FUEL CELL TECHNOLOGIES PROGRAM

IPHE – Stationary Fuel Cell Workshop

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

Overview of Hydrogen & Fuel Cell Activities

March 1, 2011

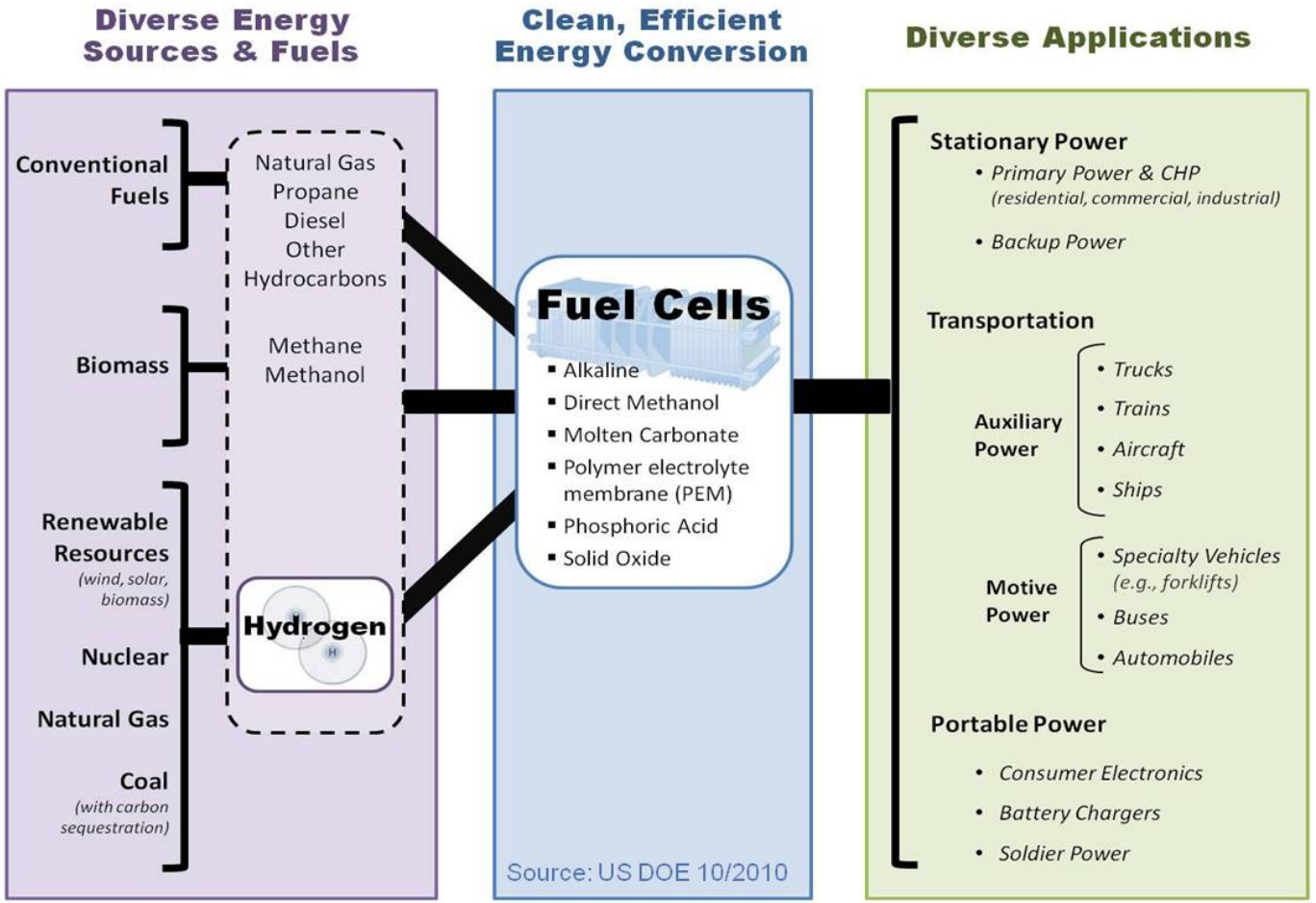
Rick Farmer

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

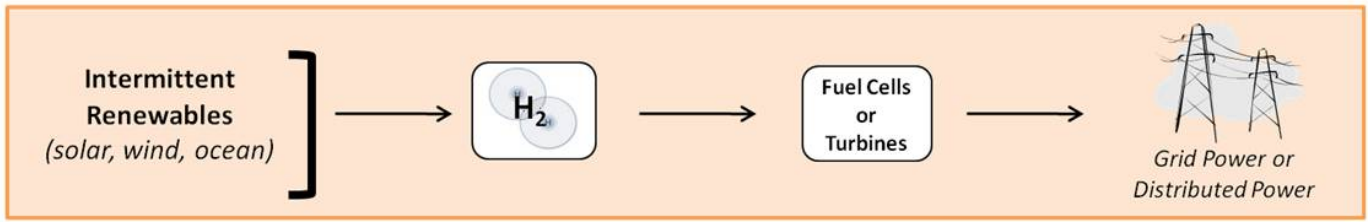
Agenda

- Overview
- R&D Progress
- Market Transformation
- Budget
- Policies
- Collaborations

Fuel Cells: Addressing Energy Challenges



Energy Storage for Renewable Electricity



Key Challenges

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The Program has been addressing the key challenges facing the widespread commercialization of fuel cells.

Technology Barriers*

Fuel Cell Cost & Durability

Targets*:

Stationary Systems: **$750 per kW, 40,000-hr durability**

Vehicles: **$30 per kW, 5,000-hr durability**

Hydrogen Cost

Target*: $2 – 3 /gge, (dispensed and untaxed)

Hydrogen Storage Capacity

Target: > 300-mile range for vehicles—without compromising interior space or performance

Technology Validation:

Technologies must be demonstrated under real-world conditions.

