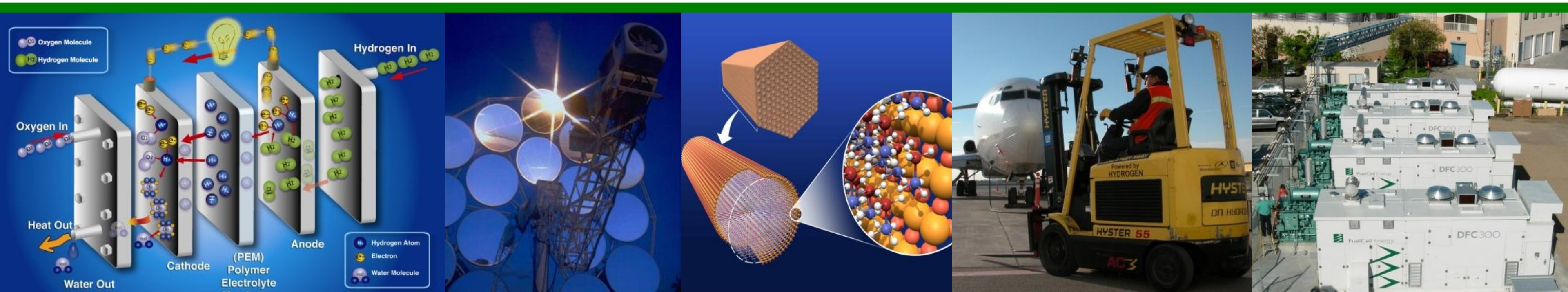


U.S. Country Update

IPHE Steering Committee Meeting

Michael Mills

Advisor – International Program

Energy Efficiency and Renewable Energy

U.S. Department of Energy

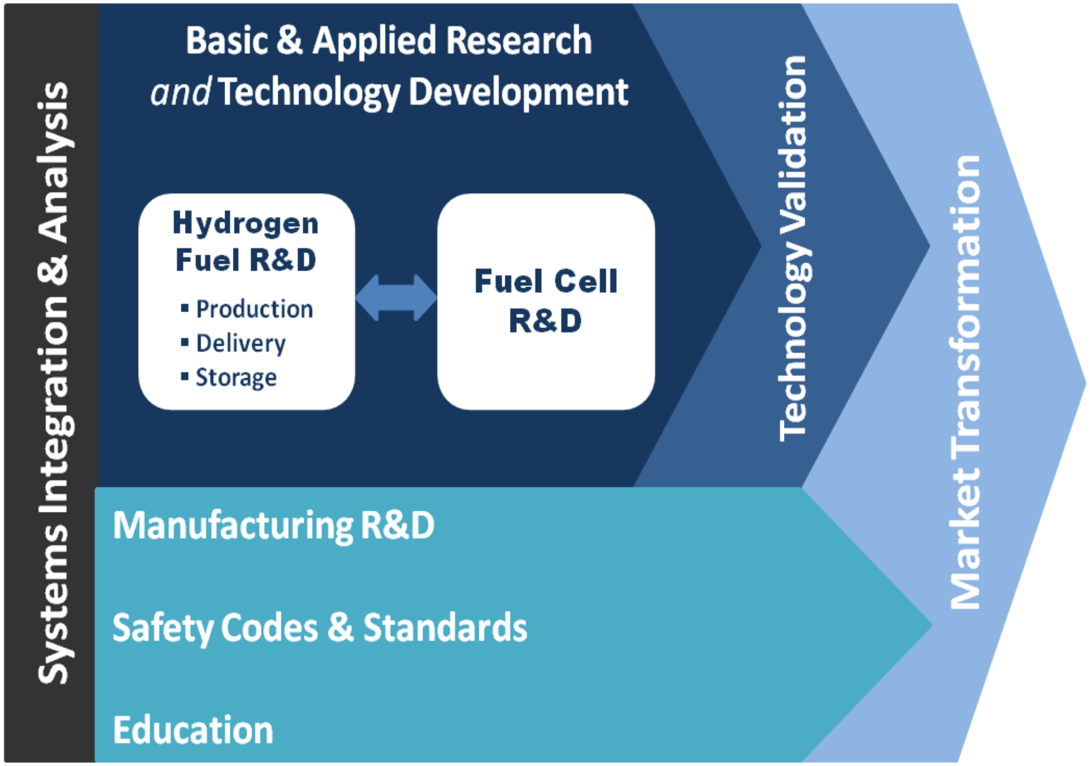
November 14, 2012

Seville, Spain

DOE Program Overview

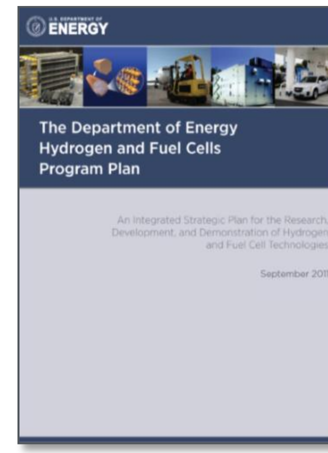
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

The Program is an integrated effort, structured to address all the key challenges and obstacles facing widespread commercialization.



WIDESPREAD COMMERCIALIZATION ACROSS ALL SECTORS

- Transportation
- Stationary Power
- Auxiliary Power
- Backup Power
- Portable Power



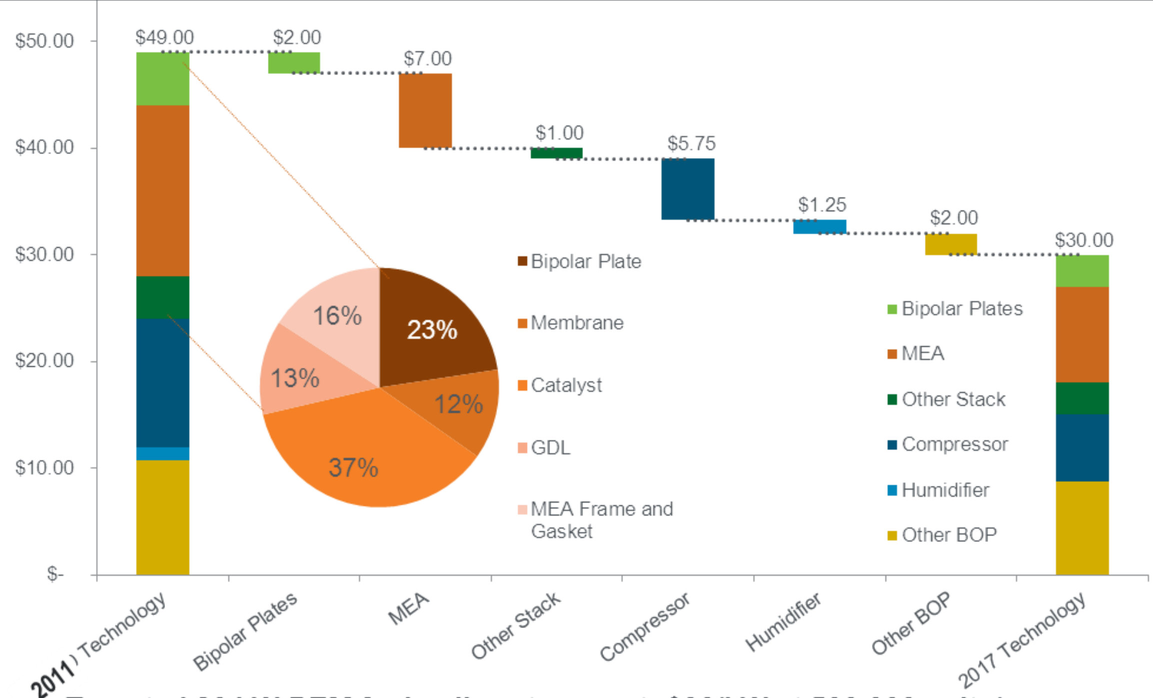
Released September 2011 Update to the Hydrogen Posture Plan (2006) Includes Four DOE Offices EERE, FE, NE and Science

Nearly 300 projects currently funded

at companies, national labs, and universities/institutes

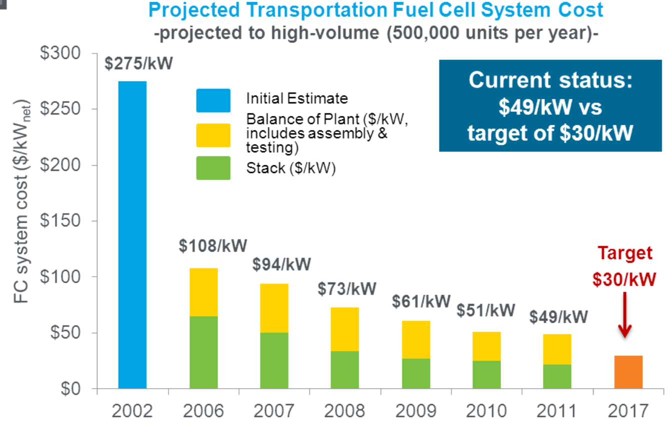
More than $1B DOE funds spent from FY 2007 to FY 2011

Strategic technical analysis guides focus areas and priorities for budget. Need to reduce cost from \$49/kW to \$30/kW and increase durability from 2,500-hr to 5,000-hr.



