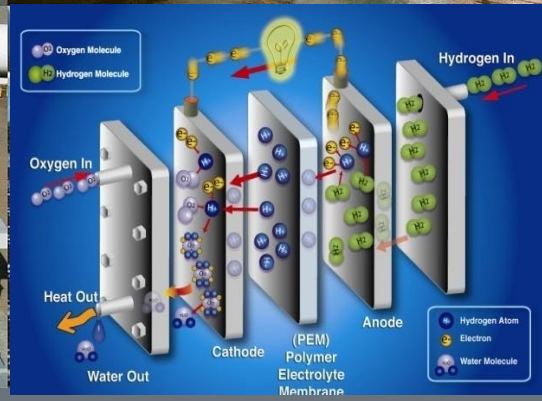
Fuel Cell Technologies Overview

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



Fuel Cell Seminar

Orlando, FL

11/1/2011

Dr. Sunita Satyapal

U.S. Department of Energy
Fuel Cell Technologies Program
Program Manager

DOE Program Overview

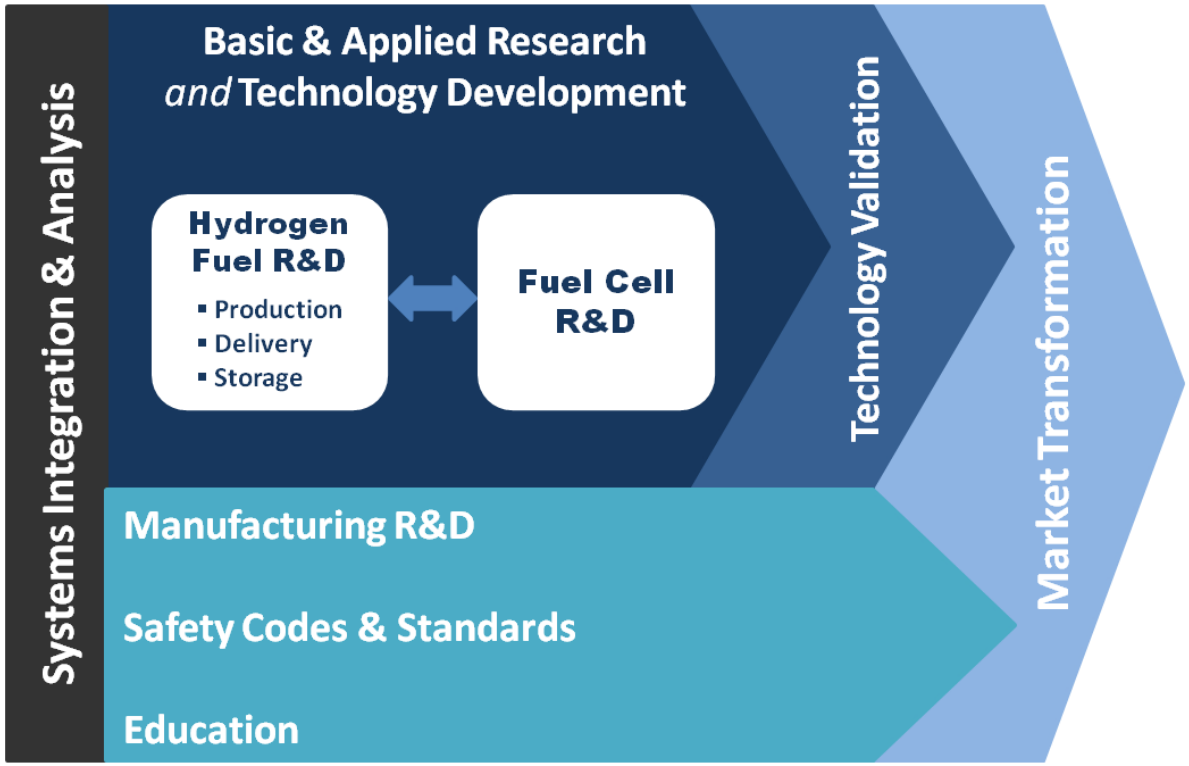
Budget

Progress

Next Steps

DOE Program Structure

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

The Program includes activities within the Offices of Energy Efficiency & Renewable Energy, Fossil Energy, Nuclear Energy, and Science. Updated Program Plan (2011).

Nearly 300 projects currently funded

at companies, national labs, and universities/institutes

DOE Support of Fuel Cell Technologies

Recent Statements by Secretary Chu

" These projects will help advance our fuel cell and hydrogen storage research efforts and bring down the costs of producing and manufacturing next generation fuel cells. 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."

"Projects like these fuel cell systems will help reduce fossil fuel use and improve energy reliability at military installations across the country."

“The benefits of a combined heat and power fuel cell system, coupled with the educational benefits of a living laboratory, not only advance clean energy technology, but help ensure that our nation remains competitive in the workforce of tomorrow.”

http://www1.eere.energy.gov/hydrogenandfuelcells/news.html

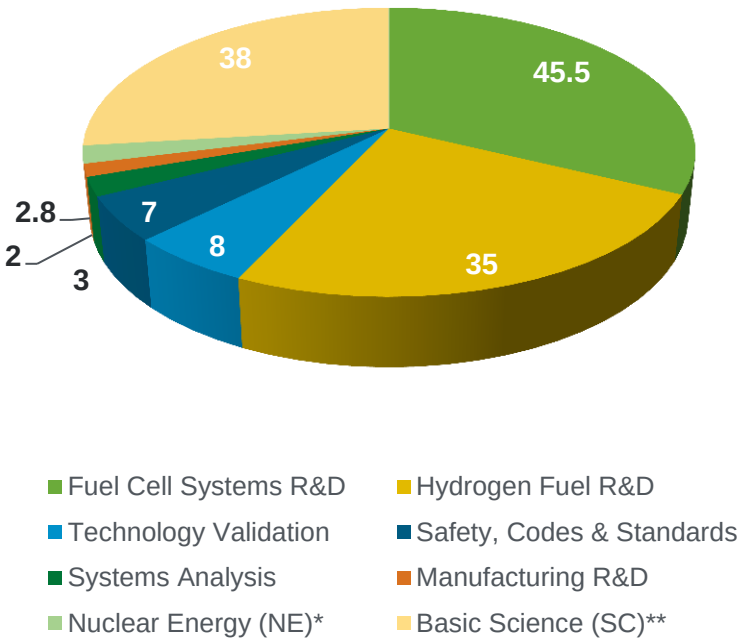
H_2 & Fuel Cells Budget

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

Approximately $100 M for Applied RD&D in Hydrogen and Fuel Cells (EERE)

Funding *($ in thousands)*				
Key Activity	**FY 2011 Appropriation**	**FY 2012 Request**	***House Mark***	***Senate Mark***
Fuel Cell R&D	43,000	45,450	41,450	42,000
Hydrogen Fuel R&D	33,000	35,000	33,000	33,000
Technology Validation	9,000	8,000	5,000	8,000
Market Transformation*	0	0	0	3,000
Safety, Codes & Standards	7,000	7,000	7,000	7,000
Education*	0	0	0	0
Systems Analysis	3,000	3,000	3,000	3,000
Manufacturing R&D	3,000	2,000	2,000	2,000
Total	**$98,000**	**$100,450**	**$91,450**	**98,000**

