

## VIII.6 Hydrogen Safety Panel, Safety Knowledge Tools and First Responder Training Resources

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Project Start Date: 2004

Project End Date: Project continuation and direction determined annually by the U.S. DOE

### Overall Objectives

- Provide expertise and recommendations to DOE and help identify safety-related technical data gaps, best practices, and lessons learned
- Help DOE integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices
- Collect information and share lessons learned from hydrogen incidents and near misses to help prevent similar safety events in the future
- Capture vast and growing knowledge base of hydrogen experience and make it publicly available to the hydrogen community and stakeholders
- Support the implementation of hydrogen and fuel cell technologies by providing technically accurate hydrogen safety and emergency response information to first responders

### Fiscal Year (FY) 2015 Objectives

- Develop a plan to update first responder training materials with revised and new content, including videos, virtual reality features, and other enhancements
- Develop and deploy a publicly available Hydrogen Tools Portal having at least four resources
- Develop a draft third party hydrogen certification guide to facilitate timely project permitting and approval by code officials

### Technical Barriers

This project addresses the following technical barriers from the DOE Fuel Cell Technologies Office (FCTO) Multi-Year Research, Development and Demonstration (MYRDD) Plan [1]:

Safety, Codes and Standards

- (A) Safety Data and Information: Limited Access and Availability
- (B) Availability and Affordability of Insurance
- (C) Safety is Not always Treated as a Continuous Process
- (D) Lack of Hydrogen Knowledge by AHJ (Authorities Having Jurisdiction)
- (E) Lack of Hydrogen Training Materials and Facilities for Emergency Responders
- (G) Insufficient Technical Data to Revise Standards

Education and Outreach

- (A) Lack of Readily Available, Objective and Technically Accurate Information
- (D) Lack of Educated Trainers and training Opportunities

### Contribution to Achievement of DOE Milestones

This project contributes to achievement of the following DOE tasks and milestones from the FCTO MYRDD Plan:

Safety, Codes and Standards

- Task 1: Address Safety of DOE R&D Projects (ongoing)

- Task 5: Dissemination of Data, Safety Knowledge, and Information (ongoing)
- Milestone 5.1: Update safety bibliography and incidents databases (4Q, 2011–2020)

#### Education and Outreach

- Task 1: Educate Safety and Code Officials (ongoing)
- Milestone 1.1: Update “Introduction to Hydrogen Safety for First Responders” course for first responders (Biannually)

### FY 2015 Accomplishments

- The 21st Hydrogen Safety Panel (HSP) meeting in West Sacramento, California, March 3–5, 2015, served to enable the consideration of timely and relevant safety issues and the engagement of key hydrogen infrastructure stakeholders in California.
- Fifteen reviews (including safety plans and project design work) were conducted since July 1, 2014, for projects in fuel cell and hydrogen storage R&D. Particular emphasis was placed on early project involvement, as discussed in the FY 2013 annual progress report [3], in order to identify significant safety-related issues early enough to allow consideration by project teams.
- PNNL and the California Fuel Cell Partnership (CaFCP) collaborated to develop the “National Hydrogen and Fuel Cell Emergency Response Training Resource,” which was made publicly available in September 2014.
- Planning sessions involving first responder trainers, facility and equipment providers, and other interested persons identified potential improvements for first responder training resources. Results suggested that improved images and videos, new props, and virtual reality tools could cost-effectively improve the instructional quality and potential reach of such resources.
- The online Hydrogen Tools Portal (<http://h2tools.org>) was developed and deployed (June 2015) as a publicly available resource. The portal is a transformative step toward disseminating safety information on hydrogen and fuel cell technologies through a variety of tools and web-based content that increase their accessibility, visibility, and value.
- Planning was completed for an outreach and educational session for the International Code Council (ICC) annual business meeting, Long Beach, California, September 27–29, 2015, to include presenting “Safety Considerations for Hydrogen and Fuel Cell Applications.”