Economic & Institutional Barriers

Safety, Codes & Standards Development

Domestic Manufacturing & Supplier Base

Public Awareness & Acceptance

Hydrogen Supply & Delivery Infrastructure

Market Transformation

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

*** Targets and Metrics are being updated in 2010 .**

Source: US DOE 2/25/2010

Stationary R&D Progress

Stationary Fuel Cells for Power

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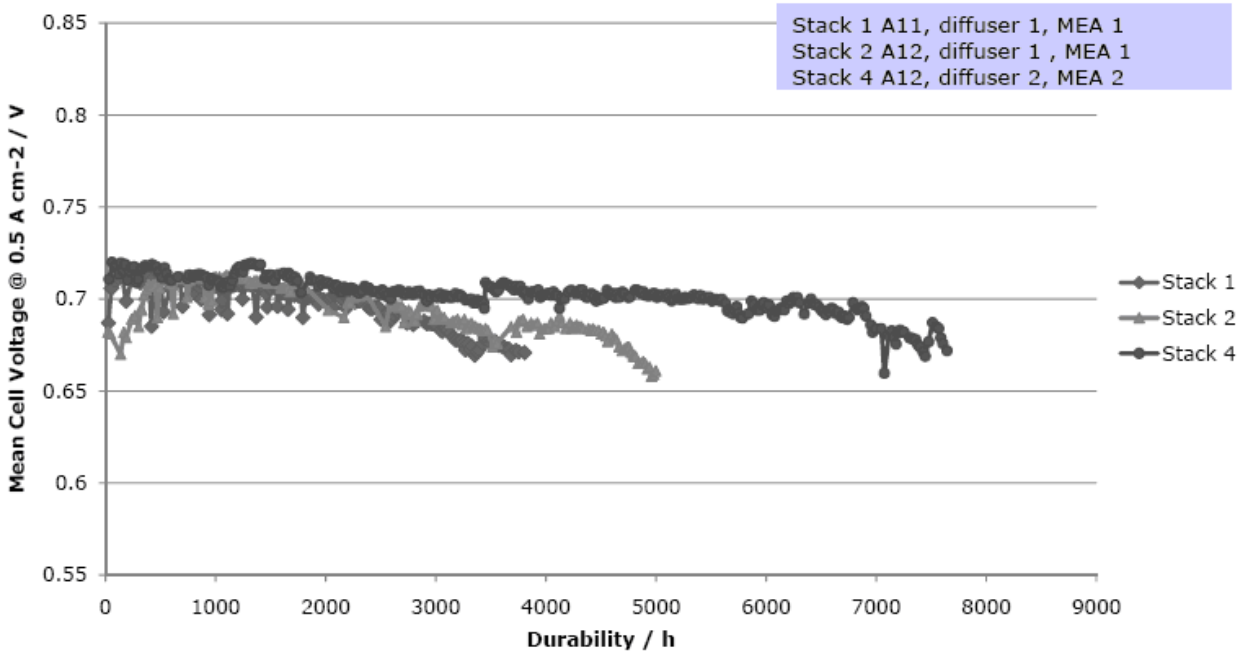
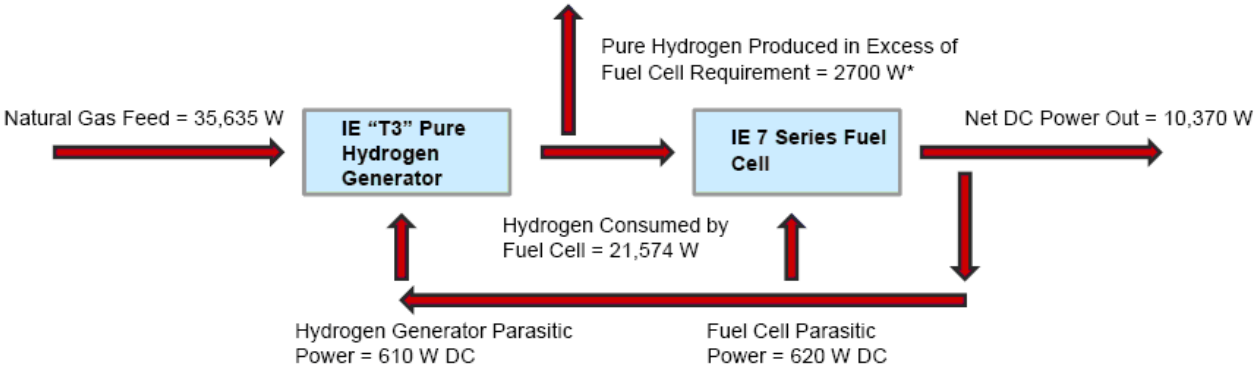
Intelligent Energy improved LT PEM durability and increased efficiency





- IE system uses reformer, pressure swing adsorption to supply pure H_2 to fuel cell stack
- 33% electrical efficiency and 61%CHP efficiency demonstrated in unoptimized system
- Implementation of adsorption-enhanced reformer expected to increase efficiency
- Over 7,000 hours durability with load cycling demonstrated in 20-cell stack

Durai Swamy et al., "Development and Demonstration of a New-Generation High Efficiency 1-10 kW Stationary Fuel Cell System"