Total DOE Hydrogen and Fuel Cell Technologies FY12 Budget Request (in millions of US $)



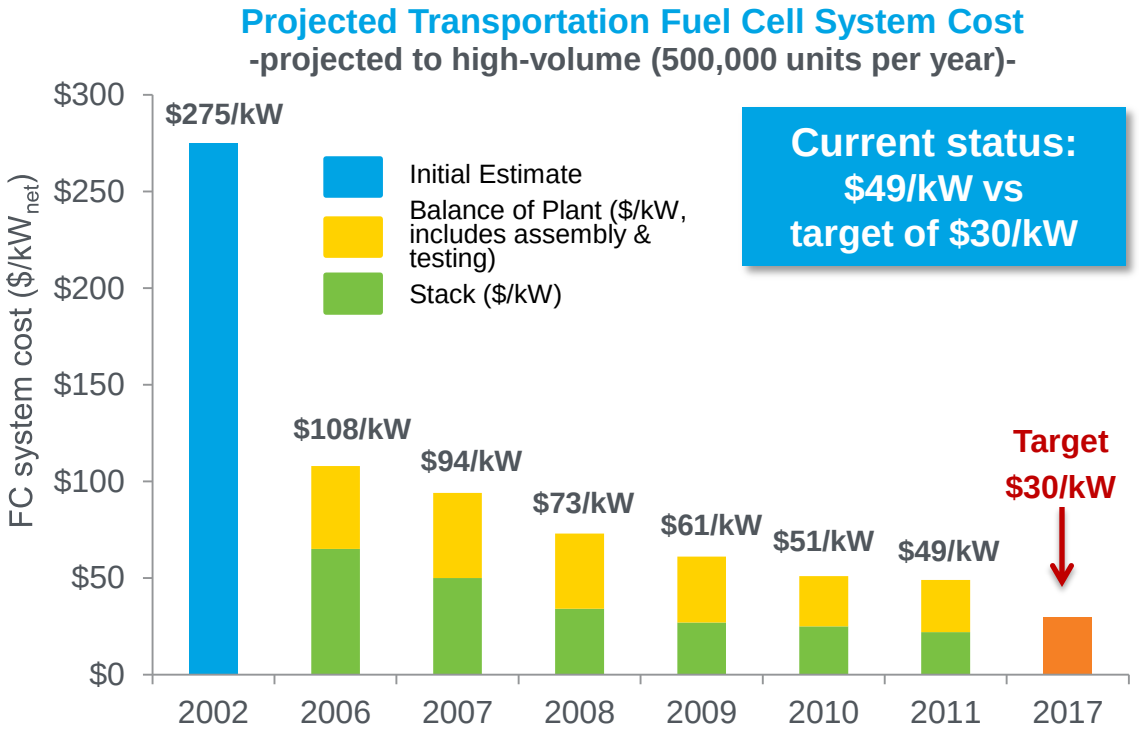
SECA: $25M for Fossil Energy (House mark)

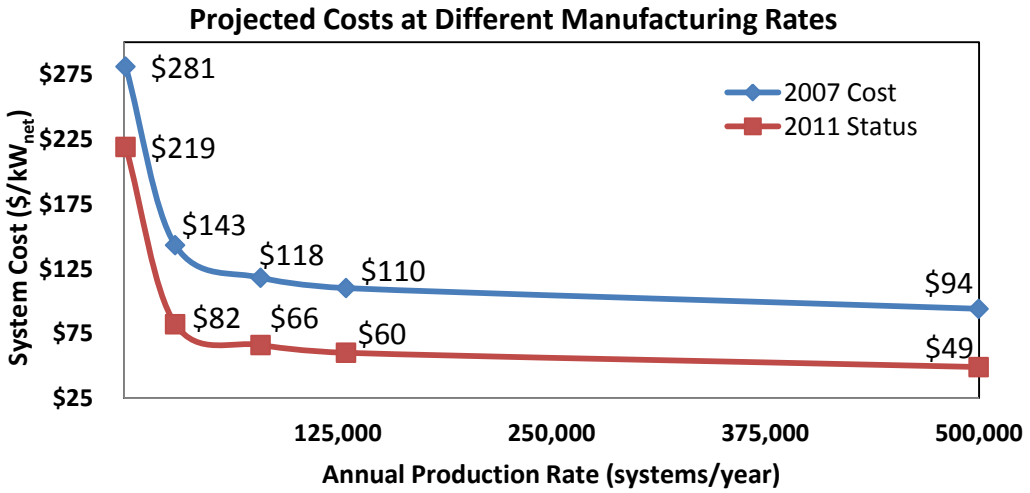
Notes: Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D.
* Due to Recovery Act funding of $42M, Market Transformation activities were deferred. Education projects were funded with FY10 appropriations.

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.*

DOE Funded Accomplishments

Reduced cost of H_2 production (multiple pathways)

Vehicles & infrastructure

- 170 fuel cell vehicles, 25 hydrogen stations
- > 3.4 million miles traveled
- > 146 thousand total vehicle hours driven
- ~ 2,500 hours (nearly 75K miles) durability
- ~ 5 minute refueling time (4 kg of hydrogen)

H_2 fuel cell buses (w/ DOT) have a 42% to 139% better fuel economy when compared to diesel & CNG buses

Projected High-Volume Cost of Hydrogen Production1 (Delivered2)—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

Feedstock variability: $4.00 - $10.00 per MMBtu

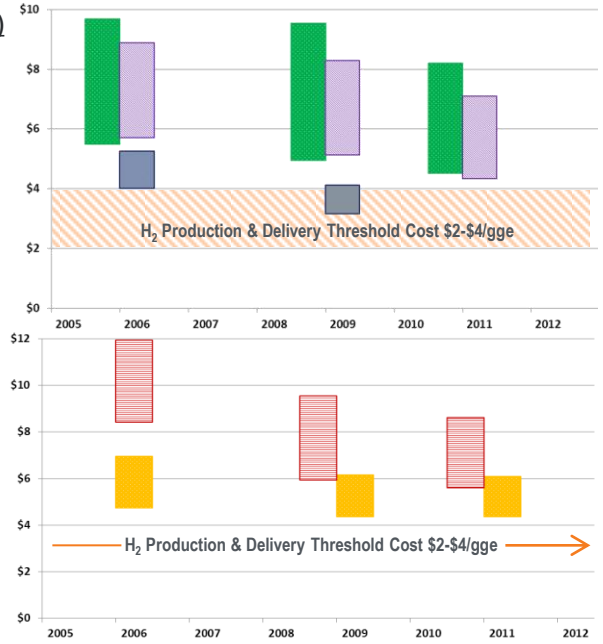
Central Production (longer term)