Targeted 80 kW PEM fuel cell system cost: \$30/kW at 500,000 units/yr

Fuel Cell – Cost Trends

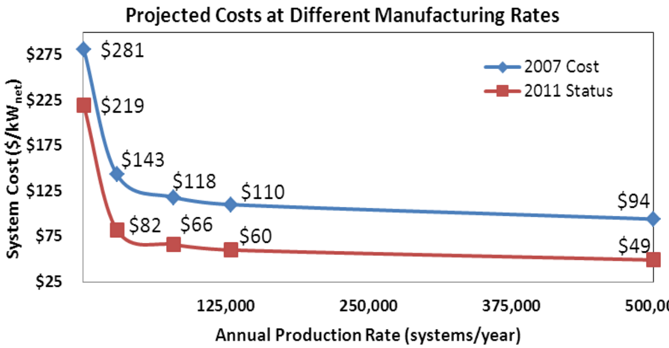


DOE-funded efforts have reduced the projected high-volume cost of fuel cells to \$49/kW (2011)*

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

Strategies to Address Challenges – Catalyst Examples

- Lower PGM Content
- Pt Alloys
- Novel Support Structures
- Non-PGM catalysts



The revised hydrogen threshold cost is a key driver in the assessment of Hydrogen Production and Delivery R&D priorities.

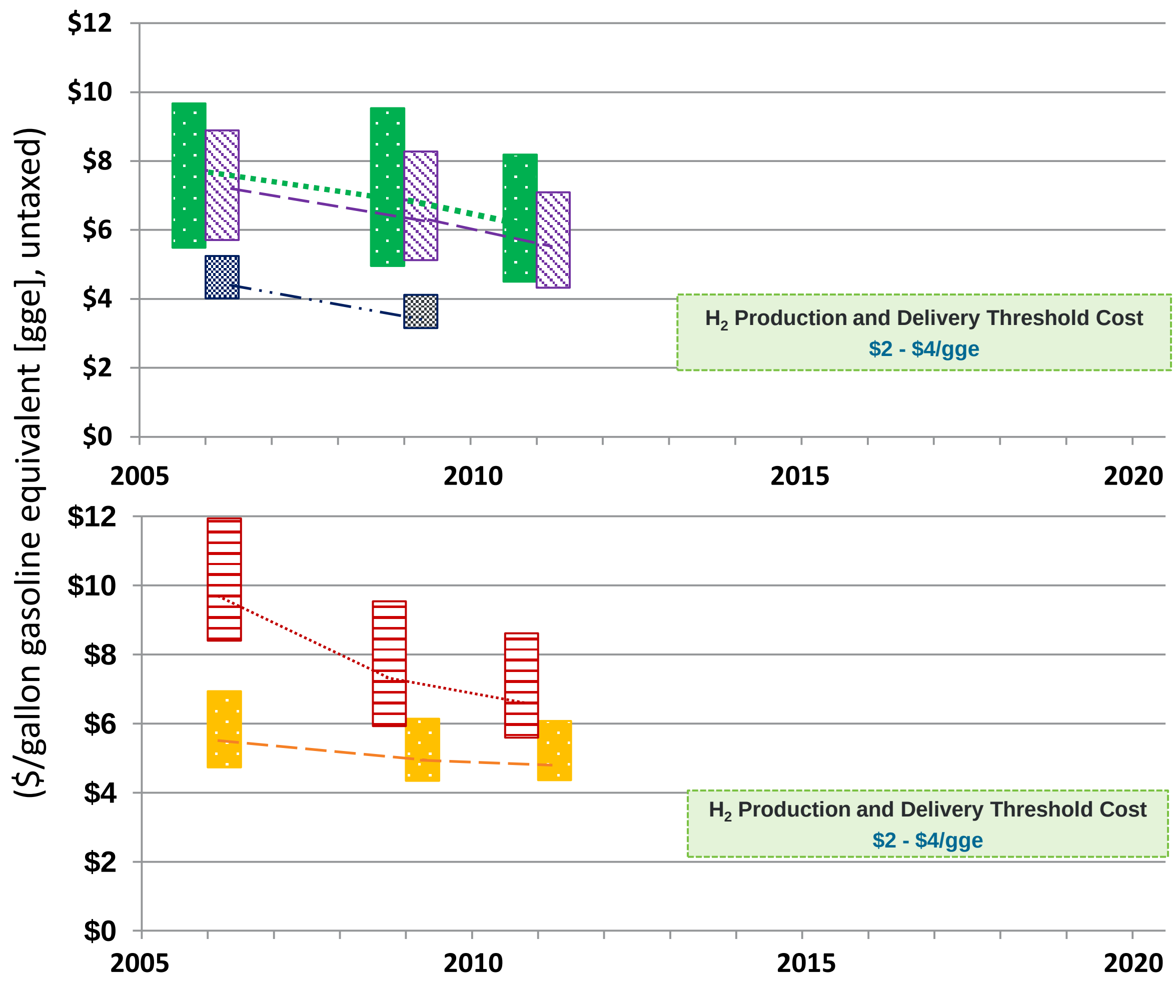
Projected High-Volume Cost of Hydrogen Production[1] (Delivered[2])—Status

Distributed Production (near term)

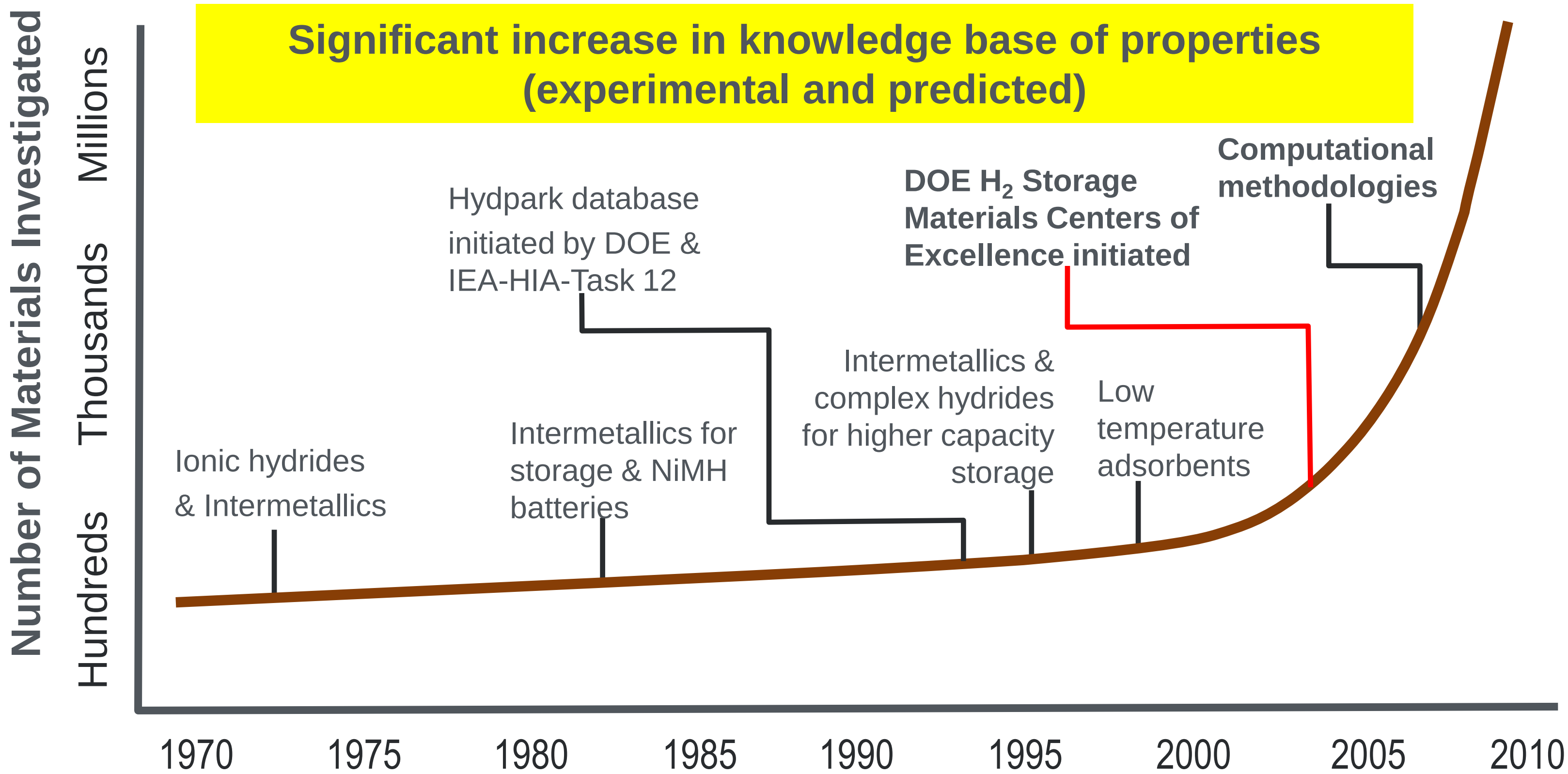
- Electrolysis
  Feedstock variability: $0.03 - $0.08 per kWh
- Bio-Derived Liquids
  Feedstock variability: $1.00 - $3.00 per gallon ethanol
- Natural Gas Reforming[3]
  Feedstock variability: $4.00 - $10.00 per MMBtu