## INTRODUCTION

Safety is essential for realizing the hydrogen economy—safe operation in all of its aspects from hydrogen production through storage, distribution and use, from research, development and demonstration to deployment and commercialization. As such, safety is given paramount importance in all facets of the research, development, demonstration and deployment work of FCTO. This annual report summarizes activities associated with three project tasks: the Hydrogen Safety Panel, Safety Knowledge Tools, and First Responder Training Resources.

Recognizing the nature of DOE fuel cell technology (FCT) programs and the importance of safety planning, the Hydrogen Safety Panel was formed in December 2003 to bring a broad cross-section of expertise from the industrial, government and academic sectors to help ensure the success of the program as a whole. The panel’s experience resides in industrial hydrogen production and supply, hydrogen R&D and applications, process safety and engineering, materials technology, risk analysis, accident investigation, and fire protection. The panel provides expertise and recommendations on safety-related issues and technical data gaps, reviews individual DOE-supported projects and their safety plans and explores ways to develop and disseminate best practices and lessons learned, all broadly benefiting the FCT programs. The panel is currently composed of 14 members having over 400 years of industry and related experience (see Table 1 for FY 2015 panel membership).

**TABLE 1.** Hydrogen Safety Panel

Nick Barilo, Program Manager	PNNL
Richard Kallman, Chair	City of Santa Fe Springs, CA
David Farese	Air Products and Chemicals
Larry Fluer	Fluer, Inc.
Bill Fort	Shell Global Solutions (ret)
Don Frikken	Becht Engineering
Aaron Harris	Sandia National Laboratories
Chris LaFleur	Sandia National Laboratories
Miguel Maes	NASA White Sands Test Facility
Steve Mathison*	Honda Motor Company
Larry Moulthrop	Proton OnSite
Glenn Scheffler	GWS Solutions of Tolland, LLC
Steven Weiner	Excelsior Design, Inc.
Robert Zalosh	Firexplo

\* New panel member; NASA – National Aeronautics and Space Administration

Widespread availability and communication of safety-related information are crucial to ensuring the safe operation of future hydrogen and fuel cell technology systems. The entire hydrogen community benefits if hydrogen safety-related knowledge is openly and broadly shared. To that end,

PNNL continues to improve the safety knowledge software tools and develop new techniques for disseminating this information. This report covers the Hydrogen Tools Portal (<http://h2tools.org>), the Hydrogen Lessons Learned database (<http://h2tools.org/lessons/>), the Hydrogen Safety Best Practices online manual (<https://h2tools.org/bestpractices>), and the Hydrogen Tools iPad and iPhone apps. These resources are key to reaching, educating and informing stakeholders whose contributions will help enable the deployment of new hydrogen and fuel cell technologies.

A suitably trained emergency response force is essential to a viable infrastructure. FCTO has placed a high priority on training emergency response personnel, not only because these personnel need to understand how to respond to a hydrogen incident, but also because firefighters and other emergency responders are influential in their communities and can be a positive force in the introduction of hydrogen and fuel cells into local markets. This report covers hazardous materials emergency response training to provide a tiered hydrogen safety education program for emergency responders. The effort started with development and distribution of the awareness-level online course in FY 2006–2007. An operations-level classroom curriculum was developed in FY 2008–2009, including the design, construction and operation of a fuel cell vehicle prop for hands-on training. PNNL and the California Fuel Cell Partnership (CaFCP) collaborated to develop a national hydrogen safety training resource for emergency responders, which was made publicly available in September 2014.

## APPROACH

The HSP strives to raise safety consciousness most directly at the project level through organizational policies and procedures, safety culture, and priority. Project safety plans and design documents are reviewed to encourage thorough and continuous attention to safety aspects of the specific work being conducted. Panel safety reviews focus on engagement, learning, knowledge-sharing and active discussion of safety practices and lessons learned, rather than audits or regulatory exercises. Through this approach, DOE and the HSP are trying to achieve safe operation, handling and use of hydrogen and hydrogen systems for all DOE projects.

