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Hydrogen Safety Panel, Safety Knowledge Tools and First Responder Training Resources

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Hydrogen Program Annual Merit Review and Peer Evaluation Meeting

Arlington, VA

June 9, 2015

This presentation does not contain any proprietary, confidential or otherwise restricted information.

SCS019

Overview

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Hydrogen Safety Panel

- Project Start Date: 2003
- Project End Date: 2015[1]
- FY14 DOE Funding: $625K
- Planned FY15 DOE Funding: $525K
- Total Project Funding: $9,504K

Safety Resources (Knowledge Tools and First Responder Training)

- Project Start Date: 2003
- Project End Date: 2015[1]
- FY14 DOE Funding: $225K
- Planned FY15 DOE Funding: $350K
- Total Project Funding: $4,294K

Barriers addressed[2]

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 AHJs
E. Lack of hydrogen training materials and facilities for emergency responders
G. Insufficient technical data to revise standards

Partners

- Panel member organizations
- California Fuel Cell Partnership (CaFCP)
- National Renewable Energy Laboratory (NREL)
- National Fire Protection Association (NFPA)

[1] Project continuation and direction determined annually by DOE
[2] Technical Plan – Hydrogen Safety, Codes and Standards, Section 3.7, Multi-Year Research, Development and Demonstration Plan, pp. 25-26, July 2012 (updated July 2013).

PNNL Hydrogen Safety Program

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Hydrogen Safety Panel

- Identify Safety-Related Technical Data Gaps
- Review Safety Plans and Project Designs
- Perform Safety Evaluation Site Visits
- Provide Technical Oversight for Other Program Areas

HYDROGEN Safety Panel

Safety Knowledge Tools and Dissemination

- Hydrogen Lessons Learned
- Hydrogen Best Practices
- Hydrogen Tools (iPad/iPhone mobile application)
- Hydrogen Tools Portal (http://h2tools.org)

HYDROGEN Tools

Hydrogen Safety First Responder Training

- Online Awareness Training
- Operations-level Classroom/Hands-on Training
- National Hydrogen and Fuel Cell Emergency Response Training Resource

HYDROGEN Emergency Response Training Resources

Objectives

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Hydrogen Safety Panel

- Provide expertise and recommendations to DOE and assist with identifying safety-related technical data gaps, best practices and lessons learned.
- Help integrate safety planning into funded projects to ensure that all projects address and incorporate hydrogen and related safety practices.

Safety Knowledge Tools and Dissemination

- Collect information and share lessons learned from hydrogen incidents and near-misses, with a goal of preventing similar safety events from occurring in the future.
- Capture vast and growing knowledge base of hydrogen experience and make it publicly available to the "hydrogen community."

First Responder Training

- Implement a national hydrogen emergency response training resource program with downloadable materials that are adaptable to the specific needs of first responders and training organizations
- Identify enhancements to first responder training content, techniques and delivery

Approach

Priority attention to safety and enhanced visibility

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Hydrogen Safety Panel

- Conduct ongoing safety evaluations of projects through design reviews, safety plan reviews and site visits and assess learnings
- Utilize Panel expertise to develop and maintain safety guidance tools; address technical safety gaps and make recommendations to DOE on safety related topics

Safety Knowledge Tools and Dissemination

- Identify and develop new tools and methods to support hydrogen and fuel cell commercialization. Disseminate hydrogen safety knowledge utilizing electronic resource tools such as a web portal and mobile apps.
- Bring greater visibility to hydrogen safety and the project's safety knowledge tools through presentations to audiences not familiar with fuel cell technologies

First Responder Training

- Develop a plan to revise first responder training materials to include new content such as videos, virtual reality features, etc., based on collaborations with first responder trainers and hydrogen facility/equipment providers
- Engage organizations and develop opportunities to provide classroom training and bring visibility to the program's training resources

Accomplishments: Hydrogen Safety Panel

Vision: Hydrogen Safety Panel

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Safety practices, incorporating a wealth of historical experience with new knowledge and insights gained, are in place. Continuous and priority attention is being given to safety in all aspects of hydrogen and fuel cell technologies: research, development and demonstration; design and manufacturing; deployment and operations.

Name	Affiliation
Nick Barilo, Program Manager	Pacific Northwest National Laboratory
Bill Fort	Consultant
David Farese	Air Products and Chemicals
Larry Fluer	Fluer, Inc.
Donald Frikken	Becht Engineering
Aaron Harris	Air Liquide
Richard Kallman, Chair	City of Santa Fe Springs, CA
*Chris LaFleur	Sandia National Laboratories
Miguel Maes	NASA-JSC White Sands Test Facility
*Steve Mathison	Honda Motor Company
*Larry Moulthrop	Proton OnSite
Glenn Scheffler	GWS Solutions of Tolland
Steven Weiner	Excelsior Design, Inc.
Robert Zalosh	Firexplo

