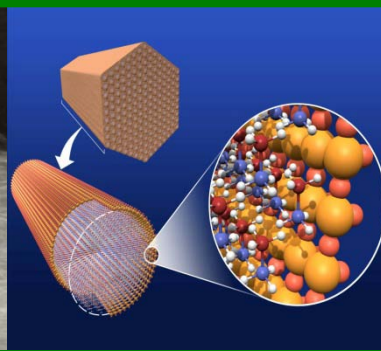




U.S. DEPARTMENT OF
ENERGY



Crosscutting and Validation

*(Manufacturing R&D; Technology Validation;
Safety, Codes & Standards; Education)*

Rick Farmer

*2012 Annual Merit Review and Peer Evaluation Meeting
May 14, 2012*

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

- 2013 - Reduce the manufacturing cost of membrane electrode assemblies by 25% relative to 2008
- 2017 - Develop fabrication and assembly processes for PEM fuel cells that cost \$30/kW

Technology Validation

- 2014 - Validate stationary fuel cell systems that co-produce hydrogen and electricity at 40% efficiency and 40,000 hour durability
- 2019 - Validate fuel cell vehicles achieving 5,000 hour durability and 300 mile driving range

Safety, Codes and Standards

- 2015 – Conduct a quantitative risk assessment to address indoor refueling requirements to be adopted by code development organizations
- 2017 - Complete material testing to develop ASME/ASTM hydrogen materials qualification guidelines, including composites

Education and Outreach

- 2012 - Develop an analysis tool to estimate economic impacts of early market fuel cells
- Expand case studies of near-term market applications

Manufacturing

- Manufacturing processes to produce high volume MEAs, bipolar plates, and balance of plant fuel cell components
- Carbon fiber fabrication techniques for conformable tanks

Technology Validation

- Sufficient data on fuel cell electric vehicle performance and durability data
- Adequate data on refueling infrastructure performance and availability data

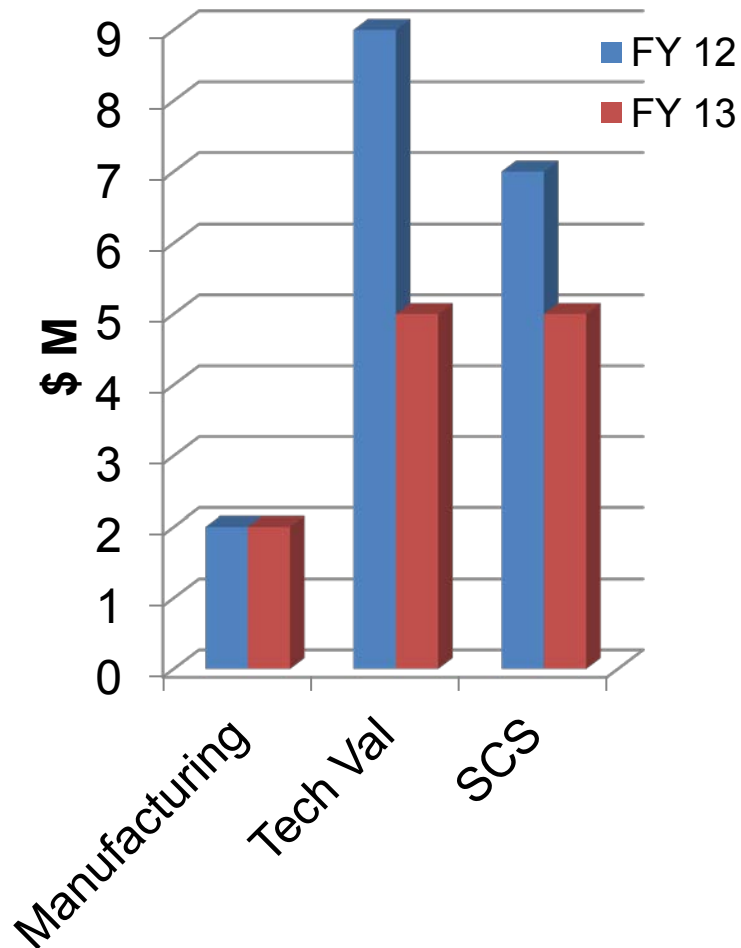
Safety, Codes and Standards

- Insufficient data to provide the scientific basis for technically sound codes and standards
- Harmonizing domestic and international regulations, codes and standards

Education and Outreach

- Resistance to change
- Lack of educated trainers and training opportunities

FY 2013 Request - \$12.0 M
FY 2012 Appropriation - \$18.0 M



EMPHASIS

Manufacturing

- Develop real-time, online measurement tools
- Demonstrate innovative precision fiber placement and filament winding for high-pressure carbon composite tanks
- Collaborate with Advanced Manufacturing Office

Technology Validation

- Data collection and analysis of fuel cells used in vehicles, fork lifts, backup power, buses, and CHHP
- Demonstration and evaluation of advanced fueling components

