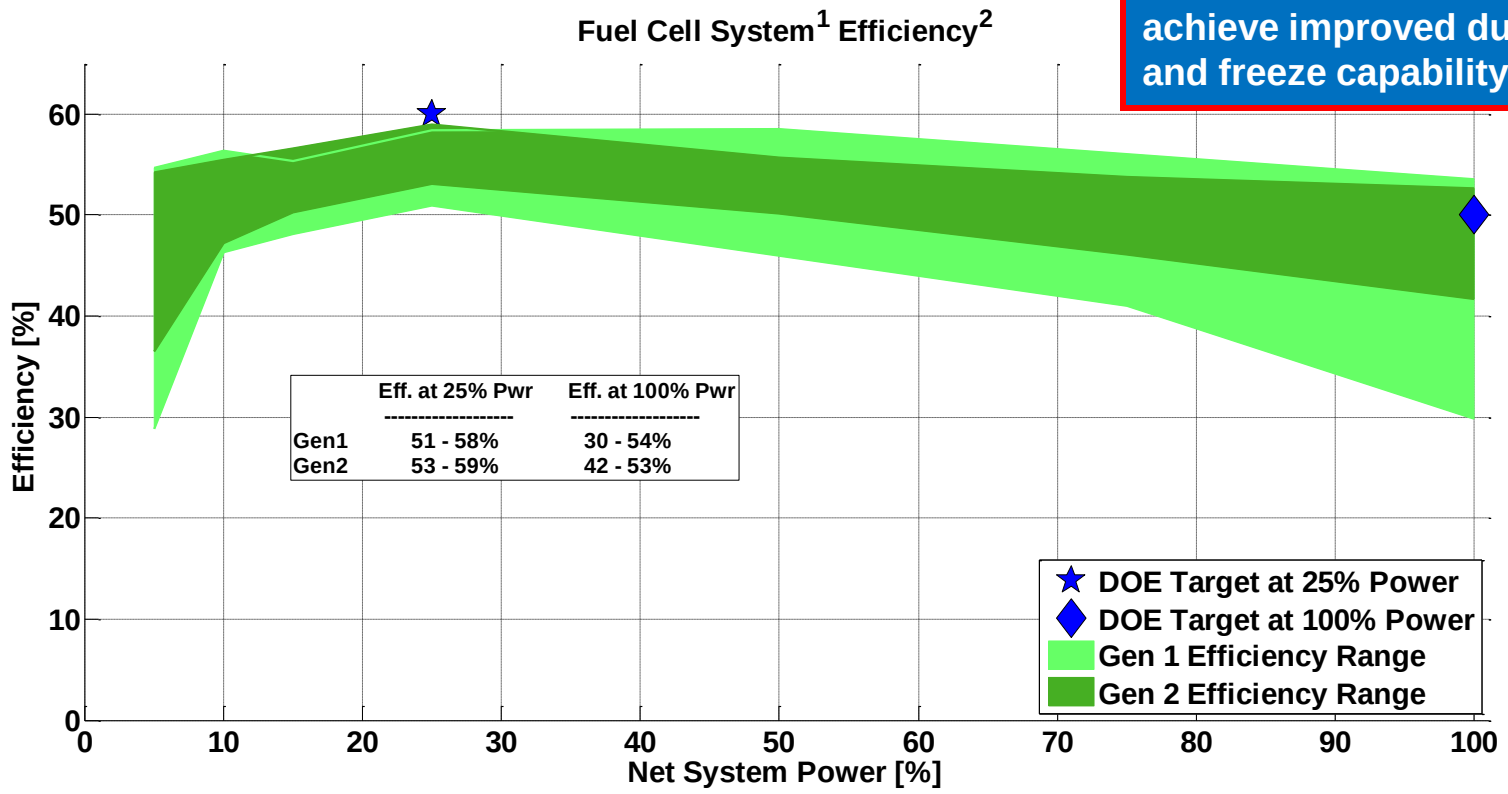
Detailed Data Products (DDPs)
- Individual data analyses
- Identify individual contribution to CDPs
- Shared every six months only with the partner who supplied the data[1]

Composite Data Products (CDPs)
- Aggregated data across multiple systems, sites, and teams
- Publish analysis results every six months without revealing proprietary data[2]

1) Data exchange may happen more frequently based on data, analysis, & collaboration
2) Results published via NREL Tech Val website, conferences, and reports (http://www.nrel.gov/hydrogen/proj_learning_demo.html)

Example of Data Collection Results

Critical result: Efficiency not sacrificed in order to achieve improved durability and freeze capability



[1] Gross stack power minus fuel cell system auxiliaries, per DRAFT SAE J2615. Excludes power electronics and electric drive.