* Indicates new Panel member

Accomplishments

Continuing the focus on early project engagement

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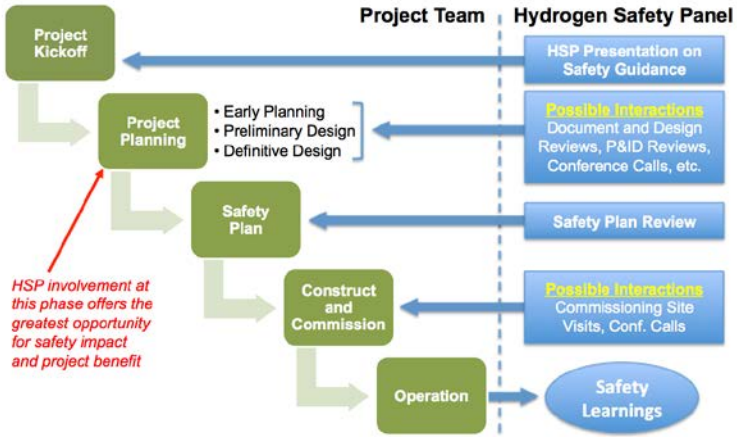
Reviews conducted in FY14 suggested that more work was needed to integrate the Hydrogen Safety Panel earlier in demonstration project activities. PNNL worked with DOE to improve the process:

- Funding Opportunity Announcements now require certain projects to coordinate with the Hydrogen Safety Panel (HSP) throughout the project life cycle. Examples of HSP involvement could include:
  - participation in post-award project kickoff meetings,
  - project design and document reviews,
  - risk assessments,
  - pre-startup reviews prior to beginning field demonstrations, and
  - safety-focused site visits.



Our presentation at the 2013 & 2014 AMRs discussed the best methods for utilizing the HSP for project reviews.

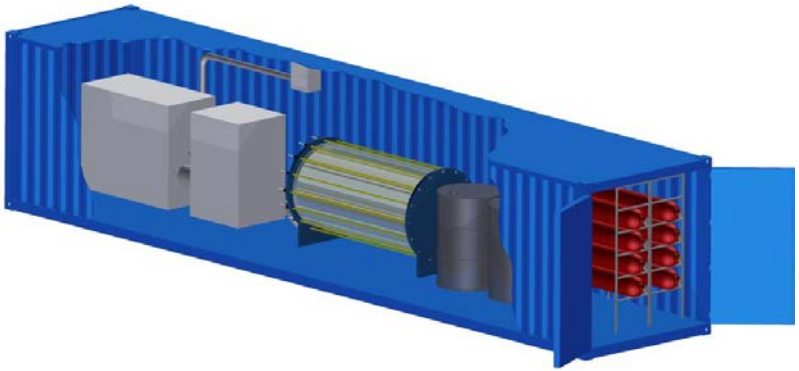
- A Panel task group is updating the project safety guidance document[1] to enhance the value of this guidance to project teams and to identify the role and use of the Hydrogen Safety Panel as an expert resource during the life of the project.
  - Emphasizing project safety planning (not just a safety plan)

[1] "Safety Planning Guidance for Hydrogen and Fuel Cell Projects," U.S. Department of Energy, Hydrogen and Fuel Cell Program, April 2010

Accomplishments

Update on supporting codes and standards

- The Panel's white paper, "Safety of Hydrogen Systems Installed in Outdoor Enclosures," and risk evaluation activities supported changes for the 2016 version of NFPA 2.
- NFPA 2, 2016 will have prescriptive requirements for Hydrogen Equipment Enclosures[1], including:
  - Ventilation
  - Isolation (gas and fire barrier)
  - Electrical requirements
  - Bonding/grounding
  - Explosion control
  - Detection



[1] A prefabricated area confined by at least three walls and a roof, not routinely occupied or used in a laboratory, *with a total area less than 450 ft^2 designed to protect hydrogen*.

* Final balloting approved in December 2014

Accomplishments

Finding solutions for the gaps…

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The lack of listed hydrogen equipment places an extraordinary burden on code officials to ensure (approve) that products include the appropriate inherent or automatic safety measures.

Certification presents significant challenges.

- Few systems or equipment that are listed, labeled or certified
- Significant costs since the technology and products are still rapidly changing and each new iteration would require recertification
- Lack of clarity on what a listing covers relative to a particular piece of equipment or system

