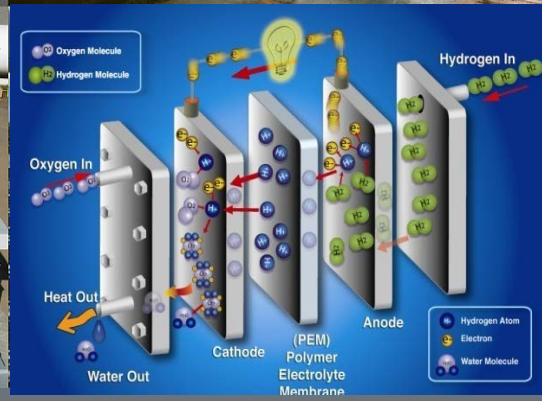
Fuel Cell Technologies Update

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



HTAC Meeting
Washington, DC
11/15/2012

Dr. Sunita Satyapal
U.S. Department of Energy
Fuel Cell Technologies Program
Program Manager

Agenda

Summary of Program Activities and Highlights since previous HTAC update (May, 2012)

- Program Update
  - Recent Accomplishments
  - Analyses, Communication and Outreach
- HTAC Input- Examples
  - Hydrogen Production Expert Panel
  - H-Prize
- Additional Information
  - Budget summary
  - Workshop examples (manufacturing)
  - Funding Opportunity Announcements

Update and Discussion with Assistant Secretary, EERE

Growth in Worldwide Investment and Markets

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Interest in fuel cells and hydrogen is global, with more than $1 billion in public investment in RD&D annually. Revenues, investment and patents are increasing.

Activity by Key Global Players

Japan: **$242 million in FY12, $400 million requested for FY13** (~$1.0 Billion in funding for FY08–FY12);

- Nearly 30,000 residential fuel cells deployed (40,000 by April 2013)
- Plans for 2 million FCEVs and 1000 H_2 stations by 2025 (100 stations by 2015)

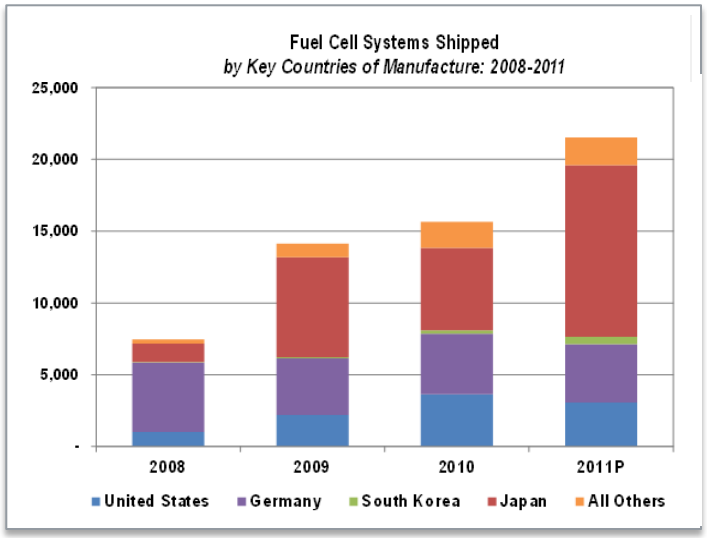
Germany: >$1.2 Billion in funding (’07 – ’16)

- plans for 1,000 hydrogen stations
- >22,000 small fuel cells shipped.

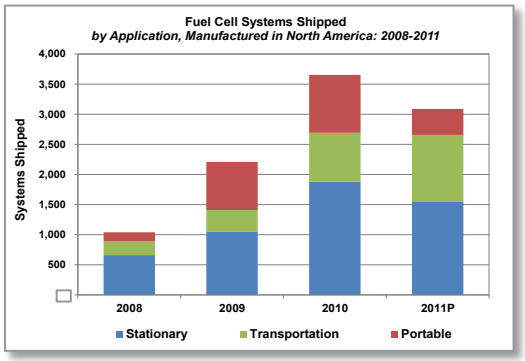
European Union: >$1.2 Billion in funding (’08–’13)

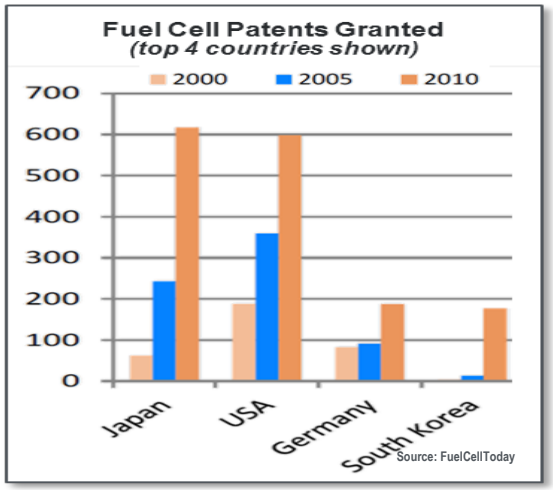
South Korea: ~$590 M (‘04-’11); plans to produce 20% of world shipments and create 560,000 jobs in Korea

China: Thousands of small units deployed; 70 FCEVs, buses, 100 FC shuttles at World Expo and Olympics



Worldwide fuel cell markets continue to grow (>20,000 units shipped in 2011; >35% increase over 2010), but North American shipments slipped by ~15% in 2011.

