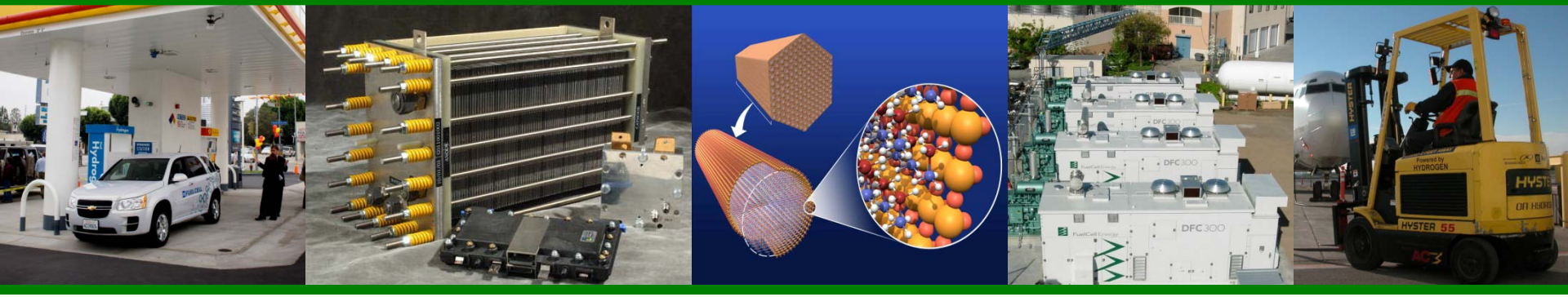
U.S. DEPARTMENT OF ENERGY



Crosscutting and Validation

Rick Farmer

2011 Annual Merit Review and Peer Evaluation Meeting

May 9, 2011

Goal and Objectives

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Enable widespread commercialization of hydrogen and fuel cell technologies through manufacturing cost reductions, technology validation, codes and standards development, and education of key stakeholders

Manufacturing

- Reduce the manufacturing cost of membrane electrode assemblies by 25% relative to 2008
- Develop fabrication and assembly processes for PEM fuel cells that will help to meet the $30/kW system target

Technology Validation

- Validate stationary fuel cell systems that co-produce hydrogen and electricity at 40% efficiency and 40,000 hour durability
- Validate fuel cell vehicles achieving 5,000 hour durability and 300 mile driving range

Safety, Codes and Standards

- Complete a quantitative risk assessment to address indoor refueling requirements to be adopted by code development organizations
- Complete material testing to develop ASME/ASTM hydrogen materials qualification guidelines

Education

- Expand availability of university curricula and of case studies of near-term market applications
- Develop an analysis tool to estimate economic impacts of early market fuel cells

Challenges

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Examples of key challenges

Manufacturing

- Lack of high-volume MEA, bipolar plate and balance-of-plant fuel cell manufacturing processes
- Lack of carbon fiber fabrication techniques for conformable tanks

Technology Validation

- Insufficient data on fuel cell performance and durability
- Inadequate data on refueling infrastructure performance

Safety, Codes and Standards

- Harmonizing domestic and international regulations, codes and standards
- Streamlining and standardizing the permitting process for hydrogen infrastructure

Education

- Resistance to change & mixed messages
- Lack of objective, “easily digestible,” information for decision makers