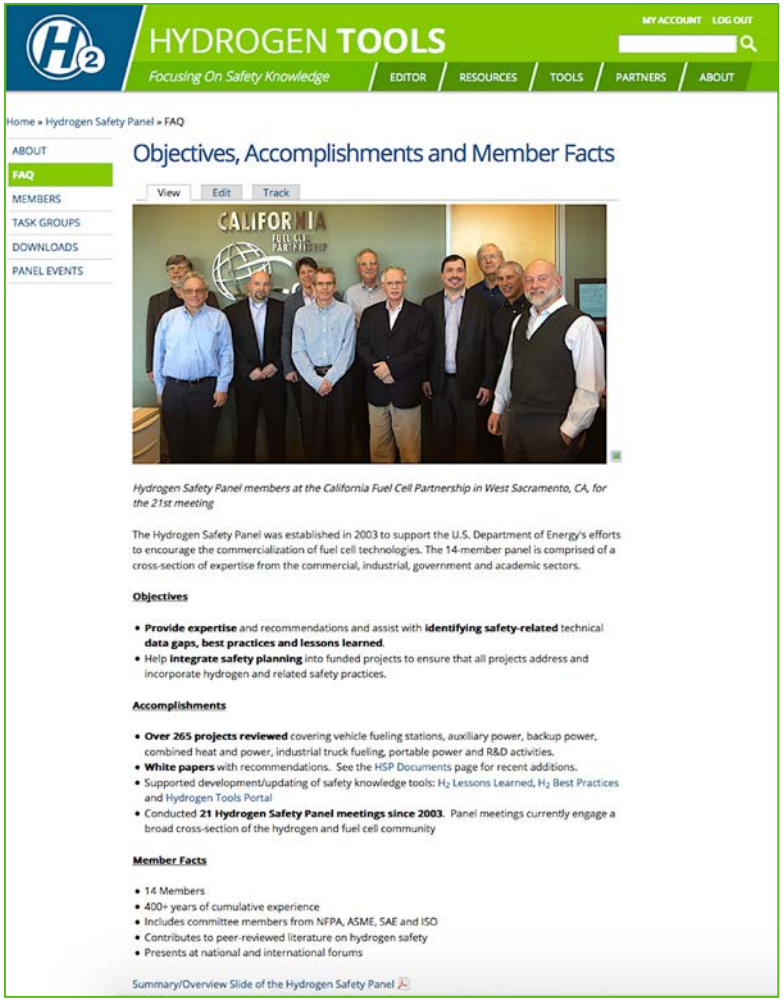
Development of a Certification Guide

Goal: Develop a Guideline that will assist authorities having jurisdiction, designers, owners, evaluators and others with the application of requirements pertinent to the design and/or installation of hydrogen equipment as regulated by the model codes. The scope of the Guideline will initially be limited to those requirements where the terms *approved*, *certified*, *listed* and/or *labeled* are used.

Accomplishments

State support and making the HSP more accessible

- Assisting the H2USA market acceleration working group through focused SCS outreach activities
- Supporting the California Governor's Office and CA Green Team
  - Included in the CA Hydrogen Station Permitting Guidebook - "this panel can be consulted to review innovative projects and provide feedback and insights to both station developers and AHJs."
- Drafted safety sections for the Hawaii implementation plan
  - Includes reference to the HSP as a safety resource
- Working with the Massachusetts Hydrogen Coalition to discuss safety issues and resources with Northeast fire officials
- Establishing public visibility – Hydrogen Safety Panel **website** online March 2015



Accomplishments

Hydrogen Safety Panel Scorecard

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Activity	Since the 2014 AMR	Total for the Project Duration
Project Reviews (including safety plans, site visits reviewed, follow-up interviews and design review activities)	18 (includes 2 early project reviews)	412
Panel Meetings	*1 (West Sacramento, CA)	21
White Papers & Recommendations (e.g., *Safety of Hydrogen Systems Installed in Outdoor Enclosures*)	0	7
Accident Investigations	0	3
Publications, Presentations and Webinars (all projects combined total)	9	46

***Highlights of the 21st Hydrogen Safety Panel Meeting**

- The HSP and an insurance industry representative discussed insurability of fueling stations. Future discussions are planned to explore the topic further.
- The incoming president of the International Association for Hydrogen Safety attended the meeting, which included discussion on establishing a European Hydrogen Safety Panel.

Accomplishments

Responses to 2014 Reviewer Comments

- "For the white papers (and other input to safety, codes and standards), the project should coordinate or work with organizations and working groups such as FCHEA and the U.S. DRIVE Partnership's Codes & Standards Technical Team."
  - *FCHEA has been invited and is participating in the HSP task group to develop a certification guide. This collaboration works well with FCHEA's own efforts to address the lack of listed hydrogen equipment (workshops to address the financial hurdles for pursuing listed equipment). PNNL also participates in the National Hydrogen and Fuel Cell Codes and Standards Coordinating Committee led by FCHEA.*
- It is excellent to see early project engagements of the HSP on early design reviews. Early stages of branding the panel should lead to increased awareness and use, leading to better safety knowledge in future projects."
  - *Thanks for the positive comment. We will continue to work with DOE and the projects to identify and implement new methods to achieve early project engagement.*
- The HSP portion has proven to be an excellent resource for the DOE programs and the hydrogen community at large. Indeed, imitation is the best form of flattery—the International Association for Hydrogen Safety (HySafe) is working to create a similar tool under the auspices of the Fuel Cells and Hydrogen 2 Joint Undertaking."
  - *Thanks for the positive comment. Thomas Jordan from HySafe attended the 21st Hydrogen Safety Panel meeting and commented, "it was a real pleasure to join you and I got a lot of inspiration for setting up the EU 'version' of the HSP." As they move forward this may be a great opportunity to collaborate and share learnings internationally.*

Accomplishments: Safety Knowledge Tools and Dissemination

Hydrogen Tools

A Transformative Step Towards Hydrogen Adoption

CENTRALIZED LOCATION — organizes current H_2 resources in one robust location—including **more than 20** existing tools, with plans for adding future content