Stationary Fuel Cell Costs

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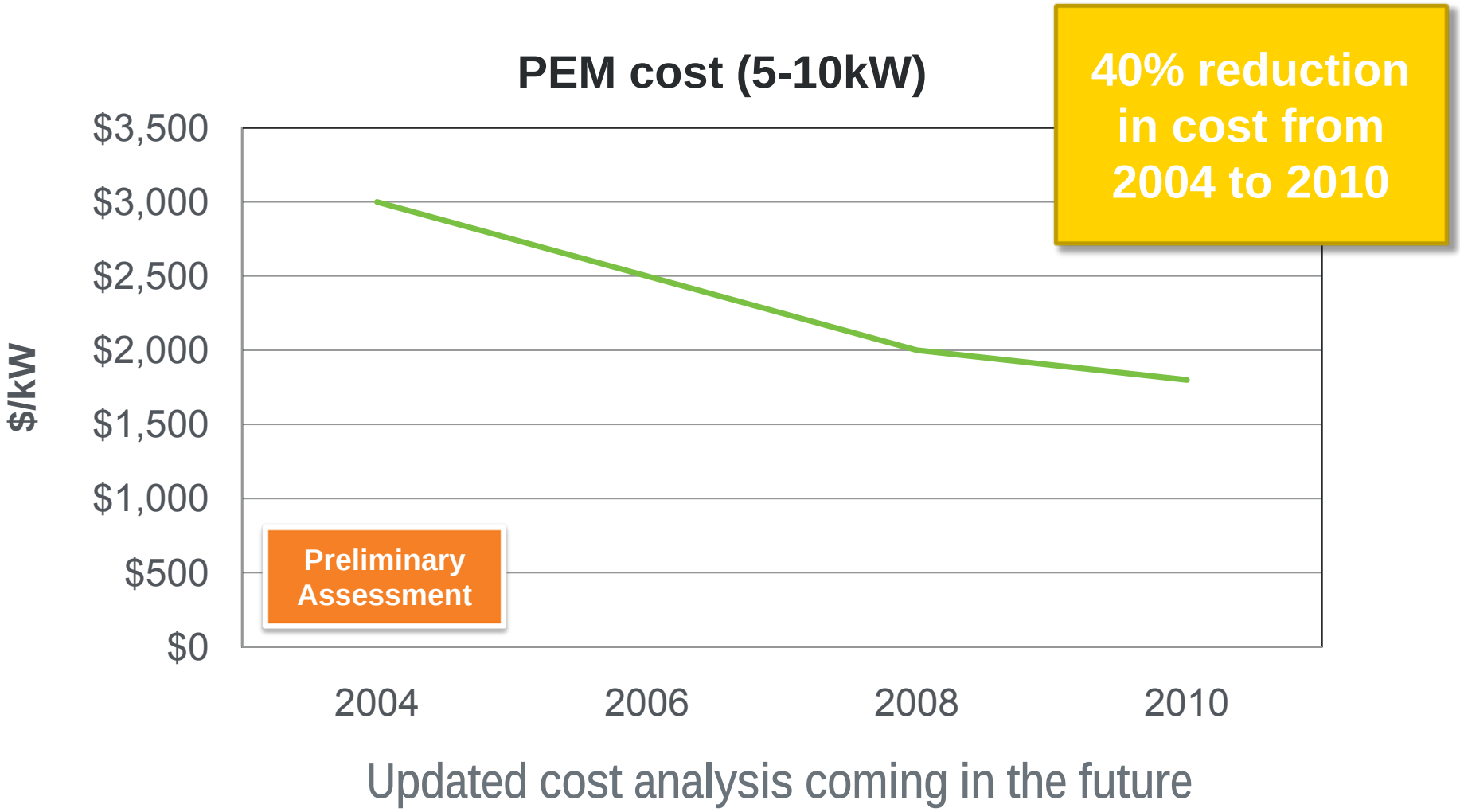
Preliminary projected cost of stationary fuel cells (> 2000 units/year) has decreased since 2004.



 Source: US DOE 2/25/2011

Micro-CHP

Targets developed with input from stakeholders and the research community

Preliminary Technical Targets: 1 – 10 kW_e Residential Combined Heat and Power Fuel Cells Operating on Natural Gas[1]

	Units	2015 Targets
Electrical energy efficiency at rated power[2]	%	42.5
CHP energy efficiency at rated power[3]	%	87.5
Cost[4]	$ / kW_e	700
Transient response time (from 10 - 90% rated power)	min	3
Start-up time from 20 C ambient temperature	min	30
System availability	%	98
Operating lifetime[5]	hours	40,000
Degradation with cycling	% / hours	0.5/1000

[1] Standard utility natural gas delivered at typical residential distribution line pressures
[2] Regulated AC net/LHV of fuel.
[3] Only heat available at 80 °C or higher is included in CHP energy efficiency calculation.
[4] Cost includes materials and labor costs to produce stack, plus any balance of plant necessary for stack operation. Cost defined at 50,000 unit/year production (250 MW in 5-kW modules).
[5] Time until >20% net power degradation.

2010 Independent Assessment of CHP Fuel Cell Status & Targets

- Confident that by 2015, LT-PEM & HT-PEM can achieve 40,000hr
- 45% electrical efficiency (2020 target) for 1-10kW systems is feasible for HT-PEM, LT-PEM depends on improved catalysts & higher operating temps
- SOFC systems are likely to achieve DOE targets for electrical and CHP efficiencies. 90% CHP efficiency is likely to be attainable by SOFC systems
- Confident that by 2020, LT-PEM & HT-PEM can achieve $450-$750/kW, while SOFC can achieve $1000-2000/kW