Electrolysis

Feedstock variability: $0.03 - $0.08 per kWh

Biomass Gasification

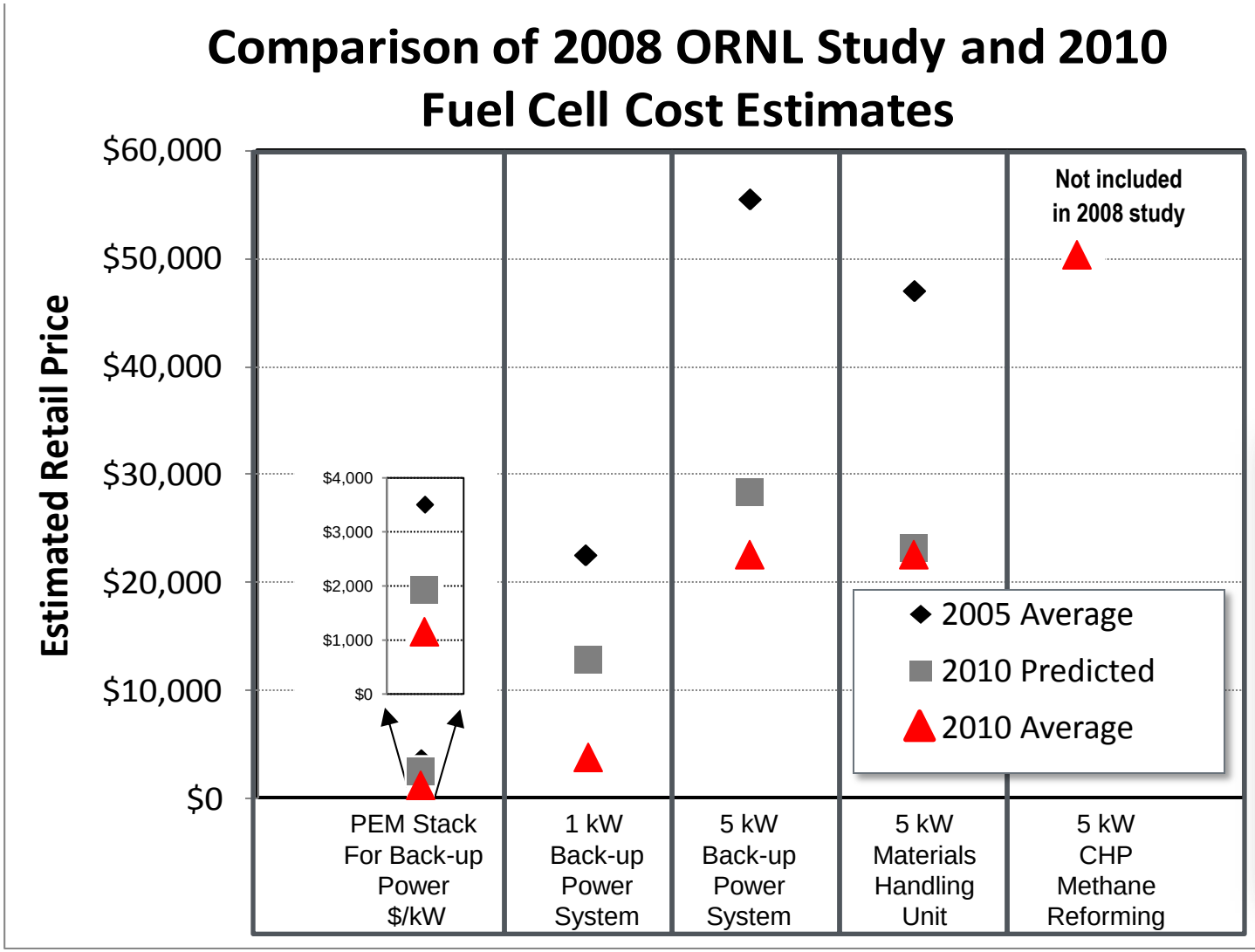
Feedstock variability: $40- $120 per dry short ton



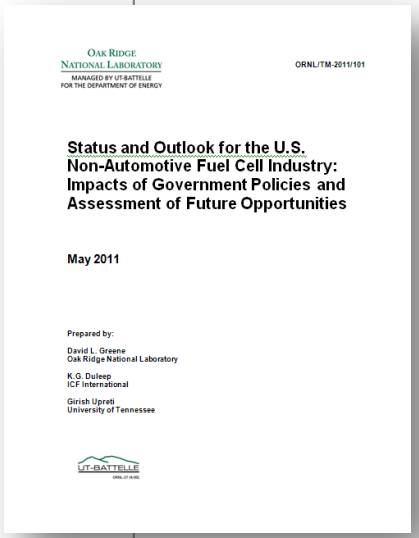
- **Tanks can achieve >250 mile range**
- **Validated vehicle that can achieve 430 mi**
- **Developed and evaluated more than 400 material approaches experimentally and millions computationally**

- **Demonstrated cycle-life of >50,000 refuelings of metal tanks for forklift applications**
- **Developed safety courses, educated >17,000 first responders and code officials through introductory web-based courses and advanced hands-on training**

Early Market Cost Reduction Analysis



- 50% or greater reduction in costs
- 2008 model generally underestimated cost reductions


OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2011/101

Status and Outlook for the U.S. Non-Automotive Fuel Cell Industry: Impacts of Government Policies and Assessment of Future Opportunities

May 2011

Prepared by:
David L. Greene
Oak Ridge National Laboratory
K.G. Duleep
ICF International
Girish Upreti
University of Tennessee

UT-BATTELLE

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

2005 and 2010 averages based on estimates supplied by OEMs. 2010 predicted assumed government procurements of 2,175 units per year, total for all market segments. Predictions assumed a progress ratio of 0.9 and scale elasticity of -0.2.

ORNL

RFI: Total Cost of Ownership for Future Light-Duty Vehicles

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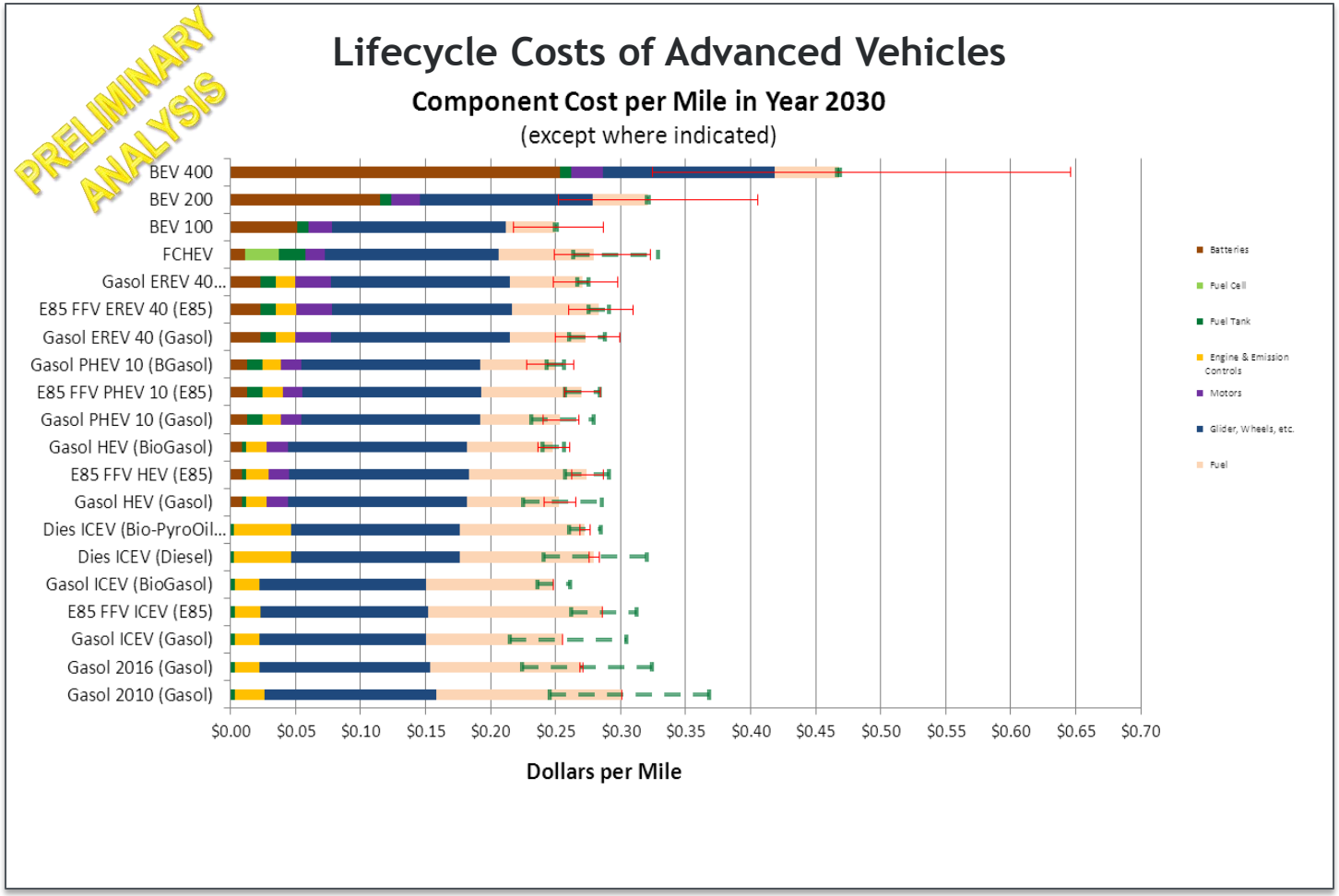
RFI Closes: December 16, 2011