FOCUSED CONTENT — tailored to the specialized needs of H_2 user groups

CUSTOMIZABLE INTERFACE — allows content to display based on the H_2 user's role or interests

RESPONSIVE DESIGN — enables H_2 safety work across both desktop and mobile devices

TRUSTED COMMUNITIES — fostered through social networking around H_2 subject matter expertise

EXPANDABLE FORMAT — built with frequently requested future feature sets in mind

Now Available

http://h2tools.org

› **Credible** and **reliable** safety information from a **trustworthy** source

Accomplishments

Hydrogen Tools Portal

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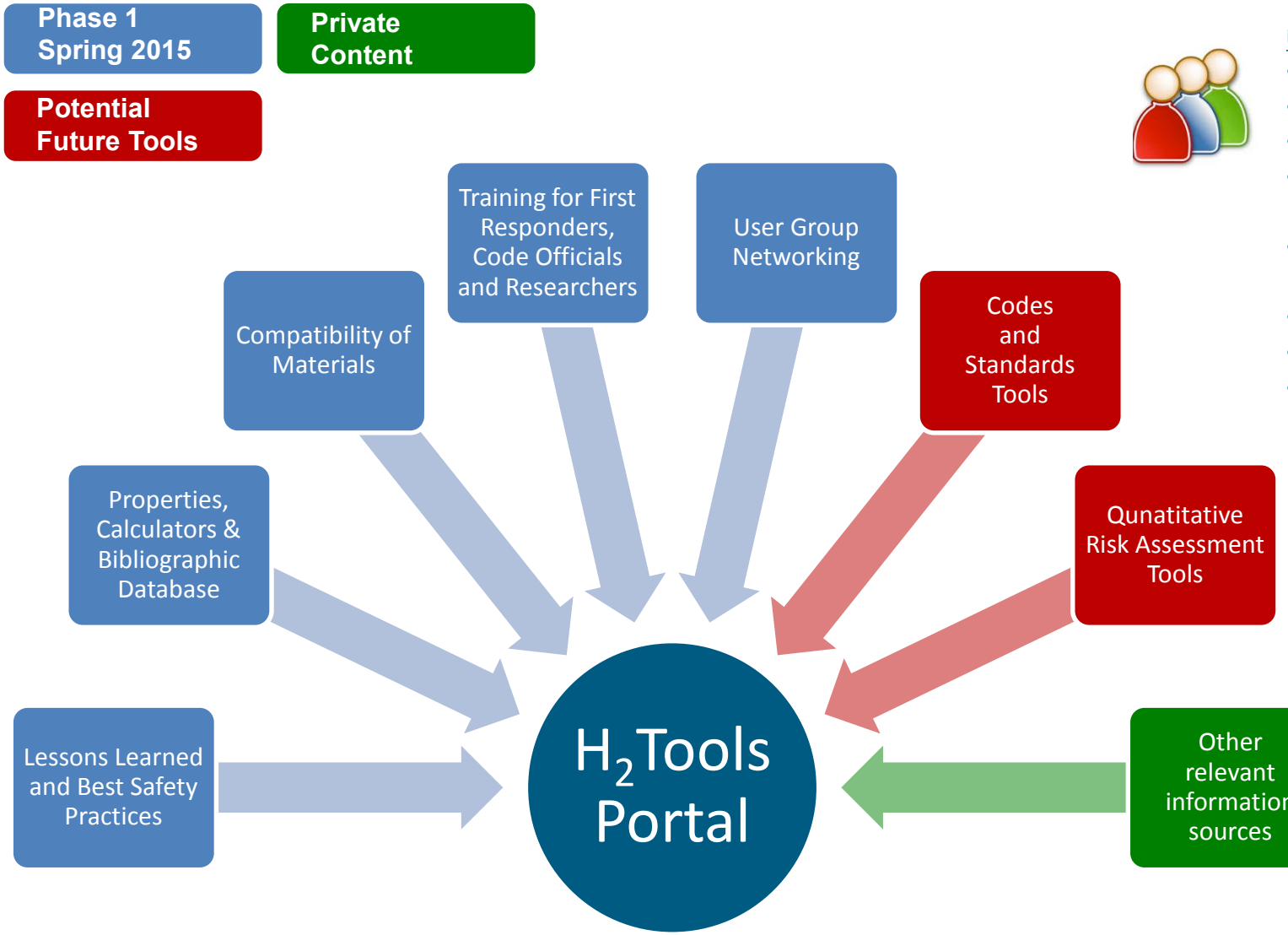

User Groups

- AHJ/code officials
- First responders
- Investors
- Insurers and risk managers
- Operations and maintenance
- Public
- Project proponents
- Research and development

Accomplishments

Disseminating safety knowledge to reach critical audiences

- **Two articles** provided for the online Building Safety Journal
  - February 2015, *Hydrogen and Fuel Cells Are Coming… Are You Ready?* – provides an overview of the technology along with the DOE program's relevant safety resources (authored by PNNL).
  - April 2015 (proposed), *Hydrogen and Fuel Cells… Focusing on Facility Safety Requirements* – Examines specific safety requirements along with their relevant code references (coauthored by PNNL and NREL).
- **Educational session** planned for the ICC annual business meeting in September 2015 (PNNL/CaFCP collaboration)
  - Classroom content (PNNL/NREL copresenters)
  - Site tour to a fueling station and stationary application
  - Combined with expo booth and ride/drive event

ICC INTERNATIONAL CODE COUNCIL®

People Helping People Build a Safer World™

The ICC's membership includes building, fire, plumbing, mechanical and energy officials representing state, county, municipal and federal governments. ICC members are architects, engineers, designers, builders, contractors, elected officials, manufacturers and other representatives of the construction industry.