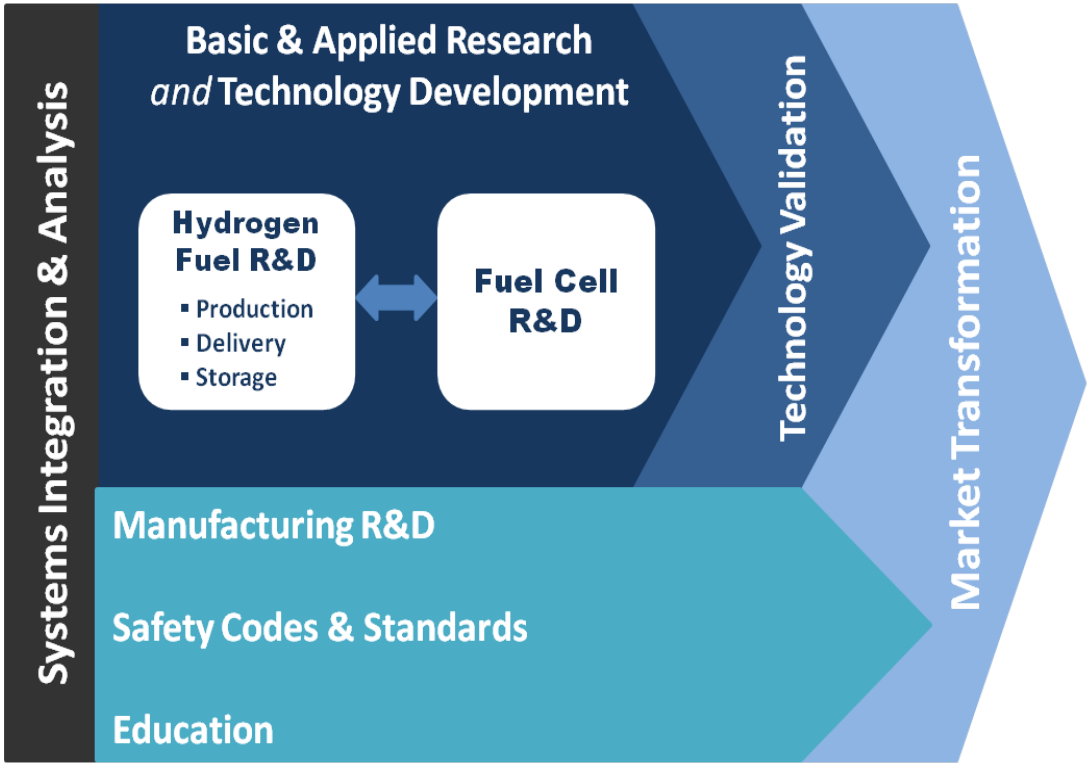




Rapid growth in number of patents filed by Japan, Korea, Germany, U.S.

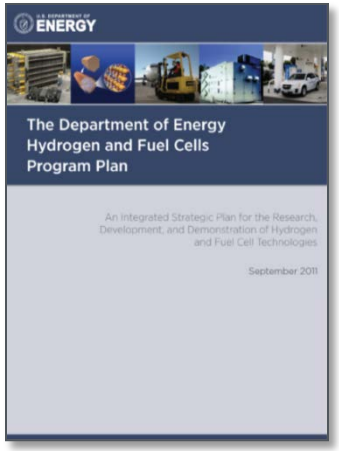
DOE Program Overview

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



DOE Hydrogen and Fuel Cells Program Plan (revised 2011)
Includes Four DOE Offices EERE, FE, NE and Science
Significant HTAC & stakeholder input provided

Nearly 300 projects currently funded at companies, national labs, and universities/institutes

