HYDROGEN
Safety Panel

Learnings and Direction:
Hydrogen Safety Panel and First Responder Training

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2014 HySafe Research Priorities Workshop

PNNL Hydrogen Safety Program

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 (listed below)

Safety Knowledge Dissemination

- Lessons Learned – h2tools.org/lessons
- Best Safety Practices – h2bestpractices.org
- Hydrogen Tools (iPad/iPhone mobile application)
- Coming soon… Hydrogen Tools Web Portal

Hydrogen Safety First Responder Training

- Introduction to Hydrogen Safety for First Responders (online)
- Hydrogen Emergency Response Training for First Responders (classroom and hands-on training with live props)
- National Hydrogen and Fuel Cell Emergency Response Training Resource (training template)

Overview of the Hydrogen Safety Panel (HSP)

Objectives

- Provide expertise and recommendations 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.

Activities

- Review safety plans for H_2 facilities and projects
- Participate in H_2 project design reviews
- Engage project teams through onsite safety reviews
- Identify safety knowledge gaps
- Support fact-finding from incidents and events

Accomplishments

- Over 400 project reviews covering vehicle fueling stations, auxiliary power, backup power, combined heat and power, industrial truck fueling, portable power and R&D activities.
- White papers with recommendations recently include:
  - Secondary Protection for 70MPa Fueling
  - Safety of Hydrogen Systems Installed in Outdoor Enclosures
- Supported development/updating of safety knowledge tools: “h2tools/lessons/”, “h2bestpractices.org” and Hydrogen Tools, an iPhone/iPad app.
- Conducted 20 Hydrogen Safety Panel meetings since 2003. Panel meetings currently engage a broad cross-section of the hydrogen and fuel cell community.

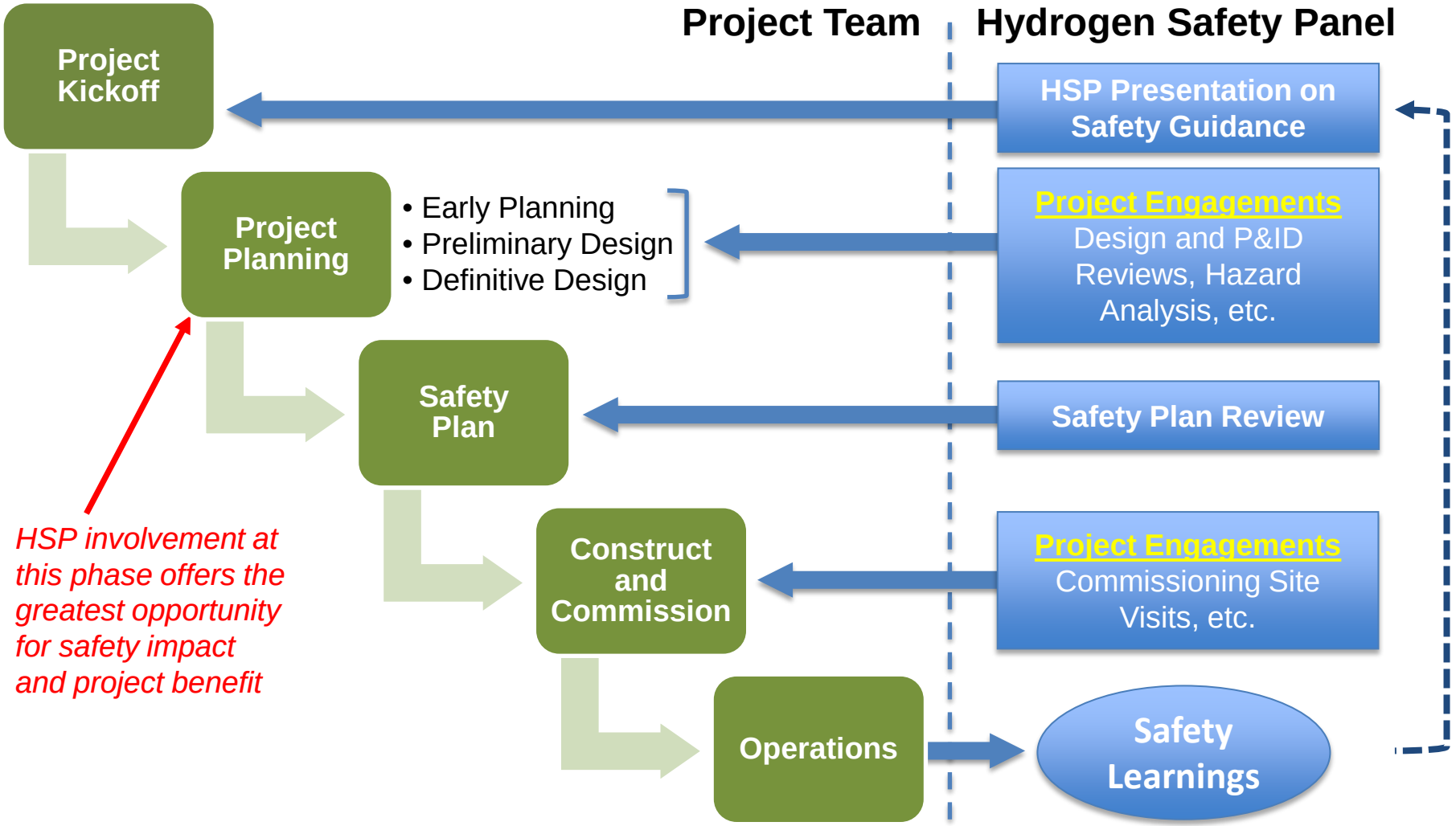
Name	Affiliation
Nick Barilo, Manager	Pacific Northwest National Laboratory
Bill Fort, Chair	Consultant
David Farese	Air Products and Chemicals
Larry Fluer	Fluer, Inc.
Donald Frikken	Becht Engineering
Aaron Harris	Air Liquide
Richard Kallman	City of Santa Fe Springs, CA
Chris LaFleur	Sandia National 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	Pacific Northwest National Laboratory
Robert Zalosh	Firexplo