Accomplishments

Safety Knowledge Tools Stats…

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Hydrogen Lessons Learned

Year	Visitors*	Max Visitors in 1 month
2006	3,357	751
2007	15,797	1,928
2008	25,539	4,568
2009	17,081	2,084
2010	17,502	1,954
2011	20,936	2,339
2012	19,635	2,347
2013	15,273	1,613
2014**	6,206	1,185

Hydrogen Best Practices

Year	Visitors*	Max Visitors in 1 month
2008	703	93
2009	1,029	113
2010	1,373	166
2011	1,373	167
2012	1,658	188
2013	1,684	194
2014	2,872	290

Total Visits for 2014

- H_2 Lessons Learned – 10,289**
- H_2 Best Practices – 4,480

New safety knowledge content: 3 lessons learned events added to H_2 Lessons Learned since the 2014 AMR (216 total)

*Visitors = unique visits as tracked by PNNL on a monthly basis. Regardless of how many times a particular individual may access a website during a particular month, they are counted as one unique visitor.

** Partial list of 5+ months. Site was moved in early June 2014 and no data is available for the new location.

Accomplishments

New Ways to Share Safety Knowledge

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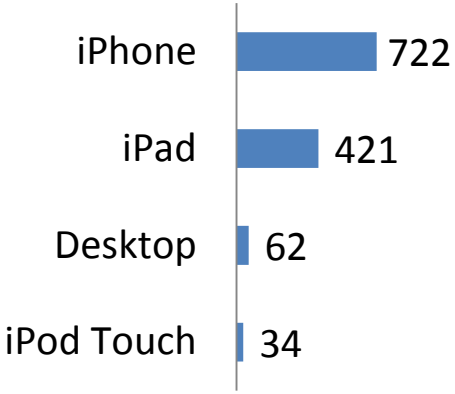
First mobile app developed for the Fuel Cell Technologies Office

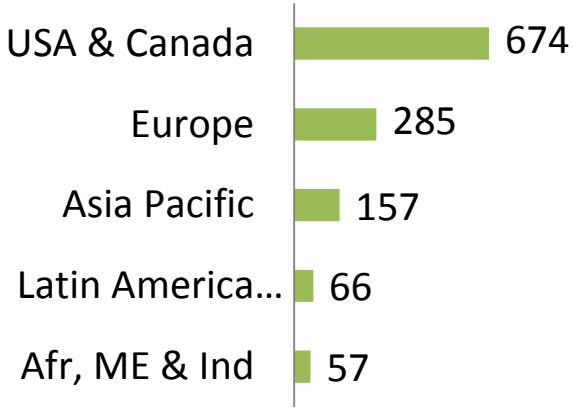
- Released in September 2013
- Integrates Hydrogen Lessons Learned and Best Practices into a single, searchable, iPad and iPhone application
- Features include safety planning guidance and checklists
- All tools (except H_2 Lessons Learned) are available without a data connection

1,239
Downloads since September 2013

By Platform



By Territory



Accomplishments

Responses to 2014 Reviewer Comments

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- "Excellent tools are being developed. This reviewer wonders whether more could be done to promote the tools, such as more interface outside the hydrogen community. The article in the NFPA Journal is an excellent start."
  - *This has been a priority for the PNNL Hydrogen Safety Program. As shown in previous slide, we are performing multiple outreaches to the ICC membership this fiscal year. This includes two Building Safety Journal articles, a webinar and an educational session at the ICC's annual business meeting. The safety resource tools are highlighted in these outreach activities.*
  - *Additionally, the HSP holds stakeholder meetings as part of its Panel meeting activities. These meetings include a wide variety of stakeholders, AHJs and project proponents. The safety resource tools are also highlighted during these interactions as well as HSP kickoff meetings.*