Safety Codes and Standards

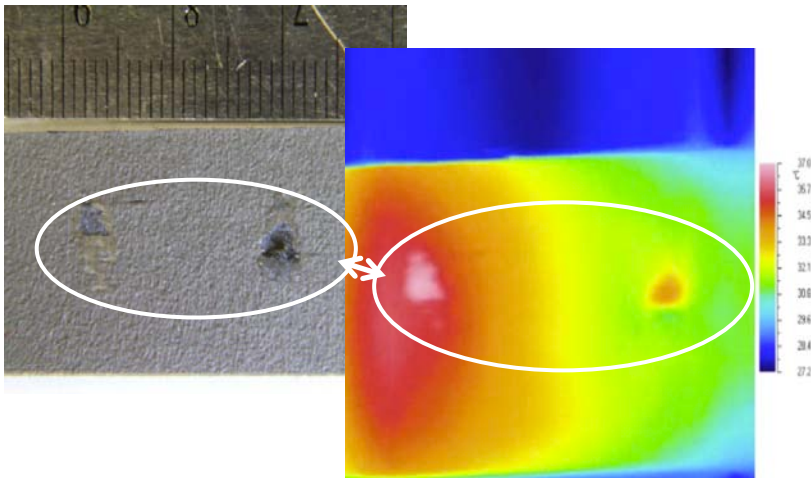
- Develop technical information and performance data to enhance codes and standards
- Facilitate the permitting of hydrogen fueling stations and early market applications

Achieved areal image of catalyst layer uniformity; technique has been scaled up for in-line testing. Sensitivity and detection time characterized for IR/RFT technique.

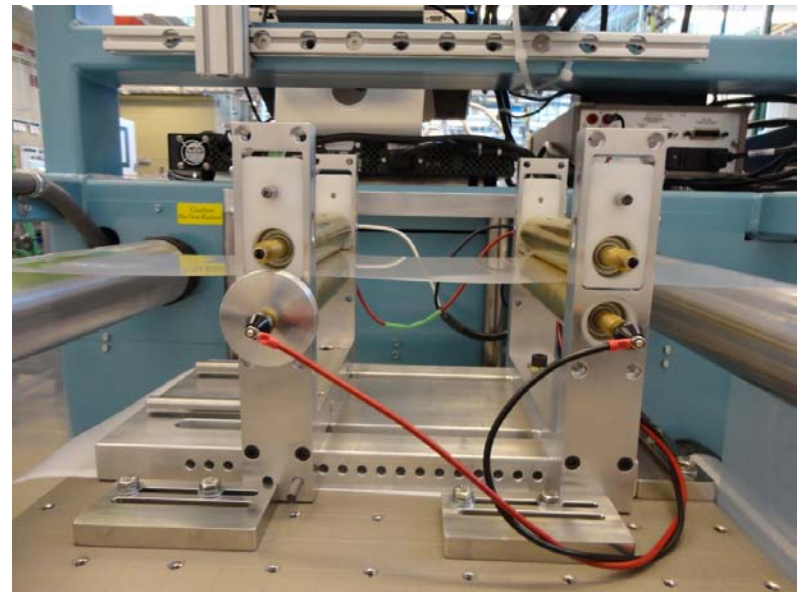
- Scaled up in-line diagnostics for MEA component quality control to 10 and 30 feet/min
- Detected all defects
- Integrating modeling to support diagnostic development and implementation



2011 - IR/Direct Current



2012 - IR/Direct Current



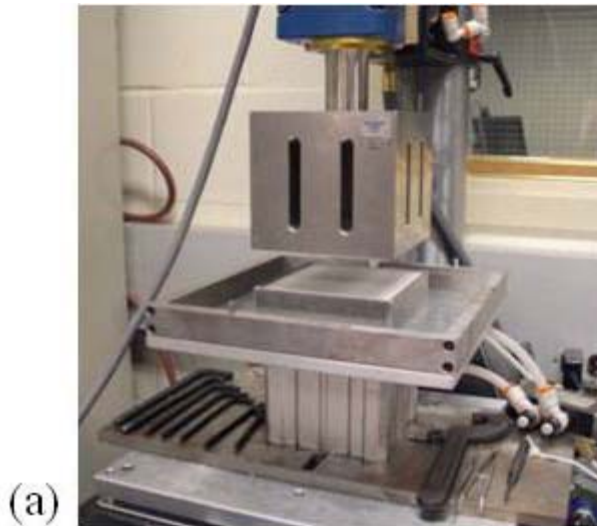
Ultrasonic sealing of MEAs provides rapid bonding and the potential for cost savings of >90% compared to thermal sealing.