Crosscutting and Validation Budgets

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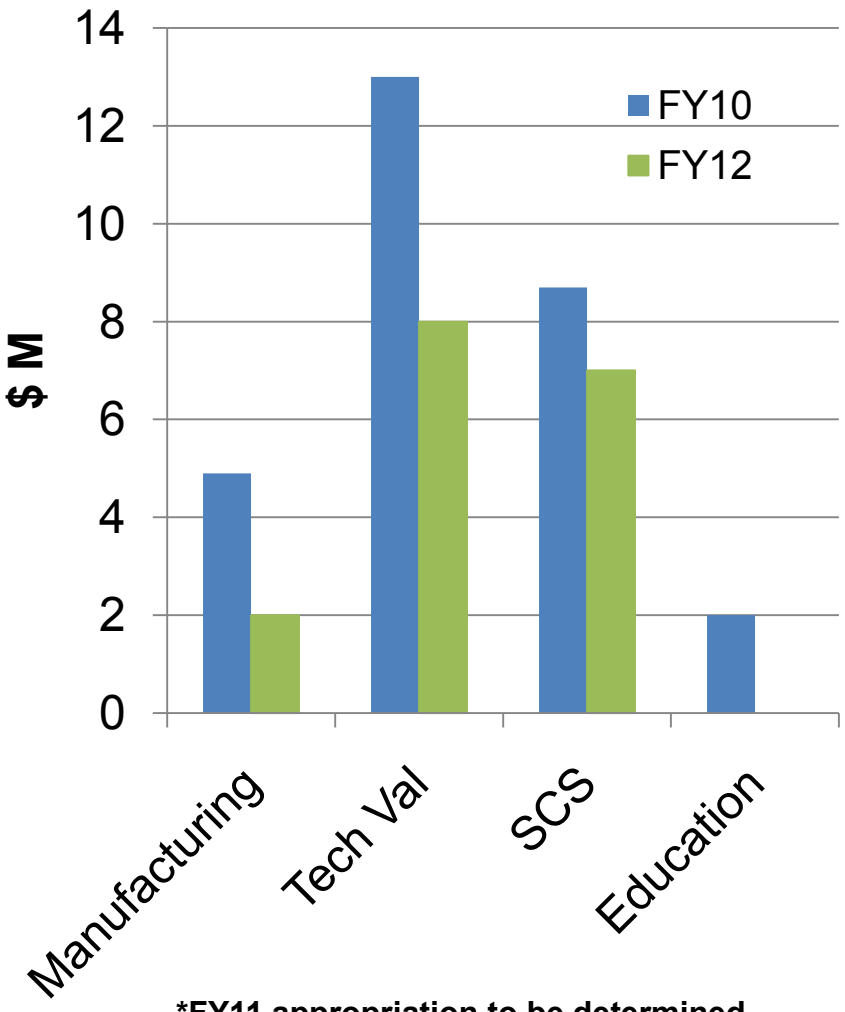
FY 2012 Request - $17 M*

FY 2010 Appropriation - $28.5 M



***FY11 appropriation to be determined.**

Emphasis

Manufacturing

- Develop robust, ultrasonic bonding processes for MEAs
- Develop real-time, online measurement tools

Technology Validation

- Data collection and analysis of fuel cells used in fork lifts, backup power, buses, and CHHP
- Develop funding opportunity announcement**

Safety, Codes and Standards

- Facilitate the permitting of hydrogen fueling stations and early market applications
- Harmonization of test protocols for qualification and certification

** Subject to appropriations

Progress – Manufacturing

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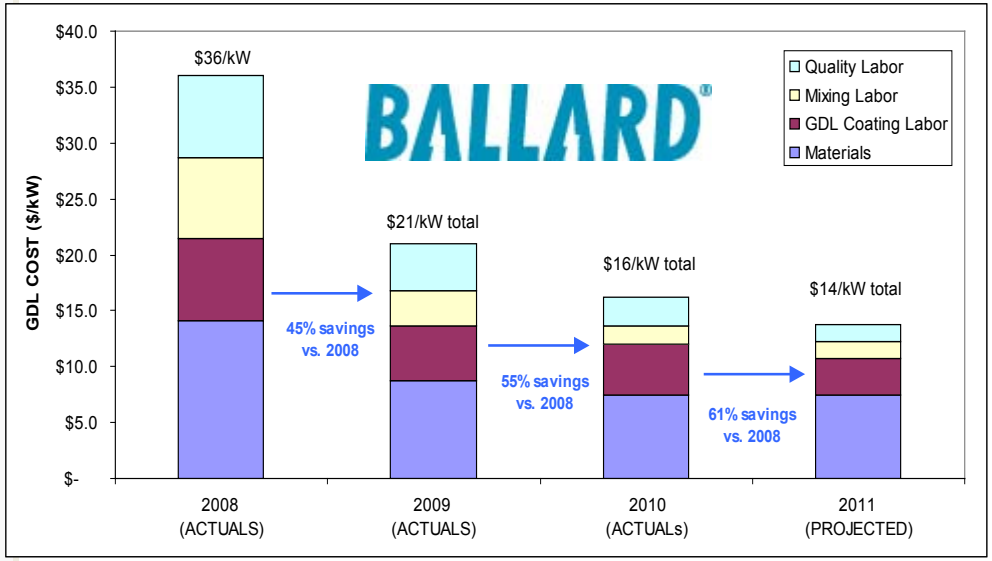
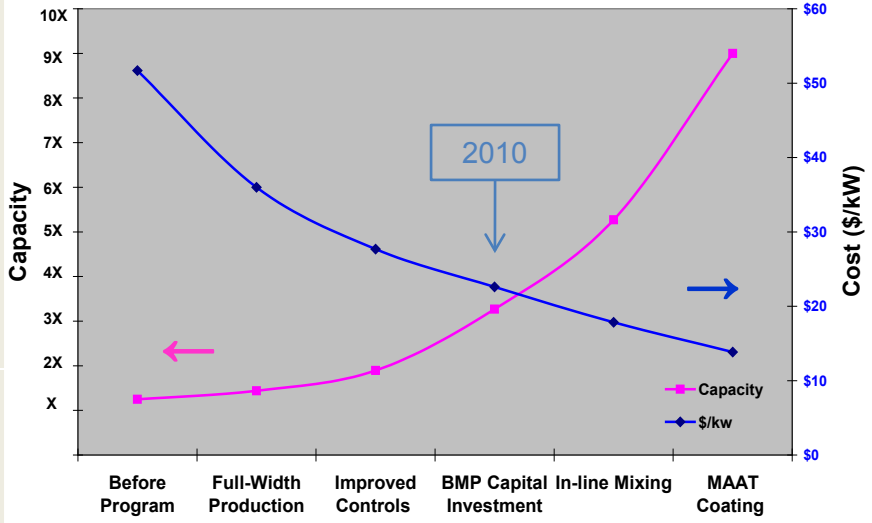
Reduced cost of GDLs by more than 50% and increased manufacturing capacity more than 4X since 2008