Progress – Micro-CHP

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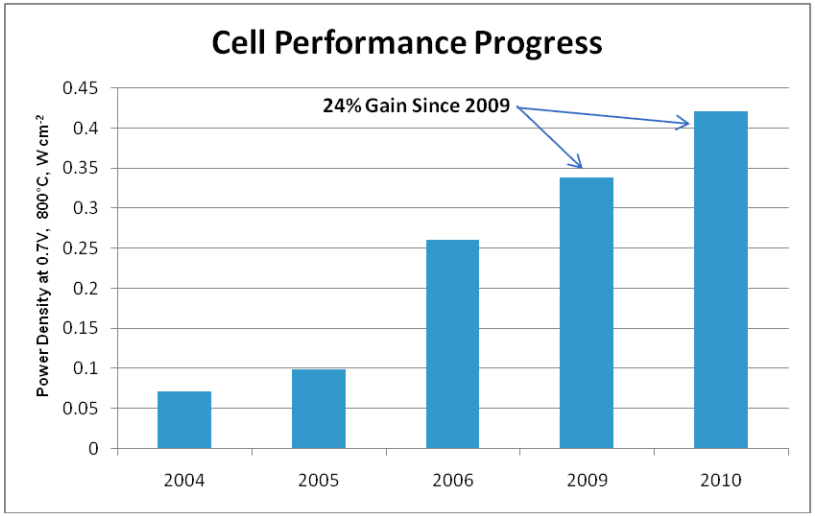
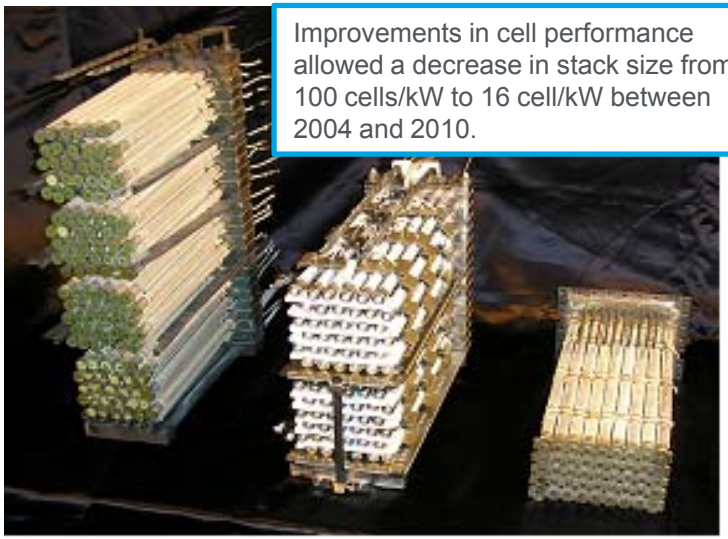
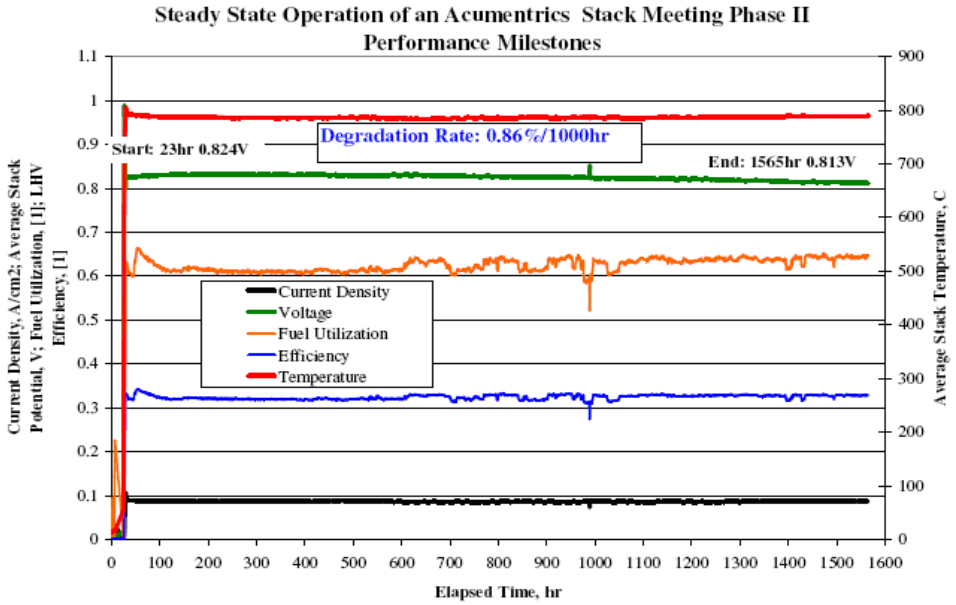
Acumentrics increased SOFC power density while improving durability





Improvements in cell performance allowed a decrease in stack size from 100 cells/kW to 16 cell/kW between 2004 and 2010.



- 24% increase in power density enabled 33% reduction in stack volume and 15% reduction in stack weight
- Low degradation rate of 0.86%/1000 hours during 1500 hours of testing
- With reduction of component cost and manufacturing cost, Acumentrics plans commercialization of residential CHP unit in European markets (partner: Ariston Thermal Group)

Norman Bessette et al., "Development of a Low Cost 3-10kW Tubular SOFC Power System"

Market Transformation

Stationary Power Fuel Cells for Combined Heat & Power (CHP) Applications

A 400-kW fuel cell (grey box) meets 85 percent of the energy needs of this Price Chopper supermarket in Albany. The installation reduces the building's carbon footprint by 71 tons, provides energy security for perishable items, and saves more than 4 million gallons of water each year. *(Photo taken from the Executive Summary of the New York State Climate Action Plan Interim Report)*