* Membership pending

HSP Facts

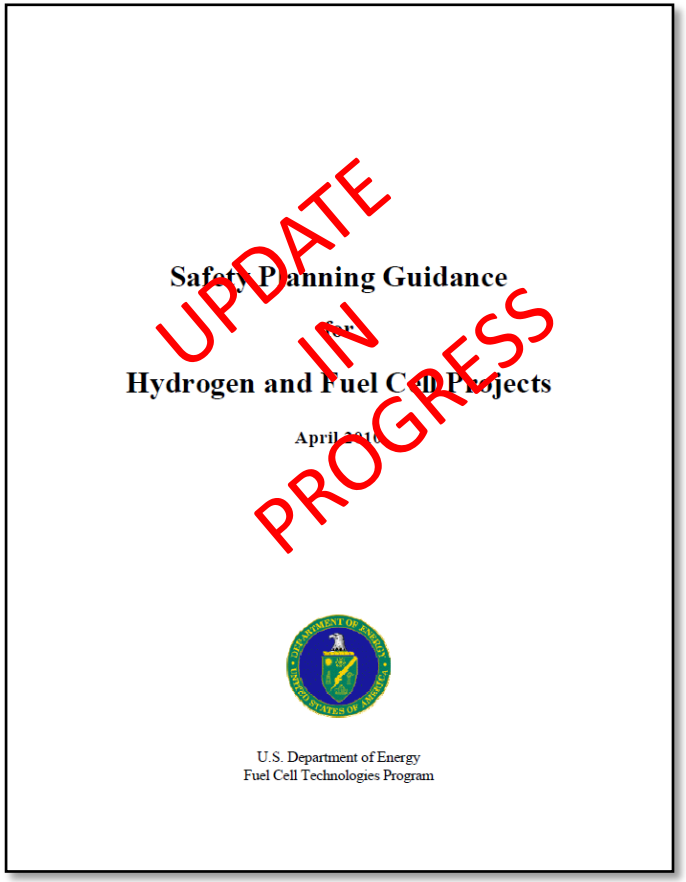
- Formed in 2003 to support U.S. DOE Hydrogen and Fuel Cells Program
- 400+ years of experience, representing many hydrogen sectors and technical areas of expertise
- Includes committee members from NFPA 2 and 55, and technical committees of ASME, SAE and ISO
- Contributes to peer-reviewed literature on hydrogen safety
- Presents at national and international forums