Summary of DOE Activities:
RD&D to Deployments

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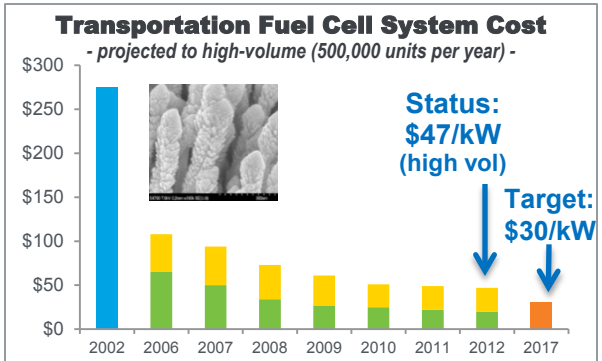
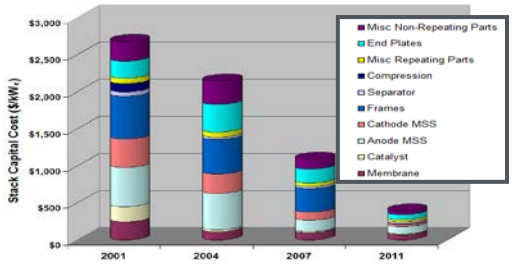
DOE R&D

- *Reduces cost and improves performance*

Examples of progress:



→ *Reduced cost of fuel cells 35% since 2008, 83% since 2002*



→ *Reduced cost of electrolyzer stacks 60% since 2007*

DOE Demonstrations & Technology Validation

- *Validate advanced technologies under real-world conditions*
- *Feedback guides R&D*

Completed **world's largest** single FCEV demonstration >180 FCEVs, 25 stations, 3.6 million miles

Examples—validated:

- *59% efficiency*
- *254 mile range (independently validated 430-mile range)*
- *75,000-mi durability*

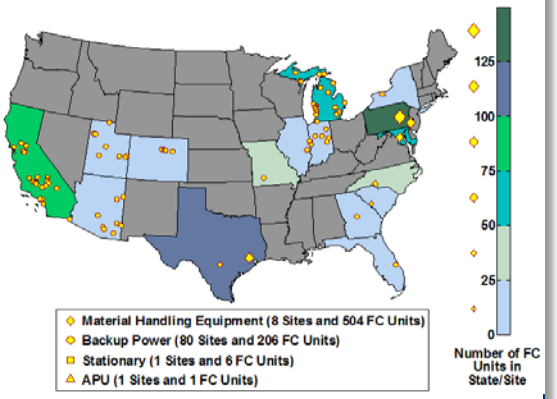
Demonstrated **world's first tri-gen** station (250 kW on biogas, 100 kg/d)

Program also includes enabling activities such as codes & standards, analysis, and education.

Deployments

- *DOE Recovery Act Projects*
- *DOE Loan Guarantees (TBD)*
- *Government Early Adoption (DoD, FAA, California, etc.)*
- *Tax Credits: 1603, 48C*

Recovery Act & Market Transformation Deployments



> 1,000 fuel cells deployed (exceeded Recovery Act goal)

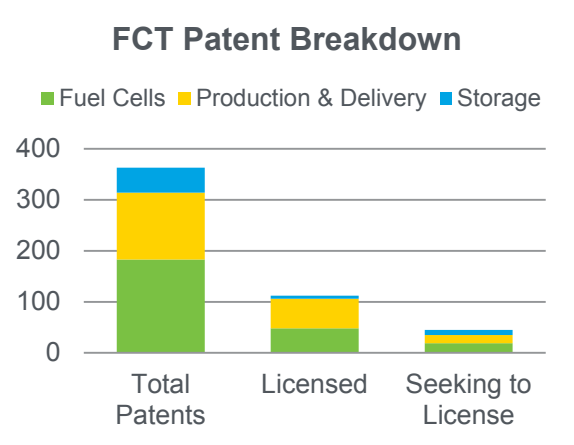
Summary: Program Impact

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

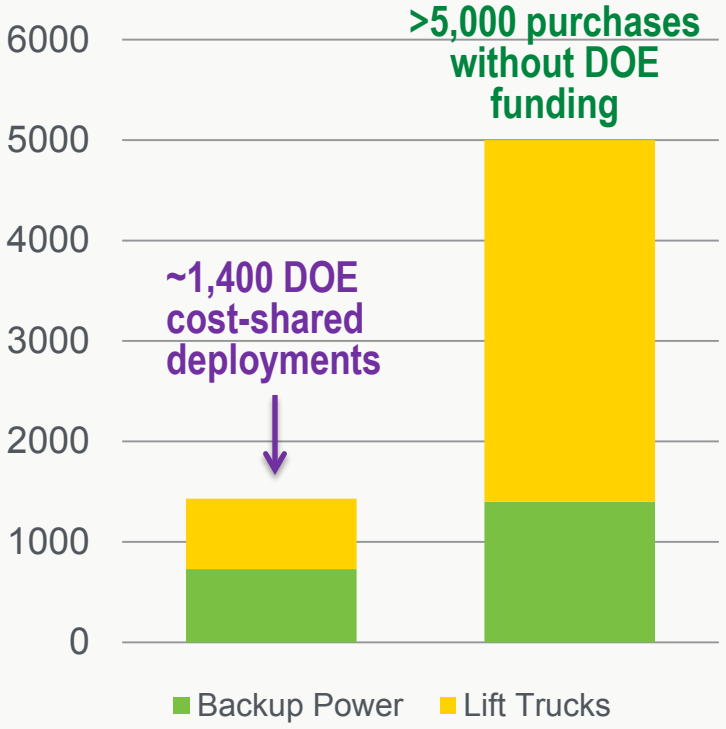
DOE FCT funding has led to 363 patents, 35 commercial technologies and 65 emerging technologies. Example of Impact: ~$70M in funding for specific projects was tracked – and found to have led to nearly $200M in industry investment and revenues.