Accomplishments: First Responder Training

Accomplishments

Transitioning to enable trainers

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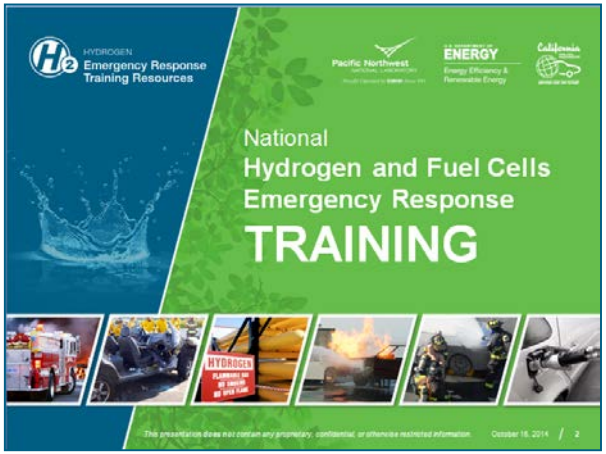
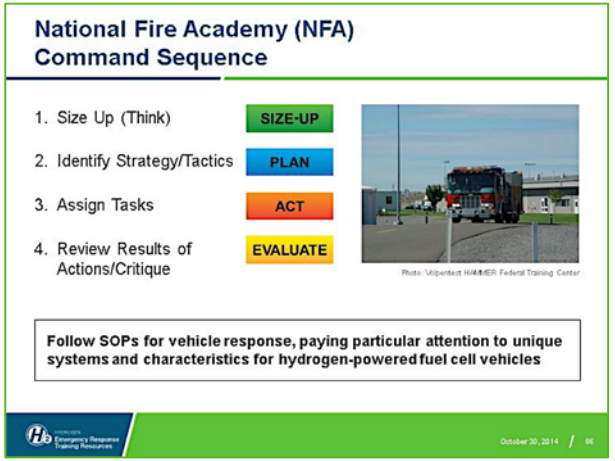
A consistent source of accurate information and current knowledge…

- …intended to serve as a resource and guide for the delivery of a variety of training regimens to various audiences
- The National Hydrogen and Fuel Cell Emergency Response Training Resource was **released** on September 30, 2014
- **Webinar** to announce the resource held on March 24, 2015 (>250 attendees)
  - Pre-webinar announcements made by DOE, PNNL, CaFCP, Fireengineering.com and the NFA
- Supporting H_2USA
  - Having properly trained first responders will address a key H2USA barrier, ensure a safe transition to fuel cell vehicles and H2 infrastructure, and pave the way for broader public acceptance.





Accomplishments

Improving the impact of training

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- A planning team was organized to consider what materials and delivery methods are best suited to enhancing the first responder learning outcomes. Recommendations were provided to serve three purposes:
  1. identify enhancements for the existing training resources,
  2. recommend new impactful resources and materials that should be added to the training portfolio, and
  3. provide guidelines that can be used to inform the direction of future training development efforts.
- Results suggested that improved images and videos, new props and consideration of virtual reality tools could help improve the instructional quality and potential reach of first responder hydrogen safety training resources in a cost effective manner.

Planning Team Membership

- Air Liquide
- Calgary Fire Department
- CA State Fire Marshal's Office
- California Fuel Cell Partnership
- Callan and Company
- Emergency Training Solutions
- LA County Fire Department
- National Fire Academy
- PNNL
- Proton OnSite
- Quong and Associates
- Rio Hondo College
- FirstElement Fuel
- West Sacramento Fire Dept.

Accomplishments

Expanding the reach of training

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- 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. This will:
  - allow a broader distribution of the materials,
  - better crediting of course completion/CEUs, and
  - Provide a good long-term landing spot for the training.
- PNNL/CaFCP will continue to provide subject matter expertise on the technical content.

Accomplishments

Classroom activities and demonstrations

- Presented at the International Workshop on Hydrogen Safety Training for First Responders held at the French Academy for Fire, Rescue and Civil Protection Officers, Aix-en-Provence, France on September 3-4, 2014
- Released the National Hydrogen and Fuel Cell Emergency Response Training Resource
- Worked with a team of trainers and stakeholders to develop a plan for revising first responder training materials to include new content including videos, virtual reality features, etc.
- Provided classroom training and prop demonstrations for the Washington State Annual Hazardous Materials Workshop on April 18-19, 2015 at the Volpentest HAMMER Federal Training Center (Richland, WA)
  - Attended by firefighters, law enforcement personnel, emergency managers, community emergency response teams and tribal responders
  - NFPA videoed the training for use in their DOE funded alternative fuels first responder training
  - NFPA also videoed the classroom content for use on the Hydrogen Tools Portal
- On May 14, 2015 a hydrogen prop demonstration will be provided for the Northwest's International Association of Fire Fighters Fire Ops 101 (80-100 participants). The goal of the event is to provide an opportunity for public office managers (city manager, etc.) to better understand the time/stress/technical demands of a firefighter through hands-on exercises and demonstrations.