The Project Cycle



Guidance for Integrating Safety into H_2 Projects

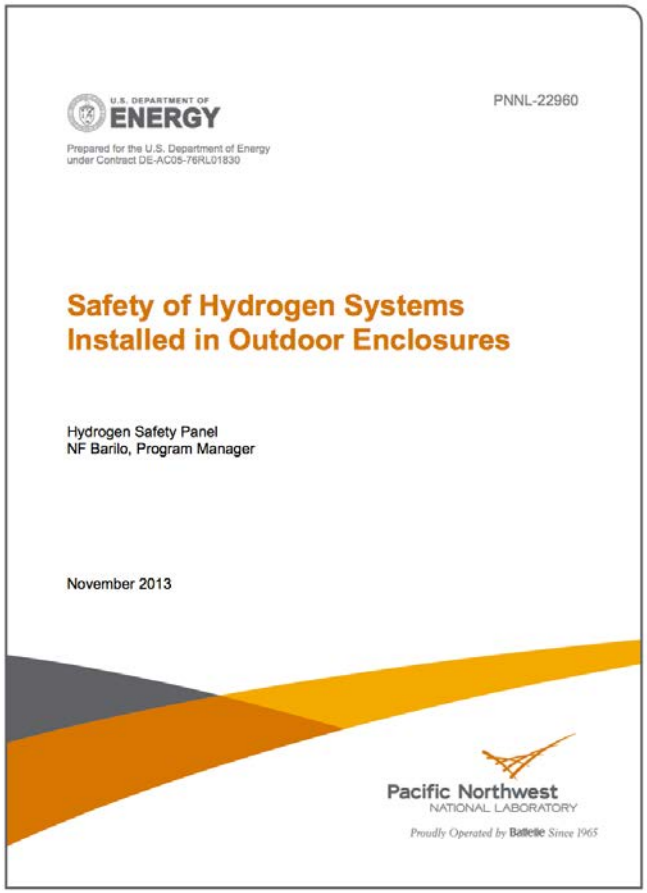
- Scope of Work
- Organizational Safety Information
  - Organizational Policies & Procedures
  - Hydrogen and Fuel Cell Experience
- Project Safety
  - Identification of Safety Vulnerabilities
  - Risk Reduction Plan
  - Management of Change Procedures
  - Project Safety Documentation
- Communications Plan
  - Employee Training
  - Safety Events and Lessons Learned
  - Emergency Response
- Safety Plan Approval



Panel Recommendations on Enclosures

A white paper produced by the Panel in 2013 suggests that a technical basis be developed for creating prescriptive and performance-based requirements for the range of enclosures used for hydrogen systems from the smallest to the largest. Variables that should be considered include:

- Leak rate, which is a function of hydrogen pressure and what components are inside the enclosure
- Probability of a leak, accounting for scenarios such as normal equipment degradation, potential for incompatible materials and Improper installations
- Ventilation required (natural or mechanical) to prevent flammable hydrogen ceiling layer concentrations from developing
- Explosion protection measures other than leak prevention and ventilation
- Damage or injuries that might result from a leak
- Necessary separation distances between enclosures and other exposures

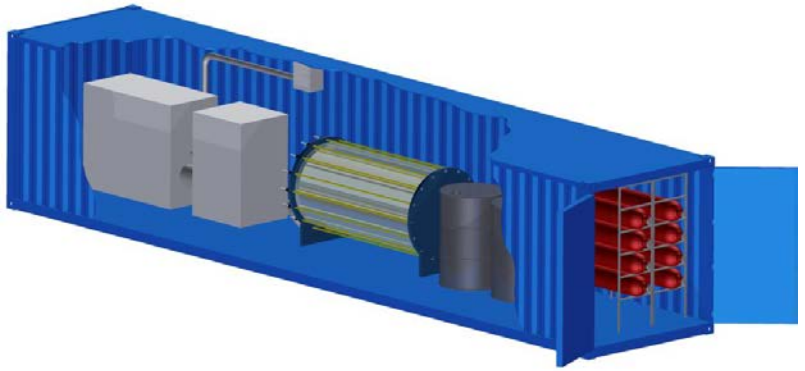


Focused research on these issues could be very beneficial for establishing long term safety benefits and support code development activities.

NFPA 2, Enclosures and Ventilation Issues

2016 Version of NFPA 2* will likely have prescriptive requirements for Hydrogen Equipment Enclosures[1], including:

- Ventilation
- Isolation (gas and fire barrier)
- Electrical requirements
- Bonding/grounding
- Explosion control
- Detection



Existing ventilation requirements taken from NFPA 2 and NFPA 55:

- Ventilation Rate. Mechanical exhaust or fixed natural ventilation shall be provided at a rate of not less than 1 scf/min/ft2 (0.3048 Nm3/min/m2) of floor area over the area of storage or use.
- Inlet and outlet openings shall each have a minimum total area of 1 ft2 /1000 ft3 (1 m2 /305 m3) of room volume.

Where do these numbers come from? Are they conservative or overly conservative? Can we identify better numbers for both mechanical or natural ventilation?

[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 ft2 designed to protect hydrogen*.

* Final balloting due in December 2014

Certification Challenges

Learning: The role and scope of third-party certification of hydrogen and fuel cell systems need to be clarified to facilitate their commercialization.