DOE FCT funding has enabled:

- > 80% cost reduction in PEM fuel cells since 2002, > 35% since 2008
- Reduction in Pt by a factor of 5 since 2005
- > Double the durability since 2006
- > 80% cost reduction in electrolyzer stacks in the last decade



Leveraging DOE funds: Early market deployments of ~1,400 have led to >5,000 additional purchases by industry with ***no*** DOE funding.



*DOE cost-shared deployments led to **>3X** additional purchases.*

Recovery Act and Market Transformation – Government as "catalyst" for market success of emerging technologies.

Communication & Outreach

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

Published more than 70 news articles this year (including blogs, progress alerts, DOE news alerts)

- ***Assistant Secretary and Secretary Participation at Events***
  - Senate Caucus, FC Summit, Auto Round Table, HPEP Kick-off
- ***Monthly Webinar Series***
  - Jobs Tool
  - R&D advances
  - Register at - http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html

We are requesting topics for future webinars and value your input!

- ***News Items***
- Energy Department Announces up to $2.5 Million to Deploy Fuel Cell Powered Baggage Vehicles at Commercial Airports (April 25, 2012)
- Energy Department Awards More than $5 Million to Reduce Cost of Advanced Fuel Cells (March 27)
- ***Monthly Newsletter***
- Visit the web site to register or to see archives (http://www1.eere.energy.gov/hydrogenandfuelcells/newsletter.html)

"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."

Hydrogen fuel cell power lights at the 2011 Golden Globes

Developed education materials and educated >9,600 teachers on H_2 and fuel cells, >23,000 code officials and first responders to date.

Hydrogen fuel cell powered light tower at Space Shuttle launch

Open Energy Information - Example

OpenEI | OPENENERGYINFO

Wiki | Apps | Datasets | Community | Linked Data

Browse | Page Actions | View | Get Involved | Help

Gateway | Edit

Hydrogen

From Open Energy Information

HyDRA

Hydrogen Dem... Assessment To...

Reports

Sandia Report: Te... Hydrogen Compat...

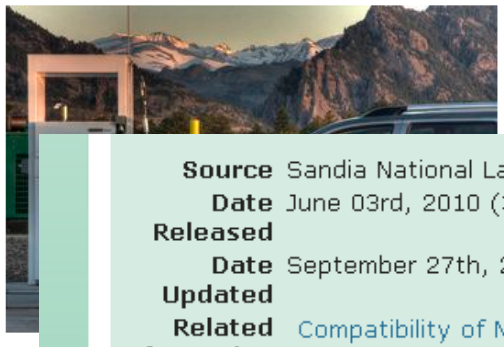
National Fuel Cell ... Demonstration Fin...

Related Links

- List of Hydrogen Ince... hydrogen related poli... be sorted by state an... provided by DSIRE.
- Controlled Hydrogen F... Demonstration and Va...
- Link to the Technical ... Compatibility of Mater...
- Hydrogen Fuel Initiati...
- Link to the Hydrogen ... information, data, an...

<-- Back to Hydrogen Gateway

Technical Reference for Hydrogen Compatibility of Materials



Guidance on materials selection for hydrogen service is needed to support the deployment of hydrogen as a fuel as well as the development of codes and standards for stationary hydrogen use, hydrogen vehicles, refueling stations, and hydrogen transportation. Materials property measurement is needed on deformation, fracture and fatigue of metals in environments relevant to this hydrogen economy infrastructure. The

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Source Sandia National Laboratories

Date Released June 03rd, 2010 (3 years ago)

Date Updated September 27th, 2012 (3 weeks ago)

Related Information Compatibility of Materials | hydrogen | NREL | Sandia | Technical Database | Technical Reference

Data
- 1100_cia85_ten_fra_fat.xlsx (xlsx, 60.9 KiB)
- 1100_san10_fra_fat.xlsx (xlsx, 58.5 KiB)
- 1100_san10b_fra_fat.xlsx (xlsx, 59.4 KiB)
- 1100_san11_fra_fat.xlsx (xlsx, 48.4 KiB)
- 1100_san11b_fra_fat.xlsx (xlsx, 48 KiB)
- 1211_nib10_fra_fat.xlsx (xlsx, 56 KiB)
- 1211_san11_fat.xlsx (xlsx, 58.4 KiB)
- 3230_san11_fra_fat.xlsx (xlsx, 48 KiB)

Other Metadata accessible through RDF/XML

Temporal and Spatial Coverage

Frequency

Time Period

Comments

500,000

Renewa...