Ultrasonic sealing of membrane electrode assemblies indicates that

- 90% cost reduction may be possible compared to thermal sealing
- U/S sealing (electrodes to membrane) is a very robust process
- U/S welding (subgasket to electrode) will enjoy similar cost savings

Lab data show the potential for

- 96% energy and 93% cycle time reductions with 50 cm² high-temperature MEAs
- 98% energy and 94% cycle time reductions with 10 cm² low-temperature MEAs



(a)

Ultrasonic tooling



(b)

Thermal Press Tooling

On April 13th, 2012, the Fuel Cell Study Group of the Defense Production Act Committee (DPAC) released a request for information.

Defense Production Act Committee/Title III

Three topic areas:

- Fuel Cell Balance-of-Plant: Standardization, Improved Manufacturing, and Improved Design/Performance
- Stack and Stack Components: Standardization and Improved Manufacturing.
- Acquisition and Deployment of Tactical Fuel Cell Systems

Responses were due May 14, 2012

- Late information may be considered by the government reviewers.

RFP may be issued

- Based on responses to the DPAC Fuel Cell RFI, RFP may be issued
- DPAC plans \$5 million for this RFP—looks for match from civilian agencies or other DOD entities.

https://www.fbo.gov/index?s=opportunity&mode=form&id=c0edaf3ff2f5eccc35309ad0f016ad33&tab=core&_cview=0

Technology Validation Progress

Completed the Learning Demonstration, which has provided valuable real-world data from fuel cell electric vehicles and hydrogen infrastructure



Data have been collected from 183 fuel cell electric vehicles and 25 hydrogen fueling stations during the Learning Demonstration

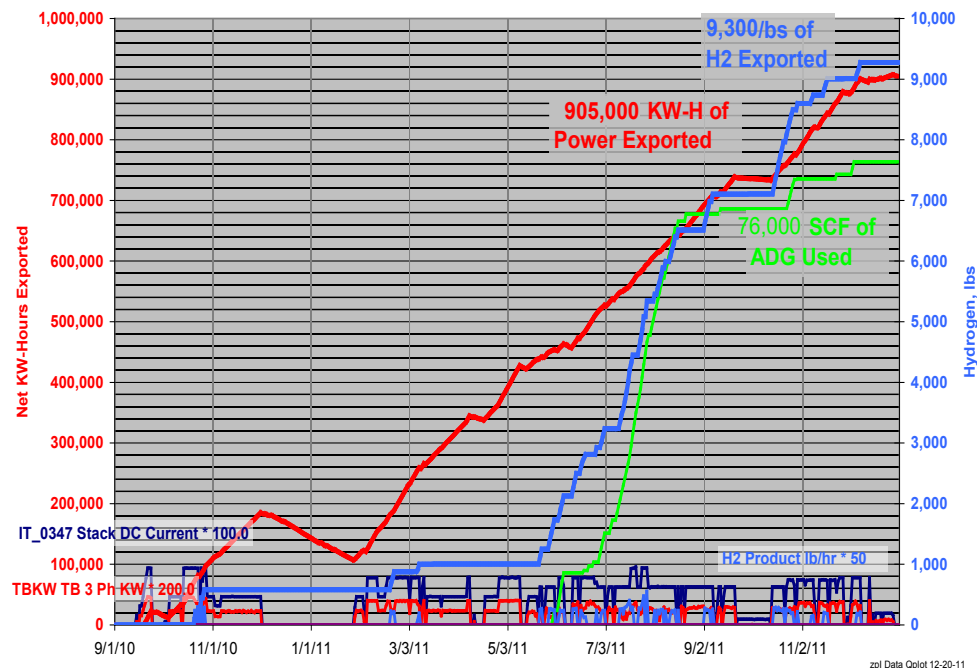
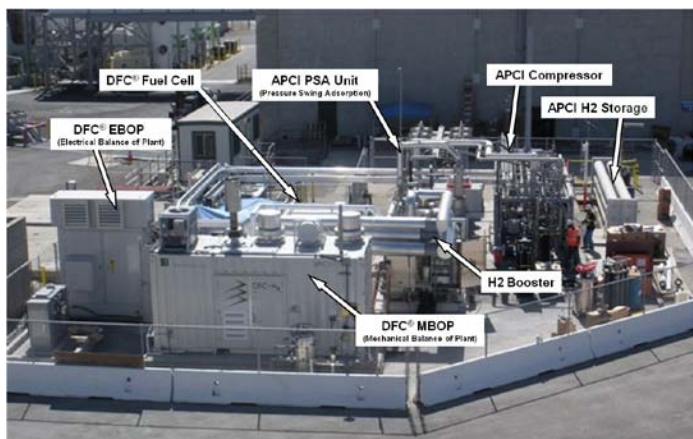
- 3.6 million miles traveled
- Over 154,000 total vehicle hours driven
- 152,000 kg of hydrogen produced or dispensed (including hydrogen used by vehicles not in the Learning Demonstration)
- Fuel cell efficiency 53 – 59%
- Range 196 – 254 miles
 - separately validated one vehicle with >430-mile range
- Fuel cell durability
 - 2,521 hours projected (~75K miles)
- 5-minute refueling time (for 4 kg of hydrogen)
- H₂ cost* (onsite reformation): \$7.70 – \$10.30
- H₂ cost* (onsite electrolysis): \$10.00 – \$12.90

*cost will reduce dramatically with increased number of stations

Technology Validation Progress

Hydrogen Energy Station at Fountain Valley, CA, achieved 54% efficiency (hydrogen + power) when operating in hydrogen co-production mode.