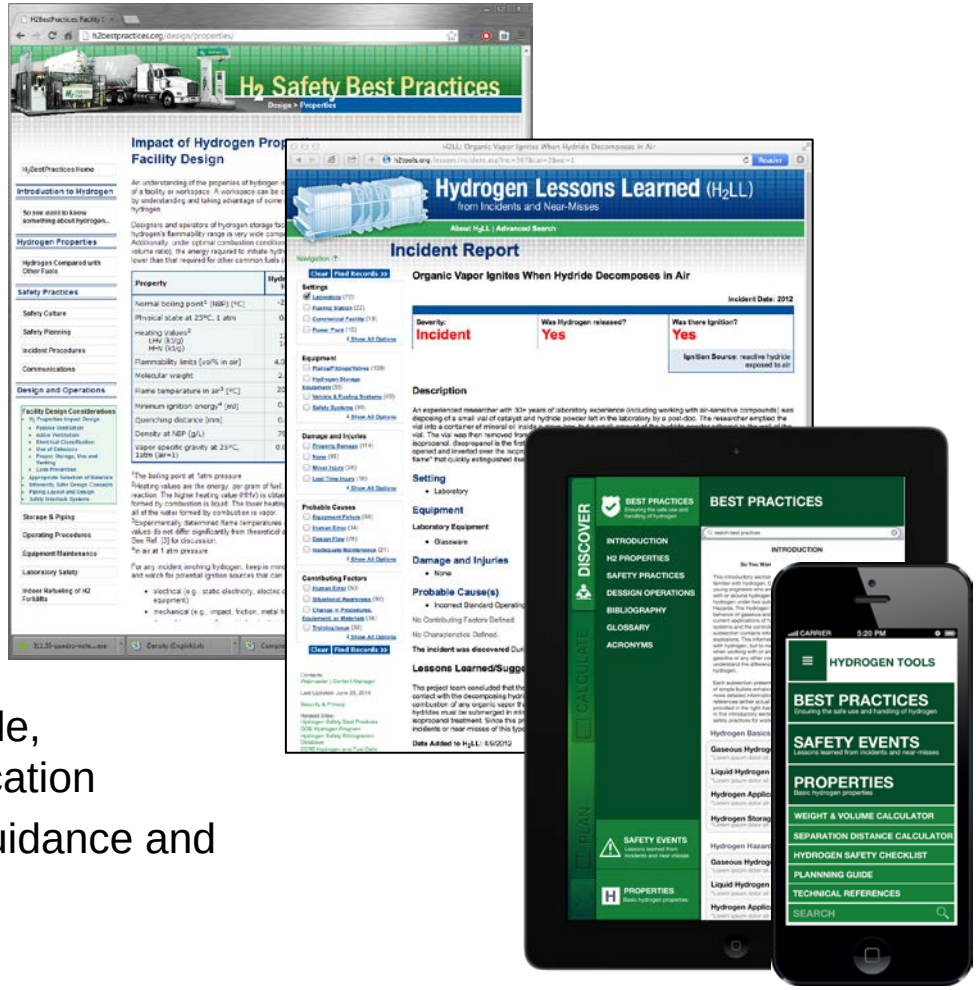
Certification presents significant challenges. The issues include:

- Confusion with terminology used in the various codes and standards
- Difficulties applying certification standards or even the absence of such standards, as well as a lack of certification organizations
- Significant costs since the technology and products are still rapidly changing and each new iteration would require recertification
- Lack of clarity on what a certification covers relative to a particular piece of equipment, system or facility
- Few systems or facilities that are listed, labeled or certified

The Hydrogen Safety Panel is currently developing a certification guide to assist code officials and project proponents.

Best Safety Practices, Lessons Learned and Hydrogen Tools IOS App

- 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” and stakeholders.
- The mobile app:
  - Integrates H_2 Lessons Learned and H_2bestpractices.org into a single, searchable, iPad and iPhone application
  - Features include safety planning guidance and checklists