- **Ballard has shown GDL production capacity increases of 4X and cost decreases of 50% by:**
  - Eliminating process steps and reducing waste
  - Improving production yields and efficiency
- **Process modifications**
  - Full width production
  - Capital investment
- **Control modifications**
  - New quality control technologies such as mass flow meters to control microporous layer loadings
    - More uniform properties and reduce the amount of ex situ testing required
  - Add an in-line visual inspection station as a final quality tool to improve processing efficiency and accuracy
- **Next Steps**
  - In line mixing and "many at a time coating" (MAAT) are projected to achieve additional improvements





Progress – Manufacturing

U.S. DEPARTMENT OF ENERGY

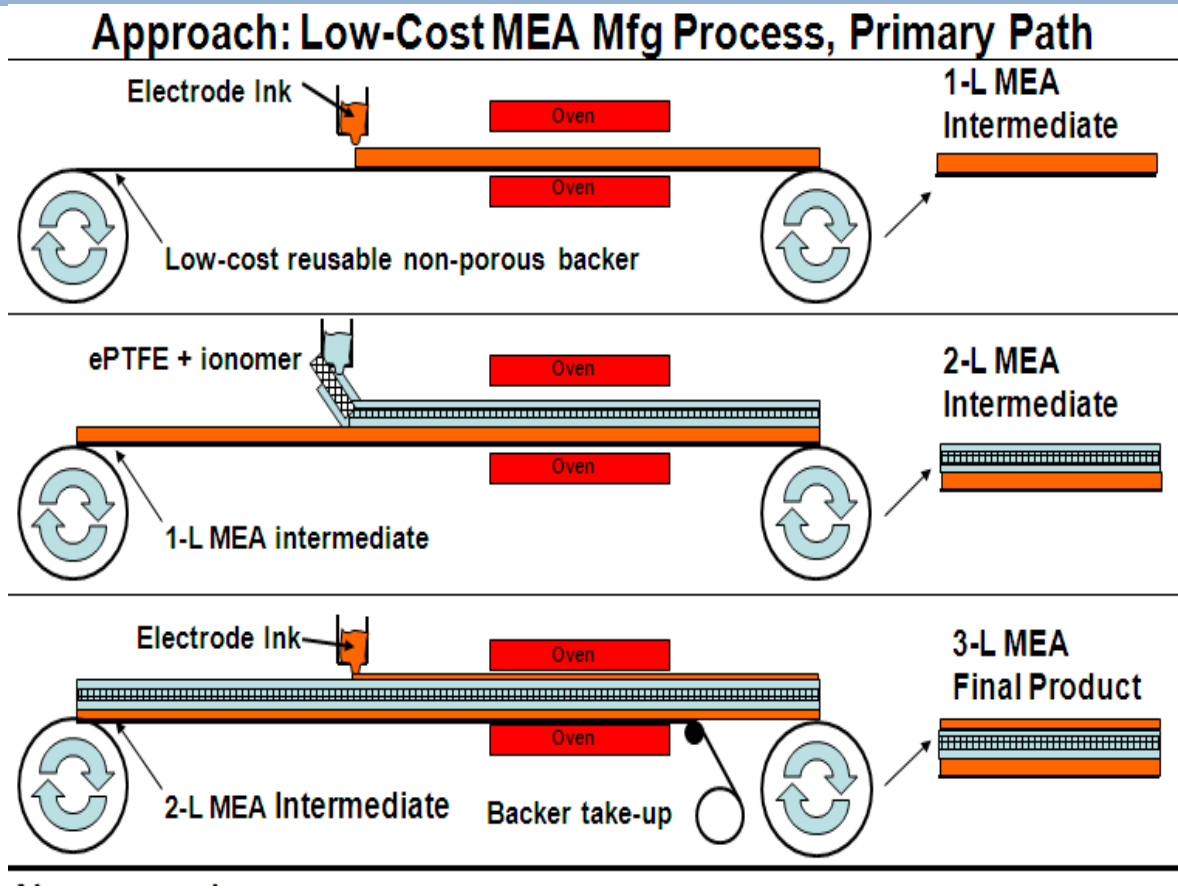
Increased performance by 200 mA/cm² at 0.4 V by improving the membrane/anode interface through direct coating