For Questions, Email: TCORFI@go.doe.gov

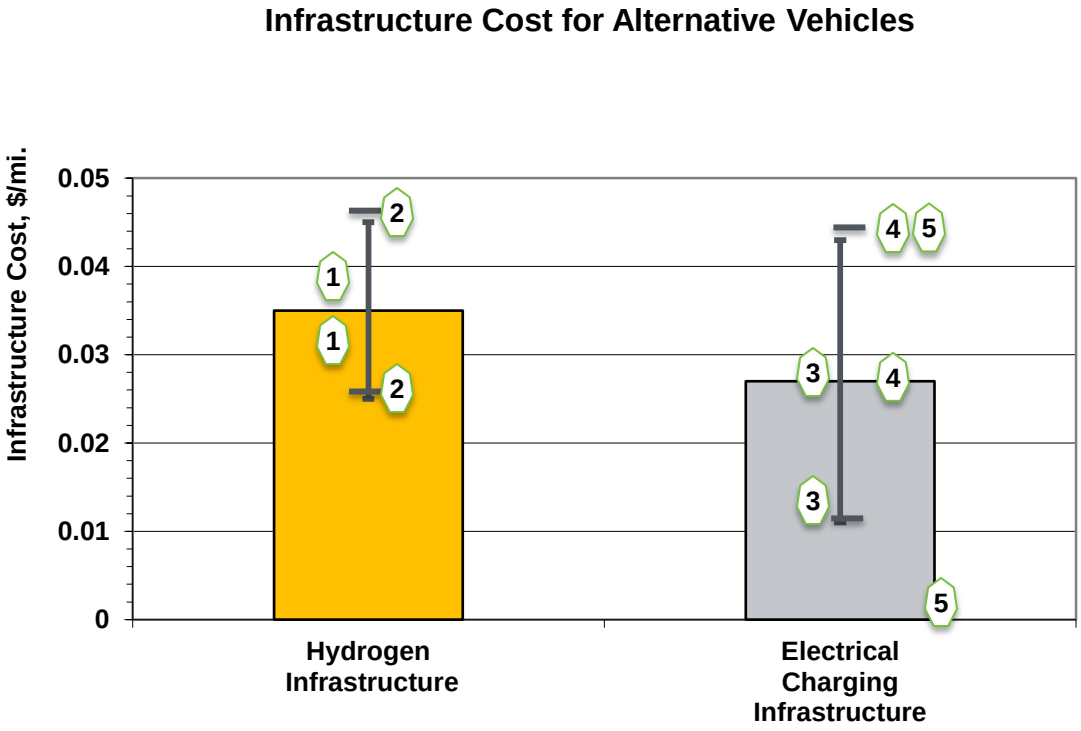


Feedback is requested on:

- The assumptions (aggressive, moderate or conservative levels of success for various technologies).
- The projection of cost reduction rates for technologies that are not yet fully commercial.
- The general financial analysis approach used.

Error bars include fuel price volatility (green) and different assumptions for technology success (red) (2030 timeframe)

Infrastructure is a Key Challenge



On a per-mile basis, infrastructure costs for electric-drive vehicles and fuel cell vehicles are comparable

Notes:

1. 2008 NRC study:
   - Low case: H2 cost $4/gge, capital for infrastructure is 40% of H2 cost, 60 mpg
   - High case: $5/gge
2. 2010 EU Mobility study (Automakers/Mckinsey):
   - Low case: $1,400 per car (5,000 H2 fueling stations in 2030, 12,000 in 2040)
   - High case: $2,800 per car (less optimistic technology progress)
3. 2009 NRC study:
   - Low case: $900 (Level 1 home charger, installed)
   - High case: $2000 (Level 2 home charger, installed)
4. 2010 EU Mobility study (Automakers/Mckinsey):
   - Low case: $2,000 (Level 2 home charger, installed)
   - High case: $3,300 (50%/50% mix of home & public chargers)
5. Vehicle Technologies Program:
   - Low case: 0-$700 (Level 1 home charger, without or with installing a dedicated circuit)
   - High Case: $800-$3,300 (Level 2 home charger, without or with panel upgrade)

Natural Gas and Hydrogen Infrastructure Opportunities

Workshop convened industry and stakeholders with expertise in natural gas and hydrogen technologies, vehicle OEMs, CHP, policy, and regulations. The focus of the workshop is to facilitate the growth of natural gas and hydrogen use in the U.S. for transportation and other applications.

Workshop Activities Included:

- Discussion led by plenary speakers and expert panels
- Break-out sessions to identify key questions and resolutions on:
  - R&D Needs
  - Regulatory / Environmental Barriers
  - Innovative Approaches

U.S. DEPARTMENT OF ENERGY

Argonne NATIONAL LABORATORY

Outcomes:

- Summarize the status of natural gas and hydrogen infrastructure
- Identify opportunities and barriers for expanding the infrastructure
- Identify synergies between natural gas and H_2 use
- Identify and prioritize specific actions to address barriers
- Identify the roles of government and industry in promoting growth of natural gas and H_2 infrastructure

Tuesday, October 18th and Wednesday, October 19th 2011
Argonne Facilities, Chicago, Illinois
Organized by the Argonne National Laboratory for the U.S. Department of Energy

"Energy Department Applauds World's First Fuel Cell and Hydrogen Energy Station in Orange County"

"By providing the added value of electricity and heat, this approach provides a significant step in overcoming economic challenges with hydrogen refueling infrastructure."