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

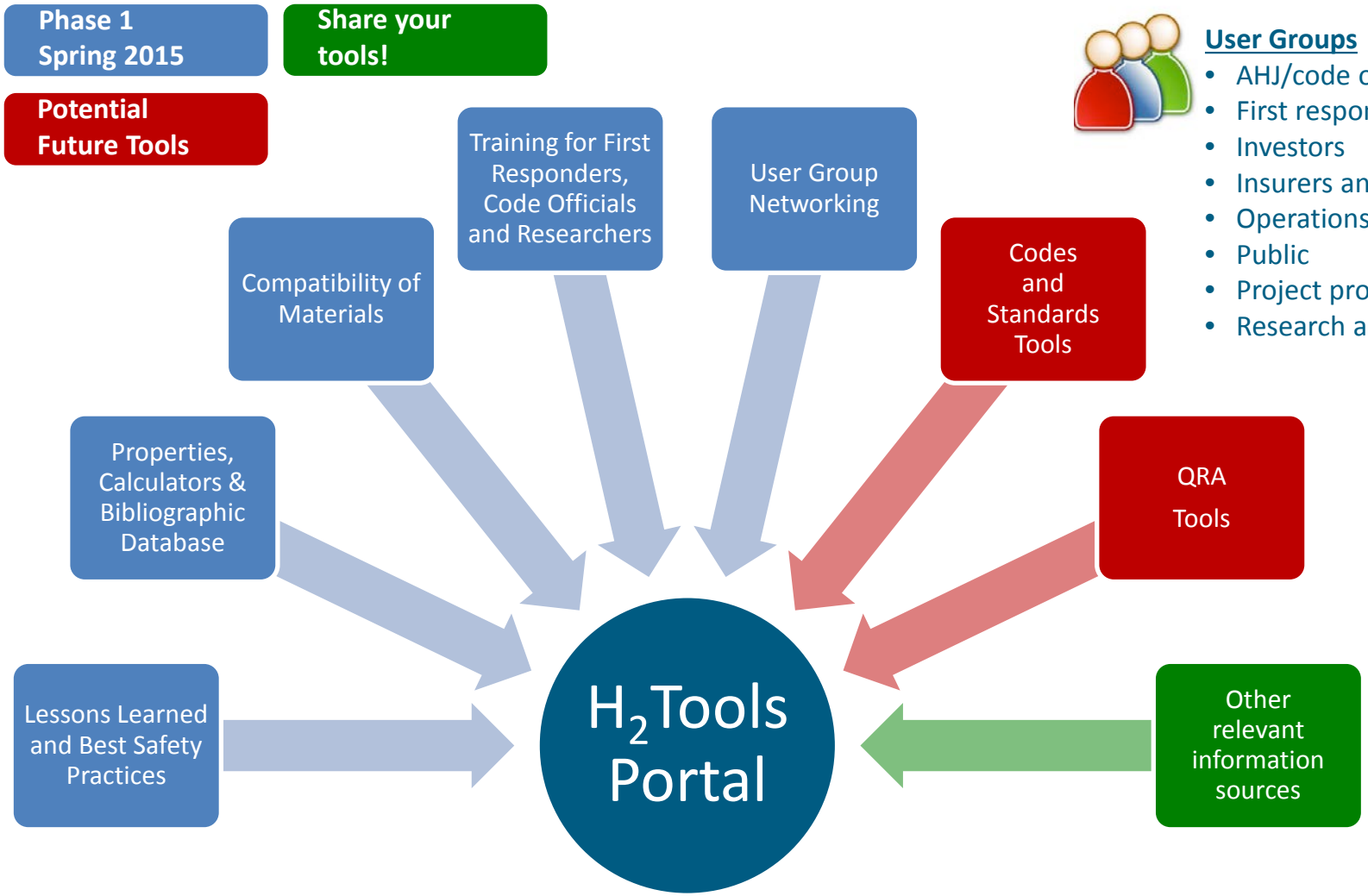
RESPONSIVE DESIGN enables H_2 safety work across both desktop and mobile devices

TRUSTED COMMUNITIES fostered through social networking around H_2 subject matter expertise