Examples of CHP Industry Deployments

The Food Industry is an emerging market for stationary fuel cells

Announced Supermarket Deployments: Nine Sites Include

- **Whole Foods (CA,CT,MA)**
  - **3 sites, 400kW each**
- **Price Chopper (NY,CT)**
  - **3 sites, 400kW each**
- **SUPERVALU (MA,CA)**
  - **2 sites, 400kW each**
- **Ahold (CT, Stop & Shop)**
  - **1 site, 400kW**

- **Completed Food Producer Deployments:**
  - **Coca-Cola (NY, 800 kW) – another 800 kW under construction**
  - **Gills Onions (CA, 600 kW)**
  - **Pepperidge Farms (CT, 1.45 MW)**
  - **Sierra Nevada Brewery (CA, 1 MW)**

Case Study: *Verizon*

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High-reliability CHP system providing primary and back-up power, heating and cooling for a telephone and data service facility

Location	Verizon Central Office Building Garden City, NY
Date Installed	2005
Equipment	• Seven UTC 200-kW natural gas fired fuel cells • Two absorption chillers, one unfired heat recovery steam generator, natural gas and diesel engines.
Facility	292,000 sq ft.
Energy Savings	$0.5 million for the first five years
Benefits	• 11.1 million pounds of CO_2 offset per year • NO_X emissions reduced by 19 tons per year • 5.5 million gallons of water saved per year
Performance* *Source: UTC Power	• Availability: 88% • Efficiency: Approaching 90%

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fccs_verizon10.pdf

Budget

EERE H_2 & Fuel Cells Budgets

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Funding *($ in thousands)*			
Key Activity	**FY 2009[4]**	**FY 2010 Current Appropriation**	**FY 2012 Request**
Fuel Cell Systems R&D[1]	**-**	**75,609**	**45,450**
Fuel Cell Stack Component R&D	61,133		
Transportation Systems R&D	6,435		-
Distributed Energy Systems R&D	9,750		-
Fuel Processor R&D	2,750		-
Hydrogen Fuel R&D[2]	**-**	**45,750**	**35,000**
Hydrogen Production & Delivery R&D	10,000		-
Hydrogen Storage R&D	57,823		-
Technology Validation	**14,789[5]**	**13,005**	**8,000**
Market Transformation[3]	**4,747**	**15,005**	**-**
Early Markets	4,747	15,005	-
Safety, Codes & Standards	12,238[5]	8,653	7,000
Education	4,200[5]	2,000	-
Systems Analysis	**7,520**	**5,408**	**3,000**
Manufacturing R&D	**4,480**	**4,867**	**2,000**
Total	**$195,865**	**$170,297**	**$100,450[6]**

[1] Fuel Cell Systems R &D includes Fuel Cell Stack Component R&D, Transportation Systems R&D, Distributed Energy Systems R&D, and Fuel Processor R&D [2] Hydrogen Fuel R&D includes Hydrogen Production & Delivery R&D and Hydrogen Storage R&D [3] No Market Transformation in FY 2012. [4] FY 2009 Recovery Act funding of $42.967M not shown in table [5] Under Vehicle Technologies Budget in FY 2009 [6] Includes SBIR/STTR funds to be transferred to the Science Appropriation; all prior years shown exclude this funding

DOE H_2 & Fuel Cells Budgets: *FY07 – FY12*

	Funding *($ in thousands)*				
	FY 2007 Approp.	**FY 2008** Approp.	**FY 2009** Approp.	**FY 2010** Approp.	**FY 2012** Request
EERE Hydrogen & Fuel Cells	189,511	206,241	195,865	174,000[2]	100,450
Fossil Energy (FE)[1]	21,513	21,773	26,400	26,400	0
Nuclear Energy (NE)	18,855	9,668	7,500	5,000	TBD
Science (SC)	36,388	36,484	38,284	38,284	TBD
DOE TOTAL	**266,267**	**276,481**	**268,049**	**243,684**	**TBD**

Note: No funding requested for SECA Program FY12 (FE)

Program Focus: Develop cost competitive hydrogen and fuel cell technologies for diverse applications to meet long-term goals of $30/kW for transportation, $750/kW for stationary power, and $2-4/gge for hydrogen production and delivery.

FY12 Key Activities- Examples

- Fuel Cell Systems R&D (45.5M): Maintains critical R&D for stationary, transportation and portable power. Key goals include:
  - Reduce costs by increasing PEM fuel cell power output per gram of platinum-group catalyst from 2.8 kW/g (in 2008) to 6.0 kW/g in 2012 and 8.0 kW/g by 2016.
- Hydrogen Fuel R&D ($35.0M): Will focus on materials R&D to achieve a 25% reduction in electrolyzer capital cost by 2012, reducing the total hydrogen cost to less than $5/gge compared to $6/gge in 2009. Develop materials with photoelectrochemical conversion efficiency of 10% in 2012 compared to 4% baseline.
- Safety, Codes and Standards ($7.0M): Will determine and demonstrate hydrogen storage system testing procedures to enable publication of a Global Technical Regulation by 2012.
- Manufacturing R&D ($2.0M): Will develop low-cost, high-volume, continuous in-line MEA quality control measurement technologies in 2012, on track to develop continuous fabrication and assembly processes for polymer electrolyte membranes by 2016.
- Technology Validation ($8.0M): Will collect real-world data from fuel cells operating in forklifts, backup power, vehicles, and buses including 2012 projects with DOD (e.g. Hawaii).
- Systems Analysis ($3.0M): Will determine technology gaps, economic/jobs potential, and quantify 2012 technology advancement.

[a] These activities are funded under Market Transformation in FY 2011.
[b] Due to deployments and ongoing data collection and analyses underway through the Recovery Act, these activities are deferred in FY 2012.