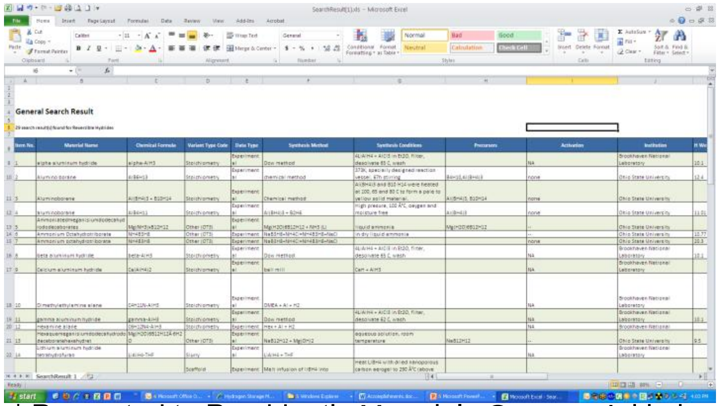
Central Production (longer term)

- Electrolysis
  Feedstock variability: $0.03 - $0.08 per kWh
- Biomass Gasification
  Feedstock variability: $40- $120 per dry short ton



Notes:
[1] Cost ranges for each pathway are shown in 2007$ based on high-volume projections from H2A analyses, reflecting variability in major feedstock pricing and a bounded range for capital cost estimates.
[2] Costs include total cost of production and delivery (dispensed, untaxed). Forecourt compression, storage and dispensing added an additional $1.82 for distributed technologies, $2.61 was added as the price of delivery to central technologies. All delivery costs were based on the Hydrogen Pathways Technical Report (NREL, 2009).
[3] Analysis of projected costs for natural gas reforming indicated that the threshold cost can be achieved with current technologies or with incremental improvements made by industry. FCTP funding of natural gas reforming projects was completed in 2008.





Launched open source database* on Hydrogen Storage Materials Properties: http://hydrogenmaterialssearch.govtools.us/

Database Analytics (since Dec 2011)

- **1450 visits from 1013 people**
- **Visits from 66 Countries**
- **Over 35 languages**
- **30.1% Return Visitor**

* Presented to President's Materials Genome Initiative Interagency Working Group

Completed world's largest single FCEV & H_2 Demonstration to date (50-50 DOE-Industry cost share)

- >180 fuel cell vehicles and 25 hydrogen stations
- 3.6 million miles traveled; 500,000 trips
  - ~152,000 kg of hydrogen produced or dispensed; >33,000 refuelings

	Status	Project Target
Durability	~2,500	2,000
Range	196 – 254*	250*
Efficiency	53 – 59%	60%
Refueling Rate	0.77 kg/min	1 kg/min

	Status (NG Reforming)	Status (Electroylsis)	Ultimate Target
H_2 Cost at Station	\$7.70 - \$10.30/kg	\$10.00 - \$12.90/kg	\$2.00 - \$4.00/kg

Demonstrated world's first Tri-generation station

Anaerobic digestion of municipal wastewater (Orange County Sanitation District)

- Produces 100 kg/day H_2,; generates ~ 250 kW; 54% efficiency co-producing H_2 and electricity
- Nearly 1 million kWh of operation
- >4,000 kg H_2 produced

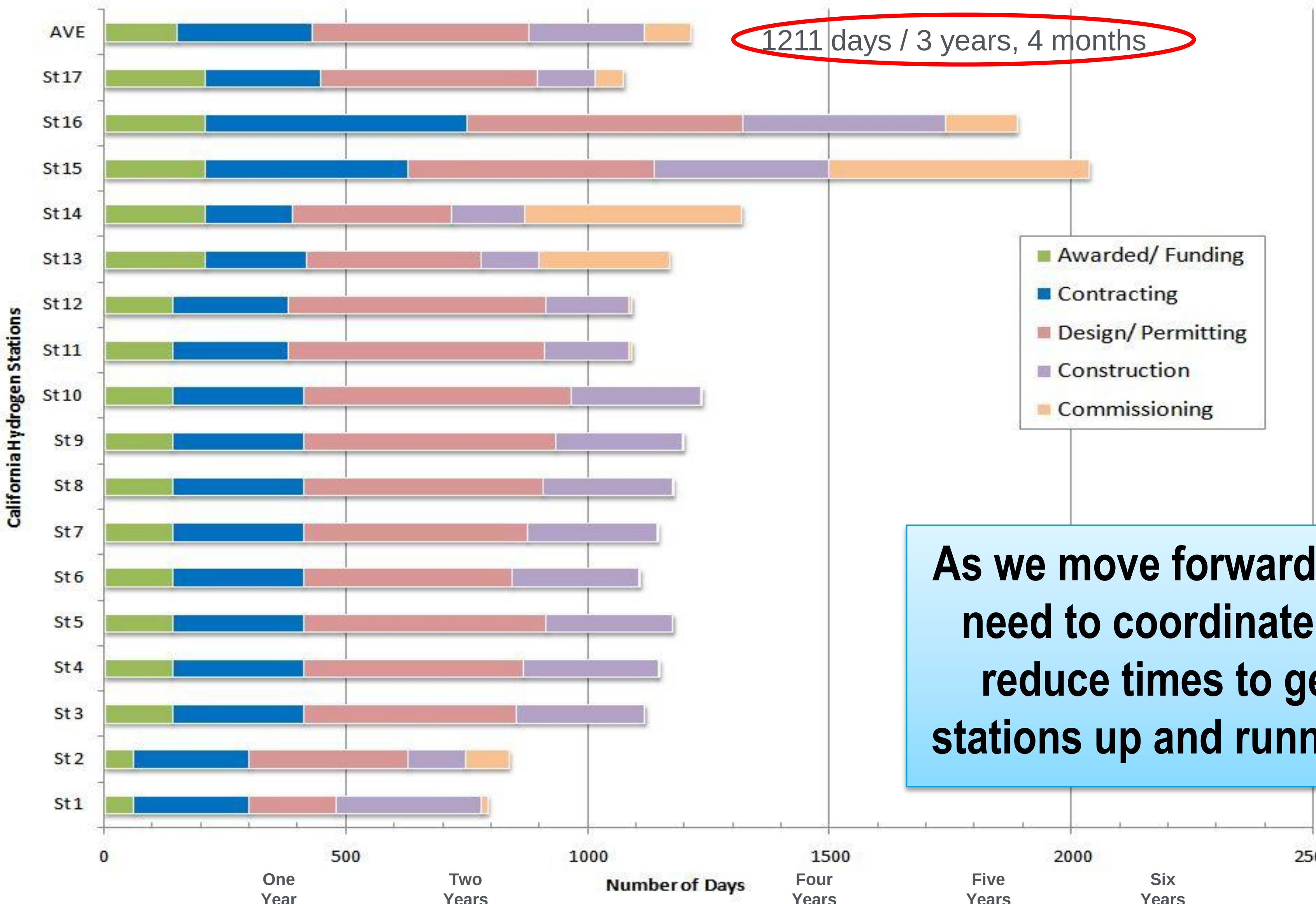
(Air Products, FuelCell Energy)

Demonstrated H_2 for Energy Storage (NREL)

- Showed PEM and alkaline electrolyzers provide grid frequency regulation, 4X faster than 'control' with no electrolyzers
- Achieved 5,500 hrs of variable electrolyzer stack operation to determine effects of wind AC power on stack degradation

*Independently validated a vehicle that can achieve a 430 mile range.