EXPANDABLE FORMAT built with frequently requested future feature sets in mind

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

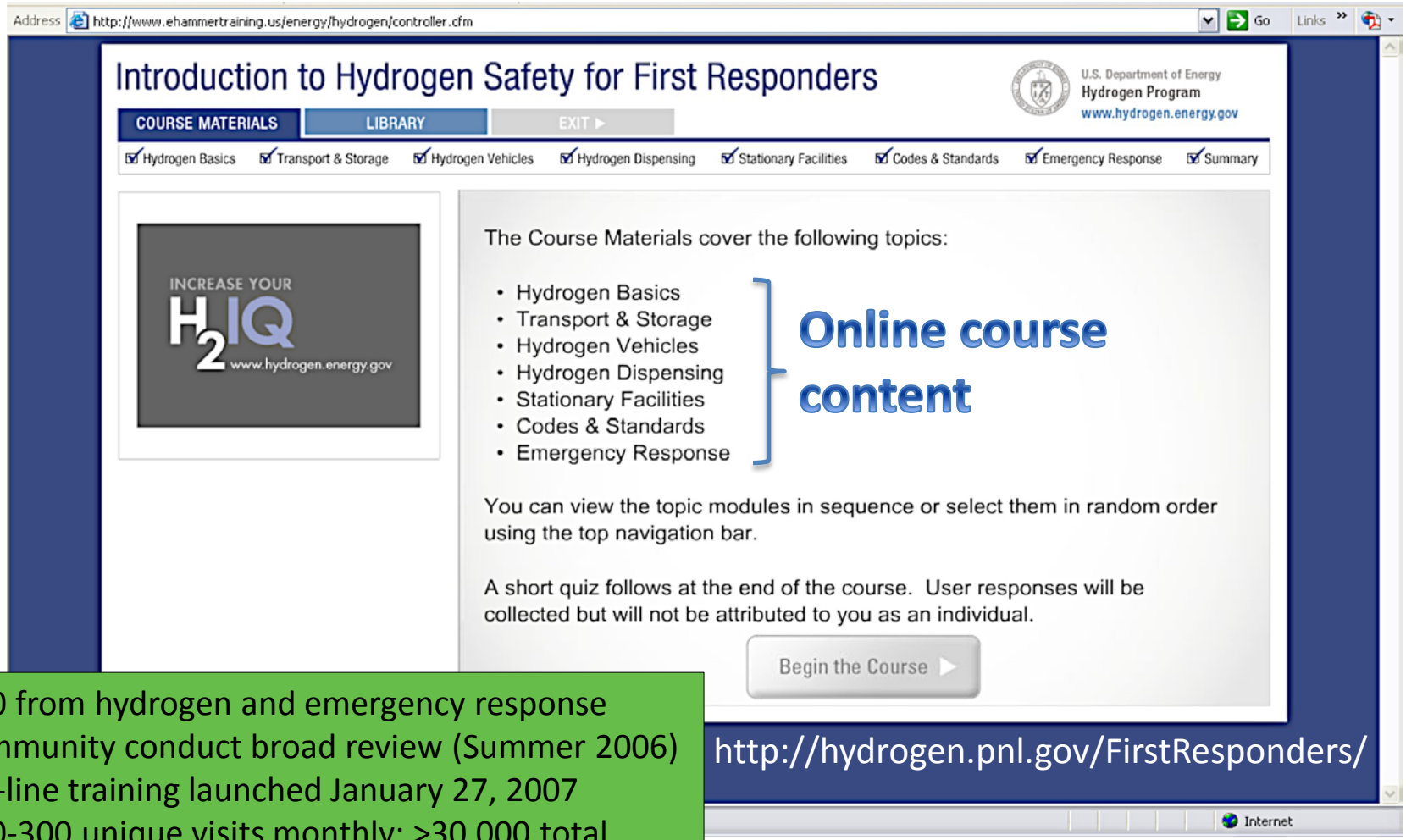
Opportunities for Information/Knowledge Dissemination



User Groups

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

Online Awareness-level Training



- 100 from hydrogen and emergency response community conduct broad review (Summer 2006)
- On-line training launched January 27, 2007
- 200-300 unique visits monthly; >30,000 total.

Classroom and Hands-on FR Training

- Classroom curriculum
  - Hydrogen and fuel cell basics
  - Hydrogen vehicles
  - Stationary facilities
  - Emergency response
  - Incident scenarios
- Demonstrations/hands-on exercise with FCEV prop
  - Demonstration of hydrogen flame characteristics
  - Student participation in rescue evolutions