W. L. Gore increased performance and reduced MEA and stack cost

- Eliminated intermediate backer materials
- Reduced number of coating passes
- Minimized solvent use
- Reduced conditioning time

Enabling Technologies:

- Direct coating to form membrane–electrode interface
- Gore's ePTFE membrane reinforcement & PFSA ionomers enable durable, high-performance MEAs
- Modeling of mechanical stress and heat / water management
- Advanced fuel cell testing & diagnostics



Next Steps: Explore new 3-Layer MEA Process

- Equipment configuration for MEA production
- Raw material formulations
- Map process windows for each layer of the MEA

Progress – Manufacturing

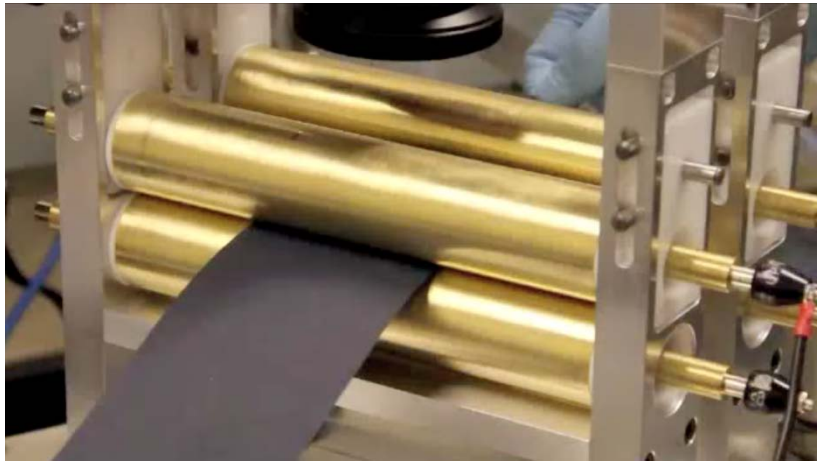
U.S. DEPARTMENT OF ENERGY

Achieved areal image of catalyst layer uniformity

Developing in-line diagnostics for MEA component quality control

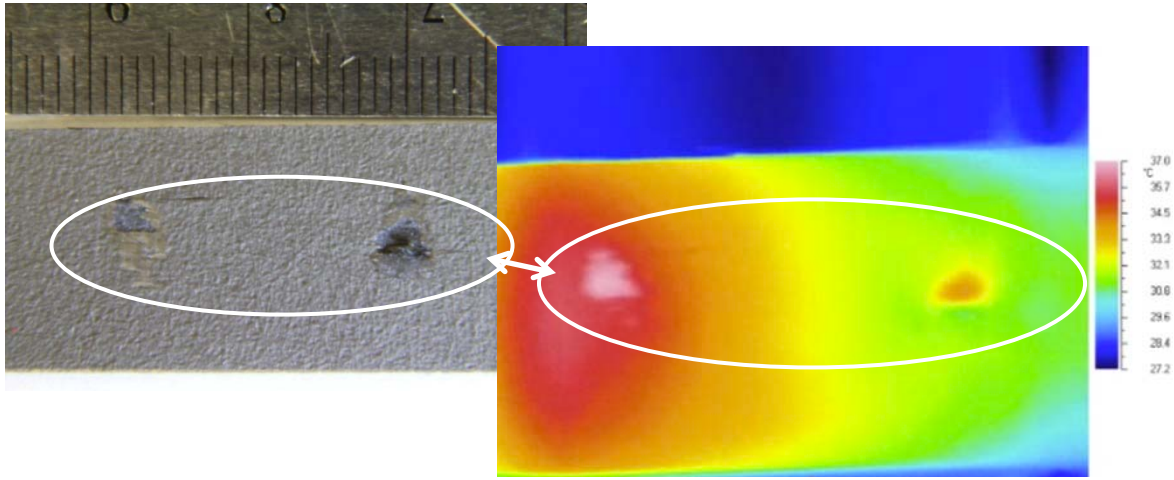
Investigating effects of manufacturing defects on MEA performance to understand the accuracy requirements for diagnostics

Modeling of the systems to improve diagnostic development and implementation



Example:

- **DC excitation of catalyst coated membrane causes thermal response**
- **Defects alter catalyst layer resistance and thermal response**
- **IR camera provides rapid, quantifiable 2D data**



NREL NATIONAL RENEWABLE ENERGY LABORATORY

BERKELEY LAB

Progress – Technology Validation

U.S. DEPARTMENT OF ENERGY

Learning Demonstration has provided valuable real-world data from fuel cell electric vehicles and hydrogen infrastructure.