Timing for Getting Stations Online is an Issue



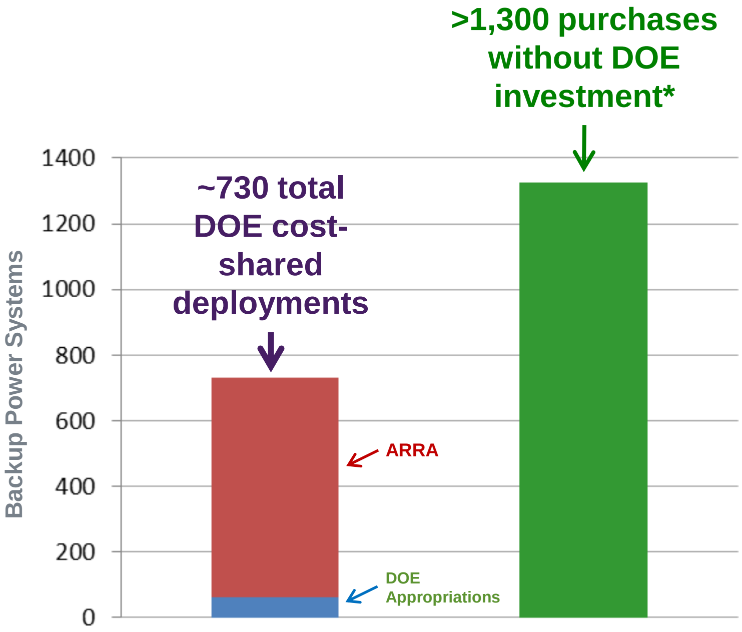
As we move forward, we need to coordinate to reduce times to get stations up and running.

Source: CaFCP October 2012

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

Early market deployments of approximately 1,400 fuel cells have led to more than 5,000 additional purchases by industry—with no further DOE funding.

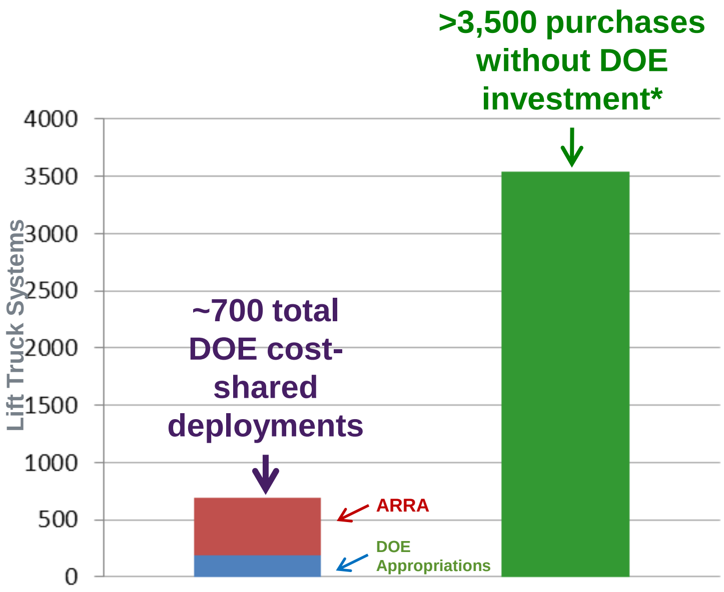
Backup Power Units



Leveraging DOE funds:

DOE deployments led to almost 2X additional purchases by industry.

Lift Truck Deployments



Leveraging DOE funds:

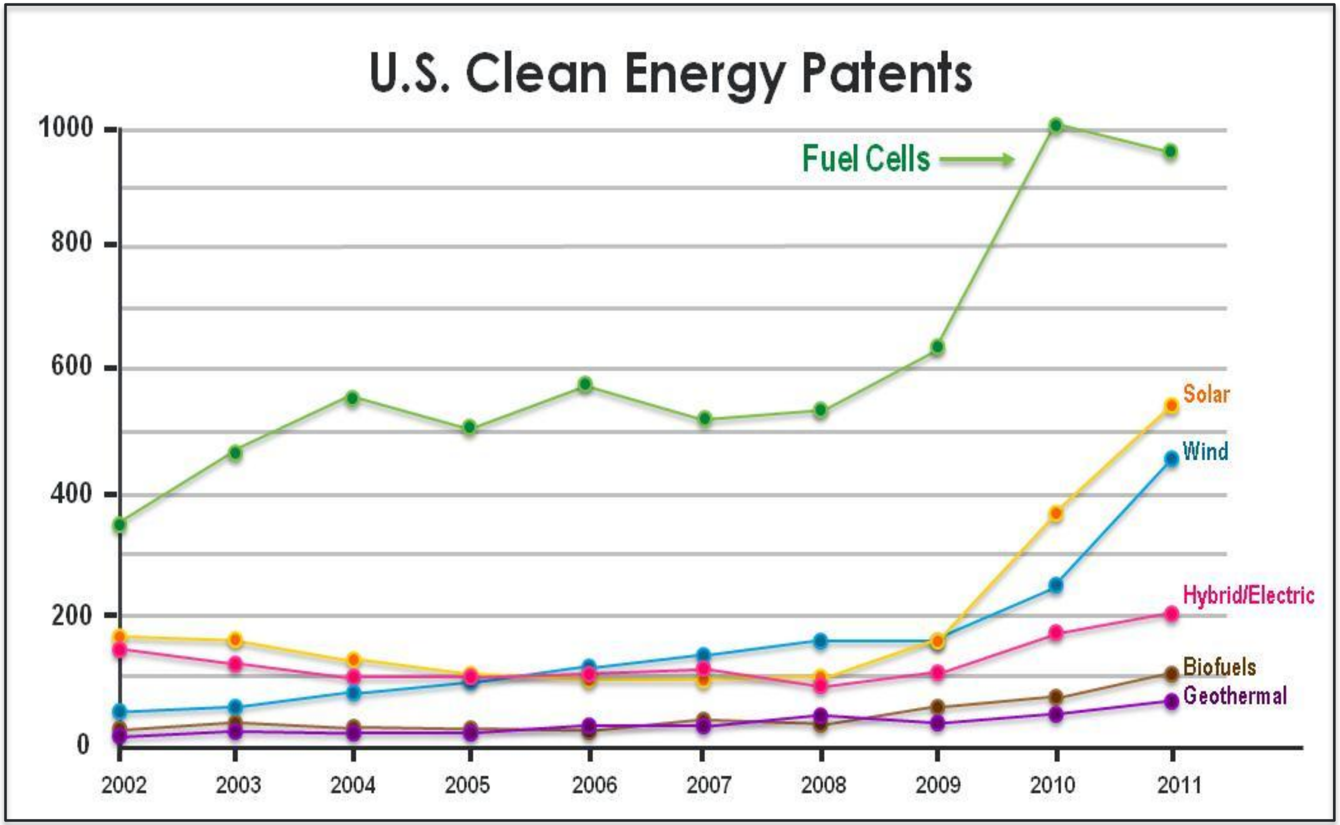
DOE deployments led to >5X additional purchases by industry.

Recovery Act and Market Transformation Activities – Government as "Catalyst" for market success of emerging technologies

**industry purchases include units on order*

Emerging Fuel Cell Industries Further Increase the Demand for Hydrogen

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



Top 10 companies: Honda, GM, Toyota, UTC Power, Samsung, Ballard, Nissan, Plug Power, Delphi Technologies, Matsushita Electric Industrial

Clean Energy Patent Growth Index[1] shows that fuel cell patents lead in the clean energy field with nearly 1,000 fuel cell patents issued worldwide in 2010, 3x more than the second place holder (solar); Number of fuel cell patents grew > 57% in 2010.