August 16, 2011

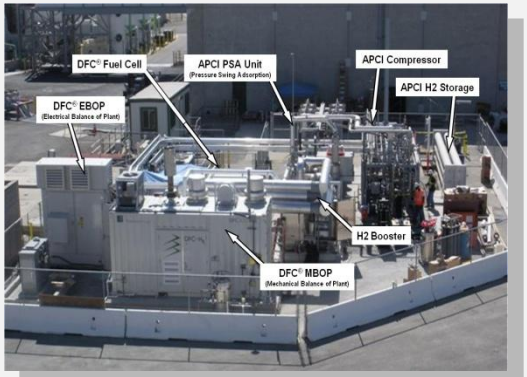
http://apps1.eere.energy.gov/news/progress_alerts.cfm/pa_id=600

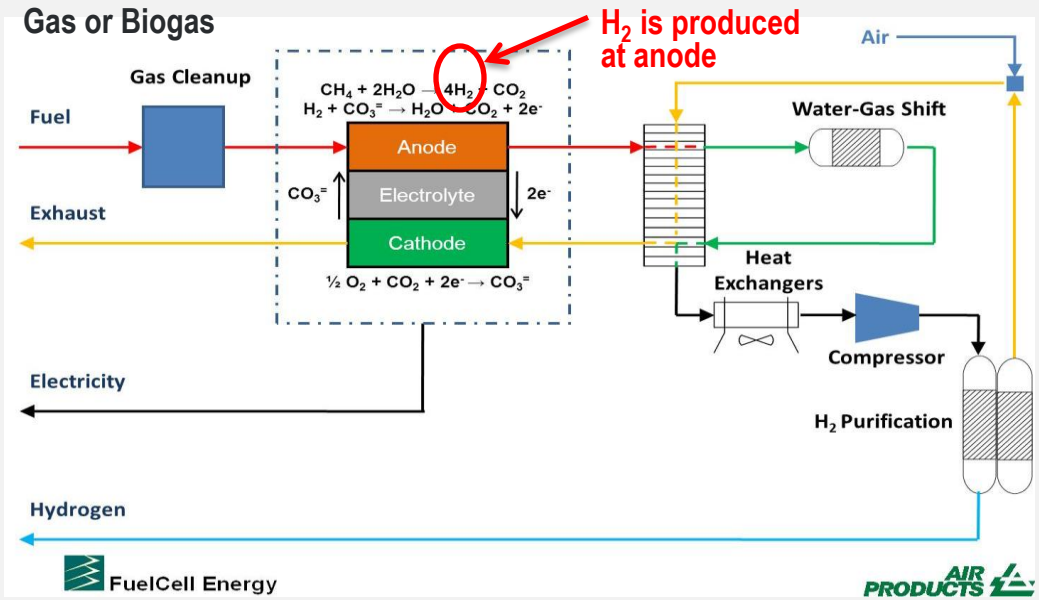
Technology Validation—Tri-Generation

Tri-Generation or Combined Heat, Hydrogen and Power (CHHP) offers opportunities for use of natural gas or waste/biogas

Demonstrated world's first Tri-generation station (CHHP with 54% efficiency)

-Anaerobic digestion of municipal wastewater-





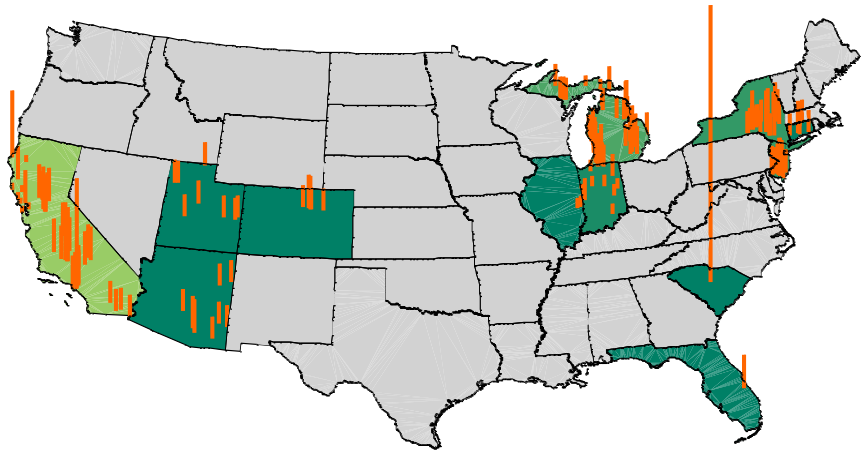
Fountain Valley demonstration

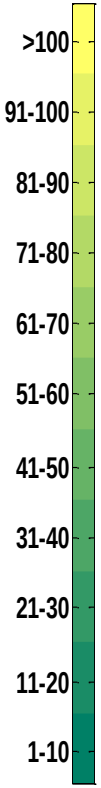
- ~250 kW of electricity
- ~100 kg/day hydrogen capacity (350 and 700 bar), enough to fuel 25 to 50 vehicles.

Backup Power Deployments

Nearly 900 kW deployed at ~200 sites

State	kW Capacity	Sites	State	kW Capacity	Sites
Arizona	40	9	Indiana	46	15
California	304	63	Michigan	148	36
Colorado	24	5	New Jersey	84	21
Connecticut	32	8	New York	116	29
Florida	6	1	South Carolina	50	1
Illinois	4	2	Utah	36	9
Totals	**kW Capacity**	**890**	**Totals**	**Sites**	**199**





Includes ARRA and DOE Interagency Agreement (IAA) Deployments

Tracked by NREL

NREL cdp_bu_03
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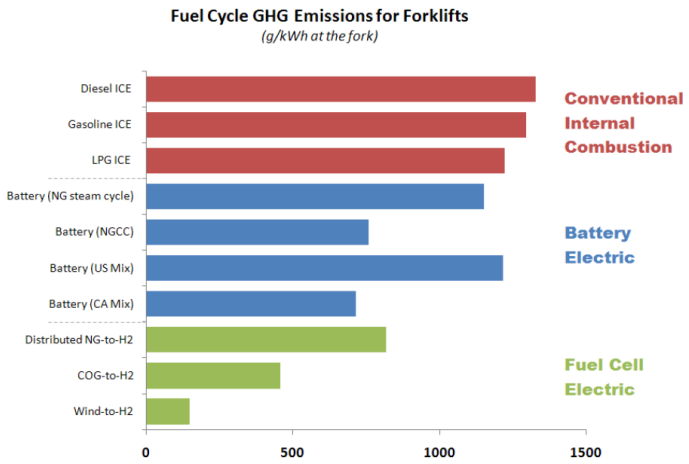
ARRA as Catalyst for Deployments