Learning Demonstration

- 155 fuel cell vehicles
- 24 hydrogen fueling stations
- Fuel cell durability: 2,500 hours projected (nearly 75K miles)
- Fuel cell efficiency: 53 – 59%
- Range: 196 - 254 miles (independently validated 430 mile range)
- Over 3 million miles traveled
- Over 131,000 total vehicle hours driven
- Over 140,000 kg of hydrogen produced or dispensed*

**Not all of this hydrogen is used in Learning Demonstration vehicles.*

Progress – Technology Validation

U.S. DEPARTMENT OF ENERGY

Fuel Economy is 42% to 139% better than diesel and CNG buses.

NREL data collection

- DOE and FTA
- 8 fuel cell buses
- 4 sites:
  - AC Transit
  - SunLine
  - CTTRANSIT
  - VTA

NREL Hydrogen Evaluations for DOE and FTA

Site/Locations	State	# Buses	Eval. Funding	2010				2011				2012				2013			
				1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
AC Transit /SF Bay Area	CA	12	DOE Technology Validation			ZEBA Demo													
SunLine /Thousand Palms	CA	1			Advanced FCB Project														
City of Burbank/Burbank	CA	1							Burbank FCB										
SunLine /Thousand Palms	CA	1	FTA National Fuel Cell Bus Program									American FCB Demo							
CTTRANSIT /Hartford	CT	4				Nutmeg Hybrid FCB Demo													
USC, CMRTA /Columbia UT, Cap Metro/Austin	SC TX	1		Hybrid FCB					Demo Site 2										
Logan Airport /Boston	MA	1							MA H2 FCB Fleet										
Albany /NY	NY	1								Light-wt FCB									
SFMTA /San Francisco	CA	1						FC APU Hybrid											
CTA/Chicago	IL	1												Chicago FCB					
BJCTA/Birmingham	AL	1												Birmingham FCB					
Ohio State/Columbus	OH	1											EcoSaver IV Hybrid FCB						
USC, CMRTA /Columbia	SC	1											Advanced Composite FCB						

Demonstration sites color coded by geographic area:

Northern California | Northeast | South | Southern California | Southeast | Midwest

Traveled: ~ 450,000 miles

Dispensed: >81,000 kg H_2

Fuel Cell Bus Program

www.nrel.gov/hydrogen/proj_tech_validation.html

Estimate of data collection/evaluation - schedule subject to change based on progress of each project

Progress – Technology Validation

U.S. DEPARTMENT OF ENERGY

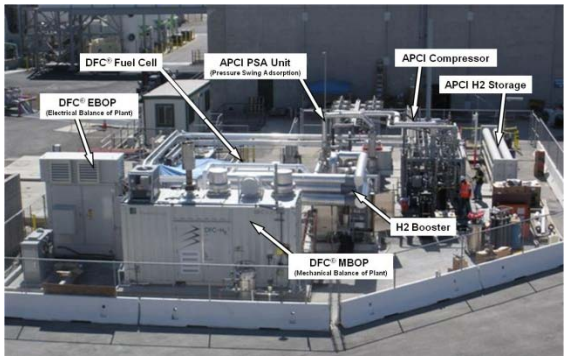
Fountain Valley Station achieved 54% efficiency (hydrogen + power) of unit when operating in hydrogen co-production mode.

BACKGROUND

- Host site: Orange County Sanitation District
- Anaerobic digestion of municipal wastewater
- 100 kg/day hydrogen capacity (350 and 700 bar)
- Funding Partners: CARB, SCAQMD and DOE

Led and coordinated by:

AIR PRODUCTS



ACCOMPLISHMENTS

- July 2010: Hydrogen Energy Station delivered to OCSD
- September 2010: First low-load power production from fuel cell unit
- September 2010: Fuel cell unit operated at full load on natural gas
- March 2011: Initial fills of fuel cell vehicles at hydrogen fueling station