[1] http://cepgi.typepad.com/heslin_rothenberg_farley_/

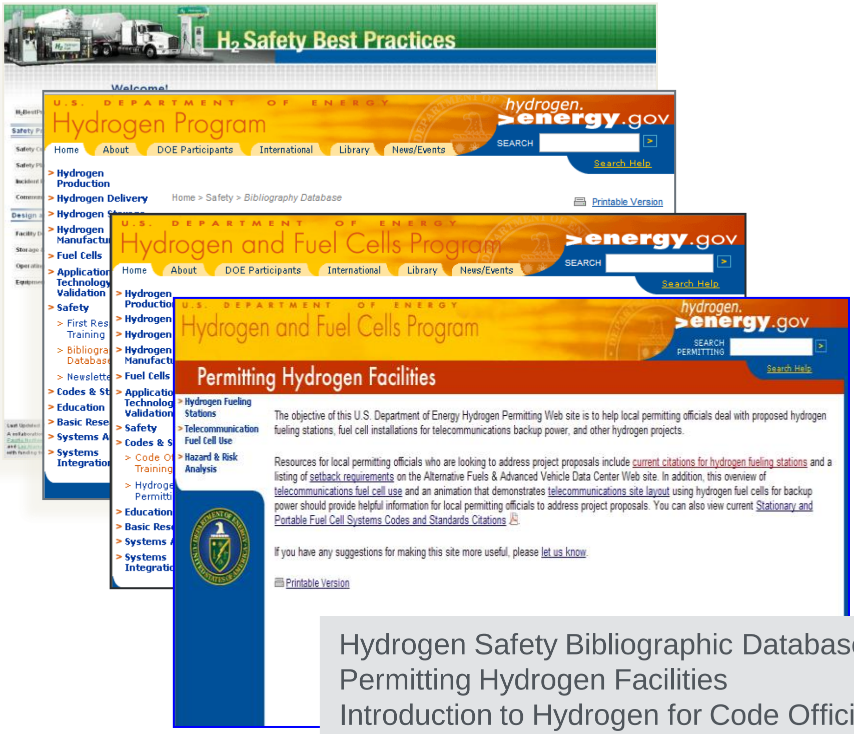
Freedom Tower to tap green fuel cell power:

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

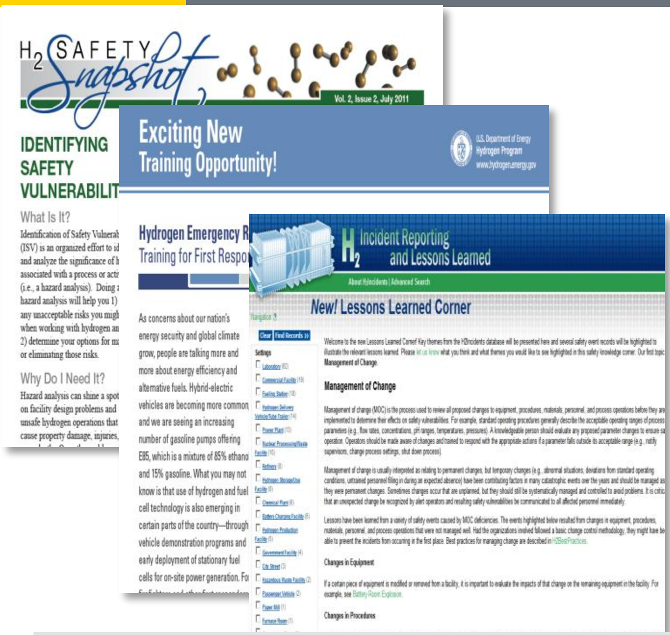
"New York's Freedom Tower, the skyscraper being constructed on the site of the World Trade Center, is to use fuel cells to power its heating and cooling systems.

*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."*

Safety, Codes and Standards



Hydrogen Safety Bibliographic Database
Permitting Hydrogen Facilities
Introduction to Hydrogen for Code Officials
Hydrogen Safety Best Practices Manual



H_2 Safety Snapshot bulletin
Introduction to Hydrogen Safety for First Responders
Hydrogen Incident Reporting Database

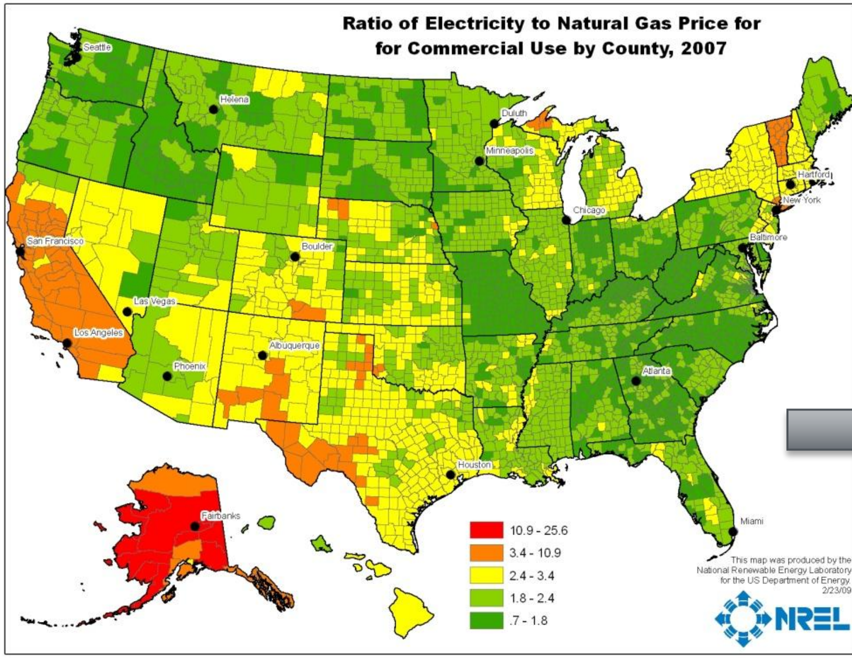
- **Trained > 23,000 first-responders and code officials on hydrogen safety and permitting through on-line and in-classroom courses**
- **>200 Lessons Learned Events in "H2Incidents.org" – need more sharing**
- **Approximately 750 entries in the Hydrogen Safety Bibliographic Database**

www.eere.energy.gov/hydrogenandfuelcells/codes/

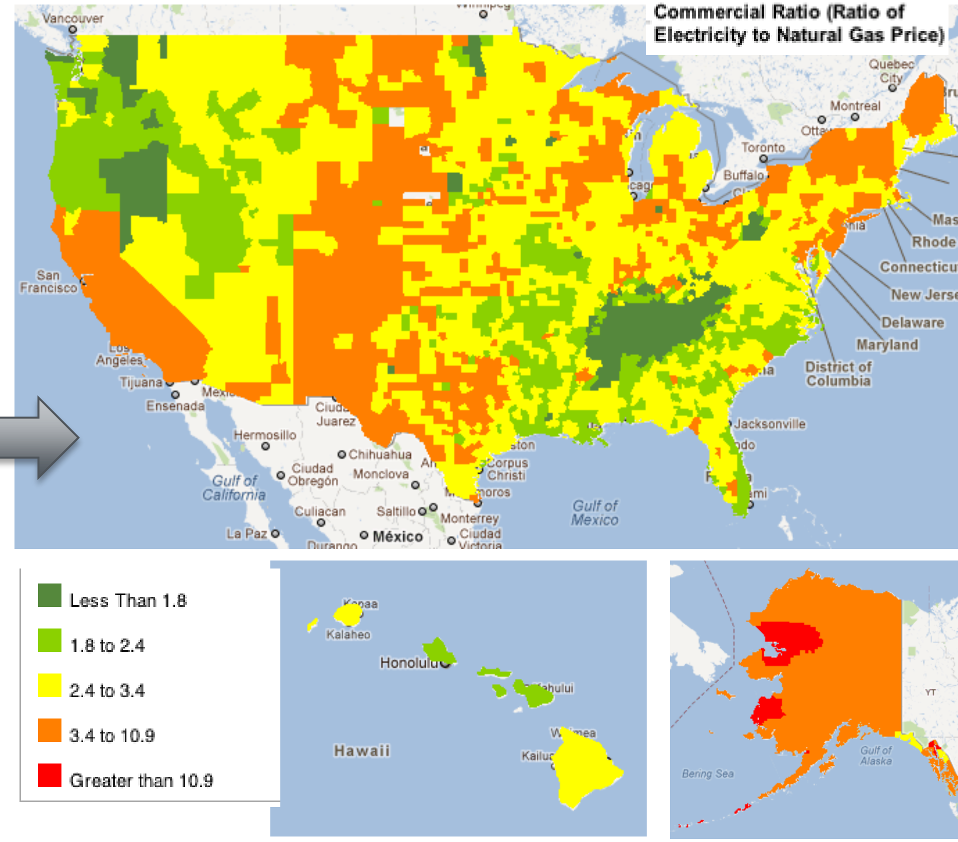
Spark-Spread Determines Regional Opportunities for DG from Natural Gas

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

2007



Latest Assessment



Spark spread determines regions for favorable use of natural gas

Red/orange regions: High electricity cost, low natural gas cost- favorable for DG

Lower natural gas prices offer increased opportunities for CHP and distributed generation- current vs. 2007

Source: NREL

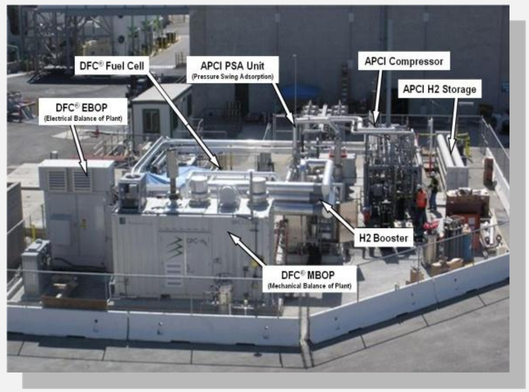
Tri-Generation of Heat, Hydrogen, and Power