Policies

Executive Order 13514

On October 5, 2009 President Obama signed Executive Order 13514 – Federal Leadership in Environmental, Energy, and Economic Performance

- Requires Agencies to:
  - Set GHG reduction Targets
  - Develop Strategic Sustainability Plans and provide in concert with budget submissions
  - Conduct bottom up Scope 1, 2 and 3 baselines
  - Track performance

Examples:

- Achieve 30% reduction in vehicle fleet petroleum use by 2020
- Requires 15% of buildings meet the *Guiding Principles for High Performance and Sustainable Buildings* by 2015
- Design all new Federal buildings which begin the planning process by 2020 to achieve zero-net energy by 2030

Potential opportunities for fuel cells and other clean energy technologies....

http://www1.eere.energy.gov/femp/regulations/eo13514.html

Source: US DOE 09/2010

Examples of Policies Promoting Fuel Cells

Some tax credits affecting fuel cells were expanded. Through new financing mechanisms, these credits can help facilitate federal deployments.

Hydrogen Fueling Facility Tax Credit	Increases the credit for a hydrogen fueling station from 30% or $30,000 to 30% or $200,000. Equipment must be installed by December 31, 2014.
Fuel Cell Motor Vehicle Tax Credit	A tax credit of up to $4,000 is available for the purchase of qualified light-duty fuel cell vehicles. Tax credits are also available for medium- and heavy-duty vehicles. Expires December 31, 2014.
Fuel Cell Tax Credit (other than residential)	Offers tax credit of 30% for qualified fuel cell property or $3,000/kW of the fuel cell nameplate capacity. Feature a 10% credit for combined-heat-and-power-system property. Equipment must be installed by December 31, 2016.
Residential Energy Efficiency Credit	Raises ITC cap for residential fuel cells in joint occupancy dwellings to $3,334/kW. Equipment must be installed by December 31, 2016.
Power Generation Credit	Offers 1.8¢/kW-hr payment to the owner/operator of a qualifying advanced power system technology facility including those using advanced fuel cells. An additional 0.7¢/kW-hr shall be paid to the owner/operator of a qualifying security and assured power facility for electricity generated at such facility. Expires 2012.

Collaborations

DOE Collaboration Opportunities

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Fuel Cell Technologies Program

Program	Program Key Focus
Buildings ($471M)	Develop and scale up deployment of technologies, tools, and standards for making residential and commercial buildings more energy-efficient, affordable, and better performing.
Industrial Technologies ($320M)	Research and develop advanced manufacturing and materials technologies and accelerate industrial adoption of energy efficient and clean energy technologies. Help U.S. producers to become global leader in production of clean energy technologies.
Solar ($457M) (e.g. EFRC)	"Sun Shot" – Enable grid parity before the end of the decade by achieving $1/W installed price for PV (without subsidies). Develop new innovative materials and thermal storage to enable CSP to compete with intermediate and baseload power markets.
Biomass ($331M)	Develop and transform domestic biomass resources into biofuels, bioproducts, & biopower: 1) Complete steps to achieve a modeled cost of less than $2/gal (by volume) of cellulosic ethanol in 2012 and progress towards $3/gal for renewable hydrocarbon fuels by 2017 (both in 2007$), 2) Collaborate with Office of Sc. to develop synthetic-biology tools to enhance national capability in biomanufacturing, 3) validate 15 M gallons of annual advanced biofuel production capacity,4) Provide incentive for advanced biofuel production via a reserve auction.
Vehicle Technologies ($588M)	Strategic research, development and deployment activities supporting the goal of 1 M electric drive vehicles on U.S. roads by 2015.
FEMP ($33M) - Federal facilities - EO 13514	Facilitates the Federal Government's implementation of sound, cost effective energy management and investment practices resulting in lifecycle saving of over 52 trillion Btus. Increased funding for technical assistance will support Federal cost and GHG reduction efforts by developing guidance, technical assistance and GHG reporting protocols.
ARPA-E ($550M) **Innovative concepts**	Focuses exclusively on high risk, high payoff concepts - technologies promising genuine transformation in the ways we generate, store and utilize energy.

Hawaii's Hydrogen Initiative (H2I)

A public/ private effort that seeks to be a major component of the solution to Hawaii's energy challenges

- **Letter of Understanding signed on Dec 8, 2010 by DOE and DOD, among others**
  - State of Hawaii, the Hawaii Gas Company, University of Hawaii, General Motors, Fuel Cell Energy, and others
- **Mission is to fill a strategic role that supports Hawaii's transformation to a clean energy economy**
- **Part of a portfolio approach of technologies and fuels for reducing emissions and petroleum use**
  - Supports the deployment of fuel cell vehicles to Hawaii as a means of reducing petroleum consumption as well as green house gas emissions
  - Takes advantage of the existing gas pipelines to deliver hydrogen for dispensing hydrogen to fuel cell vehicles