[2] Ratio of DC output energy to the lower heating value of the input fuel (hydrogen).

[3] Individual test data linearly interpolated at 5,10,15,25,50,75,and 100% of max net power. Values at high power linearly extrapolated due to steady state dynamometer cooling limitations.

NREL CDP08
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Funding Opportunity Announcements

DOE Announces up to $6M to Collect Performance Data on Fuel Cell Electric Vehicles

This FOA will collect, analyze, and validate performance data from light-duty hydrogen fuel cell electric vehicles (FCEV) operating in real-world environments. Feedback will be provided to the DOE hydrogen and fuel cell R&D projects and industry partners to help determine what additional R&D is required to move the technology forward.

Responses Due: Monday, May 21, 2012

DOE Announces up to $2M to Collect Data from H_2 Fueling Stations and Demonstrate Innovations in H_2 Infrastructure Technologies

Topic Area 1: Hydrogen Refueling Station Data Collection

Topic Area 2: Validation of Advanced Refueling Components

This FOA will test, demonstrate, and validate hydrogen refueling components and complete systems in real-world operating environments. Feedback will be provided to help determine what additional R&D is required to move the technology forward.

Responses Due: Friday, May 11, 2012

Plans include leveraging state activities (e.g. CA state funding for fueling stations)
FCT will not be funding infrastructure but can fund technology innovation that could be applicable to/enable infrastructure (e.g. innovative refueling/compression technologies)

Funding Opportunity Announcements and Future Collaboration Opportunities

Potential IPHE Collaboration Opportunities

- ✓ Tech Val Data Collection
  - *Solicitation currently open*
  - *Station and Vehicle Data*
- ✓ Hydrogen Quality Data
  - Verify CO as a canary constituent
- ✓ Testing and Validation:
  - High pressure storage vessels
  - Short stack testing (fuel quality)

International collaboration in these projects will:

- ✓ Leverage government resources in a common effort
- ✓ Send an important message regarding:
  - the viability of FCEVs
  - the contributions FCEVs will make toward the common global objective of clean, secure, and efficient energy use

FOA can be found at: www.hydrogenandfuelcells.energy.gov/news_detail.html?news_id=18136

Hydrogen & Fuel Cells - Budget

"The Committee recognizes the progress and achievements of the Fuel Cell Technologies program. The program has met or exceeded all benchmarks, and has made significant progress in decreasing costs and increasing efficiency and durability of fuel cell and hydrogen energy systems."

Funding *($ in thousands)*		
Key Activity	FY 2011 Allocation	FY 2012 Appropriation[3]
Fuel Cell Systems R&D[1]	41,916	43,556
Hydrogen Fuel R&D[2]	32,122	33,785
Technology Validation	8,988	8,987
Safety, Codes and Standards	6,901	6,893
Systems Analysis	3,000	2,925
Manufacturing R&D	2,920	1,941
Market Transformation	0	3,000
Education	0	0
SBIR/STTR	2,153	2,537
Total	$98,000	$103,624

[1]Fuel Cells 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]Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

H2 and Fuel Cells are part of a portfolio of activities within DOE and part of the President's all-of-the-above strategy.

Focus:

- ✓ Continuing key R&D activities
- ✓ Strategic and selective demonstrations and deployments
- ✓ Strategic analysis and safety, codes and standards activities
- ✓ Strengthening communication and outreach.

Hydrogen and Fuel Cell Initiatives at the State Level

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

Several states—including California, Connecticut, Hawaii, Ohio, New York, and South Carolina—have major hydrogen and fuel cell programs underway.