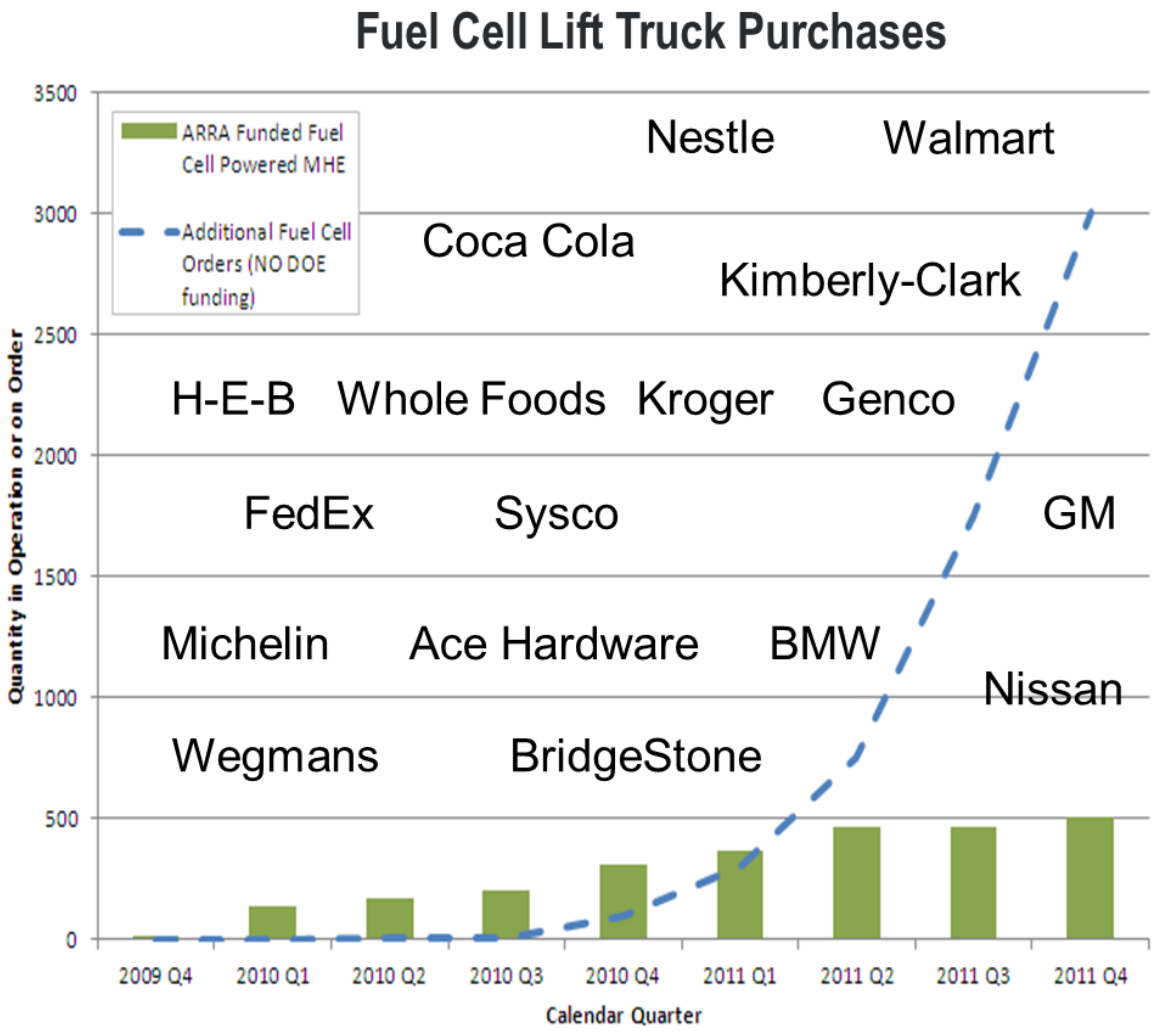
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

ARRA deployments of fuel cells for lift trucks (~400) led to industry purchases of an estimated >3,000 additional fuel cell lift trucks* with NO DOE funding

The Case for Forklifts**
Compared to conventional forklifts, fuel cell forklifts have:

- **1.5 X lower maintenance cost**
- **8 X lower refueling labor cost**
- **2 X lower net present value of total system cost**





** Based on estimates of industry orders and purchases*

***Preliminary Analysis*

Federal Policies Promoting Fuel Cells

Grants for Energy Property in Lieu of Tax Credits	Grant instead of claiming the Investment Tax Credit or Production Tax Credit. Only entities that pay taxes are eligible. (1603)	Construction must begin by expiration date, 12/31/2011.
Investment Tax Credit	30% tax credit for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity. 10% credit for CHP-system property.	Equipment must be installed by Dec. 31, 2016.
Alternative Fuel Infrastructure Tax Credit	30% of expenditures. $30,000 maximum.	Expires 2/31/2014.

Fuel Cell Motor Vehicle Tax Credit: $4,000 for LDV, $10,000-$40,000 range for heavier vehicles. Expires 12/31/2014.

Hydrogen Fuel Excise Tax Credit: $0.50/gallon. Hydrogen must be sold or used as a fuel to operate a motor vehicle. Expires 9/30/2014.

Alternative Fuel Infrastructure Tax Credit: $1,000 cap for residential use.

Residential Renewable Energy Credit: Fuel Cell maximum - $500/0.5kW. Fuel cells must have electricity-only generation efficiency greater than 50% and 0.5kW minimum.

Residential Renewable Energy Credit: 30% tax credit. Raises ITC dollar cap for residential fuel cells in joint occupancy dwellings to $3,334/kW. Expires 12/31/2016.

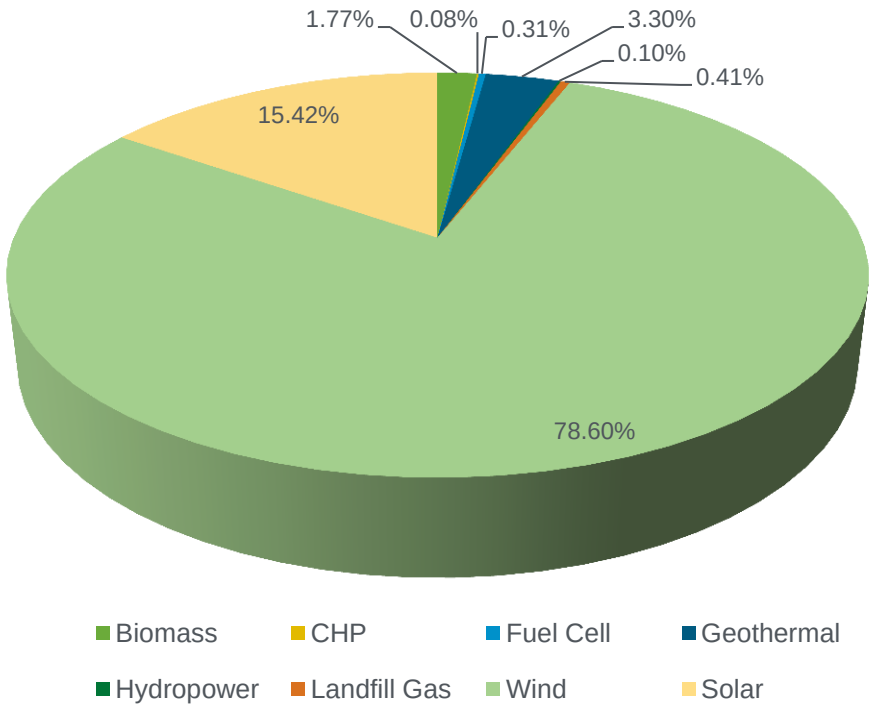
Recent Federal Grants

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

Over $25 million in federal grants supporting fuel cell technologies.

1603 is set to expire 12/31/2011.