- Fueled with anaerobic digester gas
- Produces 100 kg/day H₂ (350 and 700 bar)
- Generates approximately 250 kW
- 54% efficiency co-producing H₂ and electricity



- Nearly 1 million kWh of power produced
- Over 4,000 kg of hydrogen produced
- 76,000 SCF of digester gas used

Fuel cell buses have 2X fuel economy of conventional buses, meeting 8 mpdgc target.

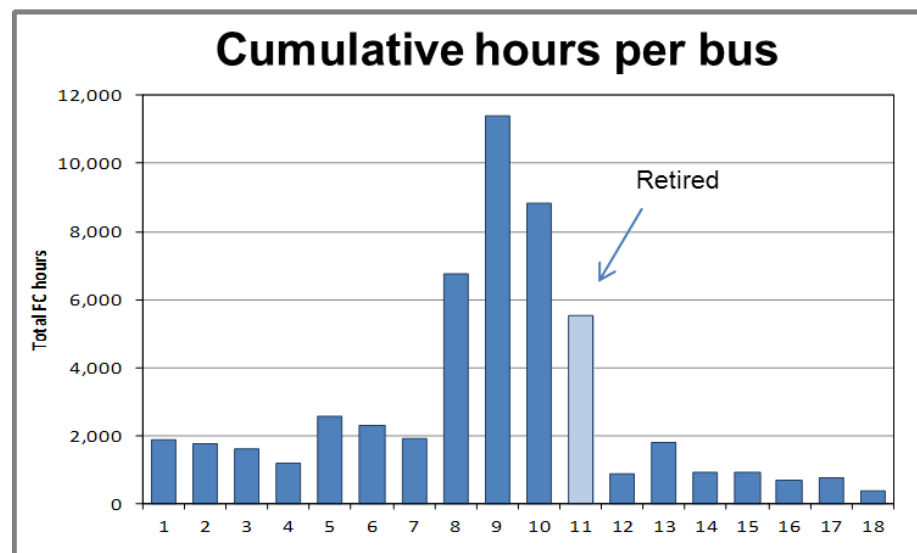
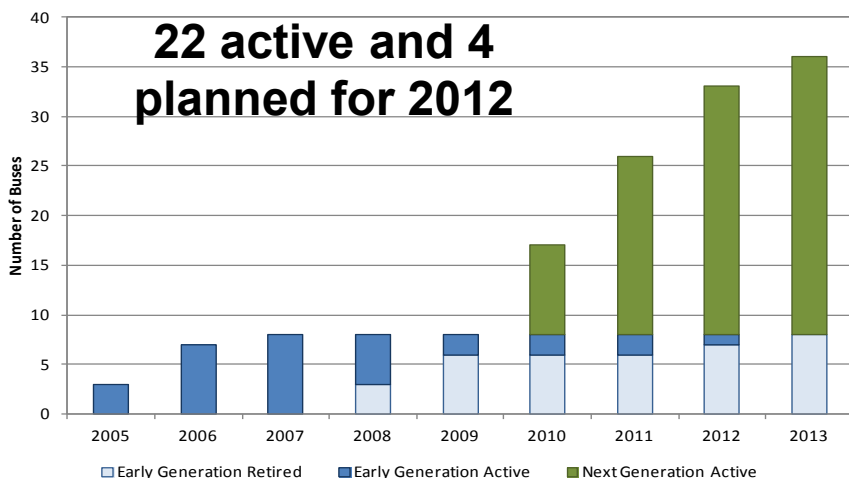
Bus fleet leaders

- 3 FCPPs** over 6,000 hours without repair or cell replacement
- Top FCPP now over 12,000 hours

** FCPP = Fuel cell power plant

Transit Agency	Project	Location	No. buses	Start-up date
SunLine	Adv. Tech FCEB	Thousand Palms, CA	1	May 2010 *
AC Transit	ZEBA	Emeryville, CA	12	June 2010 *
CTTRANSIT	NFCBP: Nutmeg	Hartford, CT	4	Aug 2010 *
SunLine	NFCBP: AFCB	Thousand Palms, CA	1	Jan 2012
SFMTA	NFCBP: Bus 2010	San Francisco, CA	1	Jun 2012
Cap Metro	NFCBP: Proterra	Austin, TX	1	April 2012

* Analyzed data



Light-Duty Fuel Cell Electric Vehicle Validation Data

Supply dynamometer and real-world vehicle data to the Hydrogen Secure Data Center (HSDC) at the National Renewable Energy Laboratory (NREL) for analysis and aggregation into composite data products for a minimum of five vehicles of the same model.