Multiple instructors for classroom training

A "rescue" at Sunnyvale (CA) Department of Public Safety

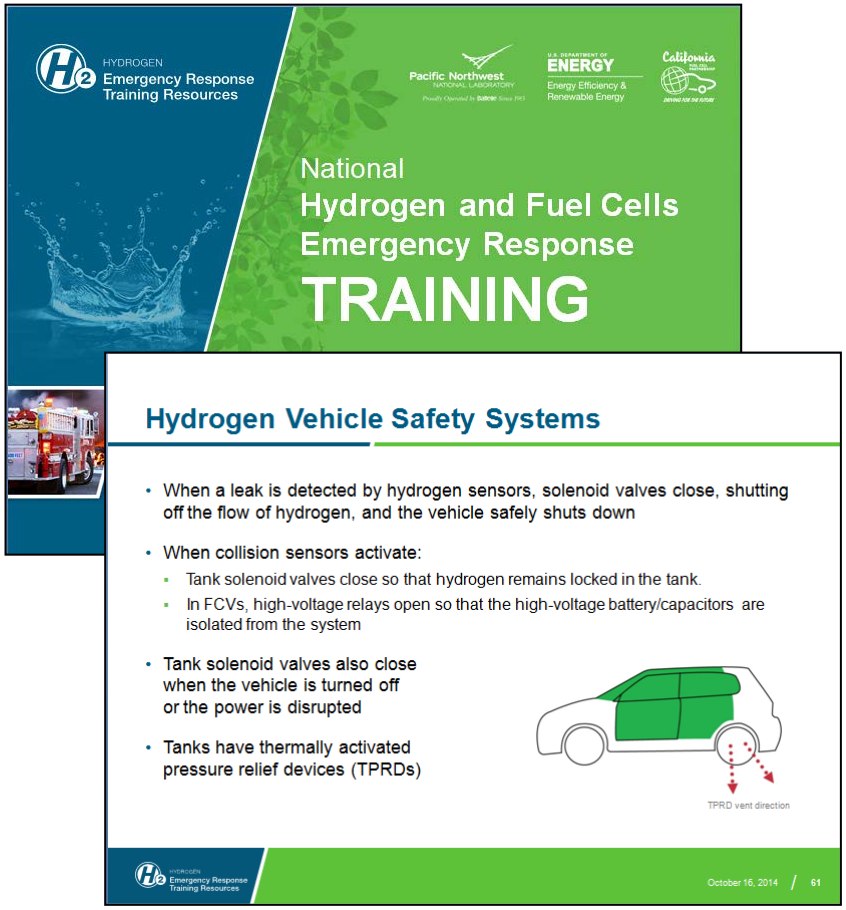
A Vision – First Responder Training

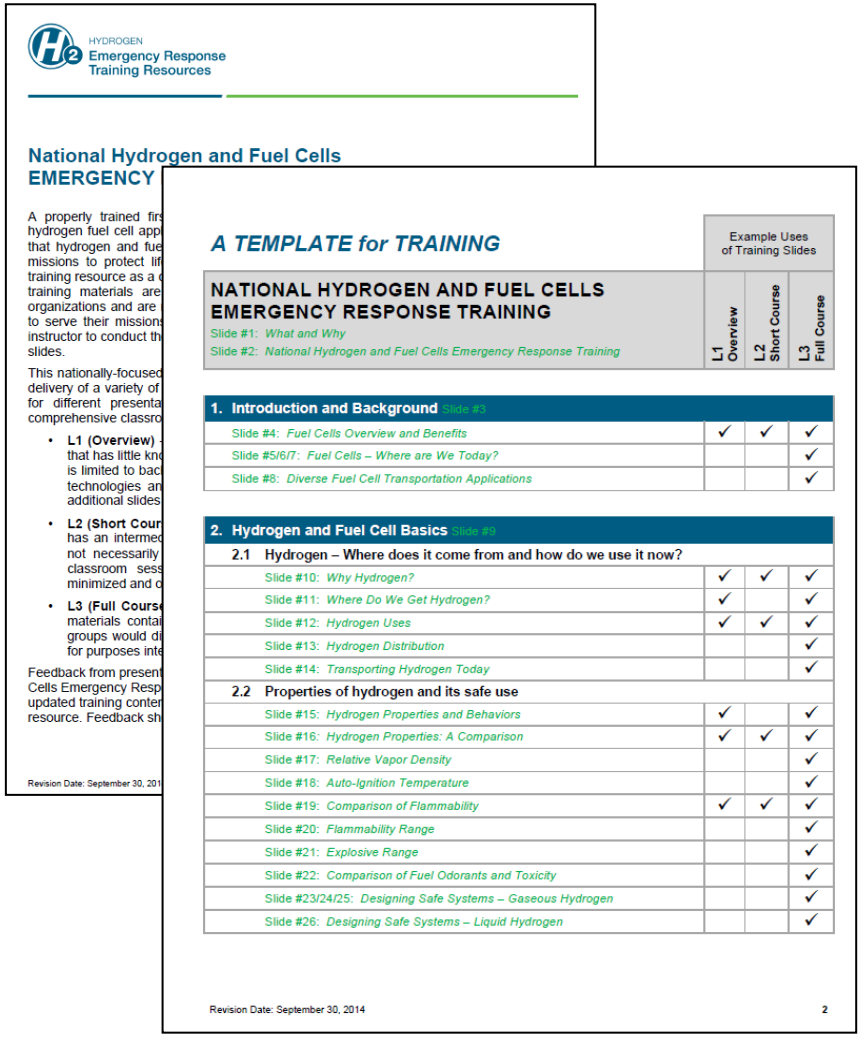
Hydrogen and fuel cell-related first responder training is delivered locally to serve missions to protect life and preserve property, utilizing a national emergency response training resource as a consistent source of accurate information and current knowledge.

A training template approach is utilized to achieve this vision by facilitating

- delivery of a variety of training regimens to various audiences,
- development of new and updated training content and techniques and
- encouragement of collaborations among various stakeholders to achieve purposeful results.