NEXT STEP

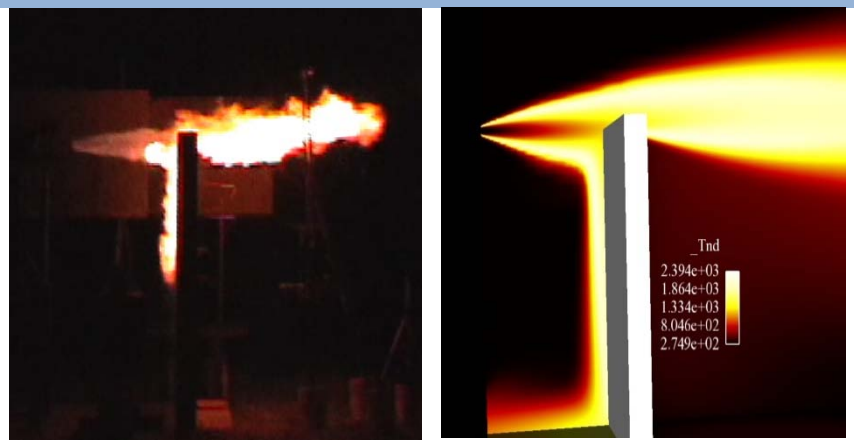
- Hydrogen to be produced from biogas in FY 11

Progress – Safety, Codes and Standards

U.S. DEPARTMENT OF ENERGY

Quantified the effect of barrier walls to reduce hazards leading to fifty percent distance reduction credit in some cases

- QRA methodology embraced by ISO TC197 WG11, analysis and data provided to support standards language
- Support of NFPA enabling update of bulk gas storage Separation Distances in the 2012 edition of NFPA2



Barrier walls reduce separation distances – experimentally validated simulations to determining allowable heat flux iso-surface for 3-minute employee exposure. (2009 IFC).

Sample Table

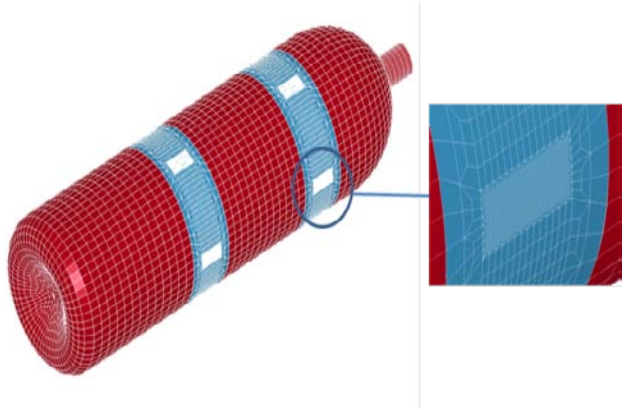
Exposure	NFPA 2005 Separation Distance	NFPA 2010 Separation Distance
Lot Lines	5 ft	10 ft
Air intakes (HVAC, compressors, other)	50 ft	10 ft
Ignition sources such as open flames or welding	25 ft	10 ft
Flammable Gas storage systems - non-bulk - bulk	 10 ft 10 ft or 25 ft	 5 ft 15 ft
Ordinary combustibles	50 ft	5 ft

Progress – Safety, Codes and Standards

U.S. DEPARTMENT OF ENERGY

Pressure cycling of steel hydrogen storage tanks exceeded 34,000 cycles.

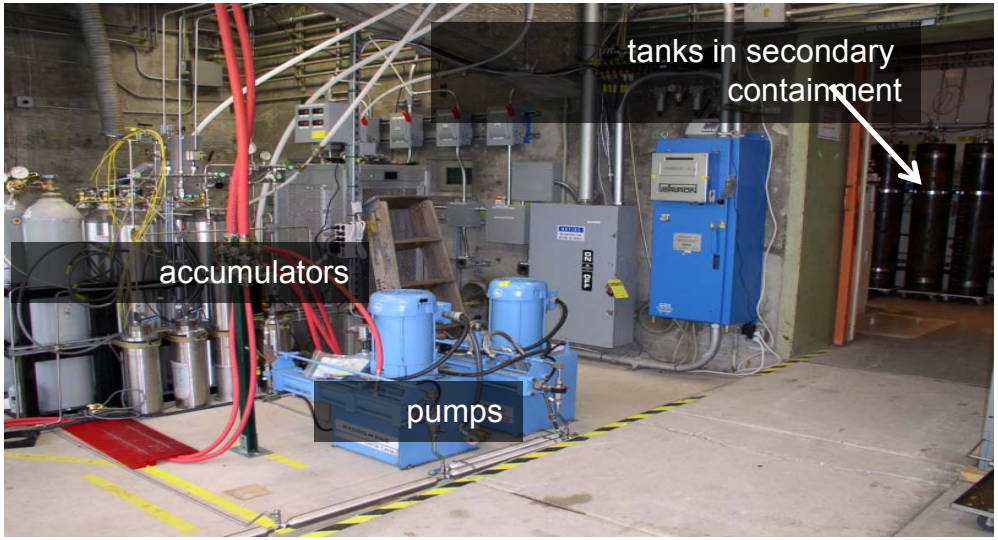
- Characterized crack initiation and growth in two tank designs that are currently in use (4130 steel)
- Conducted pressure cycling of steel storage tanks with gaseous hydrogen 3.5 to 45 MPa; 5 minute cycle time (2 min pressurization step)