Accomplishments

First responder training…by the numbers

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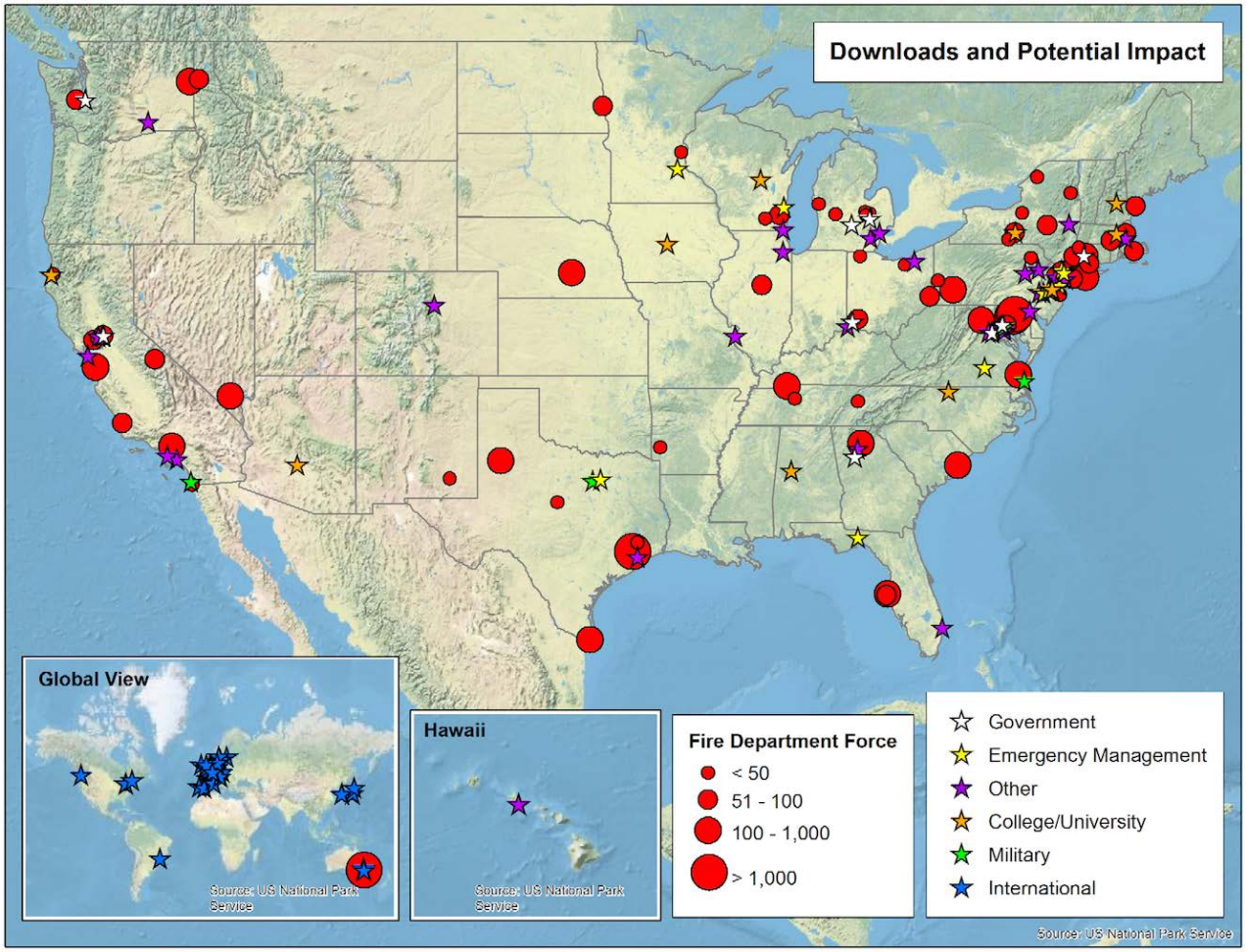
<u>Online Training</u>
(2007-present)
>32,000 visits

<u>Classroom Training</u>
2009-present
*1,000+ attendees

<u>National Template</u>
10/2014-present
246 downloads



National template - downloads and potential impact

* Four classes scheduled in Richland, WA on April 18-19, 2015 not included in total

Accomplishments

Responses to 2014 Reviewer Comments

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- "The project is getting 'old,' with little new to report. It might be time to look for ways to end the project and/or transition resources to a new project that can look for fresh ground to cover."
  - *The National Hydrogen and Fuel Cell Emergency Response Training Resource was released in September 2014. This represents a new approach for PNNL's hydrogen safety first responder resources with a focus on enabling first responder training organizations to perform their own training utilizing a consistent source of accurate information and current knowledge.*
  - *With a focus on future activities, PNNL collaborated with the CaFCP in FY 2015 to convene a group of first responder trainers, facility and equipment providers and other interested persons to consider what materials and delivery methods are best suited to enhancing the first responder learning outcomes. Recommendations were provided to serve three purposes: 1) identify enhancements for the existing training resources, 2) recommend new impactful resources and materials that should be added to the training portfolio, and 3) provide guidelines that can be used to inform the direction of future training development efforts. Results of the activity suggested that improved images and videos, new props and consideration of virtual reality tools could help improve the instructional quality and potential reach of first responder hydrogen safety training resources in a cost effective manner. We'll continue working with DOE to pursue these consistent with program priorities and resources.*
  - *As a result of the planning activities mentioned above, PNNL has initiated discussions with the National Fire Academy to transfer the online awareness training to them. This will allow for a broader distribution of the materials, better crediting of course completion/CEUs, and provide a good long-term landing spot for the training. PNNL will work with the CaFCP to support the training by providing update to the technical content. This arrangement represents a better use of DOE and PNNL's resources.*