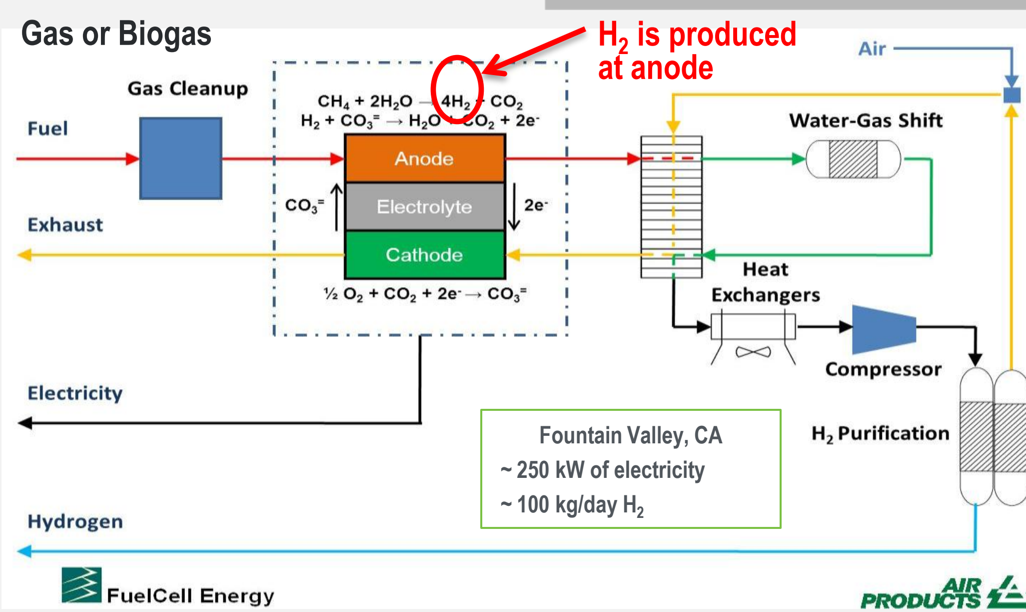
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Potential Opportunity
Synergy between stationary and transportation sectors

Demonstrated world's first Tri-generation station (54% efficiency – H_2 and power)

-Anaerobic digestion of municipal wastewater-





Is tri-generation a viable option for H_2 production:

- Co-produce H_2, power, and heat for multiple applications?
- More efficient use of natural gas?
- Use a renewable resource in anaerobic digester gas?
- Use off-gas from other waste material processing (e.g., gasifiers)?
- Establish an early market infrastructure?

Biogas as an Early Source of Renewable Hydrogen and Power

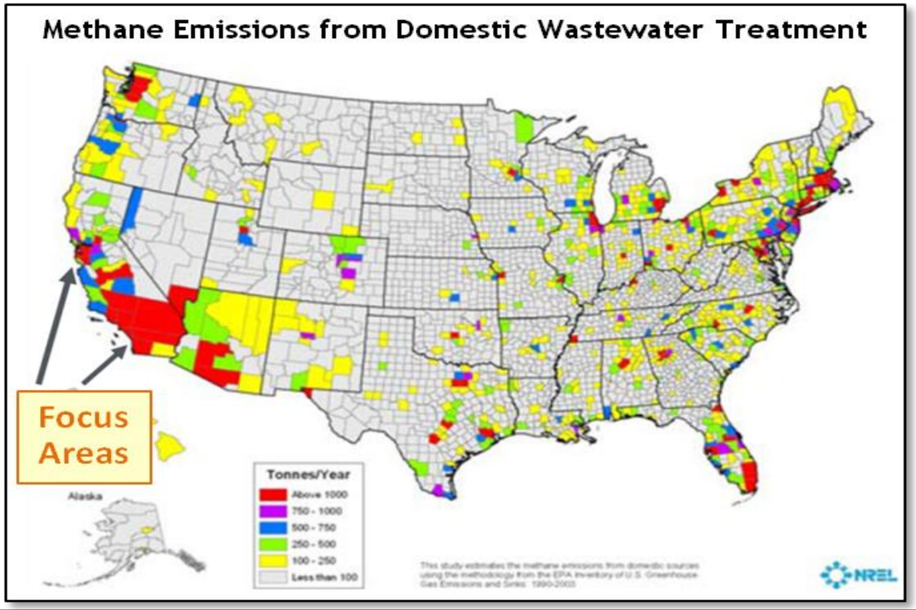
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

- ***The majority of biogas resources are situated near large urban centers—ideally located near the major demand centers for hydrogen generation for hydrogen fuel cell vehicles (FCEVs) and power generation from stationary fuel cells.***
- ***Hydrogen can be produced from this renewable resource using existing steam-methane-reforming technology.***

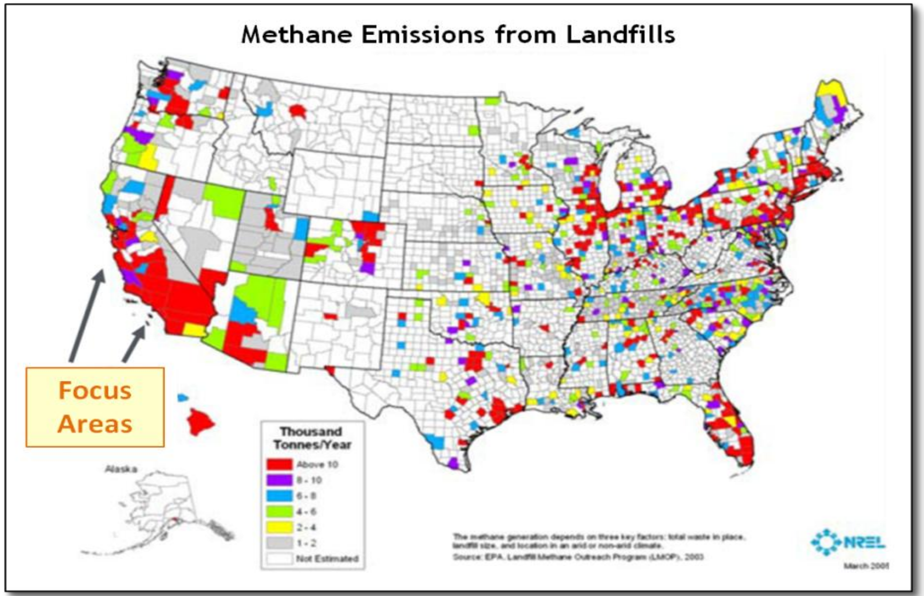
U.S. biogas resource has capacity to produce ~5 GW of power at 50% electrical efficiency.

Hydrogen generated from biogas can fuel ~8-13M FCEVs/day.

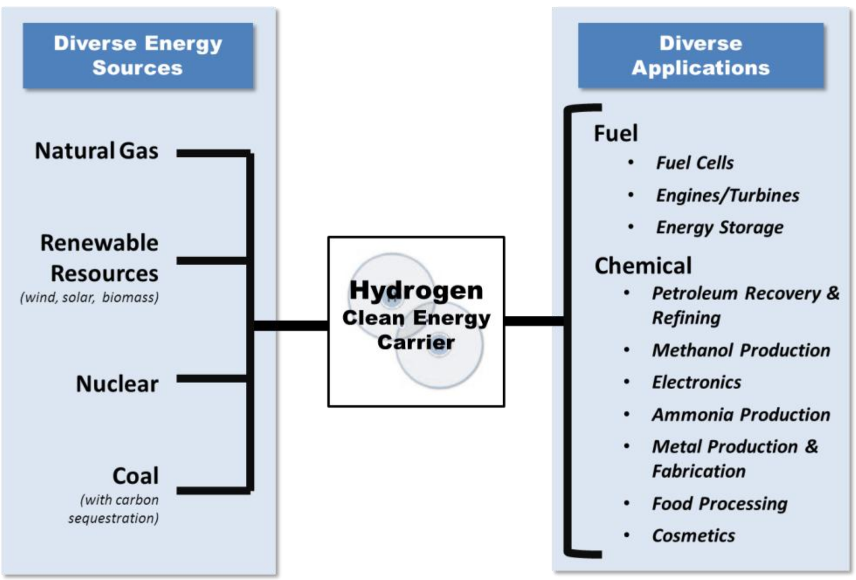
- 500,000 MT per year of methane is available from wastewater treatment plants in the U.S.
- ~50% of this resource could provide **~340,000 kg/day** of hydrogen.