California

FCEVs and Fuel Cell Buses

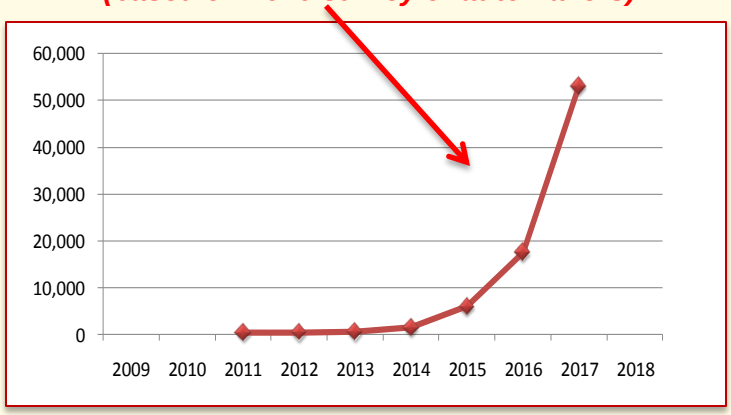
- **> 400 vehicles** in operation since 1999 — >160 currently operating
- **~3.9 million miles** driven
- **> 1 million passengers** on fuel cell buses

Investment in Hydrogen Stations (to be updated)

- **>20 stations** — including planned/funded
- **~$34M invested** *(C.A.R.B. and C.E.C.)* — with ~$23M industry cost share
- **~$18M planned** for future solicitations

Industry's Plans for FCEV Sales in CA

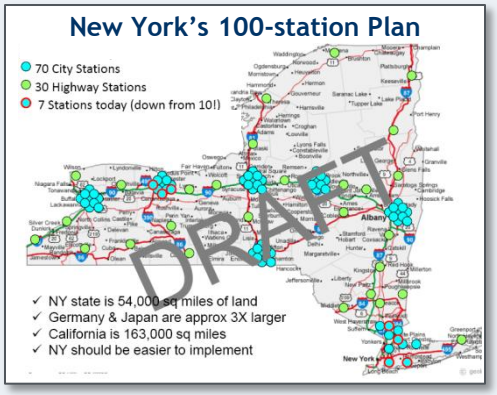
(based on 2010 survey of automakers)



New York

Plans 100 hydrogen stations (70 city, 30 highway) by 2020 to support minimum of 50,000 FCEVs — plan starts in 2015 with 1500 vehicles and 20 stations

- **Industry Investment:** Six auto companies plan total investment of nearly $3.0 Billion
- **State Investment:** NY developing plans to provide $50M to support infrastructure rollout while leveraging >$165M in Federal vehicle incentives for initial FCEV commercial deployment



Hawaii

Agreement signed by 12 stakeholders—including GM, utilities, hydrogen providers, DOD, DOE—to establish hydrogen as a major part of the solution to Hawaii's energy challenges.