The approach for disseminating safety knowledge shifted in FY 2015. While the project retained its current tools—the Hydrogen Lessons Learned database and the Hydrogen Safety Best Practices online manual—the primary focus was a new resource: the Hydrogen Tools Portal. The portal integrates a broader set of hydrogen safety resources into a single location, maximizing their efficacy and impact. Additional discussion of this resource is provided in the Results section of this report.

PNNL collaborates with subject matter experts in hydrogen safety and first responder training to develop, review, and revise training materials as needed. The PNNL project team works with DOE to inform stakeholder groups of training opportunities and to provide “live” training when appropriate. The online awareness-level course provides the student with a basic understanding of hydrogen properties, uses and appropriate emergency response actions. The operations-level classroom/hands-on prop-based course has been presented at the Volpentest Hazardous Material Management and Materials Response (HAMMER) Federal Training Center in Richland, Washington, and at several fire-training centers in California and Hawaii to reach larger audiences in areas where hydrogen and fuel cell technologies are being deployed.

New approaches are needed to meet the needs of first responders and the presentation styles of training organizations and to complement existing training programs. The National Hydrogen and Fuel Cell Emergency Response Training Resource (NTR) will help ensure a consistent source of accurate information and current knowledge. As part of this resource, a training template has been developed to guide the delivery of a variety of training regimens to various audiences.

## RESULTS

The 21st meeting of the Hydrogen Safety Panel was held in West Sacramento, California, March 3–5, 2015. The meeting provided opportunities to consider timely and relevant safety issues and provide direct input to FCTO. The topics discussed and outcomes achieved at the meeting are detailed in the minutes [2]. Two panel task groups were formed at the meeting to (1) investigate sources of information for liquid hydrogen releases and provide a summary document and (2) investigate the results from compressed natural gas tank failure incidents, tank testing, SAE J2579 requirements, and other related materials to consider what might be learned for hydrogen.

During the past year, the panel has provided safety reviews and support to projects as noted in Table 2. Since 2004, the panel has participated in 413 project reviews (including safety plans, site visit reviews, follow-up phone interviews, and design review work). Three of these projects used the early project involvement approach discussed in the FY 2013 annual progress report [3], which identified significant project issues early enough to allow consideration by project teams.

A significant panel initiative during FY 2015 was work to develop a certification guide to assist code officials and project proponents with approval of hydrogen systems and facilities when listed equipment is not available. This effort is in response to a gap that the panel identified during the American Recovery and Reinvestment Act of 2009 project

TABLE 2. HSP Project Safety Work since July 1, 2015

Work	Project Title	Contractor
Document Review [4]	Austin Fuel Cell Bus, Hydrogen Purge Failure Analysis Report 1 of 2	Proterra, Inc.
Design Review [5]	Hydrogen Refueling Trailer (Hawaii Maritime Project)	Sandia National Laboratories/Luxfer-GTM
Safety Plan [6]	Smart Matrix Development for Direct Carbonate Fuel Cell	FuelCell Energy
Design Review [7]	HyStEP	Sandia National Laboratories
Safety Plan [8]	Wide Bandgap Chalcopyrite Photoelectrodes for Direct Solar Water Splitting	HNEI
Safety Plan [9]	Linear Motor Reciprocating Compressor (LMRC) for Forecourt Hydrogen Compression	Southwest Research Institute®
Safety Plan [10]	A Novel Hybrid Reformer-Electrolyzer-Purifier (REP) for Distributed Production of Low-Cost, Low Greenhouse Gas Hydrogen	FuelCell Energy
Safety Plan [11]	Affordable, High-Performance, Intermediate Temperature Solid Oxide Fuel Cells	Redox Power Systems, LLC
Safety Plan [12]	Smart Matrix Development for Direct Carbonate Fuel Cell	FuelCell Energy
Safety Plan [13]	Boron-Based Hydrogen Storage – Ternary Borides and Beyond	HRL Laboratories
Safety Plan [14]	Particle Flow Solarthermal RedOx Water Splitting	University of Colorado
Site Visit [15]	LLNL Cryogenic and High Pressure Hydrogen Vessel Testing Facility Safety Plan	LLNL
Safety Plan [16]	Demonstration of a Fuel Cell-powered Transport Refrigeration Unit (TRU) (Safety Plan)	Plug Power
Design Review [17]	Maritime Fuel Cell Generator Project (Second Review)	Sandia National Laboratories
Safety Plan [18]	LLNL Cryogenic and High Pressure Hydrogen Vessel Testing Facility Safety Plan	LLNL