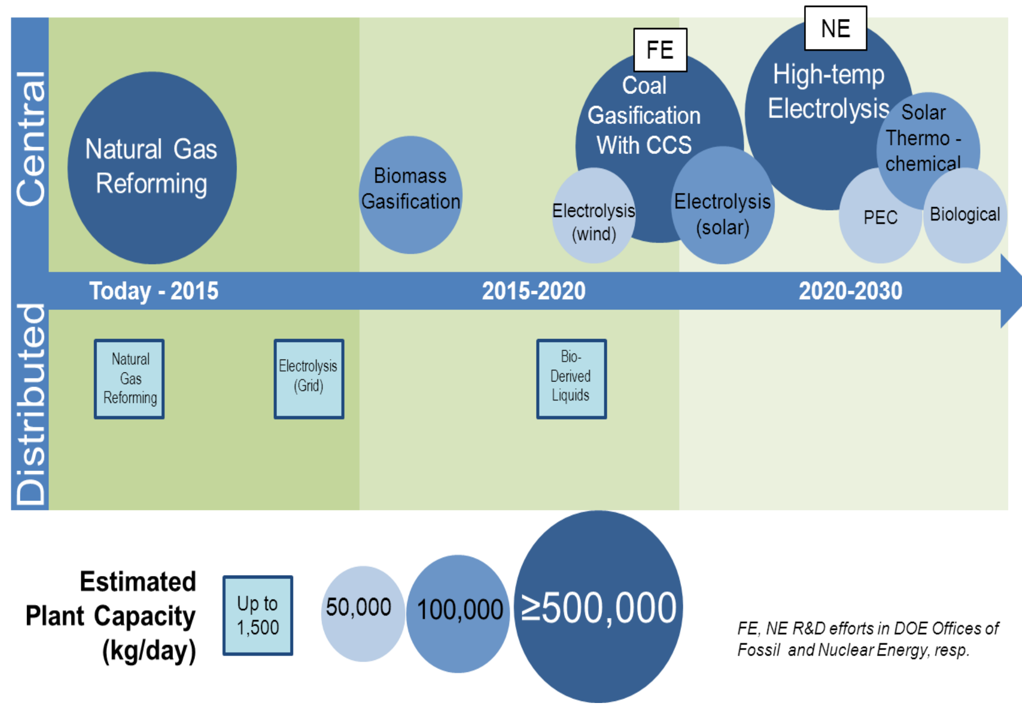


- 12.4 million MT per year of methane is available from landfills in the U.S.
- ~50% of this resource could provide **~8 million kg/day** of hydrogen**.**

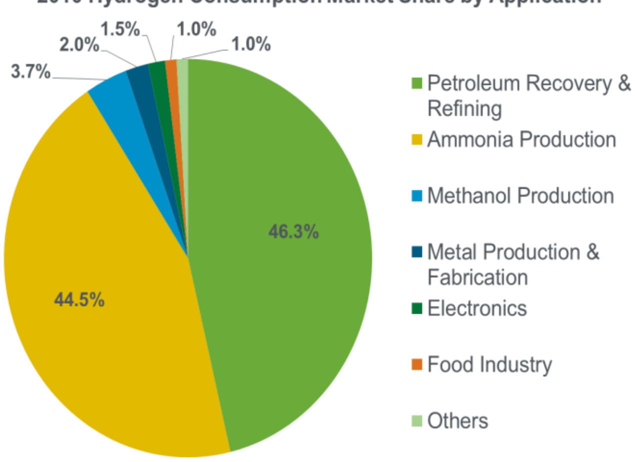


Hydrogen: Sources & Applications





2010 Hydrogen Consumption Market Share by Application



HTAC Subcommittee: H_2 Production Expert Panel Review underway to provide recommendations to DOE

International Collaboration: Resource Analysis

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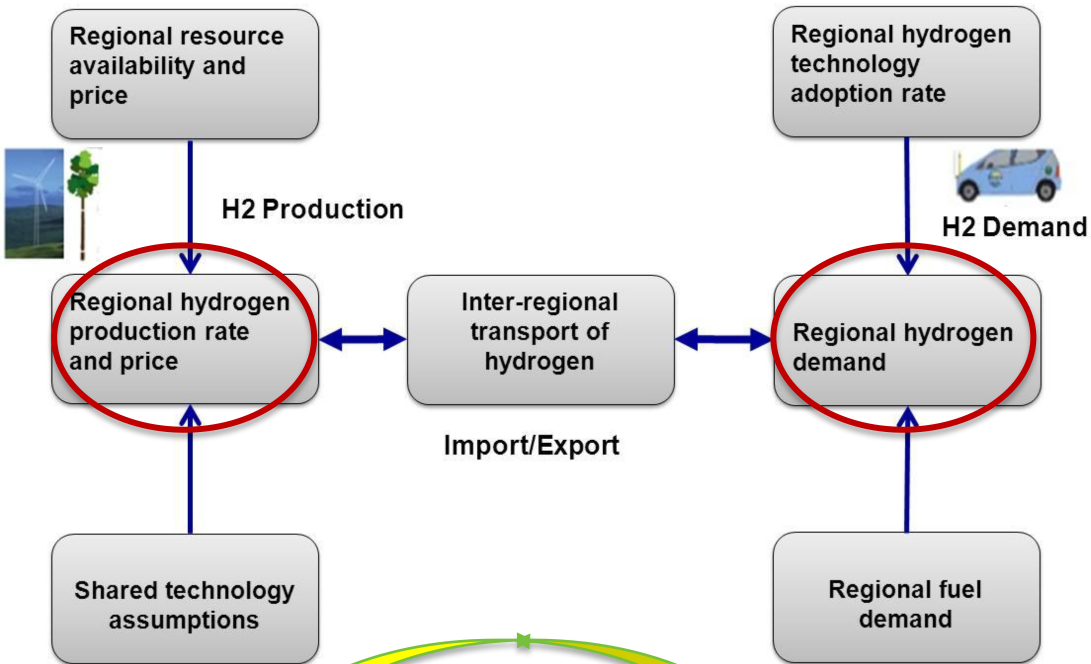

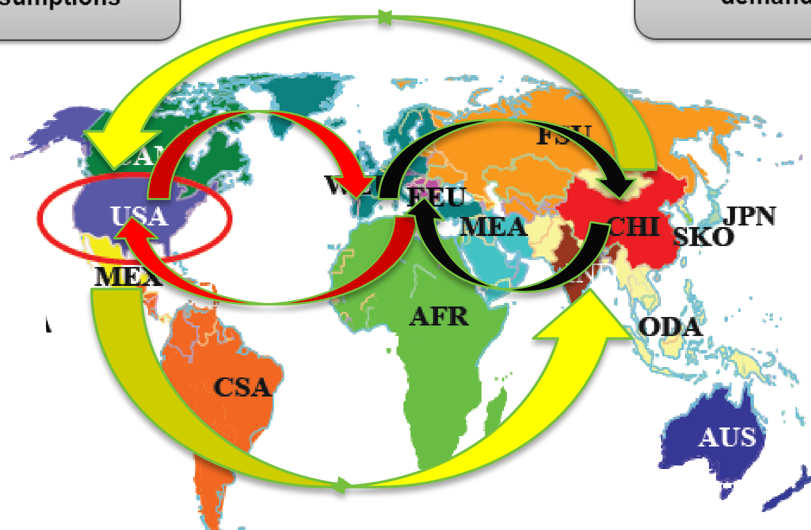

International Resource Flow

Objectives*:

- Through collaboration with IEA analysts and IPHE, perform comprehensive technical and market analysis of
  - Hydrogen technologies and resources
  - Resource supply and demand related to projected hydrogen use
  - Global hydrogen infrastructure
  - GHG emissions and petroleum reduction
- Identify international flows of:
  - Energy
  - Hydrogen
  - Natural gas, LNG, coal
  - Platinum and other materials

*Objectives for IEA Hydrogen Implementing Agreement Task 30

Policies Promoting Fuel Cells

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

Some tax credits affecting fuel cells were expanded and a new act was proposed that can help facilitate federal deployments.

Investment Tax Credit	30% for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity (i.e., expected system output), whichever is less. The equipment must be installed by Dec. 31, 2016. In addition, it features a credit of 10% for combined-heat-and-power-system property.
Fuel Cell and Hydrogen Energy Infrastructure *(proposed)*	Designed to accelerate the adoption of stationary fuel cell power generation and hydrogen infrastructure. Also addresses fuel cells in transportation applications, by increasing the tax credit for hydrogen refueling stations from 30% to 50% and removing the dollar limit. Allows for the credit to be extended to hydrogen refueling stations for fuel cell material handling vehicles.
H-Prize	Cash prizes to advance the commercial application of hydrogen energy technologies by incentivizing accelerated research production, storage, distribution, utilization, and prototypes and transformational technologies. $1M, $4M, and $10M categories.