Structural Engineering Analysis of Cylinder

- Free volume in tanks is small
- Closed system
- Periodic pressure profile:
  - ~5 min cycles
- 10 tanks can be cycled in parallel
- Gas purity is periodically monitored

Tests are accelerated, but remain relatively long: 10,000 cycles ~ 45 days



Progress – Safety, Codes and Standards

U.S. DEPARTMENT OF ENERGY

Expanded first responder training and updated hydrogen incident and safety best-practices databases

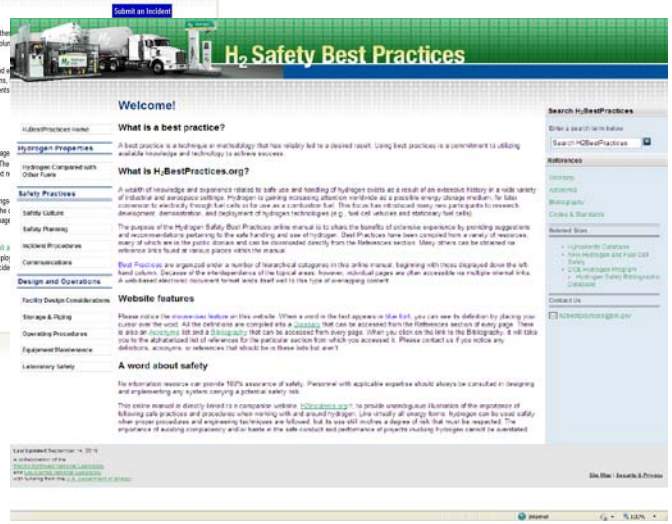
First Responder Training

- Upgraded web-based Introduction to Hydrogen Safety for First Responders –17,000 visits since January 2007.
- Conducted prop-based training at the Hazardous Materials Management and Emergency Response (HAMMER) training center and in California reaching over 300 students from 18 states.

Hydrogen Safety Awareness

- Created new "Lessons Learned Corner" to analyze hydrogen safety themes
- In collaboration with NASA, added information on hydrogen properties
- Updated hydride storage and handling for large scale experiments (SNL)

www.h2incidents.org



www.h2bestpractices.org

Progress – Education

U.S. DEPARTMENT OF ENERGY

Early Market Outreach leads to deployment of 100 new fuel cell forklifts.

- Early Market Outreach
  - Hands-on education sessions at material handling equipment dealerships, community colleges, & green business expos
  - **SUCCESS**: One site is acquiring 100 fuel cell forklifts as a result

- Fact sheets and reports for stakeholder use:
  - Fuel Cells for Material Handling
    hydrogenandfuelcells/education/pdfs/early_markets_forklifts.pdf
  - Case study Verizon Fuel Cell CHP experience
    http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fccs_verizon10.pdf
  - Case study Fuels Cells at Omaha Bank Data Center
    http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fccs_omaha10.pdf
  - Commissioned reports by Fuel Cells 2000
    - Business Case for Fuel Cells Report
    - Fuel Cells Market Report
    - State of the States Report

Progress – Education

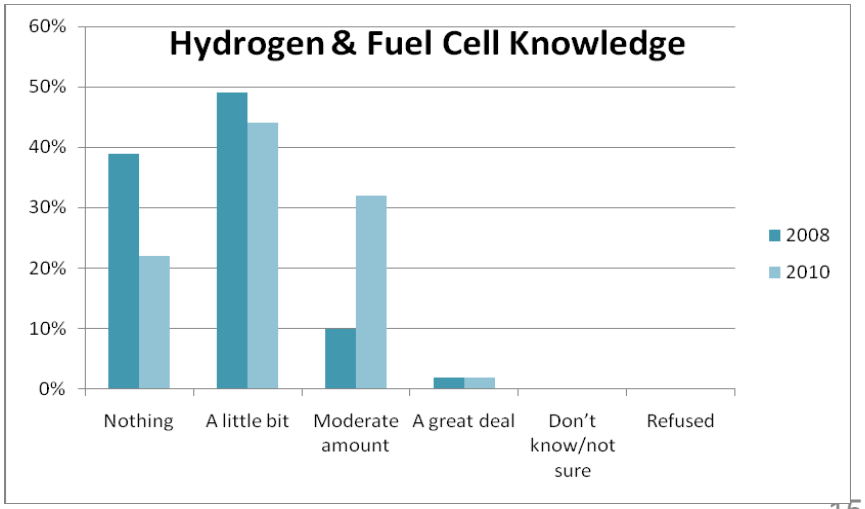
U.S. DEPARTMENT OF ENERGY

Up to 200% increase of fuel cell knowledge level

Connecticut Center for Advanced Technology

- Developed database of key stakeholders in Northeast states
- Assessed the economic impact of the hydrogen and fuel cell industry (H_2/FC) in an 8-state region (NE, NY, NJ)
- Surveyed the Level of Knowledge of State and Local Decision Makers and Key Stakeholders