Section 1603: Payments for Specified Energy Property in Lieu of Tax Credits			
Business	**State**	**Business**	**State**
Adobe Systems Incorporated	CA	Martin-Bower Company, LLC	CA
Barloworld Handling LLC	IL	Odwalla, Inc.	CA
Bloom Energy 2009 PPA Project Company	CA	Plug Power, Inc.	IL
Bloom Energy 2009 PPA Project Company, LLC	CA	Preservation Properties, Inc.	CA
Earp Meat Company	IL	Renewable Energy Holdings, LLC	NJ
FirstEnergy Solutions Corp	OH	Semiconductor Corporation	CA
Gills Onions, LLC	CA	Somerset Leasing Corp IV	IL
Logan Energy Corporation	HI	Somerset Leasing Corp IV	SC
Logan Energy Corporation	SC	US FoodService, Inc.	CA
M&L Commodities, Inc.	CA		
Totals		**~ $27M**	



Less than 0.5% of 1603 grants given to fuel cell companies.

Table Source: US DOE & US Treasury 10/2011

DOD Emergency Backup Power

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

DOE funded 18 fuel cell backup power systems at 10 installation sites will help accelerate the deployment of clean technology at Federal government facilities and provide valuable data and feedback for fuel cells.

Military Installations

- Fort Hood, TX
- Fort Bragg, NC
- The U.S. Military Academy at West Point, NY
- Aberdeen Proving Ground, MD
- Picatinny Arsenal, NJ
- Cheyenne Mountain Air Force Base, CO
- U.S. Marine Corps Air Ground Combat Center 29 Palms, CA
- The Ohio National Guard, Columbus, OH
- NASA Ames Lab, Ames, CA
- Argonne National Lab, Chicago, IL

Conducted under DOD-DOE MOU signed in July 2010

Telecom Market	
Domestic	>200,000 cell towers
India	250,000-450,000 tower (3 yrs)
Developing Markets	~80% increase over 3 yrs

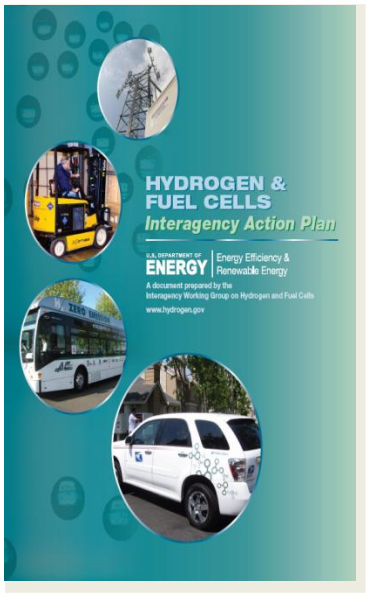
First of its kind fuel cell deployments across multiple civilian and military agencies with third party financing.

U.S. Army Construction Engineering Research Lab is managing the installation & data collection.

DOE and Interagency Activities

Developed Interagency Action Plan- integrated plan for coordinating U.S. federal agency efforts hydrogen and fuel cells RDD&D

Held High-Level Interagency Task Force Meeting across 10 Agencies.



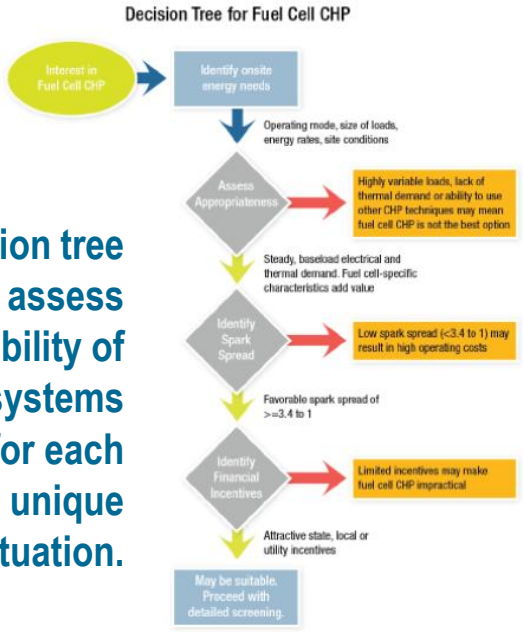
Goals

1. Strengthen and Accelerate Research and Development
2. Accelerate Development & Adoption of Codes, Standards & Safe Practices
3. Work with Industry to Validate Technologies under Real-World Conditions
4. Adopt Technologies in U.S. Government Operations
5. Track and Communicate Results

Developed Procurement Guide (ORNL)

Provides clear guidance on CHP technology – its benefits, ideal usage, and financing options.

Decision tree to help assess feasibility of CHP systems for each unique situation.

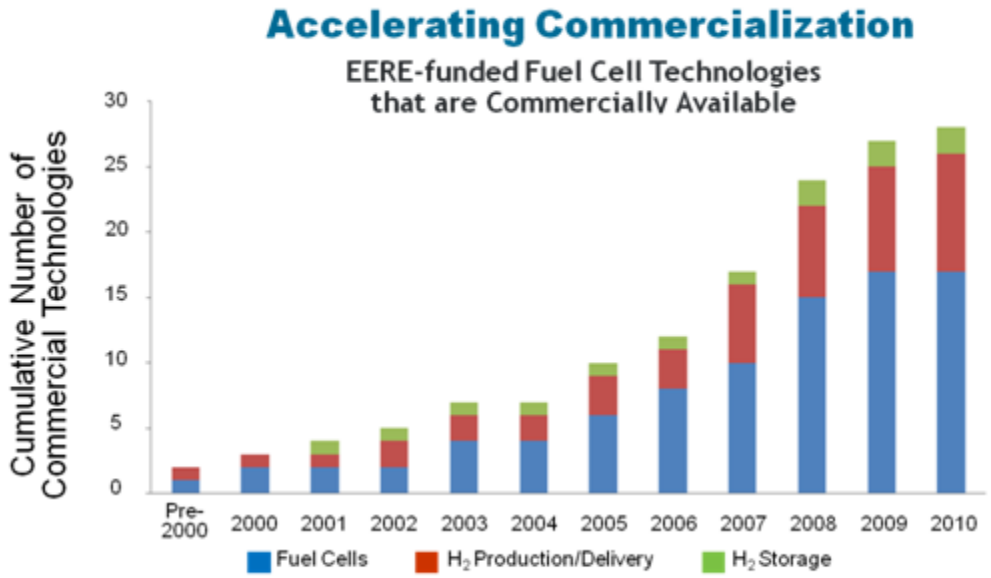


Assessing the Impact of DOE Funding - *Commercializing Technologies*

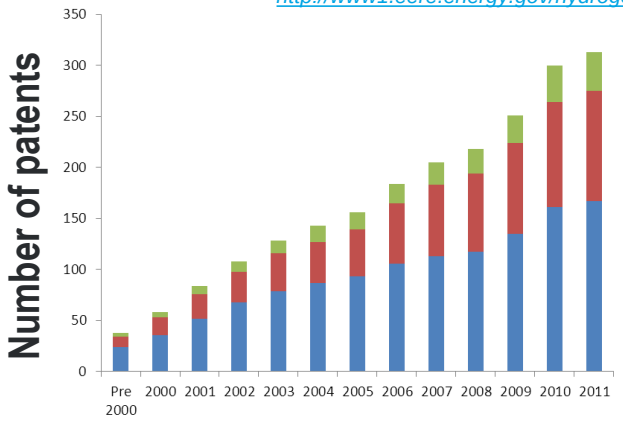
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

DOE-EERE funding enabled >310 patents, ~ 30 commercial technologies, and > 60 emerging technologies.