\$6M (\$500k to \$2M per award, up to 5 year period)

Applications Due 5/21 (Issue Date 2/29)

Validation of Hydrogen Refueling Station Performance and Advanced Refueling Components

Hydrogen Refueling Station Data Collection

Supply hydrogen refueling station data to the Hydrogen Secure Data Center (HSDC) at the National Renewable Energy Laboratory (NREL) for analysis and aggregation into composite data products. ~\$1.2M, \$400k (max) per award (up to 5 year period)

Validation of Advanced Refueling Components

Advanced components to be validated may include, but are not limited to, compressors, electrolyzers, hydrogen delivery, hydrogen storage systems, and dispenser systems or components, such as flow meters, nozzles or communications systems.

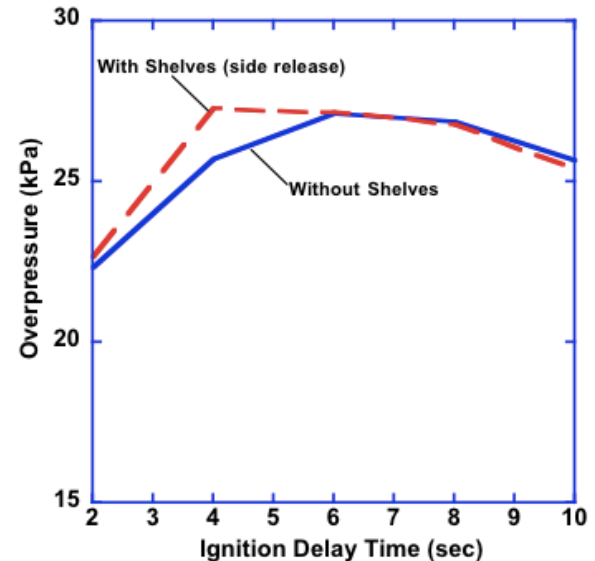
~\$3M, \$1M (max) per award (up to 5-year period)

Applications Due 5/10 (Issue Date 3/13)

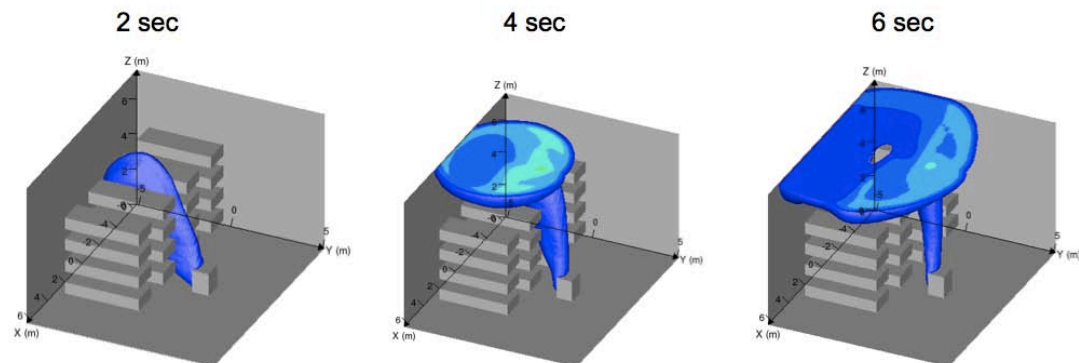
Validated hydrogen release data will impact changes being made to 2014 Edition of NFPA 2.

- Evaluated 0.8 kg H₂ release into a room (e.g., warehouses) with and without obstacles
- Showed that obstacles do not significantly impact release or overpressure characteristics for these conditions