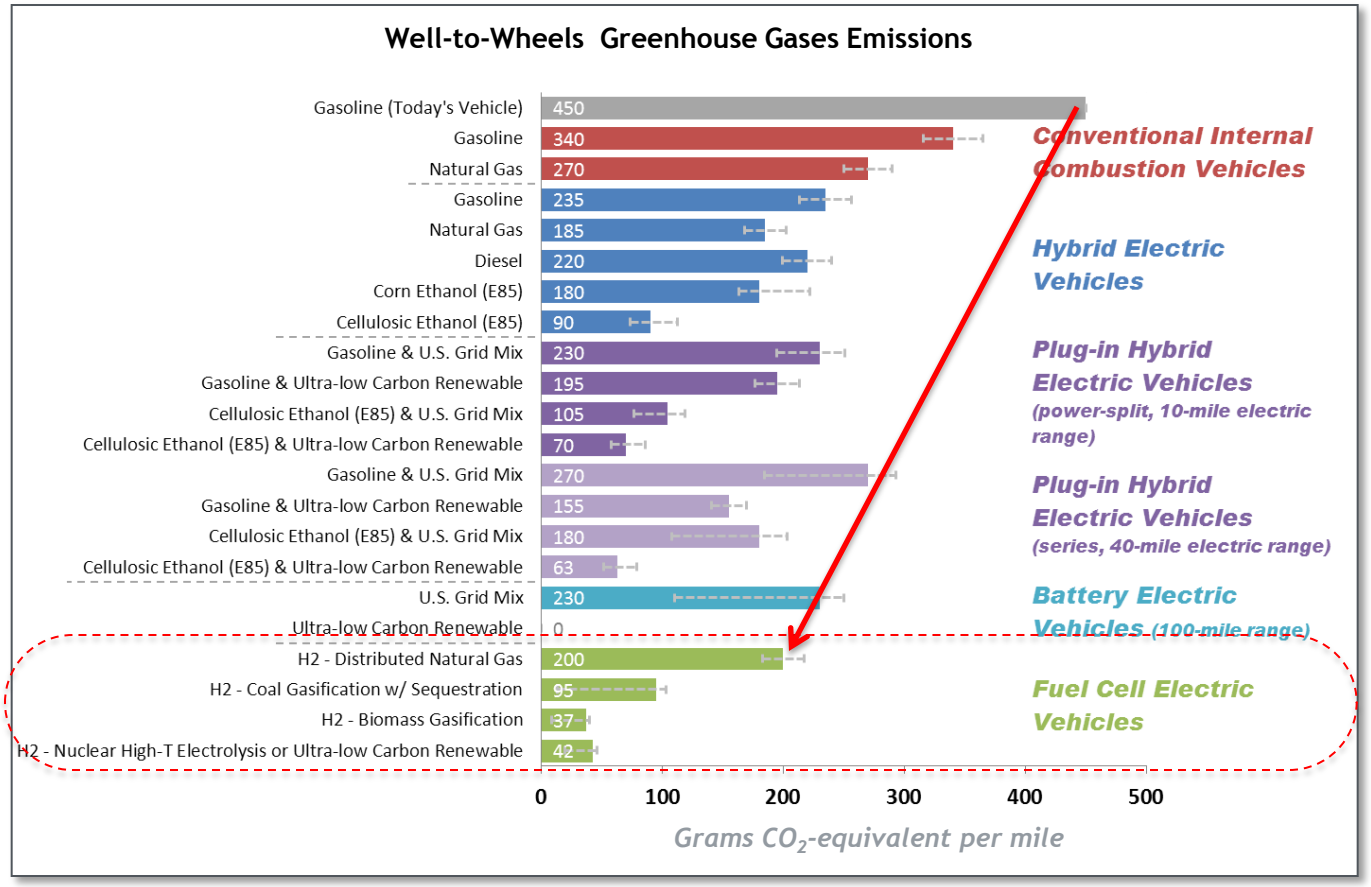
- **15 GM FCEVs** currently in demonstrations with military

- **Renewable hydrogen** (from geothermal and wind energy) will be used for buses
- Goals include **20-25 stations** on Oahu by 2015 to support annual sales of up to **5,000 FCEVs** in early years.

Well-to-Wheels CO_2 Analysis

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

Analysis by Argonne National Lab, DOE Vehicle Technologies Program, and FCT Program shows benefits from a portfolio of options



H_2 from Natural Gas

Even FCEVs fueled by H_2 from distributed NG can result in a >50% reduction in GHG emissions from today's vehicles.

Use of H_2 from NG decouples carbon from energy use—i.e., it allows carbon to be managed at point of production vs at the tailpipe.