HNEI – Hawaii Natural Energy Institute; LLNL – Lawrence Livermore National Laboratory

reviews [19]. The need for this activity was also identified at a 2014 stakeholder meeting to consider additional tools for supporting hydrogen and fuel cell commercialization [20]. The challenge with certification is that the listing process for rapidly changing products, consistent with developing technologies, tends to be cost-prohibitive for equipment providers (each revision to the equipment requires recertification). The circumstance of new technologies under development and low demand for early market applications results in few components and systems being currently listed. The scarcity of listed equipment places an extraordinary burden on code officials to ensure (and approve) that products include the appropriate inherent or automatic safety measures. The guide will identify listing requirements in the ICC codes and National Fire Protection Association (NFPA) 2 for hydrogen equipment, and suggest criteria for approval when listed equipment is not available. This will provide common criteria for code officials and third parties to use in approving unlisted equipment. It will also ensure that different vendors are considering the same criteria across a variety of projects. A draft of the certification guide is expected to be available in the fall of 2015 [21].

A publicly accessible Hydrogen Safety Panel website (<https://h2tools.org/hsp>) was made available in March 2015. The website enables visitors to explore the Panel's purpose and activities and download information and resources. A web presence will help reinforce the Panel's position as the go-to resource for serious, informed, and unbiased consideration of relevant safety issues.

The Hydrogen Tools Portal was made publicly available in June 2015. The portal is a transformative step toward disseminating safety information and enabling fuel cell commercialization. It brings together a variety of tools and web-based content on the safety aspects of hydrogen and fuel cell technologies, increasing their accessibility, visibility, and value. The portal is intended to help inform those tasked with designing, approving or using systems and facilities, as well as those responding to incidents. The portal was released with 11 resources, user workspaces, and discussion forums. The workspaces are a first of its kind tool that enables users (code officials, first responders, risk managers, operations and maintenance personnel, project proponents, and researchers) to explore resources side-by-side on a single web page. The resources include a bibliography, lessons learned, best practices, a codes and standards database, a hydrogen compatibility database, and a questions/answers section.

Disseminating safety information continues to be an important aspect of this project. During this reporting period, PNNL primarily focused outreach activities on membership associated with the ICC. ICC members include building, fire, plumbing, mechanical and energy officials representing state, county, municipal and federal governments. Ensuring that this group is informed on hydrogen safety-related issues and resources can help facilitate a safe and timely transition to fuel cell technologies. The project activities during FY 2015 included authoring/coauthoring two online articles for the Building Safety Journal [18] and coordinating a hydrogen safety educational session [22] and outreach event for the ICC's annual business meeting, September 27–29, 2015.

PNNL and the CaFCP are collaborating on the outreach to bring a ride and drive event and booth display for the attendees. Other outreach activities during FY 2015 included a presentation at the National Professional Development Symposium for the National Fire Academy [23], and a presentation at the European Technical School on Hydrogen and Fuel Cells in Crete, Greece [24].

FY 2015 activities directed toward the first responder training task included release and deployment of the NTR, developing a plan for improving first responder training materials, and providing hands-on training. The NTR is intended to serve as a consistent source of accurate and current information to enable trainers to provide their own first responder hydrogen safety training based on their needs and environments. The NTR was made publicly available in September 2014 (<http://h2tools/fr/nt>), and a webinar was conducted in March 2015 to announce its availability and provide guidance on its use. Early indications are that this will be a valuable resource. The webinar had over 250 attendees and the NTR has been downloaded on six continents and in 35 of 50 states (see Figure 1). The NTR was also translated into Japanese in February 2015 to support hydrogen and fuel cell technology initiatives in Japan. FCTO presented an R&D award to the project manager in

charge of this work for “his outstanding efforts in developing comprehensive safety training resources” in this area.