Overpressure with and w/o obstacles



Flammable volume as a function of time for 6.35mm leak

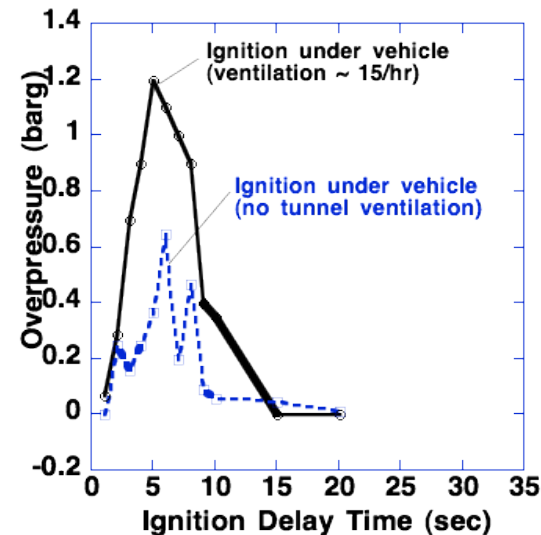
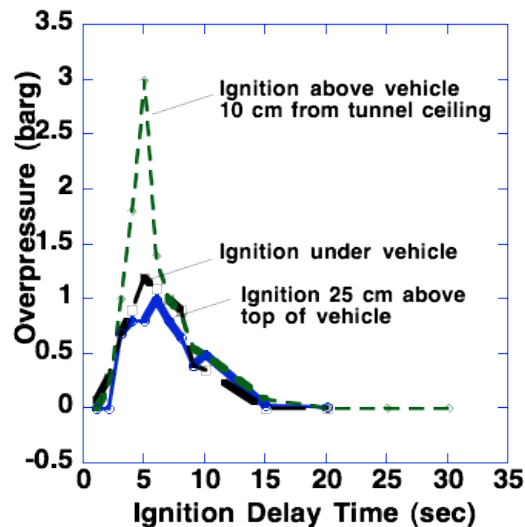
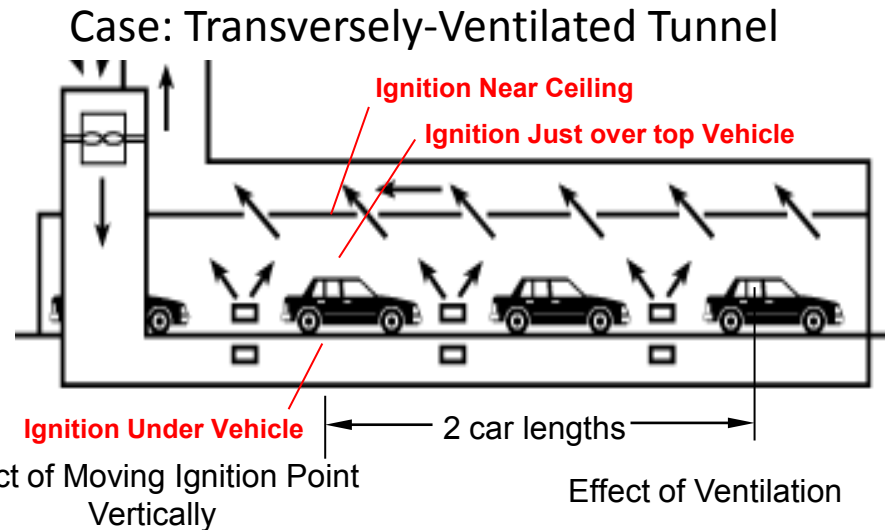


Validated hydrogen release data will aid harmonization of NFPA 2 (Hydrogen) and NFPA 502 (Tunnels).

- Early results show no increase to public risk of hydrogen vehicles in tunnels based on experimentally validated consequence simulation.

Discussion with NFPA 502:

- Presented consequence modeling results and analysis to NFPA 502 committee
- Committee accepts risk analysis results
- Acknowledged confidence in results based on thorough scientific approach



Safety, Codes and Standards Progress

Safety training of more than 23,000 first responders, researchers, and code officials to expand hydrogen knowledge base and to help expedite permitting

Training	Participants
Basic Hydrogen Education for First Responders (Hydrogen characteristics, behavior, and emergency response)	21,000
Code Official Training Workshop (Conveys information to help expedite permitting process)	1,000 (on line) 350 (in person)
Hands-on Training for First Responders (1-day classroom and live-fire training using a fuel cell vehicle prop)	710
Hydrogen Safety Training for Researchers and Technical Personnel (Covers all aspects of hydrogen safety, such as pressure devices)	100

Introduction to Hydrogen Safety for First Responders

COURSE MATERIALS LIBRARY EXIT

Hydrogen Basics Transport & Storage Hydrogen Vehicles Hydrogen Dispensing Stationary Facilities Codes & Standards Emergency Response Summary & Quiz

Hydrogen Properties and Behaviors

This prop provides a side-by-side demonstration of the flame characteristics of hydrogen and propane. It consists of two burners fed by two cylinders. One cylinder contains gaseous hydrogen and the other contains liquid propane. The gas pressures and flows have been adjusted to make the flames similar in size.

Temperatures at the base of each flame and at the top of each flame are measured using thermocouples, allowing us to compare the relative temperatures of hydrogen and propane flames.

Here we have the propane and hydrogen flames burning on a bright sunny day. The orange propane flame is clearly visible – the hydrogen flame is nearly invisible. But when we look at the flames through a thermal imaging camera, we can see both flames clearly.

A pure hydrogen flame has low radiant heat (infrared readings) – much less than the amount

Slide 5 of 13

U.S. DEPARTMENT OF ENERGY **energy.gov**

Hydrogen and Fuel Cells Program

Home About DOE Participants International Library News/Events SEARCH

Home > Codes and Standards > Introduction to Hydrogen for Code Officials [Printable Version](#)

Introduction to Hydrogen for Code Officials

The Department of Energy's [Introduction to Hydrogen for Code Officials](#) online training course provides an overview of hydrogen and fuel cell technologies, how these technologies are used in real-world applications, and references for related codes and standards.