~$70M in DOE-EERE funding has led to nearly $200M in industry investment and revenues.



Source: Pacific Northwest National Laboratory
http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pathways_success_hfcit.pdf



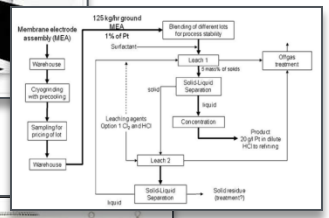
>310 PATENTS resulting from EERE-funded R&D:

- *Includes technologies for hydrogen production and delivery, hydrogen storage, and fuel cells*

Examples

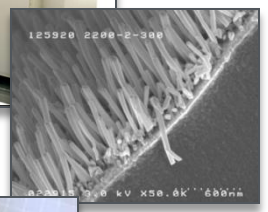
DuPont

BASF Catalysts LLC

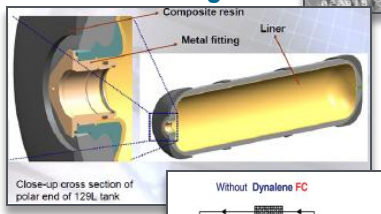


Proton On Site

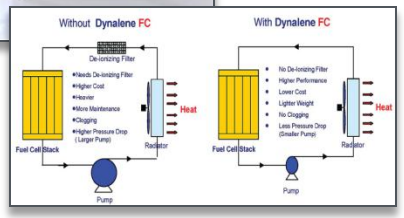
3M



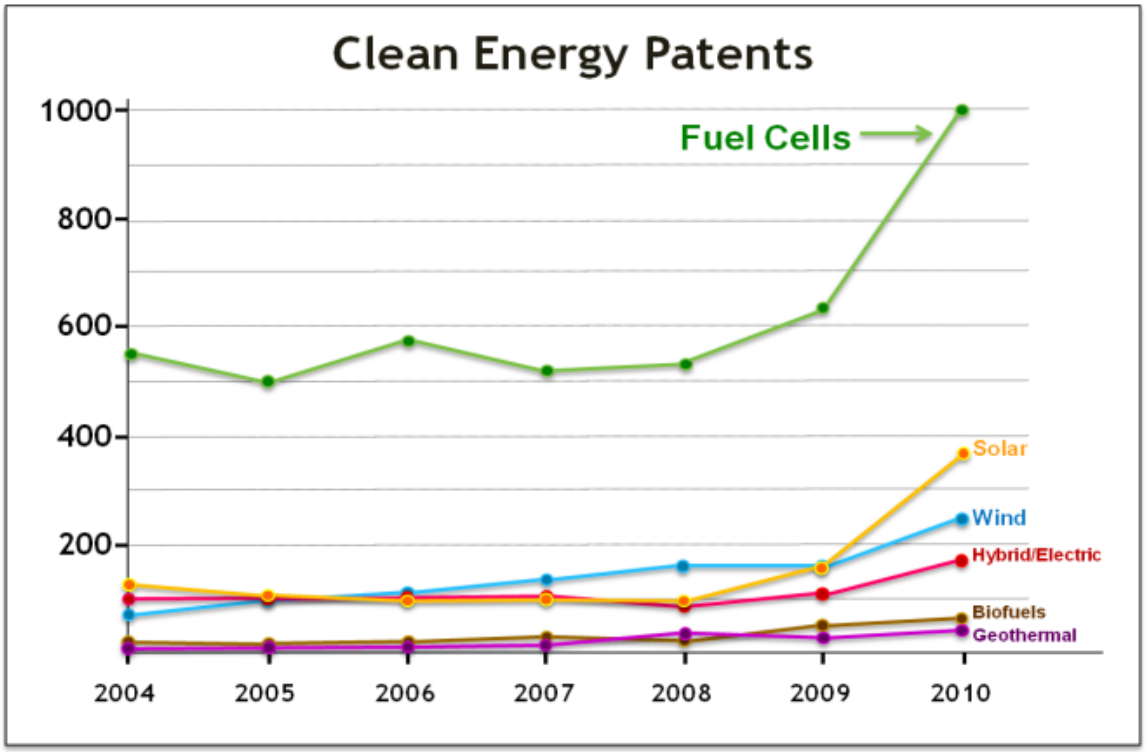
Quantum Technologies



Dynalene, Inc.



Fuel Cell Patents Reflect Emerging Growth



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, which has just ~360 patents.**
- **Number of fuel cell patents grew > 57% in 2010.**

[1} 2010 Year in Review at: http://cepgi.typepad.com/heslin_rothenberg_farley_/

Communication & Outreach

Published more than 70 news articles in FY11 (including blogs, progress alerts and DOE FCT news alerts)

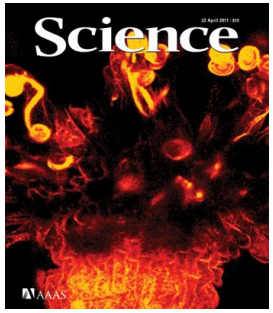
Communication and Outreach Activities include:

- Webinar Series:
  - Series of informational webinars led by FCT and partners on various topics including: Hydrogen Fuel Cells in your Area, Local Green Policies, Mobile Lighting
- MotorWeek: PBS to air a fuel cell episode in October 2011
- H_2 Student Design Contest: Registration closes November 15, 2011
- Portland Community College: Installed 1st of 38, 5KW units.
- New Awards: Nearly $7 Million - Fuel Cell and Hydrogen Storage Cost Analysis
- Jobs tool developed, ANL (Beta testing, this year)

Blogs Published to Energy.gov website include:

- Fuel Station of the Future
- Shuttle Launch

"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."



Progress in low and zero Pt catalysts highlighted in Science

Hydrogen fuel cells providing critical backup power

Hydrogen power lights at the space shuttle launch

2012 Hydrogen Student Design Contest

The Hydrogen Education Foundation's Hydrogen Student Design Contest
www.HydrogenContest.org
Supported by the U.S. Department of Energy

2012 Partners and Supporters

Challenge: Design a Combined Heat, Hydrogen and Power (CHHP) System for Your University Campus Using Local Resources

Sections: Contest addresses resource assessment, technical design, end use analysis, environmental analysis, economic analysis and business plan, as well as marketing and public education.

Outreach:

- 25,000++ stakeholders in the hydrogen industry
- 1000+ professors and students, incl. 50 top engineering schools in the U.S.

Timeline

November 4, 2011 – Webcast on Rules & Guidelines w/ CHHP Experts

November 15, 2011 – Abstract Deadline

June 3-7, 2012 – Winner presents at WHEC 2012 Conference in Toronto, CAN

DOE FY12 SBIR Funding Opportunity

New Phase I Topic:

- Two-phased topic release
  - Release 1 topics from DOE's Science Programs
  - Release 2 topics from DOE's Applied Programs

- Science Programs
  - Issued 8/1/2011
  - Closed 9/19/2011

- Applied Programs *(will include FCT topics)*
  - Pre-release topics on 11/1/2011 on SBIR website
  - FOA posted 11/28/2011 on FedConnect
  - ***Applications due 1/19/2012***

New elements: LOI required and emphasis on commercialization plan

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

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

International

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

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

Thank You

DOE Annual Merit Review: May 14 – 18, 2012

Arlington, VA

http://annualmeritreview.energy.gov/