Proposed Future Work
Remainder of FY 2015

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Hydrogen Safety Panel

- Continue early project engagements and safety plan reviews
- Provide a draft certification guide to DOE (further industry review is expected in FY 2016)
- Identify opportunities for supporting state fuel cell deployments
  - Outreach to AHJs in the Northeast
  - Work with California state agencies (e.g., CARB) to provide project reviews

Safety Knowledge Tools and Dissemination

- Complete the initial deployment of the Hydrogen Tools portal that combines H_2 Lessons Learned, H_2 Best Practices and other safety resources into one website
- Continue outreach to the ICC through a webinar and educational session at the annual business meeting

First Responder Training

- Preplan for FY 2016 operations-level training in the Northeast

Proposed Future Work
FY 2016

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Hydrogen Safety Panel

- Continue to utilize Panel resources to address safety knowledge gaps through white papers, recommendations to DOE, manuscripts, presentations and subject matter expertise for the Hydrogen Tools Portal
- Work with industry representatives and stakeholders in order to finalize and disseminate the certification guide
- Engage insurance industry representatives to explore issues for the insurability of hydrogen infrastructure and vehicles
- Support review of H-Prize submittals
- Explore and engage opportunities to directly support states/regional rollout of fuel cell vehicles, stationary applications and supporting infrastructure

Safety Knowledge Tools and Dissemination

- Expand the value and impact of the Hydrogen Tools portal by incorporating new tools and resources from other national laboratories and private organizations
- Outreach to state fire marshals for disseminating safety information and highlighting resources

First Responder Training

- Transfer the online awareness training to the National Fire Academy
- Develop pictures and video for inclusion in the national training template based on the results of the planning study
- Perform operations-level classroom training at a location in the northeastern states

Collaborations

Hydrogen Safety Panel and Safety Knowledge Tools

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Hydrogen Safety Panel

- Organizations supporting Hydrogen Safety Panel members
- FCHEA support on the certification task group
- Massachusetts Hydrogen Coalition – sharing hydrogen safety learnings and expertise with fire departments and fire marshal in the northeast

Safety Knowledge Tools

- Sandia National Laboratories support to include their materials compatibility online resources on the Hydrogen Tools Portal
- NREL for outreach activities to the ICC

First Responder Training

- California Fuel Cell Partnership in updating and publicizing the national template and other first responder training activities, and support for the ICC outreach
- Organizations supporting the development of a plan for improvements to the first responder training resources (see slide 23)
- Fuel Cells and Hydrogen (FCH) Joint Undertaking (JU) funded HyResponse Project
- National Fire Protection Association – videoing the operations-level training at HAMMER (video shared with PNNL for inclusion in the Hydrogen Tools Portal)

Summary

Hydrogen Safety Panel

- The HSP's early engagement of projects can be beneficial for the safe deployment of these technologies.
- Learnings from the Panels specific project involvement and interaction with code officials, stakeholders and project proponents can benefit the FCT program more broadly.
- The Panel can be an asset for supporting the safe commercial rollout of fuel cell vehicles, stationary applications and infrastructure.

Safety Knowledge Tools

- To remain vital and useful, databases and websites require a concerted effort beyond general maintenance. The content must be current, relevant to the community being served and valuable to the user.
- The Hydrogen Tools Portal represents a significant opportunity to broadly disseminate safety information and knowledge. Integrating information from DOE and other national laboratories is an opportunity to expand its value and impact, and warrants increased investment.
- Reaching out to new stakeholders and users is essential for enabling a safe transition to commercialization of hydrogen and fuel cell technologies.

First Responder Training

- The National Training Resource has been well received and provides the best opportunity to support first responder training for hydrogen and broader alternative fuels focused activities. Emphasis will be needed to keep the material and training materials relevant and impactful.

Thank you

- U.S. Department of Energy
  - Fuel Cell Technologies Office (Sunita Satyapal,Director; Will James and Laura Hill, Safety, Codes and Standards Team)
- California Fuel Cell Partnership
  - Jennifer Hamilton and Bill Elrick
- All of my colleagues at Pacific Northwest National Laboratory, the Hydrogen Safety Panel and other collaborators

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Technical Back-up Slides for the FY2015 Merit Review and Peer Evaluation

Project Review Reports, White Papers and Other Reports Since the 2014 AMR

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1. Safety Plan Review – New Fuel Cell Membranes with Improved Durability and Performance, May 8, 2014.
2. Safety Plan Review – FC-Based APU for Refrigerated Trucks (SAFETY PLAN-2ND REVISION), May 22, 2014.
3. Safety Plan Review – Fuel Cell Powered Airport Ground Support Equipment Deployment - GSE Gendrive (2nd Review), June 23, 2014.
4. Safety Plan Review – Fuel Cell Hybrid Electric Drayage Truck Demonstration Project, June 23, 2014.
5. Design Review – Maritime Fuel Cell Generator Project (2nd Review), July 14, 2014.
6. Safety Plan Review – LLNL Cryogenic and High Pressure Hydrogen Vessel Testing Facility, July 15, 2014.
7. Safety Plan Review – Demonstration of a Fuel Cell-powered Transport Refrigeration Unit (TRU), August 5, 2014.
8. Design Review/Site Visit – ESIF Fueling Facility, August, 15, 2014.
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