The course consists of four modules:

- Hydrogen and fuel cell technology basics
- Hydrogen and fuel cell applications
- Hydrogen fueling stations
- Fuel cell facilities

A short quiz is offered at the end of each module. At the end of the course, you may print a "certificate of completion" that tallies your quiz score.

In addition, the course features a Library section with supplementary information including publications, related links, and a glossary of terms used in the course.

Safety, Codes and Standards Progress

Safety databases provide lessons-learned and promote safe operation when using and working with hydrogen.

U.S. DEPARTMENT OF ENERGY
Hydrogen Program
hydrogen.energy.gov

Hydrogen Safety Bibliographic Database

Home > Safety > Bibliography Database

The [Hydrogen Safety Bibliographic Database](#) provides references to reports, articles, books, and other resources for information on hydrogen safety as it relates to production, storage, distribution, and use. The database includes references related to the following topics:

- Hydrogen properties and behavior
- Safe operating and handling procedures
- Leaks, dispersion, and flammable vapor cloud formation
- Embrittlement and other effects on material properties
- Fuel cells and other energy conversion technologies
- Sensors, tracers, and leak detection technologies
- Accidents and incidents involving hydrogen

In addition to bibliographic references, the database provides select full text documents or links to other Web sites that offer these documents. To obtain full text documents that aren't included in the database, contact your local library.

Looking for a safety-related bibliographic reference that isn't currently available in this database? We welcome your [suggested additions](#).

H₂ SAFETY Snapshot

Vol. 2, Issue 2, July 2011

IDENTIFYING SAFETY VULNERABILITIES

How Do I Perform A Hazard Analysis?

Perform the hazard analysis at the project's earliest stages using any of the established industry methods described on page 2.

A hazard analysis typically consists

1. Define Work Scope
2. System Description
3. Hazard Identification
4. Hazard Analysis

What Is It?

Identifying Safety Vulnerabilities (ISV) is an analytical process that identifies and analyzes safety vulnerabilities associated with a hazard. It is a hazard analysis that is performed when a hazard is identified or eliminated.

Why Hazard on facility unsafe cause p

New! Lessons Learned Corner

Welcome to the new Lessons Learned Corner! Key themes from the H₂Incidents database will be presented here and several safety event records will be highlighted to illustrate the relevant lessons learned. Please let us know what you think and what themes you would like to see highlighted in this safety knowledge corner. Our first topic is **Management of Change**.

Management of Change

Management of change (MOC) is the process used to review all proposed changes to equipment, procedures, materials, personnel, and process operations before they are implemented to determine their effects on safety vulnerabilities. For example, standard operating procedures generally describe the acceptable operating ranges of process parameters (e.g., flow rates, concentrations, pH ranges, temperatures, pressures). A knowledgeable person should evaluate any proposed parameter changes to ensure safe operation. Operators should be made aware of changes and trained to respond with the appropriate actions if a parameter falls outside its acceptable range (e.g., notify supervisors, change process settings, shut down process).

Management of change is usually interpreted as relating to permanent changes, but temporary changes (e.g., abnormal situations, deviations from standard operating conditions, untrained personnel filling in during an expected absence) have been contributing factors in many catastrophic events over the years and should be managed as they were permanent changes. Sometimes changes occur that are unplanned, but they should still be systematically managed and controlled to avoid problems. It is critical that an unexpected change be recognized by alert operators and resulting safety vulnerabilities be communicated to all affected personnel immediately.

Lessons have been learned from a variety of safety events caused by MOC deficiencies. The events highlighted below resulted from changes in equipment, procedures, materials, personnel, and process operations that were not managed well. Had the organizations involved followed a basic change control methodology, they might have been able to prevent the incidents from occurring in the first place. Best practices for managing change are described in [H₂BestPractices](#).

Changes in Equipment

If a certain piece of equipment is modified or removed from a facility, it is important to evaluate the impacts of that change on the remaining equipment in the facility. For example, see [Battery Room Explosion](#).

Changes in Procedures

It is important to anticipate all potential consequences of a change in procedures, whether the change involves modifying a procedure or omitting some steps. For example, see [Hydrogen Reforming Tubes Ruptured during Startup from High Pressure Generated by Residual Water Flashing to Steam](#).

Changes in Materials

- Approximately 750 entries in the Hydrogen Safety Bibliographic Database
- 200 safety event records in the hydrogen incident database and now global input

<http://h2bestpractices.org/>
http://www.hydrogen.energy.gov/biblio_database.html
www.eere.energy.gov/hydrogenandfuelcells/codes/
<http://h2incidents.org/>

Studies identify impact of early market applications and deployments.