National First Responder Training Resource





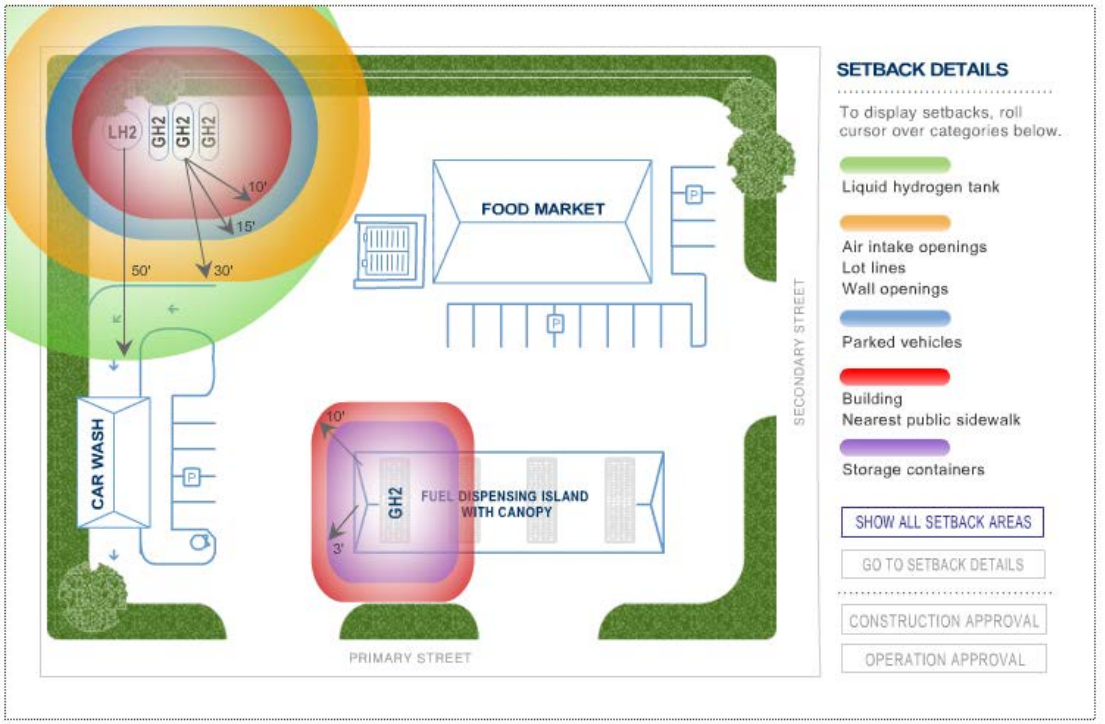
[Can be downloadded at http://h2tools.org/fr/nt/](http://h2tools.org/fr/nt/)

Opportunities for HySafe Involvement in FR Activities

- Establish an international forum to facilitate discussion on FR training with a focus on user experiences, needs and products
  - Identify and address frequently asked questions and concerns of FR
- Sharing of videos for FR training!

HSP Input

- Identify better hydrogen leak data to:
  - improve the findings from the Sandia report, "Analyses to Support Development of Risk-Informed Separation Distances for Hydrogen Codes and Standards," SAND2009-0874, in support of possible separation distance reductions
  - Better quantify SNL risk models & support QRA tools development



NFPA Research Foundation Conclusions

In 2010 the NFPA Fire Protection Research Foundation issued a report on, "Research Needs in Support of Hydrogen Safety Standards." The purpose of the effort behind the report was to to assist NFPA technical committees in establishing research needs to inform the technical basis for the safety requirements in NFPA 2, NFPA 55, and other relevant standards. This includes: (i) identifying and evaluating research needed to support the development of hydrogen safety requirements in the NFPA codes; and (ii) making recommendations on research projects that need to be completed to support these code changes. In its assessment of the data needed to inform developing NFPA codes and standards for hydrogen infrastructure safety, the Hydrogen Research Advisory Council identified the following priority research needs:

- Wide area detection in the refueling station environment (both indoor fork lift refueling and partially confined outdoor refueling)
- Application and validation of modeling to the explosion scenarios relevant to NFPA standards, with a focus on Detonation/Deflagration transition studies which can lead to mitigation methods
- Performance data to inform listing standards for refueling components such as hoses
- Set back distances for liquid hydrogen refueling hazards
- Additional validation of the research work from Sandia National Laboratories on separation distances for gaseous hydrogen for the scenarios covered in NFPA 55
- Relative effectiveness of barriers as opposed to spatial separation to mitigate the hazards associated with hydrogen events
- Application of Sandia research on hydrogen dispersion hazards in tunnels
- Non destructive testing methods for evaluation of hydrogen effects on components

Recommendations for Future HySafe Activities

Research Opportunities

- Consider further work on the open issues identified by the Hydrogen Safety Panel's work on Enclosures (ventilation, leak rates, explosion protection, separation distances, etc.)
- Work to identify minimum natural ventilation rates for enclosed spaces
- Establish an international forum to facilitate discussion on FR training with a focus on user experiences, needs and products
- Identify better hydrogen leak rate data
- Needs based on the NFPA Research Foundation Report

Collaboration

- Sharing information on the h2tools.org portal
- Sharing videos to support FR training

Contact Information

Please let me know if you have any questions or comments!

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