	2008	2010
Nothing	39%	22%
A little bit	49%	44%
A Moderate amount	10%	32%
A great deal	2%	2%
Don't know/not sure	0%	0%
Refused	0%	0%

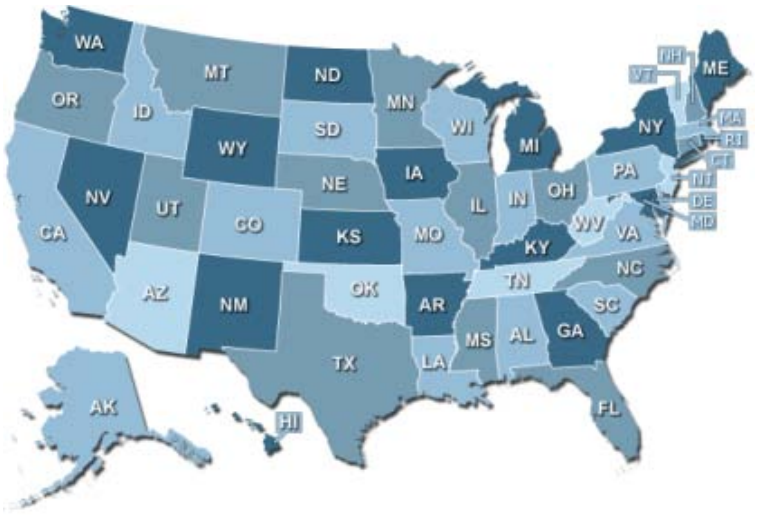


Progress – Education

U.S. DEPARTMENT OF ENERGY

Webinar Series targets state & local government officials and stakeholders to facilitate market acceptance.

- Co-hosted by the Clean States Energy Alliance and the Technology Transition Corporation
- Topics included:
  - Fuel Cells for Supermarkets (April 2011)
  - H_2 Production and Storage for Fuel Cells (Feb 2011)
  - DOE Fuel Cell Technologies Program Budget Overview (Dec 2010)
- Future Topics:
  - May 17, 2011: Local Leaders Create Fuel Cell Success Stories
  - June 9, 2011: Fuel Cells and Renewable Portfolio Standards
  - June 21, 2011: The Top 5 Fuel Cell States: Why Local Policies Mean Green Growth
  - July 19, 2011: Where the Jobs Are: Hydrogen Fuel Cells in Your Area
  - August 16, 2011: Go Local: Maximizing Your Local Renewable Resources With Fuel Cells



hydrogenandfuelcells/education/state_local_calls.html

Key Events – Technology Validation

U.S. DEPARTMENT OF ENERGY

RFI issued March 31, 2011 and closes June 1, 2011.

Areas of Interest

- Innovative concepts for:
  - Stationary fuel cell systems for residential and commercial applications, including combined-heat-and-power (CHP)
  - Combined-heat-hydrogen-and-power (CHHP) co-production fuel cell systems
- Technology Validation projects for other markets

For more information:

http://www1.eere.energy.gov/hydrogenandfuelcells/news_detail.html?news_id=16873

http://www07.grants.gov/search/search.do?&mode=VIEW&oppId=84333

Key Events – Safety, Codes and Standards

U.S. DEPARTMENT OF ENERGY

The International Conference on Hydrogen Safety will enhance public awareness and trust in hydrogen technologies.

Organized by

Università di Pisa · Sandia National Laboratories · hySafe International Association for Hydrogen Safety

Endorsed by

U.S. Department of Energy · IPHE · HIA

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 Events – Education

U.S. DEPARTMENT OF ENERGY

New opportunities exist for postdoctoral research in hydrogen and fuel cell technologies

- Fuel Cell Technologies Program Opportunities Available
  - Conduct applied research at universities, national laboratories, and other research facilities
  - Up to five positions are available in the areas of hydrogen production, hydrogen delivery, hydrogen storage, and fuel cells

- Applications are due June 30, 2011
- Winners will be announced mid-August
- Fellowships will begin in mid-November 2011

Postdoctoral fellowships in hydrogen and fuel cell research

www. eere.energy.gov/education/postdoctoral_fellowships/

For More Information

U.S. DEPARTMENT OF ENERGY

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