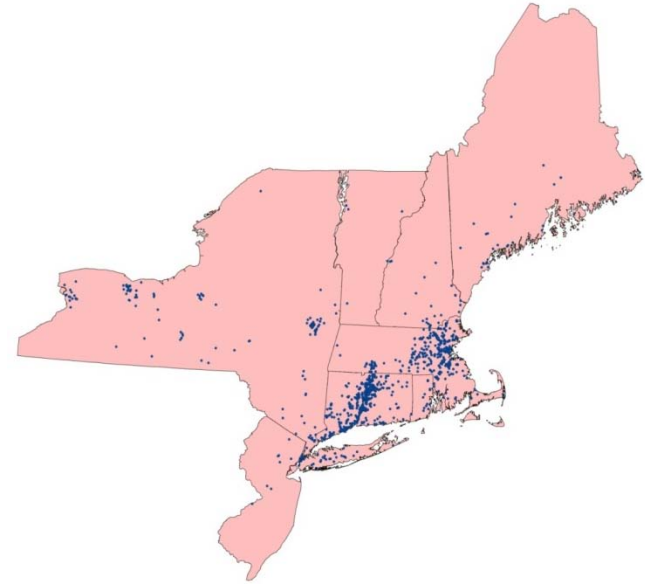
Connecticut Center for Advanced Technology*

Developed web-based virtual resource center

- Identified state economic impacts
- Mapped favorable deployment targets for environmental and energy reliability performance
- Deployment reinforces economic value

Organized event to “match” suppliers and manufacturers

Initiated Northeast Cluster group for state leader collaboration



	CT	NY	MA	ME	NH	RI	VT	NJ	Regional
Total Employment	2,529	1,728	964	18	45	32	16	111	5,443
Total Revenue / Investment (\$ million)	\$496	\$292	\$171	\$2.9	\$8.7	\$6.9	\$3.3	\$26.5	\$1,009
Total Supply Chain Companies	599	183	322	28	25	19	5	8	1189



Connecticut Center for
Advanced Technology, Inc.

Videos and webinars expand the Program's reach to a wider audience with over 1,500 webinar attendees in the past year.

Virginia Clean Cities - PBS *Motorweek* Series

Vehicles and Infrastructure Update - Began airing 10/22/2011

<http://video.pbs.org/video/2165096277>



Webinars:

- Past topics have included:
 - Federal Facilities Guide to Fuel Cells (May 2012)
 - America's Next Top Energy Innovator Runner Up (April 2012)
 - National Hydrogen Learning Demonstration Status (Feb 2012)
- Upcoming Webinars:
 - May 22, 2012: Jobs Tool
 - June 2012: Recent fuel cell licenses
 - July 2012: Portable power
 - August 2012: Mobile lighting

<http://www1.eere.energy.gov/hydrogenandfuelcells/webinars.html>

Education and Outreach Progress

Published more than 70 news articles in FY 2011 to continue communication of program accomplishments

News Items

- “Energy Department Awards More than \$5 Million to Reduce Cost of Advanced Fuel Cells”
- “Energy Department Announces up to \$10 Million to Promote Zero Emission Cargo Transport Vehicles”
- “SBIR/STTR Phase I Release 3 Technical Topics Announced, Fuel Cells and Hydrogen Storage Included”
- “DOE Announces up to \$2 Million to Collect Data from Hydrogen Fueling Stations and Demonstrate Innovations in Hydrogen Infrastructure Technologies”



“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.”

Blogs Published to Energy.gov Website

- “Leaders of the Fuel Cell Pack”
- “Fuel Cell Lift Trucks: A Grocer's Best Friend”



Hydrogen fuel cells providing critical backup power

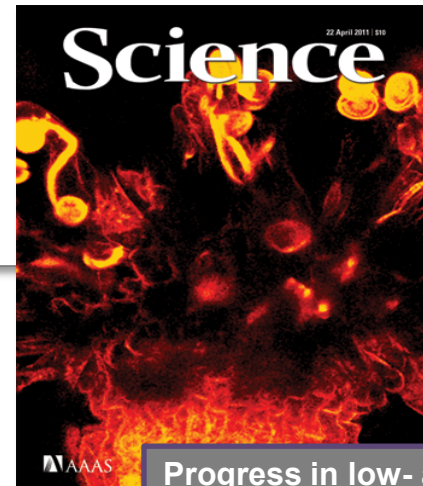
Launched the Fuel Cell Technologies Program Newsletter

Monthly newsletter recaps news and events and previews upcoming activities.

Visit the web site to register or to see archives (<http://www1.eere.energy.gov/hydrogenandfuelcells/newsletter.html>)



Fuel cell – powered lights at the 2011 Golden Globe Awards



Progress in low- and zero-Pt catalysts highlighted in *Science*

FY 2012 FOAs	FY 2012 Funding
Collect Performance Data on Fuel Cell Electric Vehicles	\$6.0 million
Hydrogen Fueling Stations and Innovations in Hydrogen Infrastructure Technologies	\$2.0 million
Zero-Emission Cargo Transport Vehicles (Vehicle Technologies)	\$10.0 million

Request for Information

Potential Topics for H-Prize—*extended to May 31, 2012*

(www.hydrogenandfuelcells.energy.gov/m/news_detail.html?news_id=18182)

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