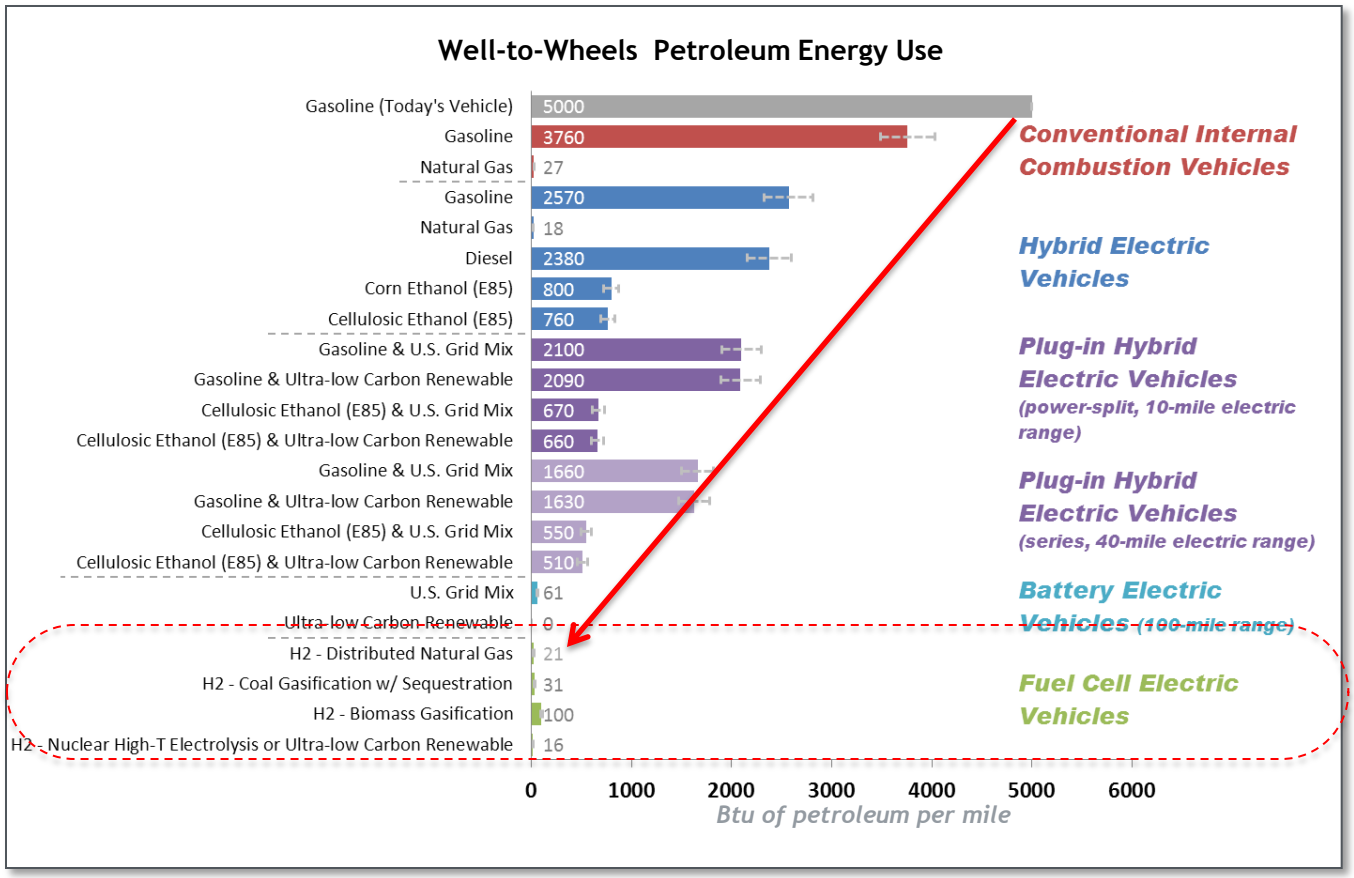
Even greater emissions reductions are possible as hydrogen from renewables enter the market.

Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the lifecycle effects of vehicle manufacturing and infrastructure construction/decommissioning.
Analysis & Assumptions at: http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

Well-to-Wheels Petroleum Analysis

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

Analysis by Argonne National Lab, DOE Vehicle Technologies Program, and FCT Program shows benefits from a portfolio of options.



H_2 from Natural Gas

FCEVs fueled by H_2 from distributed natural gas can almost completely eliminate petroleum use.