Expand this visualizatio...

The US Energy In...

read more

What links here | Relate...

For more information, visit:
http://en.openei.org/wiki/Main_Page

H-Prize Summary

- $1 million prize from the storage H-Prize remains available for future competitions
  - Meter topic discussed at previous HTAC as option
    - Information received through RFI and other sources
    - FOA/grant may be more appropriate mechanism for meter
  - Investigating other potential topics
    - Small-scale waste-to-hydrogen (compost, trash, etc.)
    - Open to HTAC and stakeholder input and other ideas

- Potential Future Prizes: "Transformational Technologies" Category
  - For hydrogen distribution or production that meet or exceed far-reaching objective criteria, with minimal carbon emissions
  - Prize authority is a lump sum of at least $10 million + matching funds
  - Topics discussed include Hydrogen Campus, launching fueling stations for FCEV rollout, and low cost/low emission hydrogen production for infrastructure

Contact Sarah Studer at sarah.studer@ee.doe.gov

H_2 Expert Panel Workshop

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

Held 10-12th May 2012 in Arlington VA: Event featured kick-off by U.S. Secretary of Energy Steven Chu

EXPERT PANEL GOALS

- **EVALUATE** the status and prospects for hydrogen production, quantifying supply and demand in current markets and in possible future scenarios (energy, transportation, chemicals and fuels, etc.)
- **IDENTIFY** the key technologies and critical challenges in producing hydrogen for today's markets, and for large-scale central and distributed renewable production
- **PRIORITIZE** research and development needs to advance promising hydrogen production technologies
- **STRATEGIZE** on how to best leverage R&D efforts in hydrogen production among DOE Offices and Programs (including EERE-FCT, SC, ARPA-E and the Innovation Hubs), and with other agencies

WORKSHOP PROCESS

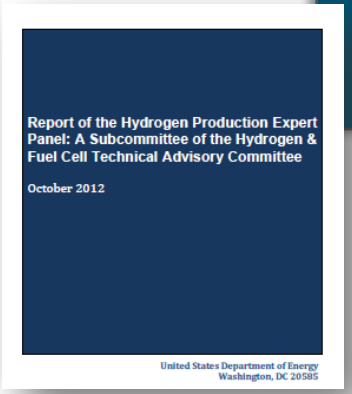
Panel Steering Committee with broad spectrum of expertise oversees workshop flow and report generation

Panel Technical Experts present on opportunities and challenges in near-term to long-term H_2 production technologies

Breakout sessions of Panelists and invited stakeholders identify key challenges and research priorities in near- and long-term technologies

✓ **Report Approved by HTAC on 9/05/2012, and submitted to the Secretary of Energy on 10/29/2012**