Communication and Outreach are Critical

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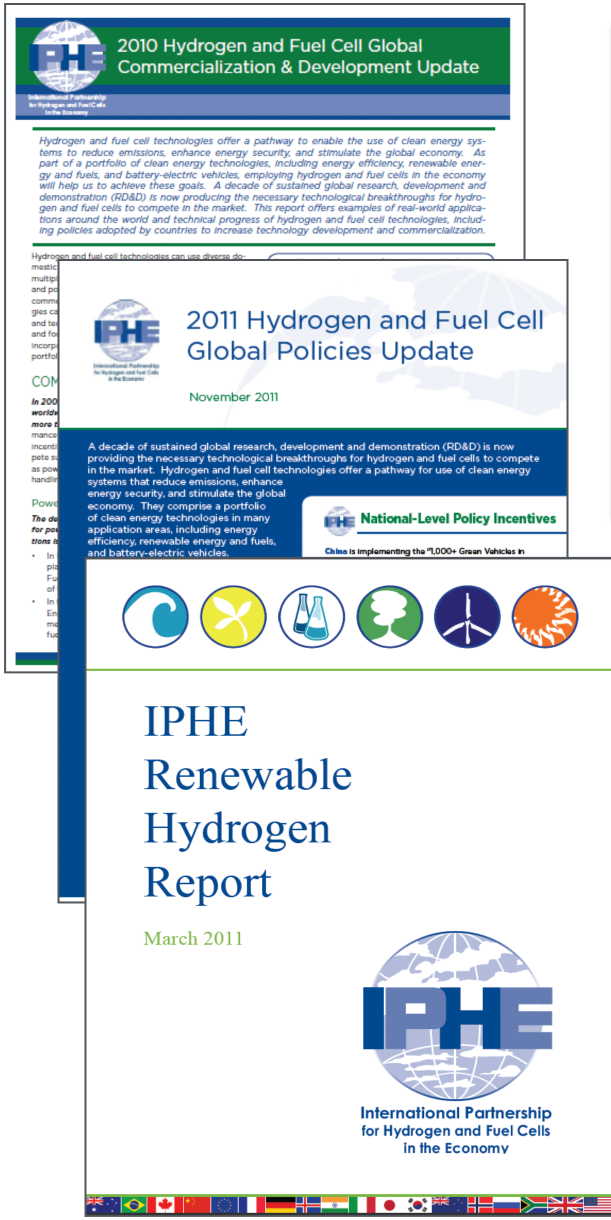


Increasing the dissemination and communication of our hydrogen and fuel cell RDD&D activities and budgets will be instrumental in our effort to increase technology development and commercialization through coordination and collaboration.

Examples of Communications:

- ✓ IPHE Public Webinars (rotating host)
- ✓ Member Program Project Lists
- ✓ Publish IPHE Paper in International Journal of Hydrogen Energy
- ✓ Publish IPHE Newsletter (external proposal submitted to Secretariat)

World Class Researchers - Examples

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

Professor Thomas Jaramillo (Stanford) received a 2012 Presidential Early Career Award for Scientists & Engineers (PECASE). PECASE is the highest honor bestowed by the U.S. government on outstanding scientists and engineers who are early in their independent research careers. Jaramillo is the first ever EERE awardee.

Dr. Adam Weber (LBNL) and Professor Vijay Ramani (IIT) honored as Energy Technology Division Supramaniam Srinivasan Young Investigator Award from The Electrochemical Society in Seattle.

Professor Scott Samuelsen (UC Irvine) named a White House Champion of Change for his work as Director of the Advanced Power and Energy Program and the National Fuel Cell Research Center.

Dr. Fernando Garzon (LANL) was elected President of the National Electrochemical Society (ECS).

Dr. Radoslav Adzic (BNL) honored as 2012 Inventor of the Year by the NY Intellectual Property Law Association.

Other Presidential Awardees:

- **Professor Susan Kauzlarich** – UC Davis, a 2009 recipient of the ***Presidential Award for Excellence in Science, Mathematics and Engineering Mentoring***—and a partner of the Chemical Hydrogen Storage Center of Excellence

- **Dr. Jason Graetz** – Brookhaven National Laboratory, a 2009 recipient of the ***Presidential Early Career Award for Scientists and Engineers***—and a partner of the Metal Hydride Center of Excellence

- **Dr. Craig Brown** – NIST, a 2009 recipient of the ***Presidential Early Career Award for Scientists and Engineers***—and a Partner of the Hydrogen Sorption Center of Excellence

Hydrogen & Fuel Cells - Budget

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

"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

Potential FY13 Budgets: $104M, $82M, $80M, or other. TBD by March 2013.

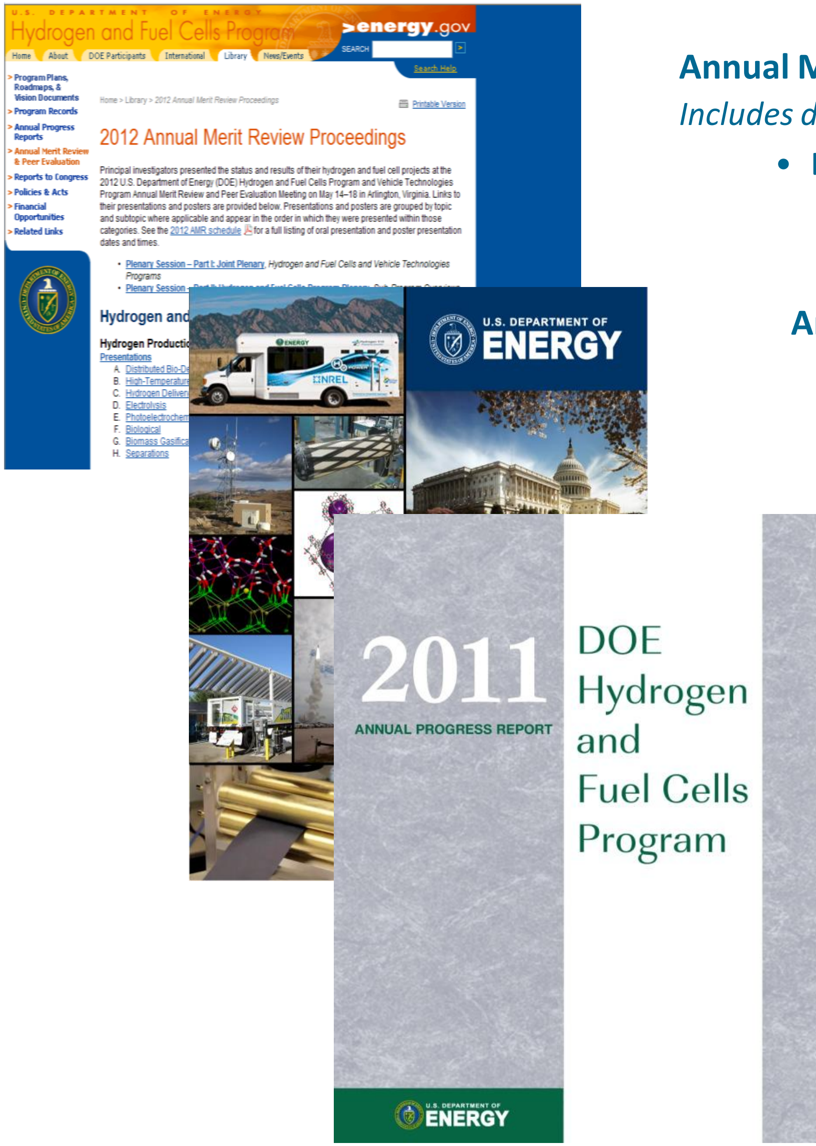
[1]Fuel Cells Systems R&D includes Fuel Cell Stack Component R&D, Transportation Systems R&D, Distributed Energy Systems R&D, and Fuel Processor R&D

[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

Key Program Documents

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



Annual Merit Review & Peer Evaluation Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- **Latest edition released July 2012**

http://www.hydrogen.energy.gov/annual_review12_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

- **Released September 2011**

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

2012 Report Coming Soon

Annual Progress Report

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

- **To be released October 2011**

www.hydrogen.energy.gov/annual_progress.html

2012 Report Coming Soon

SAVE THE DATE

Next Annual Review: May 13 – 17, 2013 Arlington, VA

http://annualmeritreview.energy.gov/

Thank you

Michael.Mills@ee.doe.gov