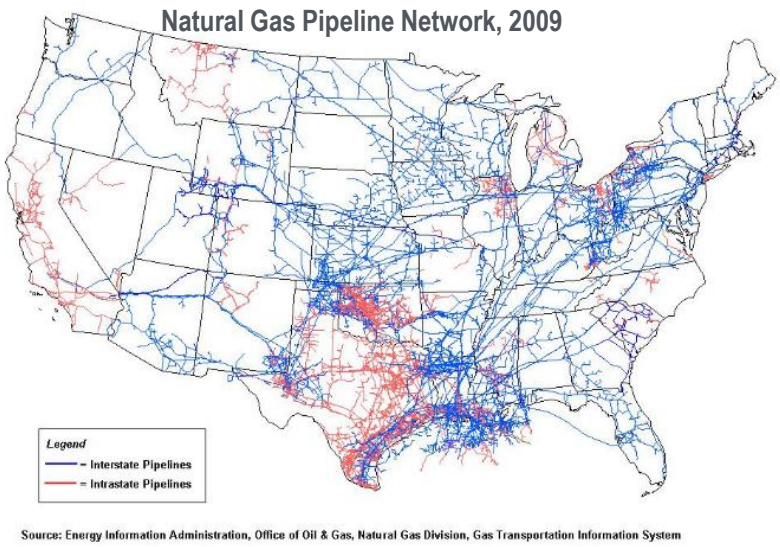
Notes:
For a projected state of technologies in 2035-2045. Ultra-low carbon renewable electricity includes wind, solar, etc. Does not include the life-cycle effects of vehicle manufacturing and infrastructure construction/decommissioning.
Analysis & Assumptions at: http://hydrogen.energy.gov/pdfs/10001_well_to_wheels_gge_petroleum_use.pdf

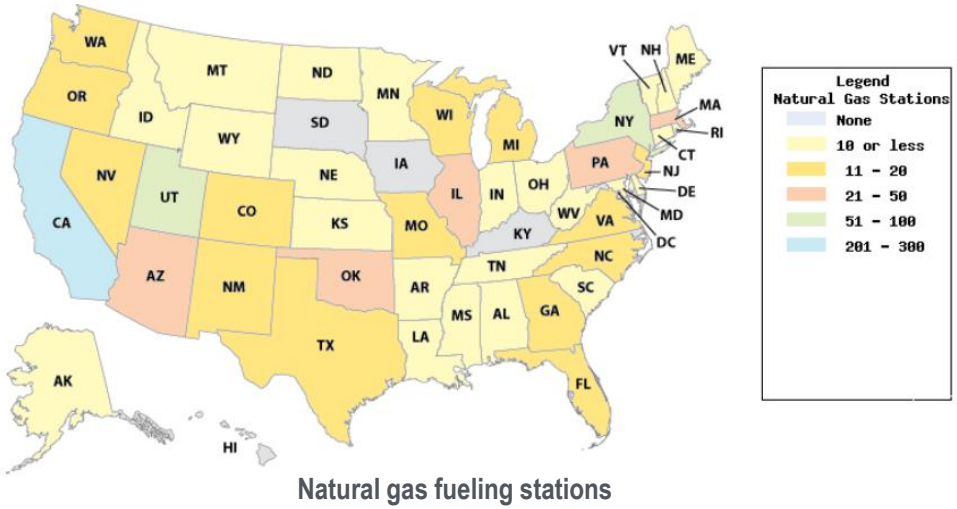
Two Main Options for Low-cost Early Infrastructure

1. **Hydrogen delivered from central site**
   - Low-volume stations (~200-300 kg/day) would cost <$1M and provide hydrogen for $7/gge *(e.g., high-pressure tube trailers, with pathway to $5/gge at 400–500 kg/day- comparable to ~$2.10/gallon gasoline untaxed)*
2. **Distributed production (e.g. natural gas, electrolysis)**

Other options

1. Co-produce H_2, heat and power (tri-gen) with natural gas or biogas
2. Hydrogen from waste (industrial, wastewater, landfills)





Worldwide Commitment to FCEVs

The world's leading automakers have committed to develop FCEVs. Germany and Japan have announced plans to expand the hydrogen infrastructure.

Major Auto Manufacturers' Activities and Plans for FCEVs

Toyota

- 2010-2013: U.S. demo fleet of 100 vehicles
- 2015: Target for large-scale commercialization
- "FCHV-adv" can achieve 431-mile range and 68 mpgge

Ford

- Alan Mulally, CEO, sees 2015 as the date that fuel cell cars will go on sale.