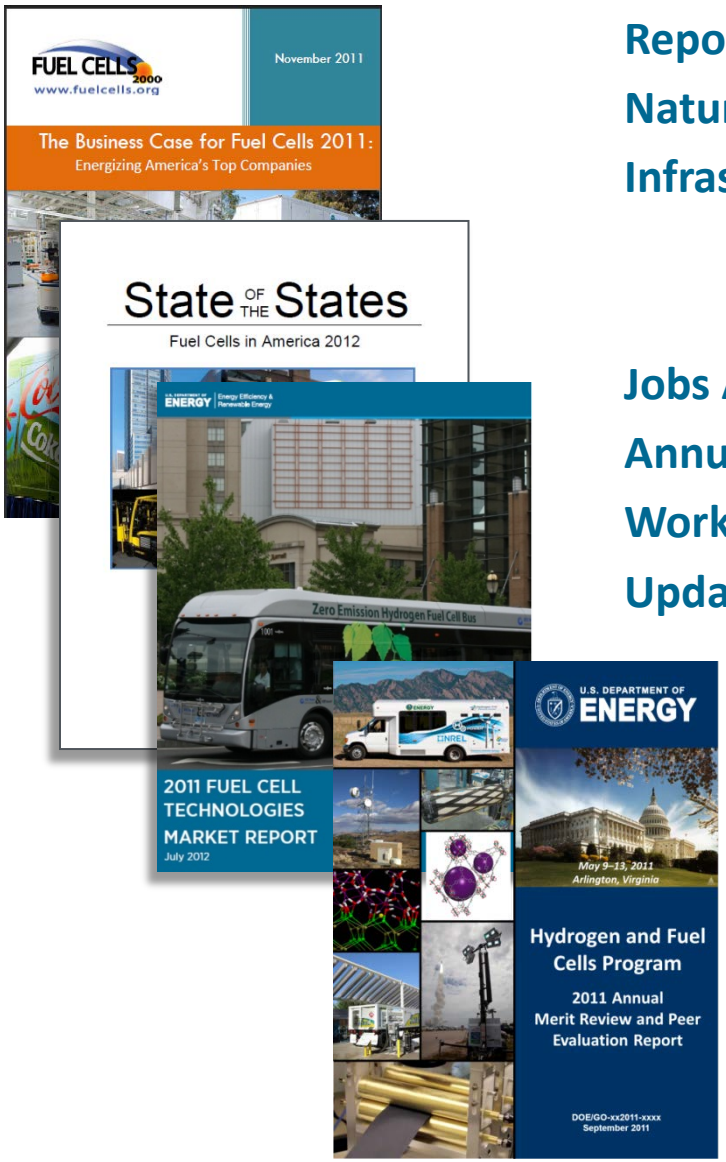
	HPEP Chair: Dr. Levi Thompson, University of Michigan	
	Near Term Technologies	*Longer Term Technologies*
Steering Committee	*Proton OnSite*	*Air Liquide*
	Air Products & Chemicals, Inc.	*The Earth Institute - Columbia University*
	Aretê Corporation	*University of Colorado Boulder*
	Hydrogenics Corporation	*University of Oregon*
Technical Expert Presenters	*Proton Onsite*	*Sun Catalytix*
	Air Products & Chemicals, Inc.	*California Institute of Technology*
	Hydrogenics Corporation	*Pennsylvania State University*
	Air Liquide	*National Renewable Energy Laboratory*
	FuelCell Energy	*Pacific Northwest National Laboratory*
	Nuvera Fuel Cells	*University of Colorado Boulder*



Recommendation Examples

- Examples of HPEP Recommendations and Implementation
  - "Strategies should be developed to establish and maintain effective communications between BES, EERE, and ARPA-E"
  - DOE-wide Fuel Cells "Tech Team" is being established
    - EERE, ARPA-E, Office of Science (Basic Energy Sciences), Fossil Energy
    - Examples of proposed activities
      - Assessment of gaps, additional needs, potential workshops/RFIs
      - Technology & project coordination
      - Sharing best practices, active project management
      - Assessment of relevant diagnostics and capabilities as well as gaps
      - Development and sharing of technical targets, metrics
      - Strategic portfolio development (basic vs applied R&D- e.g., alkaline exchange membranes, non-PGM catalysts)
      - Ideas and feedback welcome

Analyses and Reports- Examples



- Report on commercial products, patents
- Natural Gas and H_2 Pipelines Report
- Infrastructure Analysis
  - Northeast Regional Cluster
  - Station Cost Calculator
- Jobs Analysis Tool
- Annual Merit Review & Peer Evaluation Proceedings
- Workshop Proceedings (Biogas, Manufacturing)
- Updates to Multi-Year RD&D Plan (including target updates)

Active Project Management

More than $6M saved through go/no go decisions in FY12

SAVE THE DATE

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

http://annualmeritreview.energy.gov/

Acknowledgements
World Class Researchers - Examples

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

Thank You

Sunita.Satyapal@ee.doe.gov

New energy data initiative to share the latest energy information and data. Please visit:

http://en.openei.org/wiki/Gateway:Hydrogen

hydrogenandfuelcells.energy.gov

DOE Hydrogen and Fuel Cells Budget

	Funding *($ in thousands)*						
	FY 2007 Approp.	FY 2008 Approp.	FY 2009 Approp.	FY 2010 Approp.	FY 2011 Allocation	FY 2012 Approp.	FY 2013 Request
EERE Hydrogen & Fuel Cells	189,511	206,241	195,865	170,297	95,847	101,087	77,850
Fossil Energy (FE)	21,513	14,891	20,151	13,970	11,394	0	0
Nuclear Energy (NE)	18,855	9,668	7,340	5,000	2,800	0	0
Science (SC)	36,388	36,483	38,284	38,053	34,611	~34,611	TBD
DOE TOTAL	**266,267**	**267,283**	**261,640**	**227,320**	**144,652**	**~135,698**	**TBD**

EERE FY 13 House Mark: $82 M

EERE FY 13 Senate Mark: $104 M

SECA House & Senate Mark: $25 M

Notes

Nuclear Energy: In 2010 and 2011, development of HTSE at the Idaho National Laboratory (INL) continued with funding from the NGNP project. Several industry partners now have stack technologies for high temperature steam electrolysis in development. After demonstration of pressurized HTSE stack operation in FY 2012 by INL, the technology readiness is expected to be sufficiently advanced (TRL5) to allow for further development by industry.