A plan to revise first responder training materials was drafted in FY 2015. The goal of this activity is to consider what types of materials (videos, virtual reality tools, etc.) would enhance the first responder learning experience the most. The effort included collaboration with a variety of first responder trainers, facility and equipment providers and other interested persons. Results suggested that improved images and videos, new props, and virtual reality tools could cost-effectively improve the instructional quality and potential reach of first responder hydrogen safety training resources. Dissemination of training resources was also discussed. As a result of this activity, PNNL has begun discussions with the National Fire Academy to transfer the online awareness training to them in order to:

- Allow a broader distribution of the materials.
- Improve crediting of course completion/continuing education units.
- Provide a good long-term landing spot for the training.

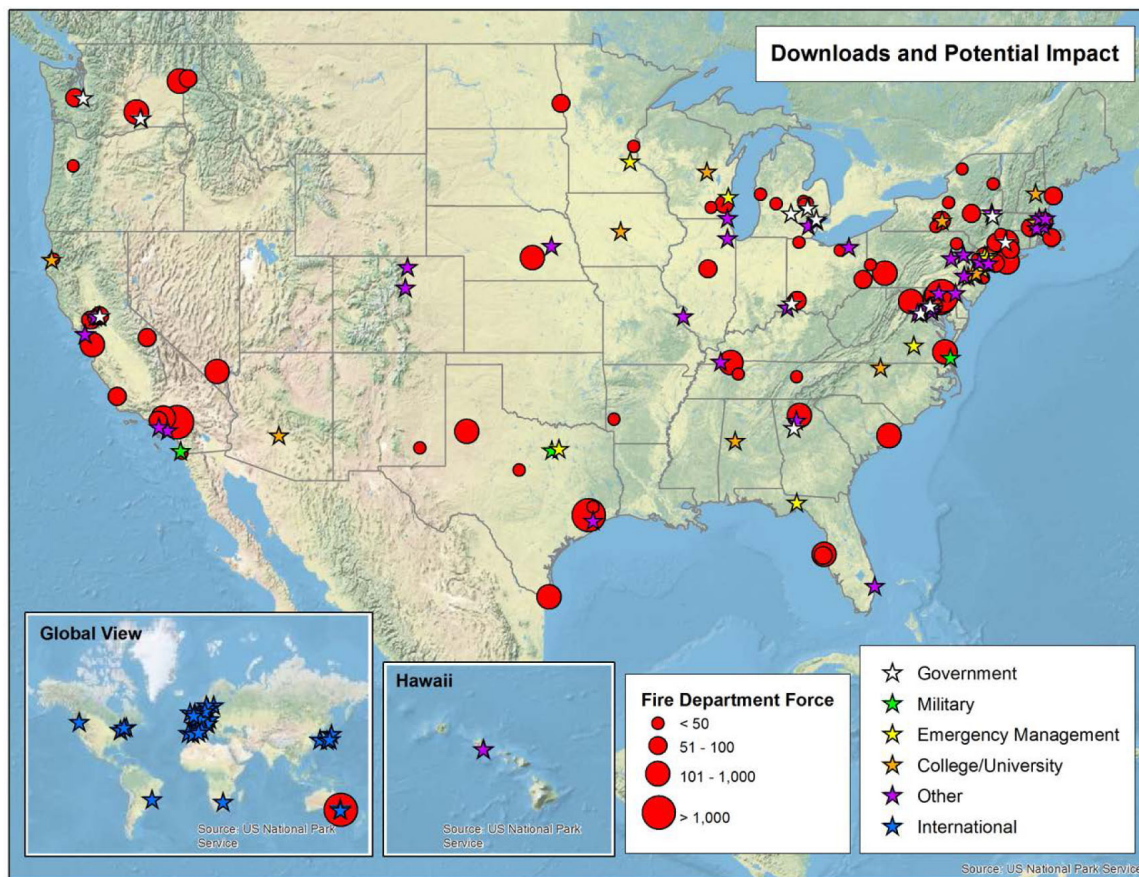


FIGURE 1. NTR Downloads and Potential Impacts

PNNL and CaFCP would continue to provide subject matter expertise on the technical content after the transfer.