Daimler

- Small-series production of FCEVs began in 2009
- Plans for tens of thousands of FCEVs per year in 2015 – 2017 and hundreds of thousands a few years after
- In partnership with Linde to develop fueling stations.
- *Recently moved up commercialization plans to 2014*

General Motors

- 115 vehicles in demonstration fleet
- 2012: Technology readiness goal for FC powertrain
- 2015: Target for commercialization

Volkswagen

- Expanded demo fleet to 24 FCEVs in CA
- Recently reconfirmed commitment to FCEVs

SAIC (China)

- Partnering with GM to build 10 fuel cell vehicles in 2010

Honda

- Clarity FCX named "World Green Car of the Year"; EPA certified 72mpgge; leasing up to 200 vehicles
- 2015: Target for large-scale commercialization

BMW

- BMW and GM plan to collaborate on the development of fuel cell technology

Hyundai-Kia

- 2012-2013: 2000 FCEVs/year
- 2015: 10,000 FCEVs/year
- "Borrego" FCEV has achieved >340-mile range.

Based on publicly available information during 2011

High Profile CHP Installation Underscores Benefits

Freedom Tower to tap green fuel cell power:

Low emission fuel cells to provide onsite heat and power for landmark project

"New York's Freedom Tower, the skyscraper being constructed on the site of the World Trade Center, is to use fuel cells to power its heating and cooling systems.

UTC Power, the fuel cell division of engineering conglomerate United Technologies, announced that it has received orders from the ***New York Power Authority (NYPA)*** *for 12 fuel cells totaling 4.8MW of power to serve the Freedom Tower and three other new towers under construction at the site in Manhattan."*

Education Activities

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

Education: *Based on prior year funds – projects are being completed*

ACTIVITIES

- Increase acceptance and inclusion of technologies as a part of a clean energy portfolio
- Reduce "soft costs" associated with early adoption (e.g., insurance, permitting, uniform codes and standards)
- Increase general knowledge of the benefits multiple applications
- Increase awareness of broad range of applications—beyond light-duty vehicles and buses

PROGRESS *(key examples)*

Educated **over 23,000** first responders and code officials through introductory web-based courses and advanced hands-on training.

Continued to promote and deploy the "H2 Educate" middle-school learning module—reaching a total of **more than 9,550 teachers** in 35 states since the project was launched.

Conducted seminars and developed fact-sheets and case studies for end-users

Conducted **more than 80 workshops** to help state officials identify deployment opportunities

2011 Hydrogen Student Design Contest had 54 university teams registered from 19 countries, including seven of the top 20 engineering schools in the world.

Increased offering of university certificates and minors at universities (examples include: Michigan Tech, Univ. of NC at Charlotte)

Communication & Outreach

Published more than 70 news articles in FY 2011 (including blogs, progress alerts, and DOE FCT news alerts)

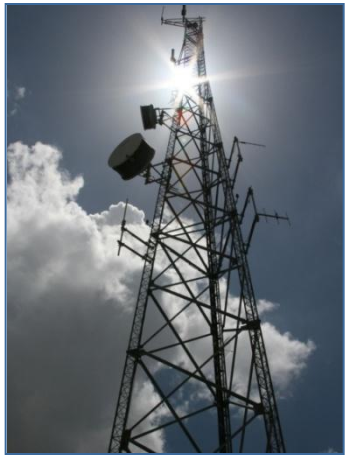
Communication and Outreach Activities include:

- Webinar Series:
  - Feb. 6 – National Hydrogen Learning Demonstration Status
  - Continuing series of informational webinars led by FCT and partners on various topics.
- News Items:
  - Energy Department Awards More Than $7 Million for Innovative Hydrogen Storage Technologies in Fuel Cell Electric Vehicles
  - DOE Launches Comprehensive Hydrogen Storage Materials Clearing House
- Monthly Newsletter

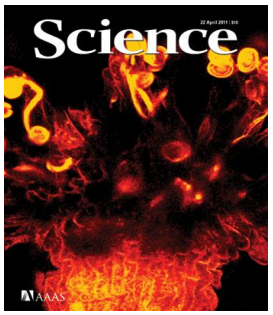
"These technologies are part of a broad portfolio that will create new American jobs, reduce carbon pollution, and increase our competitiveness in today's global clean energy economy."