EERE: FY 2012 appropriation and FY 2013 request exclude the estimated SBIR/STTR funding.

Budget: FCT Program Key Activities

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Funding *($ in thousands)*					
Key Activity	**FY 2010 Appropriation**	**FY 2011 Allocation**	**FY 2012 Appropriation**	**FY 2013 Request**	**FY 2013 Senate Mark**
Fuel Cell R&D[1]	75,609	41,916	43,556	36,899	31,000
Hydrogen Fuel R&D[2]	45,750	32,122	33,785	26,177	34,000
Technology Validation	13,005	8,988	8,987	4,992	14,000
Safety, Codes and Standards	8,653	6,901	6,893	4,921	5,000
Systems Analysis	5,408	3,000	2,925	2,922	3,000
Manufacturing R&D	4,867	2,920	1,941	1,939	2,000
Market Transformation	15,005	0	3,000	0	15,000
Education	2,000	0	0	0	0
SBIR/STTR	3,703	2,153	2,537	2,150	TBD
Total	$174,000	$98,000	$103,624	$80,000	$104,000

FY 13 House Mark (HFCT) $82M

[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

FY 2012 Senate Mark Language and Impact

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

DOE FCT Program adjusted FY 2012 budget based on Senate Mark language.

Excerpts from Senate Mark Language in the FY 2012 Appropriation

" 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."

" Within the available funds, the Committee recommends funding is provided for Technology Validation focused on passenger vehicle and hydrogen infrastructure applications, hydrogen fuels R&D, and for Market Transformation in early markets."

"Further, the Committee believes fuel cell and hydrogen energy systems for stationary, transportation and other motive, mobile and portable power applications have the potential to enable clean and efficient use of our domestic energy resources. The Committee affirms its support for stable and continued funding for these programs now and in the future."

IMPACT

FY 2012 Request: $100.5 M **FY 2012 Appropriation: $104 M**

Following guidance from the Senate mark language:

- **$1 M was added to the original request for Technology Validation (total $9M)**
- **$3 M was added for Market Transformation (total $3M)**

($33.8 M already planned for Hydrogen Fuels R&D)

Funding Opportunity Announcements (FOAs)

FOAs	$M Planned
Collect Performance Data on Fuel Cell Electric Vehicles	$6.0
Hydrogen Fueling Stations and Innovations in Hydrogen Infrastructure Technologies	$2.4
Fuel Cell Powered Baggage Vehicles at Commercial Airports	$2.5
Fuel Cell Hybrid for Refrigerated Truck Delivery (PNNL)	$0.65
Zero-Emission Cargo Transport Vehicles (VTP)	$10.0
Hydrogen Production Cost Analysis	Up to $1.0

DOE/NREL Hydrogen and Fuel Cells Manufacturing R&D Workshop

- Held 8/11 in Washington, D.C. with reps from industry, academia, lab, and government
- Identified and prioritized needs and barriers to manufacturing
- Outputs support potential FY13 FOA for H_2 & FC Manufacturing R&D

Issue	Votes
PEM Fuel Cells/Electrolyzers BOP: Facilitate a manufacturing group for DOE to expand supply chain.	21
Electrodes: How to apply ink directly to membrane; dual direct coating of CCM; *membrane dimensional change with deposition of current inks (Fuel cell R&D)*	20
PEM Fuel Cells/Electrolyzers BOP: *Develop low cost manufacturing of natural gas reformers (Fuel cell R&D)*	18
Stack Assembly: High volume stack assembly processes: reduced labor, improved automation	15
Quality/Inspection/Process Control: Develop methods of identifying coating defects on a moving web, then rejecting single pieces downstream; defect detection after MEA assembly when defect may no longer be visible; ability to separate materials with defects from rolled goods with minimum production of scrap	15
SOFC: Multi-layer/component sintering	14

http://www1.eere.energy.gov/hydrogenandfuelcells/wkshp_h2_fc_manufacturing.html

PEMFC and SOFC Manufacturing: Status vs. Needs

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PEM Fuel Cells

Current MEA
- Large batch mixing
- Roll-to-roll processes for membrane, electrode, and GDL fabrication
- Decal transfer of electrode to membrane
- Manual assembly of MEA with seals
- Hot pressing

Advancements
- Continuous mixing
- Robotic or roll-to-roll assembly of MEAs with seals
- Direct coating of electrode on membrane
- Hot-roll lamination or improved pressing