HAWAIIGAS

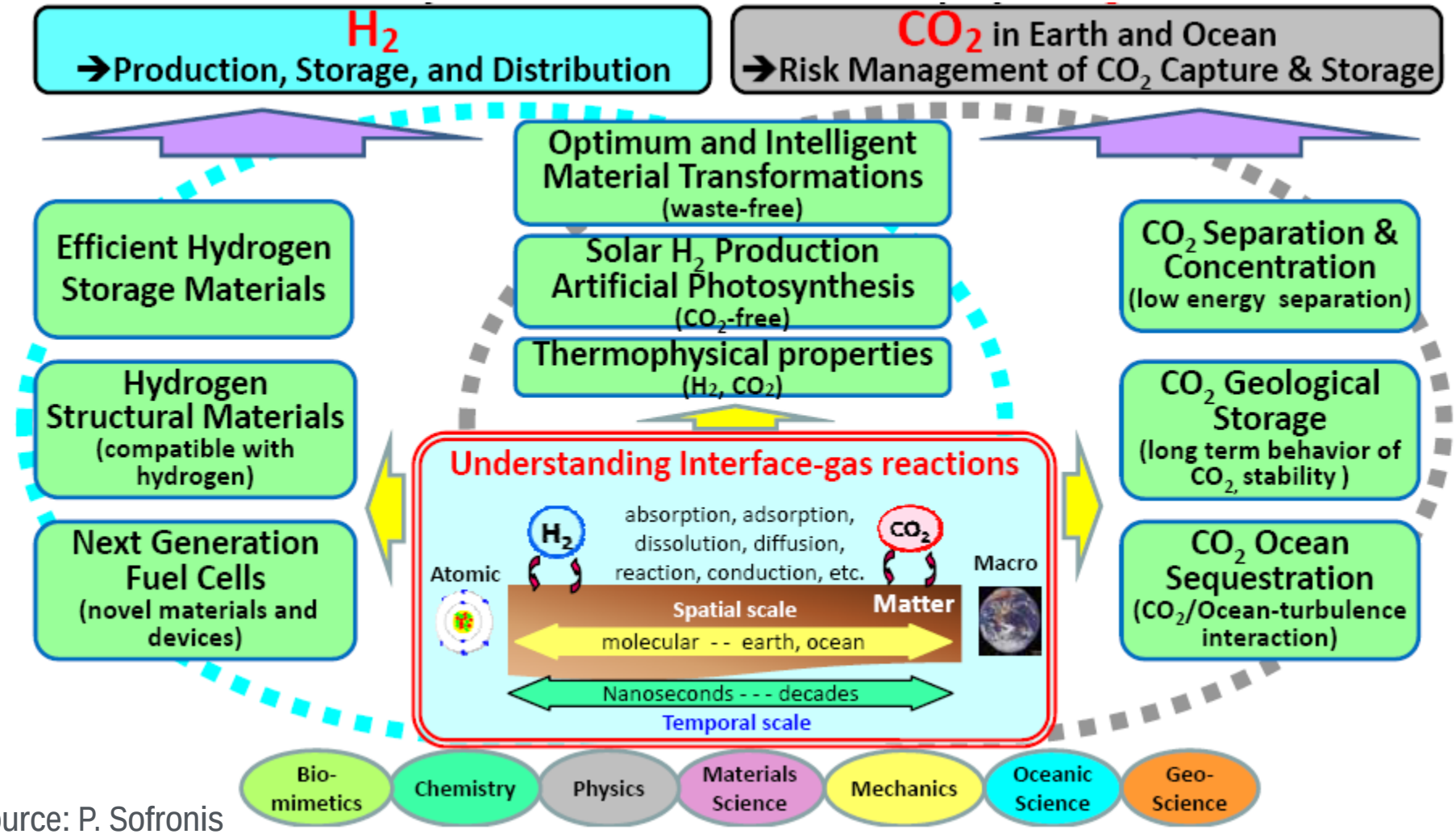
FuelCell Energy
Ultra-Clean, Efficient, Reliable Power

NREL

Example of Recent International Collaboration:

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

University of Illinois – Kyushu University collaboration directed by Petros Sofronis to advance the fundamental science for a "Carbon-Neutral Energy Fueled World" and offer science driven solutions for energy technologies that will enable environmentally friendly and sustainable development



Source: P. Sofronis

Collaborations

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.*

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 Fuel Cell Technologies Program*

– ***Applied RD&D***

– ***Efforts to Overcome Non-Technical Barriers***

– ***Internal Collaboration with Fossil Energy, Nuclear Energy and Basic Energy Sciences***

Industry Partnerships & Stakeholder Assn's.

- **FreedomCAR and Fuel Partnership**
- **Fuel Cell and Hydrogen Energy Association (FCHEA)**
- **Hydrogen Utility Group**
- **~ 65 projects with 50 companies**