First responder outreach and training for FY 2015 included a hydrogen first responder prop demonstration at the Volpentest HAMMER Federal Training Center, Richland, Washington, for the Northwest's International Association of Fire Fighters Fire Ops 101 (approximately 75 participants). Operations-level training, including classroom and prop demonstration, was provided for the Washington State Annual Hazardous Materials Workshop, and was also conducted at HAMMER. For the latter, the NFPA video recorded the prop demonstration for use in their DOE-funded alternative fuels first responder training. NFPA also video recorded the classroom portion of the training for the project to include in the Hydrogen Tools Portal.

## CONCLUSIONS AND FUTURE DIRECTIONS

The HSP will continue to focus on how safety knowledge, best practices, and lessons learned can promote the safe conduct of project work and the deployment of hydrogen technologies and systems in applications of interest and priority in FCTO. The Panel can also be used more broadly as an asset for safe commercialization by reaching out to new stakeholders and users involved in early deployment.

HSP initiatives over the next fiscal year will include the following.

- Support project activities with the focus on early engagement, including kickoff meetings, safety plan reviews, site visits, and other interactions with project teams
- Engage non-DOE entities to identify opportunities to use the panel to review hydrogen and fuel cell initiatives and promote safety
- Identify opportunities to support H2USA (H2USA is a public-private partnership to promote the commercial introduction and widespread adoption of fuel cell electric vehicles across the United States with a mission to address hurdles to establishing hydrogen fueling infrastructure)
- Submit a draft hydrogen certification guide to DOE and work with stakeholders, code officials, and other interested parties to review the content in preparation for public release of the document by the end of FY 2016
- Support the H-Prize competition, including a safety planning webinar and participant submittal reviews to ensure that safety is considered and prioritized for this initiative

- Continue to evaluate the panel membership to maintain its leadership role in hydrogen safety through an appropriate mix of safety expertise and perspective to perform safety reviews and address relevant issues
- Seek opportunities to share safety knowledge with new audiences to facilitate the safe deployment of hydrogen and fuel cell technologies
- Meet with code officials, project proponents and stakeholders from recently completed fuel station projects to discuss safety learnings and needs (three to six trips)

Hydrogen safety knowledge tools help remove barriers to the deployment and commercialization of hydrogen and fuel cell technologies. The introduction of the Hydrogen Tools Portal opens new opportunities for sharing safety information and reaching broader audiences. In FY 2016, PNNL will enhance the Hydrogen Tools Portal, including workspace customization, mobile device display improvements, search engine optimization, and improved site performance. PNNL will also explore opportunities to collaborate with other national laboratories, state organizations and industry partners to identify and integrate new resources into this valuable website. Outreach will focus on state fire marshal organizations through focused meetings and key conferences.

The project's first responder training resources address a key H2USA barrier, ensure a safe transition to fuel cell vehicles and hydrogen infrastructure, and pave the way for broader public acceptance. Potential activities for FY 2016 include development of new pictures and videos for use in all first responder training resources and processing the NFPA video for use on the Hydrogen Tools Portal. Onsite operations-level training may also be provided in the Northeast if sufficient resources are available.

International collaboration is important to PNNL's hydrogen safety work. In October 2015, PNNL will participate in the International Conference in Hydrogen Safety in Yokohama, Japan, and present on two topics, "Hydrogen and Fuel Cells – Emphasizing Safety to Enable Commercialization" and "First Responder Training: Supporting Commercialization of Hydrogen and Fuel Cell Technologies." PNNL is also exploring opportunities to collaborate with the International Association on Hydrogen Safety to develop best practices for safety issues related to current and emerging fuel cell technologies.

## FY 2015 PUBLICATIONS/PRESENTATIONS

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