Current Stack
- Manual assembly
- Manual leak/performance test

Advancements
- Automated assembly
- Automatic leak/performance test

Current BOP
- Lean manufacturing cells and flow
- Unique components

Advancements
- Standardized designs
- Robotic BOP/system assembly line

Solid Oxide Fuel Cells

Current Cell
- Large batch mixing of powders and slurries
- Single layer tape casting with lamination of layers (planar)
- Batch pressing or extrusion of tubes (tubular)
- Semi-automated coating of electrolyte and cathode (tubular)
- Batch heat treatment and sintering
- Manual assembly of cells with seals
- Manual winding of interconnect wire

Advancements
- Continuous mixing
- Multi-layer tape casting (planar)
- Continuous pressing or extrusion of tubes (tubular)
- Continuous firing and sintering
- Robotic assembly of cells with seals
- Automated winding of interconnect wire

Current Stack
- Manual assembly
- Manual shaping of insulation
- Manual leak/performance test

Advancements
- Automated assembly
- Net-shape or other methods for insulation
- Automatic leak/performance test

Current BOP
- Manual assembly
- Unique components

- Lean manufacturing cells and flow

Advancements
- Standardized designs
- Robotic BOP/system assembly line

Biogas and Fuel Cells Workshop

NREL and EERE held a **Biogas and Fuel Cells Workshop** on June 11-13, 2012 in Golden, Colorado focused on biogas sourced from wastewater treatment plants (WWTP), landfills, and industrial facilities that generate or process large amounts of organic waste, including large biofuel production facilities (biorefineries). The workshop was attended by 58 participants from industry; trade associations; national laboratories; universities; and federal, state, and local government agencies.

Objectives:

1. Discuss current state-of-the-art for biogas and waste-to-energy technologies for fuel cell applications
2. Identify key challenges (technical and non-technical) preventing or delayed the near-term, widespread deployment of biogas fuel cell technologies
3. Identify synergies and opportunities for biogas and fuel cell technologies
4. Develop strategies for accelerating the use of biogas for stationary fuel cell power and/or hydrogen fueling infrastructure for motive power fuel cells

Wastewater biogas clean-up system at the Joint Base Lewis McChord (JBLM), near Tacoma, WA.
As part of a Defense Logistics Agency demonstration project at JBLM, the equipment is used for on-site hydrogen production from wastewater biogas for use in fuel cell-powered forklifts and fuel cell electric vehicles. *Photo from LMI*.

Three types of CHP were addressed: (1) projects that use biogas from WWTP anaerobic digester gas (ADG), (2) projects that use landfill gas (LFG), or (3) projects in industrial facilities that generate or process large amounts of organic waste (e.g., food production).

Participant proposed actions:

What were the top three most valuable outcomes for you at the workshop?

- Biogas, natural gas, hydrogen, and fuel cells are clearly aligned and do not need to be competing platforms
- low natural gas prices could impede utilization of our biogas resources
- leverage resources between the biogas industry and DOE; and learning that the value proposition for biorefineries can be enhanced by hydrogen and fuel cells.

What were the top three items you would like to see addressed?

- Pursue RFS2 renewable credits for hydrogen as a fuel
- Increased retrofitting of ADG or LFG systems that currently flare or waste biogas to make use of biogas for heat/electricity
- Establishment of carbon credits to drive system payback period.
- Study how different biorefinery technologies can benefit from integration with fuel cells and hydrogen
- Establish a joint collaboration with U.S. Department of Agriculture (USDA)

What follow-up actions or next steps would you suggest?

- Promote technology that can be quickly installed at existing facilities to make use of biogas;
- Government solicitation opportunities for ADG and stationary fuel cell power projects;
- Promote use of renewable energy over non-renewable energy (such as natural gas).

Tulare, CA, Municipal Wastewater Treatment Plant with fuel cells and ancillary equipment in foreground

Renewable liquefied natural gas (LNG) from landfill gas plant in Altamont, CA

World's first trigeneration plant at the Orange County Sanitation District's WWTP in Fountain Valley, CA

Collaboration Examples

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 (HTAC)
- National Academies, GAO, etc.

Industry Partnerships & Stakeholder Assn's.

- Tech Teams (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

National Laboratories

National Renewable Energy Laboratory P&D, S, FC, A, SC&S, TV, MN	Sandia P&D, S, SC&S	Lawrence Livermore P&D, S, SC&S
Argonne A, FC, P&D, SC&S	Pacific Northwest P&D, S, FC, SC&S, A	Savannah River S, P&D
Los Alamos S, FC, SC&S	Oak Ridge P&D, S, FC, A, SC&S	Brookhaven S, FC
	Lawrence Berkeley FC, A	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