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*

2011 4th International Conference on Hydrogen Safety - ICHS

Organized by

Università di Pisa

Sandia National Laboratories

hySafe International Association for Hydrogen Safety

Endorsed by

U.S. DEPARTMENT OF ENERGY

IPHE

H I A

September 12-14, 2011

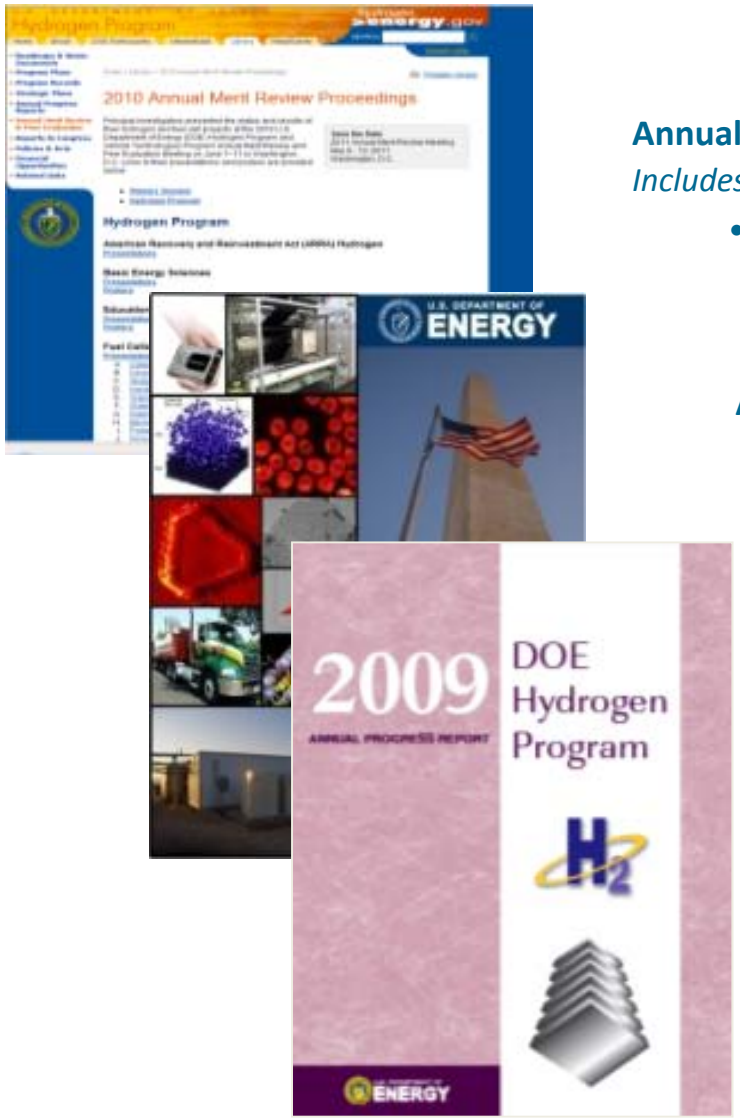
San Francisco, CA-USA

The ICHS 2011 will focus on the improvement, knowledge, and understanding of hydrogen safety to overcome barriers to the wide spread use of hydrogen as an energy carrier.
Therefore, this conference seeks papers focused on the following three major themes:

1) **International Progress on Enabling Opportunities**
2) **Latest Advances in Hydrogen Safety R&D and**
3) **Risk Management of Hydrogen Technologies. All contributions to be included in the ICHS 2011 will be evaluated exclusively in the light of their scientific content and relevance to hydrogen safety.**

The conference will improve public awareness and trust in hydrogen technologies by communicating a better understanding of both the hazards and risks associated with hydrogen and their management.

Key Program Documents



Annual Merit Review & Peer Evaluation Proceedings

Includes downloadable versions of all presentations at the Annual Merit Review

- **Latest edition released June 2010**

www.hydrogen.energy.gov/annual_review10_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 January 2011**

http://www.hydrogen.energy.gov/annual_review10_report.html

Annual Progress Report

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

- **Released February 2011**

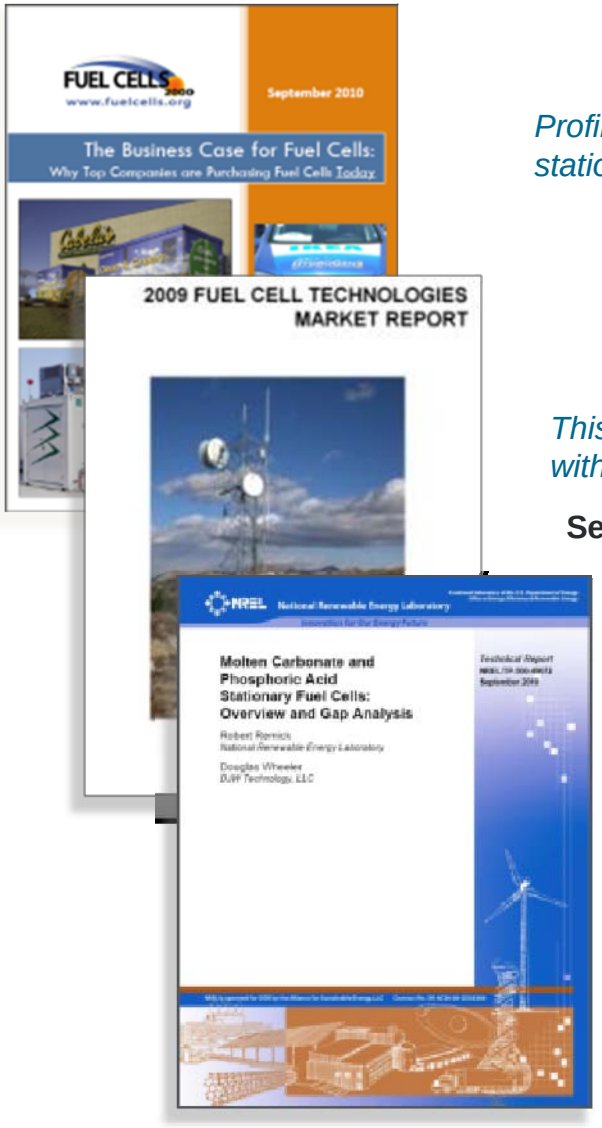
www.hydrogen.energy.gov/annual_progress.html

Next Annual Review: May 9 – 13, 2011

Washington, D.C.

http://annualmeritreview.energy.gov/

Key Reports Recently Published



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

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

Profile of 38 companies who have ordered, installed, or deployed fuel cell forklifts, stationary fuel cells or fuel cell units.

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

2009 Fuel Cell Technologies Market Report

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

This report describes data compiled in 2010 on trends in the fuel cell industry for 2009 with some comparison to previous years. (July 2010).

See report: http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/48219.pdf

Molten Carbonate and Phosphoric Acid Stationary Fuel Cells: Overview and Gap Analysis

By NREL and DJW Technology, LLC

This report describes the technical and cost gap analysis performed to identify pathways for reducing the costs of molten carbonate fuel cell (MCFC) and phosphoric acid fuel cell (PAFC) stationary fuel cell power plants.

See report: http://www.nrel.gov/docs/fy10osti/49072.pdf

Fuel Cell Today 2009 Market Analysis

The report describes sales of fuel cells in US and worldwide.

October 2010

Thank you

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www.hydrogenandfuelcells.energy.gov