Blogs Published to Energy.gov website include:

- Fuel Cell Powers Up Festivities at Sec. Chu's Holiday Party
- Fuel Cell Lift Trucks:
  A Grocer's Best Friend



Hydrogen fuel cells providing critical backup power



Progress in low and zero Pt catalysts highlighted in Science

Hydrogen power lights at the 2011 Golden Globes

Partnerships & Collaboration

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

Federal Agencies

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

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

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

External Input

- Annual Merit Review & Peer Evaluation
- H2 & Fuel Cell Technical Advisory Committee
- National Academies, GAO, etc.

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (USCAR, energy companies- U.S. DRIVE)
- Fuel Cell and Hydrogen Energy Association (FCHEA)
- Hydrogen Utility Group
- ~ 65 projects with 50 companies

Universities

~ 50 projects with 40 universities

International

- IEA Implementing agreements – 25 countries
- International Partnership for Hydrogen & Fuel Cells in the Economy – 17 countries & EC, 30 projects

DOE Hydrogen & Fuel Cells Program

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, MN

Argonne A, FC, P&D, SC&S

Los Alamos S, FC, SC&S

Sandia P&D, S, SC&S

Pacific Northwest P&D, S, FC, SC&S, A

Oak Ridge P&D, S, FC, A, SC&S

Lawrence Berkeley FC, A

Lawrence Livermore P&D, S, SC&S

Savannah River S, P&D

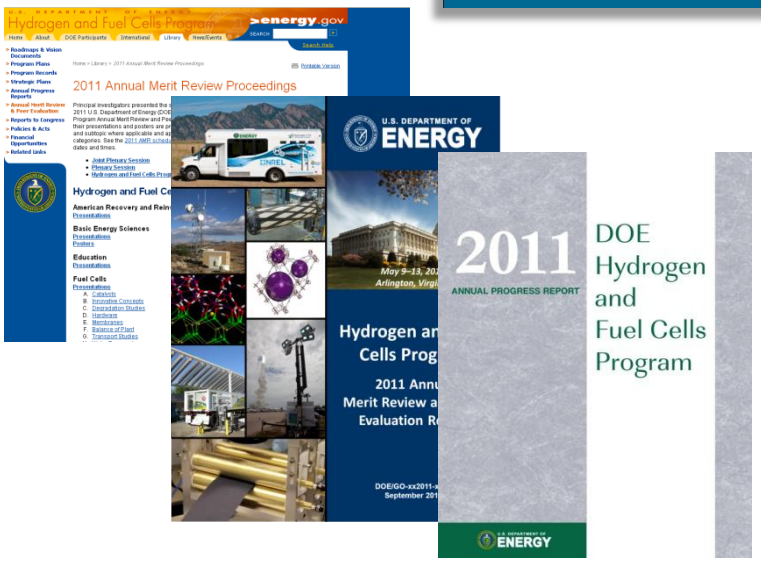
Brookhaven S, FC

Idaho National Lab P&D

Other Federal Labs: Jet Propulsion Lab, National Institute of Standards & Technology, National Energy Technology Lab (NETL)

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

Key Reports



The DOE Fuel Cell Technologies Program also funds the development and publication of key reports

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

By FuelCells2000, http://www.fuelcells.org

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

State of the States: Fuel Cells in America

By FuelCells2000, http://www.fuelcells.org

See report: ttp://www.fuelcells.org/StateoftheStates2011.pdf

2010 Fuel Cell Market Report

By Breakthrough Technologies Institute, Inc. http://www.btionline.org/

See report:

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2010_market_report.pdf

Annual Merit Review & Peer Evaluation Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

http://www.hydrogen.energy.gov/annual_review11_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

http://hydrogen.energy.gov/annual_review11_report.html

Annual Progress Report

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

www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 14 – 18, 2012 Arlington, VA

http://annualmeritreview.energy.gov/

Examples of DOE-funded Projects and Locations

Source: US DOE 12/2010

Thank you